Quantitative Evidence Research Consultancy Services cc
Reg No: 2011/068223/23
VAT No: 4030258414

PO Box 92088
Mooikloof 0059
Email:
apouris@icon.co.za

Tel: 083 6305996

POLICY RESEARCH STUDY

TO

DETERMINE THE ADOPTION AND INTERGRATION OF SCIENCE, TECHNOLOGY AND INNOVATION (STI) INTO GOVERNMENT POLICIES AND PLANNING FRAMEWOKS

Principal Investigator

Prof Anastassios Pouris
University of Pretoria and
Member: Quantitative Evidence Research cc
Tel: 083 630 5996
Email: apouris@icon.co.za / anastassios.pouris@up.ac.za

September 2021

The study was conducted by Quantitative Evidence Research cc as commissioned by the DSI and ASSAf. The report was compiled by Quantitative Evidence Research cc under the guidance of the DSI and ASSAf policy research study committee.

Approved by:

Prof Himla Soodyall – Executive Officer

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

ASSAf
ACADEMY OF SCIENCE OF SOUTH AFRICA

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

4IR	4th Industrial Revolution
ARC	Agricultural Research Council
ASSAf	Academy of Science of South Africa
CoC	Centres of Competence
CSIR	Council of Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
DBE	Department of Basic Education
DCDT	Department of Communications and Digital Technologies
DG	Director General
DHET	Department of Higher Education and Training
DoD	Department of Defence
DoH	Department of Health
DPWI	Department of Public Works and Infrastructure
DSI	Department of Science and Innovation
DST	Department of Science and Technology
Dtic	Department of Trade, Industry and Competition
DWS	Department of Water and Sanitation
EU	European Union
GIST	Government Institute for Science, Technology and Innovation
HESTIIL	Higher Education Science Technology Innovation Infrastructure Landscape
HYSA	Hydrogen South Africa
ICT	Information and Communications Technology
IDC	Industrial Development Corporation
Mintek	Council for Mineral Technology and Research,
NCRI	National Council on Research and Innovation
NDP	National Development Plan

NHFCT RDI	National Hydrogen and Fuel Cell Technologies Research, Development and Innovation
NHLS	National Health Laboratory Service
NIH	National Institutes of Health
NSF	National Science Foundation
NSI	National System of Innovation
NVP	National Ventilator Project
NWPR	National Water Policy Review
OECD	Organisation of Economic Cooperation and Development
ORIP	Office for Research and Innovation Policy
OST	Office of Science and Technology
POST	Parliamentary Office for Science and Technology
R&D	Research and Development
SAASTA	South African Agency for Science and Technology Advancement
SANEDI	South African National Energy Development Institute
SDG	Sustainable Development Goal
SLA	Service Level Agreement
SSC	Senate science Committee
STI	Science Technology Innovation
TFP	Total Factor Productivity
TYIP	Ten-Year Innovation Plan
US(A)	United States (of America)
WRC	Water Research Commission

1 EXECUTIVE SUMMARY

Government Departments and relevant agencies turn to operate in silos in the area of Science, Technology and Innovation (STI). The recent Cabinet approved White Paper on Science, Technology and Innovation (2019) sets a number of objectives and it suggests that in addition to these objectives, measures to support partnerships among the actors of the National System of Innovation (NSI) at all levels, interventions, aimed at improving the policy coherence and coordination, as well as the governance of the NSI, will be introduced.

It is on this basis that the Department of Science and Innovation (DSI) and the Academy of Science of South Africa (ASSAf) commissioned Qualitative Evidence Research (QER) to conduct a policy research study in order to assess (1) how national and provincial government departments' policies are open to the uptake of innovation; (2) how the departments have integrated Science, Technology and Innovation (STI) in their policies and different institutional programmes; and (3) instilled the innovation culture within and across the departments. **The objectives of the investigation were therefore set as follows (SLA 2021):**

Objective	Question to be addressed	Data collection Tool
Assess how national and provincial government departments' policies are open to innovation uptake.	1. Is innovation described in the policy documents of Departments? 2. Is innovation recognised by government officials as important?	1. Literature review; policy documents analysis and case studies 2. Survey
Ascertain how policies and different institutional programmes have integrated STI and instilled the innovation culture within and across the departments.	1. Are STI integrated in departmental programs? 2. What are the constraints for STI incorporation? 3. Do departments have STI capabilities, structures or budgets? 4. Do Departments monitor policy coherence with other Departments? 5. Are there mechanisms for monitoring the incorporation of STI in policies?	1. Literature review; policy documents analysis; case studies and Survey 2. Survey 3. Survey 4. Survey 5. Survey
Inform DSI to formulate policy interventions that accelerate the realisation of the value of STI in public service and society in general	Develop Recommendations for the DSI and ASSAf	Findings: Literature review; policy documents analysis; case studies and Survey

This report presents the results of an investigation related to the adoption and integration of Science, Technology and Innovation (STI) into national government policies and frameworks of 12 government Departments.

The report is structured into various sections including the following:

A. Basic Research (Section 3). The section is divided into three sections:

1. Literature review (Section 3.1), which is divided into several sub-sections:

i. Section 3.1.1 "The Importance of Research, Development and Innovation" highlights the pervasiveness of research and innovation for economic growth and discusses empirical and theoretical findings. It is argued that the issue of research and development (R&D) is probably the only one that qualifies for government intervention across the board.
ii. Section 3.1.2 "Coherence and Policy Failures" refers to the interdependence and interrelations between different policies. Two dimensions of complexity are distinguished in STI policy: the policy-mix and multi-level governance. The relevant literature identifies a number of coordination mechanisms. Examples include: the creation of centralised agencies, coordination councils, super-ministries, leadership at the cabinet level, intermediary agencies, collaboration programmes, lead organisations, standards setting bodies, etc.
iii. Section 3.1.3 "Organisational Structures of Research Systems" discusses the three research systems which can be distinguished into the pluralist, the coordinated, and the centralist systems.
iv. Section 3.1.4 "The South African National System of Innovation" describes the country's National System of Innovation (NSI) and refers to a number of government documents recognising the importance of science and technology for economic growth and development, and they are referring to the concept of coherence. There is emphasis on the intensions of the White Paper on Science, Technology and Innovation of 2019 to establish a coordinated system of Science and Technology (STI).

2. Analysis of Policy Documents of Selected Government Departments (Section 3.2): The section describes the results of an analysis of selected policy documents of the departments under investigation. Concept analysis is the application of a specified method to examine the existence of a concept of interest in a particular document. The investigation identifies that only a limited number of Departments consider science, technology and innovation issues in their policy documents.

3. Case studies (Section 3.3): The first case study "The Take-off of Science and Technology in China" (Section 3.3.1) elaborates on the way China reached its current technological position. It is identified that the characterisation of science and technology as one of the four modernisations/driving forces, by Premiers Zhou Enlai and Deng Xiaoping, have been critical. It is also argued that the involvement of the Premiers in the science system resolves issues of coherence, alternative approaches etc. The second case study elaborates on the Department of Human Settlements – Department of Science and Innovation Collaboration (Section 3.3.2). The case study reveals that appropriate actions of the two departments led to initiatives addressing issues of the country's poorest and least advantaged citizens.

B. Primary Research (Section 4): Survey of the Government Departments, describes the results of the survey of 12 government departments.

C. Findings and Discussions (Section 5): expounds on the findings of the investigation

D. Recommendations (Section 6): describes recommendations put forward based on the findings.

The main findings are as follows:

1. The literature review and case studies confirm that STIs are critical drivers for social and economic development. Several countries, including China, succeeded in developing their economies and societies based on science, technology and innovation.
2. Both the survey and the concept analysis show that South African government departments are aware and agree on the importance of the concept of 'innovation' for policy.
3. An issue of interest was the adaption and integration of STI in departmental programmes, policies and frameworks. Six departments offered examples, and nine departments declared that they had a dedicated unit working on STI programmes or activities. The following constraints were identified - namely budget/cost (4); technical skills (3); and lack of capacity/resources (2).
4. Another issue revolved around monitoring coherence and incorporation of STI in departmental policies and possible solutions of improving coherence. Seven departments declared monitoring activities. Three departments mentioned the Ministerial Clusters as possible approach to improve coherence and another three suggested R&D; two departments mentioned collaboration and other policies.
5. The broad findings appear to show that STI can be accommodated in most of the investigated departments, but clarifications should be provided on what is expected from possible amalgamations/ incorporations**. It is emphasised that the findings cannot be extrapolated in the entire government body as the departments were not selected randomly**.

Based on the literature review, challenges identified and suggestions from the participants, the following recommendations were developed:

- DSI to consider submitting the issue of STI Coherence to the Economic Cluster.
- DSI to consider activating the Intergovernmental Relations Framework Act (Act 13 of 2005) for the establishment of a national intergovernmental forum. The Forum can include stakeholders from different levels of government.
- DSI should consider the establishment of the Government Institute for Science, Technology and Innovation (GIST). The Institute will undertake *ex ante* impact assessments of issues with high impact in society and will inform the relevant authorities in the country.
- ASSAf should consider establishing a National Programme for the Appreciation of Science and Technology in Government. The programme should aim to improve the appreciation of science and technology among government officials.
- To expand the investigation to cover all government departments at both National and Provincial levels.

2 INTRODUCTION

South Africa has historically, a pluralistic system of STI. Government departments, as well as relevant agencies, operate independently from each other in the domain of STI. However, recent experiences have shown that achievements of government objectives, ranging from economic growth to elimination of unemployment (as stated in NPC 2011), require alignment and harmonisation.

The issue is of particular importance due to the approval by Cabinet of the White Paper on Science, Technology and Innovation (2019). The White Paper sets a number of objectives, and it states: "*In addition, measures to support partnerships among NSI actors at all levels, interventions aimed at improving the policy coherence and coordination, as well as the governance, of the NSI will be introduced.*

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

The Department of Science and Innovation (DSI) and the Academy of Science of South Africa (ASSAf) commissioned Qualitative Evidence Research (QER) to conduct a policy research study in order to assess (1) how national and provincial government departments' policies are open to the uptake of innovation; (2) how the departments have integrated Science, Technology and Innovation (STI) in their policies and different institutional programmes; and (3) instilled the innovation culture within and across the departments. **The objectives of the investigation were therefore set as follows:**

Objective	**Question to be addressed**	**Data collection Tool**
Assess how national and provincial government departments' policies are open to innovation uptake.	1. Is innovation described in the policy documents of Departments? 2. Is innovation recognised by government officials as important?	1. Literature review; policy documents analysis and case studies 2. Survey
Ascertain how policies and different institutional programmes have integrated STI and instilled the innovation culture within and across the departments.	1. Are STI integrated in departmental programs? 2. What are the constraints for STI incorporation? 3. Do departments have STI capabilities, structures or budgets? 4. Do Departments monitor policy coherence with other Departments? 5. Are there mechanisms for monitoring the incorporation of STI in policies?	1. Literature review; policy documents analysis; case studies and Survey 2. Survey 3. Survey 4. Survey 5. Survey
Inform DSI to formulate policy interventions that accelerate the realisation of the value of STI in public service and society in general	Develop Recommendations for the DSI and ASSAf	Findings: Literature review; policy documents analysis; case studies and Survey

The study focuses on the Departments listed in Table 1. A limited number of Departments was chosen due to resource limitation.

Table 1: List of Government Departments under Investigation

Government Departments	Government Departments
Agriculture, Land Reform and Rural Development	National Treasury
Basic Education	Public Works and Infrastructure
Health	Trade, Industry and Competition
Communications and Digital Technologies	Water and Sanitation
Cooperative Governance	Mineral Resources and Energy
Human Settlements	Social Development

2.1 PROPOSED RESEARCH STUDY METHODOLOGY

2.1.1 BASIC RESEARCH

The basic research aimed to enhance knowledge on the integration of STI into national and provincial government policies and planning frameworks. The research focused on:

- Desktop literature review of relevant policies and programmes from the relevant departments;
- Concept analysis of relevant policy documents;
- Case studies: nationally and internationally.

The intention of the case studies was to give guidance on how STI can be integrated into policies/programmes successfully. The first case study will investigate the performance of China in the 1980s. Before that period South Africa was performing better than China in terms of publications. After that however, China became the top country in the World. What were the underlying forces; can they be duplicated in South Africa. The second case study will identify how STI has been integrated successfully in local policies.

2.1.2 PRIMARY RESEARCH

The primary research aimed to:

- Identify the capabilities and constraints of departments in incorporating STI in their policies;
- Assess the linkages and potential implementation gaps between government departments and policies to ensure that there is policy coherence across;
- Identify the effectiveness of current mechanisms used by government departments to track and monitor the incorporation of STI in policies and planning;
- Provide concrete and practical recommendations to address the integration of STI in government department policies and work plans (activities, programmes etc. that affect and embrace STI), based on the findings;
- Provide recommendations on ways the DSI and ASSAf can monitor the uptake of STI-related activities by government departments, on an ongoing basis.

The **primary research** consisted of a structured survey in a form of a questionnaire and telephonic interviews of department representatives/officials (Appendix 3).

3 BASIC RESEARCH

3.1 LITERATURE REVIEW

3.1.1 THE IMPORTANCE OF RESEARCH, DEVELOPMENT AND INNOVATION

The role of S&T as an engine of development has been globally recognised (NEPAD OST, 2006; Chataway *et al*., 2009; NACETEM, 2010). Ilori (2002) points out that the application of S&T increases the efficiency of production systems and enhances industrial competitiveness. In fact, what gives a nation the competitive edge is the speed it can identify, utilise and diffuse new knowledge (Prusak, 1996). Romer (1990) states that the pervasiveness of research and innovation for economic growth has changed fundamentally the relevant understanding during the most recent thirty years.

It should be emphasised in this context that the East Asian Tigers (Hong Kong, Singapore, South Korea, and Taiwan) based their development on technology and innovation (Mathews *et al.,* 2000). Similarly, China, India and Brazil adopted such approaches (Mathews, 2009). A number of researchers show that R&D has played a key role for growth in the Asian miracle economies (Ang *et al.,* 2011).

Innovation can also make a difference in addressing urgent developmental challenges such as providing access to drinking water, eradicating neglected diseases or reducing hunger. The transfer, and when necessary, adaptation of technologies developed in developed countries can often contribute significantly to these goals (OECD, 2012). Examples of transformative technologies include the polio vaccine; the new seed varieties, which launched the Asian Green Revolution; anti-retroviral drugs that rendered HIV/AIDS a chronic and manageable disease; the M-PESA mobile payment platform and others (Kumar, 2014). OECD (2012, p12) states that "There is evidence that agricultural R&D has a greater impact on poverty reduction than most other public investments".

A multitude of studies exploring the gains from research and innovation identify substantial gains. In one of the bedrock papers in this field, Edwin Mansfield (1991) estimated that academic research delivered an annual rate of return of 28%. The figure has been widely quoted ever since. Recent investigations focused on research in the medical field. Murphy *et al* (2013) concluded that the likely returns from medical research are so extraordinarily high that the pay-off from any plausible 'portfolio' of investments in research would be enormous. Coe *et al*., (1995), of the Centre for Economic Policy Research, examined the links between R&D and productivity gains in OECD countries from 1970 to 1990. They concluded that an increase in business R&D increases total factor productivity (TFP - the output for a given input of labour and capital) with a response which was related to the total 'stock' of R&D from domestic and foreign sources. The rate of return on industrial R&D was over 100% at the national level.

It should be noted that R&D provides high rates of return in all scientific disciplines (e.g. academic research; medical research; business research etcetera).

The importance of RDI is not more evident than in the recent (2008) international recession - crisis. Countries despite the crisis, set R&D expenditure targets and utilised R&D expenditure as stimulus for economic recovery. For example, the European Union (EU) has urged member countries to increase investment in R&D and consider ways to increase private sector R&D investments. Similarly, in the USA, the Government, as part of the *American Reinvestment and Recovery Act* of 2009, has increased its spending on R&D related to climate change by US$ 26.1 billion and to energy by US$ 6.36 billion.

In addition, US$ 10 billion was allocated to US National Institutes of Health (NIH) for biomedical research and an additional US$ 2.3 billion was allocated for research funded by the National Science Foundation (OECD, 2009).

From a theoretical perspective, governments' interference with the market has been justified as a remedy for the existence of public goods, of externalities, increasing returns to scale and informational asymmetries. It is believed that consumption of public goods by one person does not diminish their availability to others. This implies that their price to consumers should be zero, since their consumption by one party is at no cost to others. In many cases, though, the production of public goods is costly, which creates contradiction. Private firms are not supposed to charge for the public goods, in which case they will not produce them, or if they are able to charge for them, there will be too little of them consumed. A free market alone will not produce an optimal result, so the government must intervene to do so.

The above context includes deficiencies when market incentives are not sufficiently strong to drive the necessary innovation. Where markets are not strong, additional approaches are required to bridge the gap. This is the case in the development of new treatments for neglected tropical diseases. A similar situation occurs with any technology needed to address the needs of poor populations. When the primary incentives for innovation are market-based, the inability-to-pay often translates into an inability-to-access. There is a need for a proactive policy agenda that focuses innovation on the needs of the poor and makes the products of that innovation more readily available to those who may need them.

An externality occurs when production or consumption by one firm or individual influences the well-being of another and the effect is not valued on any market. There is a tendency for overproduction of negative externalities, such as pollution, and a likelihood of underproduction of positive externalities (such as knowledge).

Government intervention related to returns to scale refer to the investments that need to be made at the outset for the establishment of a new industry, industrial sector or facility for which the costs may be prohibitive from the perspective of one firm or involve high-risk long-term return potential. Research also falls under this category.

Informational asymmetries may arise in a number of circumstances. Debt- and equity-finance create informational asymmetries between shareholders and managers and between lenders and borrowers. For example, because of the difficulty to monitor intangible investments (e.g. R&D intensive companies), such investments may not be able to secure debt finance. Government should find a way to accommodate finance if these types of investments are required.

Finally, the advent of competitiveness in a global economy sets the background for a different and additional role for governments. Governments in this context have the responsibility to promote and protect the interests of their industries. Game theory provides a natural way to think about the interactions of nations. As governments from competing countries promote their interests through the introduction of certain policy instruments, other countries have to follow suit in order to maintain their relative competitiveness. Issues of citing R&D facilities by multinationals, of brain drain, promotion of cultural values and of adoption of particular methods and techniques can be considered in this context.

The issue of R&D is probably the only one that qualifies for government intervention across all counts. Efforts to improve the operations of research, development and innovation in a particular domain requires the existence of an appropriate model. The concept of the NSI has been accepted by a number of countries including South Africa. An NSI has been defined as "... the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies." (Freeman, 1987)

OECD (1997) argues that "For policy-makers, an understanding of the national innovation system can help identify leverage points for enhancing innovative performance and overall competitiveness. It can assist in pinpointing mismatches within the system, both among institutions and in relation to government policies, which can thwart technology development and innovation. Policies which seek to improve networking among the actors and institutions in the system and which aim at enhancing the innovative capacity of firms, particularly their ability to identify and absorb technologies, are most valuable in this context" (p 7).

The concept of the national innovation systems that focuses on the flows of technology and information among people, enterprises and institutions is key to the innovative process. However, this does not negate the traditional idea that focused on inputs (such as expenditures on research and development and the number of research personnel) and outputs (such as patents). It is apparent that innovation systems with small or subcritical size will firstly require to put attention on appropriate growth and then on the issues of flows.

3.1.2 Coherence and Policy Failures

Policy coherence is about acknowledging the interdependence and interrelations between different policies. Innovation and policy studies theory suggest that a number of policies in any country, which can be considered as a system, would affect or be affected by other policies in trying to achieve their goals. More specifically, two dimensions of complexity are distinguished in STI policy: the policy-mix and multi-level governance. The policy-mix concept denotes the diversity of innovation instruments from different domains that can be applied, while multi-level governance focuses on the levels in which policies are designed and administered. STI policies administered at supranational, national, regional or even local levels and instruments belonging to STI but also to other domains such as health, industrial or energy, influence the orientation of regions towards innovation. This calls for better governance of the policies where policy makers have to ensure that in addressing the issues to achieve government objectives there is alignment and harmonisation. Coherence is particularly challenging to assess in pluralistic systems.

The most often failures appearing in the relevant literature (Magro *et al*., 2014) are:

- Avoidance or minimisation of duplication and overlap;
- Avoidance of policy inconsistencies;
- Minimisation of conflict (bureaucratic and political);
- Quest for coherence and cohesion and agreement in ordering of priorities; and
- Promotion of a comprehensive perspective against the advocacy of particularistic (i.e. sectoral) perspectives.

The relevant literature identifies a number of coordination mechanisms (i.e. instruments, structures or agents) that could fill the coordination modes (Bonvillian, 2013; Lindner, 2012; OECD, 2010). The creation of centralised agencies, coordination councils, super-ministries, leadership at the cabinet level, intermediary agencies, collaboration programmes, lead organisations, standards setting bodies, etc. can be regarded as examples of such efforts. Despite the variety of instruments there is a range of reasons for the persistence of the 'silos' that exist in most governments:

Specialisation: Bouckaert *et al*., (2010) argued that reform in the public sector was moving back and forth from specialisation to coordination.

Performance management: Setting targets on an organisation, it will tend to ignore collective goals.

Protecting the turf: Organisations defend their budgets, personnel and policies. They fear that coordination with other organisations will endanger their 'turf'.

Information as power: Many organisations would be concerned to share information with 'competitors'.

Peters (2018) argues that "Despite numerous attempts to make public organisations work together more effectively, there is still no standardised method for approaching coordination issues, and much of the success or failure of attempts to coordinate appears to depend upon context."

The OECD has identified different types of policy incoherence. Policy coherence for development, policy coherence for food security and policy coherence for sustainable development.

Policy coherence for development is an approach and policy tool for integrating the economic, social, environmental and governance dimensions of development at all stages of domestic and international policy making.

Food security is a major development challenge and to address this, the EU amongst others has effectively put global food security high amongst its development priorities. However, while the EU is the world's major development actor on food security, other actors argue that other policies are still contested as harmful to global food security and agricultural development.

Policy coherence for sustainable development in achieving the 2030 Agenda is probably the issue that has attracted most attention at OECD. Addressing interactions between economic, social and environmental goals in a balanced manner, while avoiding negative effects on the wellbeing of people here and now, elsewhere and later, has been recognised by many countries as one of the most difficult challenges to implementing the Sustainable Development Goals (SDGs).

OECD recommendations for any kind of coherence include vision and leadership; policy interactions and monitoring and reporting.

Another OECD mechanism has been, to confront or evaluate national policies in the fields of science, technology and innovation. This mechanism has been widely and successfully used in economic policy, but also in science and technology policy.

3.1.3 Organisational Structures of Research Systems

The research systems can be distinguished into the pluralist, the coordinated and the centralist systems (Brickman, 1979 **;** Ronayne, 1984).

In a pluralist system, government departments receive an appropriation and decide how much money to spend on research and on its various elements. There are shortcomings and advantages of such a system. In this system, the various departments would have to develop expertise and understanding in research management and policy. The onus is upon the departments to ensure that their requirements for research and development are met. There is no supervision or coordination, and the science policy is the sum total of the activities of the various departments.

To do so they must be able to make informed decisions about the science and technology services they need and how these are to be provided. They must acquire or retain scientific and technological expertise if they are to have the capabilities of an intelligent customer and the ability to enable the planning, specification, acquisition, implementation and use of science and technology to achieve objectives at best value for money. In a small scientific system, it is expected that there will be scarcity of such skills and hence, a number of centres will not operate appropriately or at all.

On the other hand, under a properly operating system research managers and administrators will be closer to their researchers and the needs of their 'clients' and they will be better equipped to address the various concerns. Similarly, researchers will have access to multiple sources of funds (addressing bias of peer review in scientifically small countries) and research issues could be addressed from multiple sides (with better chances of resolution).

It is apparent that the major challenge is to establish and make operational the various science units nationally**.** Lord Rothschild (1971) recommended the establishment of the post of Chief Scientist within government departments. Organisations with a Chief Scientist sometimes consist of more than 50 professionals which can make it challenging in small scientific countries, which also suffer financially.

Probably the most important deficiency of a pluralist system is the lack of a champion promoting the well-being of S&T in government. Consequently, when government departments are faced with budgetary cuts, they limit their expenditure on S&T, which has long term effects. Under these conditions governments set up advisory bodies which monitor the research system and advise the government.

In a coordinated system, the various government departments initiate and manage their own research activities as in the pluralist system, but they set up mechanisms in order to be aware of each other's activities and be able to integrate them.

The mechanism most often used for collaboration is the establishment of a coordinating, advisory body. This arrangement is potentially unstable, however, as it depends on the goodwill of the participants, it may create competition between members regarding who is going to receive the credit; and participants have to be careful not to infringe upon the autonomy of each other.

Stronger integration is provided when the government's research efforts are coordinated by a ministry. Under this approach, the minister responsible for science policy acts with the concurrence of all ministers with science and technology responsibilities.

An inter-ministerial committee finalises the decisions usually prepared in the ministry for S&T policy. The ministry prepares background papers, formulates strategies and assessments, and provides budgetary analysis.

The Senate Special Committee on Science Policy in Canada considered this type of co-ordination as the most desirable one. (SSC, 1977). Their criteria were:

- To maintain a diffused government organisation for science and technology;
- The need for a stronger and effective central machinery to complement the specific science policies developed by operating and supporting departments and agencies; and
- For the central machinery's mandate to include specific authority to review and approve the science budget within the broad lines determined by the Treasury."

Despite the conceptual appeal of the system, it seems to have limited durability. Ronayne (1984) reports "the efficiency of the coordinated system is now in question after a number of years' experience in many OECD countries". The coordinating body usually struggles to find an appropriate balance between its own responsibility and authority and those of the other government departments. Most often the coordinating body is marginalised or becomes a 'Noah's Ark', taking whatever responsibility the other departments allow.

The heart of the problem is that the coordinating body, because of the nature of the system, lacks the policy instruments to achieve its policy objectives. For example, the most powerful policy instrument in the field of science and technology is institutionalisation. Any suggested restructuring, however, is bound to face the resistance of those who benefited from the previous system.

In the centralist system, the majority of government scientific activities is administered by one government department. A number of approaches can be distinguished under this system. For example, all government scientific activities may be administered by one government department with its own funds; or, other departments concern themselves with short-term tactical research only; or the R&D system is placed within the framework of a national 5-year plan as it happens in India, France and other countries.

It is interesting to note that countries with relatively stable research and innovation infrastructure are becoming alert of the importance of closer collaboration and seek to introduce changes in their research systems.

The Endless Frontiers Act (S. 3832) proposed a major reorganisation of the National Science Foundation (NSF), creating a technology directorate that, within 4 years, would grow to more than four times the size of the entire agency's existing $8 billion budget. NSF has been the most important agency in the USA supporting all fields of fundamental science and engineering excluding medical sciences. The amalgamation would be renamed the National Science and Technology Foundation, and both the science and technology arms would be led by a deputy reporting to the NSF director (NSF now has a single deputy director; the slot has been unfilled since 2014.). This will permit investments linking basic research and innovation.

Similarly, in the United Kingdom (UK) the seven research councils were brought together under the UK Research and Innovation Council. Despite the changes in organisational structures, new policy instruments also appear internationally. Inter-agency programming, i.e. formal arrangements between agencies that result in joint action, is a new policy instruments to co-ordinate policy action at the level of implementing agencies. Under such initiatives, the funding agencies fund research projects that have to be submitted by university-industry consortia.

3.1.4 THE SA NATIONAL SYSTEM OF INNOVATION

In South Africa, a broad and inclusive conception of the framework of the system of innovation has been featured in all policy documents since 1995, beginning with the Green Paper on Science and Technology. The main benefit of the approach is that it recognises the importance not only of multiple actors in the innovation process, each performing according to their respective mandates, but also of strong or weak relationships among these actors. Figure 1 shows the main funders and research performers in the SA National System of Innovation.

The country's Constitution sets the way for science and technology policy in the country. It is stipulated in the Constitution (RSA, 1996) that the policies of the government-of–the day should be executed in a cooperative manner, because in the Republic of South Africa, government is constituted as national, provincial and local spheres that are distinctive, interdependent and interrelated. The Constitution further stipulates that all spheres of government and all organs of state within each sphere must exercise their powers and perform their functions in a manner that does not encroach on the geographical, functional or institutional integrity of government in another sphere, and co-operate with one another in a mutual trust and good faith.

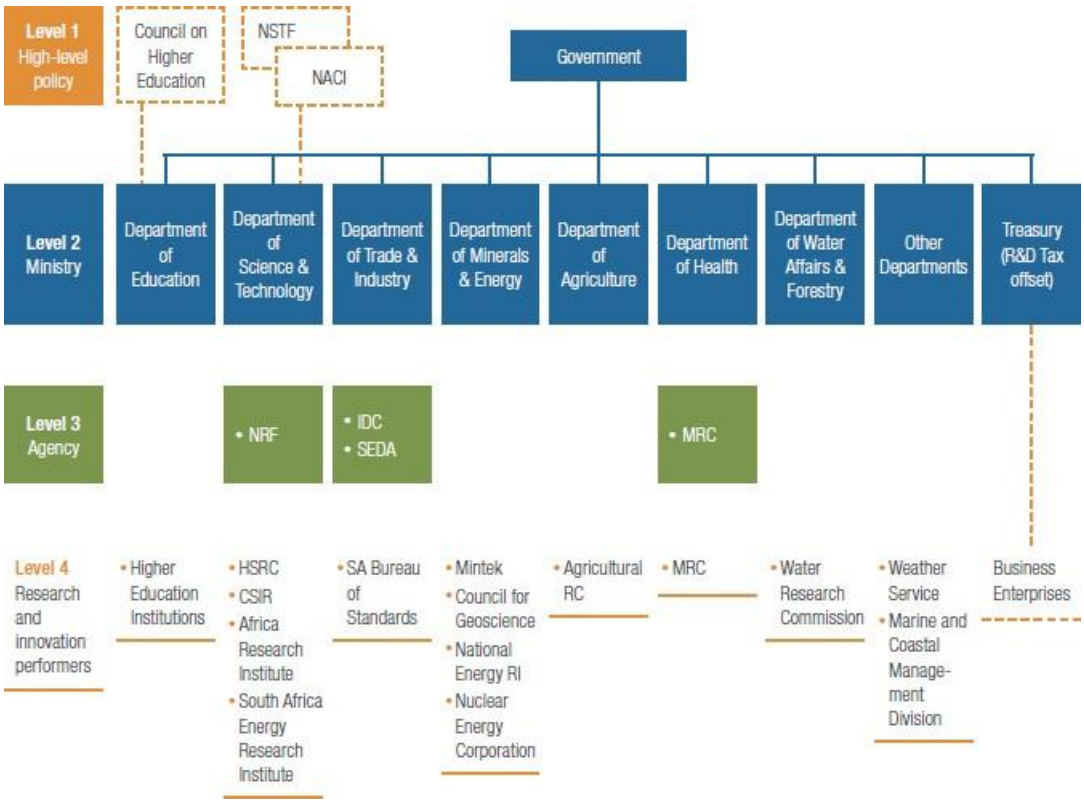

Figure 1: SA Organisational Structure; funders and research performers

Source: Ministerial Review Committee 2019

In 2007 the DST published the Ten-Year innovation plan (TYIP) which charted the course for the enhancement of innovation in the country, contributing to sustained economic growth on the basis of pillars of a properly functional knowledge economy - human capital development, R&D and knowledge infrastructure. The TYIP identified 'Grand challenges' that needed to be addressed.

More recently the National Development Plan (NDP, 2011) states "South Africa needs to sharpen its innovative edge and continue contributing to global scientific and technological advancement. This requires greater investment in research and development, better use of existing resources, and more nimble institutions that facilitate innovation and enhanced cooperation between public science and technology institutions and the private sector" (p23).

The first Ministerial Review Committee on the Science, Technology and Innovation (STI) Landscape (DST, 2012) identified a number of weaknesses in the system among which were limited horizontal and vertical coherence, poor support for innovation activities other than formal research and development, and inadequate oversight or analysis.

A number of recommendations were related to new structures (e.g. the National Council on Research and Innovation (NCRI) and the Office for Research and Innovation Policy (ORIP)) which apparently were not accepted by the government.

To manage and address the challenges of policy coherence and coordination, the South African Government established the Ministerial clusters system. These were established to foster an integrated approach to governance that is aimed at improving government planning, decision making and service delivery. The main functions of the clusters were to ensure alignment of government wide priorities; facilitate and monitor the implementation of priority programmes; and provide a consultative platform on cross-cutting priorities and matters being taken to Cabinet.

The intentions of the Intergovernmental Relations Framework (Act 13 of 2005) were:

- to establish a framework for the national government, provincial governments and local governments to promote and facilitate intergovernmental relations;
- to provide for mechanisms and procedures to facilitate the settlement of intergovernmental disputes; and
- to provide for matters connected therewith." (Government Gazette, No 27898).

The Act furthermore, refers to President's Coordinating Council and National Intergovernmental Forums among others. The Council is a consultative forum for the President, to raise matters of national interest with provincial governments and organised local government and to hear their views on those matters; to consult with provincial governments on the implementation of national policy and legislation in provinces and municipalities and on the coordination and alignment of priorities, objectives and strategies across national, provincial and local governments.

More recently, the Department of Science and Innovation (DSI, 2019) in its White Paper, is committed to several policy shifts. These are:

- Increasing the focus on inclusivity, transformation and linkages in the NSI
- Enhancing the innovation culture in society and government
- Improving policy coherence and budget coordination across government
- Developing a more enabling environment for innovation
- Developing local innovation systems

- Supporting social and grassroots innovation
- Expanding the research system
- Developing human capabilities
- Accelerating the implementation of the pan-African STI agenda
- Increasing investment in the NSI" (p iii)

Furthermore, the White Paper aims to transform the system into a coordinating one, through the establishment of the Inter-ministerial Committee on STI, to be chaired by the Minister of Science and Innovation. The committee will aim to ensure that STI is integrated into the planning of relevant government departments and STI programmes (DSI, 2019).

The Higher Education Science, Technology and Innovation Infrastructure Landscape Ministerial Review also recognised the importance of coherence for science, technology and innovation policy and it made a number of recommendations. While the government has not approved the report yet, it appears that the recommendations were structural (like the first Ministerial Committee's recommendations) and operational. The later include suggestions for the establishment of incentives for the collaboration of researchers and institutions.

3.2 Analysis of Policy Documents of Selected Government Departments

Content analysis was conducted on policy documents of government departments shown in Table 1. (Section 2: Introduction). The documents selected for the study are policies and strategies and do not include legislation documents such as Acts and Bills. Table 2 outlines a summary of **32 policies** used in content analysis. The number was limited as some of the Departments do not have their policies readily available online (from their website or a google search) and so they could not be accessed for the study.

Table 2: Government Departments – Summary List of Policies

Government department	Policy
Agriculture, Land Reform and Rural Development	• Poultry Master plan 2010 • Agricultural Land Holdings Policy Framework (2013) • Department of Agriculture, Forestry and Fisheries (DAFF) Agro-processing Strategy (2012) • Rural Development Framework (2013) • The Integrated Sustainable Rural Development Strategy (2000)
Basic Education	• White Paper on Education and Training (1995) • The National Policy Framework for Teacher Education and Development in South Africa (2007) • Policy Document on Adult Basic Education and Training (2003) • Plan of Action Improving access to free and quality basic education for all (2003)

Government department	Policy
	• The National Policy for an equitable Provision of an Enabling School Physical Teaching and Learning Environment (2010) • White Paper on e-Education (2004)
Health	• White Paper for the Transformation of Health System in South Africa (1997) • National eHealth Strategy, South Africa 2012/13-2016/17 • The National Health Promotion Policy and Strategy 2015 - 2019 • National Policy Framework and Strategy on Palliative Care 2017 – 2022 • National Digital Health Strategy for South Africa 2019 - 2024 • National Health Research Strategy: Research Priorities for South Africa 2021-2024
Communications and Digital Technologies	• National Integrated Information and Communications Technology (ICT) Policy White Paper (2016)
Cooperative Governance	• Policy process on the system of Provincial & Local Government (2007) • The White Paper on Municipal Service Partnerships (2004)
Human Settlements	• Department of Housing White Paper a New Housing Policy and Strategy for South Africa (1994) • Towards a Policy Foundation for the Development of Human Settlements Legislation (2016)
National Treasury	• Economic Transformation, Inclusive Growth, and Competitiveness: Towards an Economic Strategy for South Africa (2019)
Public Works and Infrastructure	• White Paper Public Works towards 21st century (1997) • Government-wide immovable asset management policy (2005)
Water and Sanitation	• The Strategic Framework for Water Services (2003) • White Paper on Basic Household Sanitation (2001) • National Water Policy Review (NWPR) Approved Water Policy Positions (2014)
Mineral Resources and Energy	• White Paper Minerals and Mining Policy for South Africa (1998) • A Beneficiation Strategy for the Minerals Industry of South Africa (2011)
Social Development	• Framework for Social Welfare Services (2013)
Trade, Industry and Competition	• Re-imagined Industrial Strategy (2019)

Content analysis is a research tool used to determine the presence of certain, themes or concepts within some given document. Using content analysis, researchers can quantify and analyse the presence, meanings and relationships of such certain themes, or concepts.

There are two general types of content analysis: conceptual analysis and relational analysis. Conceptual analysis determines the existence and frequency of concepts in a text. Relational analysis develops the conceptual analysis further by examining the relationships among concepts in a text (Hsieh, 2005).

The use of concepts such as: research and development; science; technology; innovation; fourth industrial revolution; smart; and DST or DSI (Table 3 and Appendix 1) were examined. The expectation is that the terms DSI will not appear often as the DST changed its name during 2019. However, future investigations should identify the use of the term DSI more often.

It should be mentioned that differences in policy documents from one Department to another are expected to manifest in big differences in the use of the concepts of technology. Innovation on the other hand was not a widespread concept, until recently and was therefore not expected to appear in high frequencies.

These specific concepts were used in the keywords search in order to establish if the selected government departments used them in their policies. Since the overall objective of the study is to determine the integration and adaption of science, technology and innovation in policies and planning, these concepts and the likes, were used in the keywords search.

Department of Agriculture, Land Reform and Rural Development

None of the selected policies of the DLRRD reflected the keyword "research and development". There is however specific reference to "science" and "technology" and the "Department of Science and Technology" by the Department of Agriculture, Forestry and Fisheries (DAFF) Agro-processing Strategy (2012). There is specific mention of the entities managed by the DSI such as the Council of Scientific and Industrial Research (CSIR) and Agricultural Research Council (ARC). There is no direct mention of the keyword "innovation" in the selected policies. The selected policies are relatively old, the lasted being the Agricultural Land Holdings Policy Framework adopted in 2013. This has an impact on the newly adopted words in policies such an "innovation", "smart" and "Fourth Industrial Revolution".

Department of Basic Education

The mention of the concept "research and development" is only in the White Paper on Education and Training (1995); Policy Document on Adult Basic Education and Training (2003); and White Paper on e-Education (2004); and it is in the context of doing the written research and developing the work further, it is not in the context of performing the technological activities to produce products or services. The role of science and technology in the sector is well documented in the selected policies and there is a definitive recognition for the role of the DST. The concept of "innovation" is used to some extent in order to address the challenges in the sector. No use of the concepts "4th Industrial Revolution" and "smart".

Department of Health

The concept "research and development" is barely used in the selected policies, only the National eHealth Strategy, South Africa 2012/13-2016/17 pointed out the need to 'strengthen research and development' but there is no further elaboration in the document. The concept "science" is not prominently used however the concepts "technology" and "innovation" are used extensively in almost all the selected policies. The concept "fourth industrial revolution" is used in the National Digital Health Strategy for South Africa 2019 – 2024. Policies that have been adopted in recent years tend to have the newly adopted concepts of "innovation", "smart" and "fourth industrial revolution". There is a definite recognition of the role of the DST/DSI by the Department of Health, there is mention of the DST in three of the selected policies.

Department of Communications and Digital Technologies

For this particular Department, only one policy was selected: National Integrated Information and Communications Technology (ICT) Policy because this recent policy showed a direct significant use of the concepts "research and development", "science", "technology", "innovation", "smart" and acknowledges the role of the "Department of Science and Technology". The policy, however, does not mention the concept "fourth industrial revolution". The policy refers to the DST's ICT Research, Development and Innovation Roadmap and the DST's Meraka Institute.

Department of Cooperative Governance

The concepts "research and development", "science", "Fourth Industrial Revolution", "smart" and "Department of Science and Technology" do not appear in both policies. There is minimal reference to concepts "technology" and "innovation".

Department of Human Settlements

The White Paper makes little or no reference to concepts "science", "fourth industrial revolution", "smart" and "Department of Science and Technology". The concept "research and development" is mentioned once in the White Paper. The concepts "technology" is mentioned a few times and there is recognition of the role of the DSI' s Council of Scientific and Industrial Research (CSIR). The concept "innovation" is mentioned significantly in the policy considering the policy was adopted in 1994. The Towards a Policy Foundation for the Development of Human Settlements Legislation (2016) only mentions the concept "technologies" and no other concepts.

National Treasury

For this particular Department, only one document was selected: Economic Transformation, Inclusive Growth, and Competitiveness: Towards an Economic Strategy for South Africa (2019). It is not the official policy of the Department, however; it outlines the position of the Department. The document only mentions once the concepts "research and development", "science", "smart" and "Department of Science and Technology". The role of the DST is clearly articulated in the document. The concepts relating to "technology" are used extensively.

Department of Public Works and Infrastructure

The White Paper Public Works towards 21st century does not reflect any of the keywords searches however the White Paper Public Works towards 21st century significantly mentions the concepts "technology" and "innovation".

Department of Water and Sanitation

The concepts "research and development" and "science" are mentioned once in the Strategic Framework for Water Services. The concepts related to "technology" are mentioned significantly in the same policy. The concepts "innovation", "fourth industrial revolution", "smart" and "Department of Science and Technology" are not mentioned in all three policies.

Department of Mineral Resources and Energy

Both policies mention most of the concepts searched to a large extent. The Minerals and Mining Policy for South Africa White Paper mentions extensively the concepts "research and development",

"science" and "technology". The concept "innovative" is mentioned twice while the concepts "fourth industrial revolution", "smart" and "Department of Science and Technology" are not mentioned in the White Paper. The Beneficiation Strategy for the Minerals Industry of South Africa explicitly acknowledges the role of the DST.

Department of Social Development

For this particular Department, only one policy was selected: Framework for Social Welfare Services (2013). The Framework only mentions the concepts relating to "science" and "technology". None of the other concepts are mentioned in the framework.

Department of Trade, Industry and Competition

For this particular Department, only one strategy was selected: Re-imagined Industrial Strategy (2019). This is the only strategy that mentions all the concepts being searched. The concepts "science" and "technology", "innovation" "Fourth Industrial Revolution" and "smart" are mentioned to a large extent. The concept "research and development" is mentioned twice. The role of the DST is explicitly articulated in the strategy.

In summary, the name of DST/DSI has its highest frequency in the Department of Agriculture, Land Reform and Rural Development (4) and the Department of Communications and Digital Technologies (3). Most of the Departments do not mention DSI at all.

The concept of innovation appears more often in the Department of Communications and Digital Technologies (103). Interesting enough the highest frequency of the concept of technologies (132) appears also in the same department. The Department of Trade and Industry and competition has the second highest combination of terms technology and innovation (25-17). Further analysis of the Departments is shown in Appendix 2.

Table 3: Summary of keywords identified in selected government departments' policies

Government Department	Selected Policies and Strategies	Number of keywords searches in selected policies/strategies						
		Research and development	**Science / scientists / scientific / scientifically**	**Technology / technologies / technological / technologically**	**Innovation / innovated / innovative / Innovators**	**Fourth / 4th industrial revolution**	**Smart**	**DST/ Department of Science and Technology / DSI/ Department of Science and Innovation**
Agriculture, Land Reform and Rural Development	Poultry Master Plan 2010	0	0	0	0	0	0	0
	Agricultural Land Holdings Policy Framework (2013)	0	0	2	1	0	0	0
	Department of Agriculture, Forestry and Fisheries (DAFF) Agro-processing Strategy (2012)	0	6	21	0	0	0	4
	Rural Development Framework (2013)	0	0	3	3	0	0	0
	The Integrated Sustainable Rural Development Strategy (2000)	0	0	2	4	0	0	0
Basic Education	White Paper on Education and Training (1995)	6	29	14	4	0	0	0
	The National Policy Framework for Teacher Education and Development in South Africa (2007)	0	0	0	0	0	0	0

	Policy Document on Adult Basic Education and Training (2003)	1	9	5	3	0	0	0
	Plan of Action Improving access to free and quality basic education for all (2003)	0	2	1	0	0	0	0
	The National Policy for an equitable Provision of an Enabling School Physical Teaching and Learning Environment (2010)	0	0	0	0	0	0	0
	White Paper on e-Education (2004)	3	3	74	9	0	0	1
Department of Health	White Paper for the Transformation of Health System in South Africa (1997)	0	0	3	0	0	0	0
	National eHealth Strategy, South Africa 2012/13-2016/17	1	0	30	5	0	2	0
	The National Health Promotion Policy and Strategy 2015 – 2019	0	0	1	3	0	0	0
	National Policy Framework and Strategy on Palliative Care 2017 – 2022	0	7	4	1	0	1	0
	National Digital Health Strategy for South Africa 2019 – 2024	0	6	30	26	4	1	2
	National Health Research Strategy: Research	0	6	6	13	0	0	1

	Priorities for South Africa 2021-2024							
Communications and Digital Technologies	National Integrated Information and Communications Technology (ICT) Policy White Paper (2016)	9	7	132	103	0	4	3
Cooperative Governance	The White Paper on Municipal Service Partnerships (2004)	0	0	3	6	0	0	0
	Policy process on the system of Provincial & Local Government (2007)	0	0	1	1	0	0	0
Human Settlements	Department of Housing White Paper a New Housing Policy and Strategy for South Africa (1994)	1	0	3	9	0	0	0
	Towards a Policy Foundation for the Development of Human Settlements Legislation (2016)	0	0	3	0	0	0	0
National Treasury	Economic Transformation, Inclusive Growth, and Competitiveness: Towards an Economic Strategy for South Africa (2019)	1	1	49	13	0	1	1
Public Works and Infrastructure	White Paper Public Works towards 21st century (1997)	0	0	8	7	0	0	0

	Government-wide immovable asset management policy (2005)	0	0	0	0	0	0	0
Water and Sanitation	The Strategic Framework for Water Services (2003)	1	1	14	0	0	0	0
	White Paper on Basic Household Sanitation (2001)	0	0	1	0	0	0	0
	National Water Policy Review (NWPR) Approved Water Policy Positions (2014)	0	0	0	1	0	0	0
Mineral Resources and Energy	White Paper Minerals and Mining Policy for South Africa (1998)	17	16	26	2	0	0	0
	A Beneficiation Strategy for the Minerals Industry of South Africa (2011)	7	4	30	5	0	0	2
Social Development	Framework for Social Welfare Services (2013	0	4	7	0	0	0	0
Trade, Industry and Competition	Re-imagined Industrial Strategy (2019)	2	5	25	17	8	12	2

3.3 CASE STUDIES: CHINA AND SOUTH AFRICA

3.3.1 CASE STUDY 1: THE TAKE-OFF OF SCIENCE AND TECHNOLOGY IN CHINA

3.3.1.1. INTRODUCTION

China and a number of other East Asian countries are known for their successes to grow their economies based on science and technology. China is of particular interest because of science's prosecution during the Cultural Revolution. Moreover, China is more impressive even than such well-known tech success stories as South Korea and Singapore. As China moved from the world's factory to one of its tech powers, the Chinese government pumped money, sent its students around the world, developed a series of master plans, boosted patenting, and took a progressive stance towards changing the whole science, technology and innovation system.

This case study describes the success of China and the underlying forces.

3.3.1.2. THE LEAP FORWARD AND THE CULTURAL REVOLUTION

Table 44 shows that China had very few publications during the end of the 60s compared to South Africa. However, it bypassed South Africa in the mid-1980s. Currently China competes with the United States for the top position in the scales of research publications.

Table 4: Number of Publications - China and South Africa from 1966-2010

Year	South Africa	China
1966	46	2
1970	130	1
1974	2 059	82
1978	2 941	217
1982	3 439	2 839
1986	4 643	4 687
1990	4 090	8 196
1994	4 870	13 541
1998	5 172	27 910
2002	5 656	53 696
2006	7 401	129 099
2010	11 204	218 693

Source: Web of Science

It should be emphasised that during political radical periods such as the Great Leap Forward (1958–60) and the Cultural Revolution (1966–76) science and technology suffered together with the economy. The Leap Forward campaign aimed to reconstruct the country from an agrarian economy into a communist society through the formation of people's communes. The experiment however failed, and it was characterised as an expensive disaster which left millions of people starved.

During the Cultural Revolution (1966-1976) schools and Universities were closed and the traditional entrance exams cancelled. Intellectuals were prosecuted and a number of scholars and scientists were killed or committed suicide. All inventions and innovations belonged to the government and as a

result, property rights in patents were completely abolished in 1963. The lack of research outputs (Table 4) agrees with the historical events during that time.

3.3.1.3. SCIENCE *RENAISSANCE*

In 1970, China only had 47 000 undergraduate students and essentially no graduate students (Freeman et al, 2015). Recovering from the Cultural Revolution in the 1970s and 1980s saw enrolments in four-year programs increasing to 2.1 million in 1990 while enrolments in all programs, including more vocationally oriented less than bachelor's programs, reaching 3.8 million. Still, China's share of world enrolments of 5.6% fell short of its one-fifth (31%) of the world's 1990 population.

In the early 1970s, Premier Zhou Enlai and his associate Deng Xiaoping attempted to improve the working conditions of scientists and to promote research. At the January 1975 session of the Fourth national People's Congress, Zhou Enlai defined China's goal for the rest of the century as the 4 Modernisations, that is, of agriculture, industry, science and technology and national defence.

Positions of authority in research institutes and universities were replaced with professionally qualified scientists and intellectuals around 1977. Academic and research institutions that had been closed were reopened, and scientists were summoned back to their laboratories from manual labour in the countryside. Scientific journals resumed publication, often carrying reports of research completed before everything stopped in the summer of 1966. The media devoted much attention to the value of science and the admirable qualities of scientists. It denounced the repressive and anti-intellectual policies of the disposed Gang of Four, who were blamed for the failure of China's science and technology to match advanced international levels. The news media now characterised scientists and technicians as part of society's "productive forces" and as "workers" rather than as potential counter revolutionaries or bourgeois experts divorced from the masses. Considerable publicity went to the admission or readmission of scientists.

Deng Xiaoping became the new leader in China in 1978. The anti-intellectual policies of the Cultural Revolution were reversed and such top leaders as Xiaoping encouraged the development of science. It should be emphasised that China's leaders in the 1980s remained, like their predecessors over the past 100 years, interested in science primarily as a means for national strength and economic growth. The policy makers' goal was the creation of a vigorous scientific and technical establishment that operated at the level of developed countries while contributing in a fairly direct way to agriculture, industry, and defence.

Government-led science planning and initiatives have remained a priority of Beijing during the post-Mao Zedong reform era. At the 1978 Conference on Science and Technology, Deng Xiaoping reaffirmed China's major commitment to scientific development, arguing that in his "four modernisations" program, the modernisation of science and technology was key to the three other modernisations, those of agriculture, industry, and national defence. By the early 1980s, China had settled on a policy orientation of having science and technology "serve economic development." National funding programs for research took shape in the 1980s as part of S&T plans nested in five-year national economic plans, designed to shuttle money to scientific projects deemed critical to economic and military needs. One legacy of this state-centric approach to science has meant that tasks with direct economic and military benefit are favoured in China and that applied research is preferred over curiosity-driven discoveries and basic research.

3.3.1.4. THE THEORY OF PRODUCTIVE FORCES

The theory of productive forces found philosophical defence in G Kohen's (1978) book *Karl Marx's Theory of History: A Defence*. According to this view, technical change can beget social change; in other words, changes in the means and intensity of production causes changes in the relations of production i.e., in people's ideology and culture, their interactions with one another, and their social relationship to the wider world.

In this view, actual socialism, being based on social ownership and a wide distribution of an abundant surplus product, cannot come to pass until that society's ability to produce wealth is built up enough to satisfy its whole population and to support socialist production methods. Using this theory as a basis for their practical programmes meant that communist theoreticians and leaders in most socialist states, while paying lip service to the primacy of ideological change in individuals to sustain a communist society, actually put productive forces first and ideological change second.

The March 1978 National Science Conference in Beijing was a milestone in science policy. The conference, called by the party's Central Committee, was attended by many of China's top leaders, as well as by 6,000 scientists and science administrators. Its main purpose was to announce publicly the government and party policy of encouragement and support of science and technology. Science and technology were assigned a key role in China's "New Long March" toward the creation of a modern socialist society by the year 2000. A major speech by the then-Vice Premier Deng Xiaoping reiterated the concept of science as a productive force and scientists as workers, an ideological formulation intended to remove the grounds for the political victimisation of scientists.

Deng Xiaoping set science and technology in the heart of the four modernisations, amongst others. He said "The crux of the four modernisations is the mastery of modern science and technology. Without the high-speed development of science and technology, it is impossible to develop the national economy at a high speed."

The draft Eight-Year Plan for the Development of Science and Technology, discussed at the 1978 National Science Conference, called for a rapid increase in the number of research workers, for catching up to advanced international levels by the mid-1980s, and for substantial work in such fields as lasers, space flight and high energy physics (Wikipedia 2021).

In February of 1981, a report of the State Science and Technology Commission reversed the overly ambitious 1978 eight-year scientific development plan and called for renewed emphasis on the application of science to practical problems and on training more scientists and engineers.

Between 1981 and 1985, a number of new journals discussed China's scientific system and suggested improvements, while national and local administrators sponsored a wide range of experimental reforms and reorganisations of research bodies. The extensive discussion and experimentation culminated in a March 1985 decision of the party Central Committee calling for thorough reform of China's science system.

3.3.1.5. INNOVATION SYSTEM

The origin of the Chinese innovation system can be traced back to the mid-1980s when reform of the science and technology system was included in the broader agenda of economic reforms. S&T industrial parks, university science parks and technology business incubators were started under the

Torch programme as new infrastructures to encourage industry-science relationships, and spin-offs from public research organisations started to fill the gap. The maturing of this embryonic system was accelerated in the 1990s through the combined effect of continued international openings (e.g. accession to the World Trade Organization in 2001), improvement of corporate governance and key framework conditions for innovation (e.g. protection of intellectual property rights, as well as further reforms of the university and public research sectors). In 1990, China spent negligible amounts on research and development. Two decades later, China's research spending surpassed that of all of the major R&D spending countries save for the US. While China spent less than the EU on R&D, the ratio of R&D expenditures/GDP in China jumped from 0.76 in 1999 to 1.84 in 2011, nearly the same ratio as the EU.

In May of 1995, the government of China convened the National Science and Technology Conference, the largest, highest level national conference on science, technology and education that China has held since 1978.

This five-day conference followed a decision made by the Chinese Communist Party Central Committee (CCPC) and the State Council, China's Cabinet. The 40-article document on this decision, called for carrying out the theory that "science and technology [are] the top productive force" in all fields.

On May 26 1995, China's government called together top national leaders, State Council ministers, military commanders, presidents of national corporations, leading scientists, and leaders of the provinces, regions, municipalities, and some major cities, filling the Great Hall of the People in Beijing for the opening session.

Both President Jiang Zemin and Prime Minister Li Peng addressed the conference. Jiang said that the meeting would have a crucial impact on China's overall economic and social development and called on "the whole nation to join the drive of 'invigorating China through science and education,' symbolising the country's decisive shift toward a science-oriented course of development."

Prime Minister Li Peng in his speech emphasised the urgent problem of quickly translating technological achievement into agricultural and industrial productivity. Both announced that China will triple its investment in R&D, from 0.5% of Gross Domestic Product in 1994, to 1.5% by 1999.

To ensure that China's scientific capacity grows, it was announced that not only funds dedicated to research and development would be tripled, but regional leaders will also be made responsible to 'personally administer' S&T. The government set a target of being the world leader by 2050, amongst others.

In 1999 the CCPCC decided on Strengthening Technological Innovation and developing High Technology and Realising its Industrialisation. The Government was led by the Premier Zhu Rongji who established the State Leading Group for Science, Technology and education to co-ordinate the national S&T and Innovation Policy (OECD, 2008).

3.3.1.6. The Patenting Era

In 1984, China enacted a patent law that contained basic provisions, such as the subject matter that patents can cover, how to file a patent, the examination process of patents, and how patents should be protected. Nevertheless, it lacked the essential features necessary to make it an effective and

successful system. For example, the 1984 Chinese patent law excluded patents for inventions involving food, beverages, and pharmaceuticals. This law was subsequently amended in 1992 to cover pharmaceutical patents, but it still offered little patent protection. The Chinese patent law was later amended in 2001 and again in 2008 in an attempt to make it more comprehensive and effective. However, mechanisms for preventing infringement were malfunctioning up to the current period.

The delay in accepting patenting in pharmaceuticals assisted China to develop its pharmaceuticals industry. A survey was conducted between Feb. 7 and Feb. 22 of 2019 among 54 members of the council located across the globe, including the subset of North America-based chief financial officers. A question was asked to the US CFO Council members about Chinese companies stealing IP from US companies. 21.7% answered yes in the past year; 4.3% yes in the past 2-5 years; 4.3% yes in the past 6-10 years; and 69.6% responded I don't know.

The issue of intellectual property revealed that the Chinese government will go to extremes to protect the trade and intellectual property rights of its own companies. This is in contrast to the South African intellectual property regime that facilitates the creation of obstacles to the local IP and facilitates the protection of foreign IP (Pouris *et al*., 2011).

3.3.1.7. The Lessons

The OECD (2008) summarising the Chinese efforts related to science, technology and innovation concluded the following:

The State Council providing co-ordination across ministries and policy domains at the highest level has proven effective.

The legacy of the planned economy still results in a lack of policy co-ordination for carrying out the responsibilities of the various ministries and institutions between the layers of government.

The important role of long-term planning seems useful and "very effective" at the current NIS governance.

Freeman *et al* (2015) provided evidence that "China's leap benefited greatly from the country's positive response to global opportunities to educate many of its best and brightest overseas and from the deep educational and research links it developed with the US. The findings suggest that global mobility of people and ideas allowed China to reach the scientific and technological frontier much faster and more efficiently" (p.1).

It is interesting to note that all announcements about science and technology were made by the country's President or Premiers and not by officials of the Department of Science and Technology. This is indicative of the importance of S&T that the President and Premiers wanted to endow to science and technology.

It is also important to note that the historians of science and technology in China wrote little if anything about implementation and coherence challenges. It is apparent that competing theories and approaches cease to exist the moment the Leader announces the plan. China despite the geographical and population size has been able to bring its S&T in the international frontier starting from a non-existing level.

It is emphasised that as a one-party state, the general Secretary of the Chinese Communist Party holds ultimate power and authority over state and government. The offices of President, General Secretary and Chairman of the Central Military Commission have been held simultaneously by one individual since 1993, granting the individual de jure and de facto power over the country.

In summary, China utilised to its benefit the international resources when available (e.g. educational infrastructure, public research and development etc.) and avoided compliance with international agreements and conventions when there were limited benefits for China (e.g. patent system).

Probably the most important factor for other countries is the fact that the importance of science and technology for economic growth and development was recognised at the highest levels of the communist party and there was even a theory developed around it (the 4 productive forces).

The role of science and technology as an engine of development has been globally recognised (NEPAD OST, 2006; NACETEM, 2010). However, a number of countries, particularly in Africa, are weak to implement their rhetoric.

An issue that may require further debate is whether governments in democratic countries can exhibit the same single-mindedness as the communist one-party China.

Probably the challenges for South Africa and other countries are:

How to co-ordinate Ministers and Government Departments to be coherent and committed in the field of science, technology and innovation.

Should political parties also be targeted in efforts to improve appreciation of S, T and I.

3.3.2 Case Study 2: Department of Human Settlements – Department of Science and Innovation Collaboration

The case study looks at the collaborative efforts between the DSI and the South African National Department of Human Settlements.

3.3.2.1. Missions of the two Departments and Collaborative Efforts

The mission of Department of Human Settlement (DHS is) "to facilitate the creation of sustainable human settlements and improve quality of household life. The Department determines finances, and promotes, communicates and monitors the implementation of housing programs in South Africa (and aims to) provide households with security of tenure and access to essential services in sites that are close to economic and other social amenities" (https://nationalgovernment.co.za/units/view/19/department-of-human-settlements-dhs).

The Department of Science and Innovation (DSI) seeks to boost socio-economic development in South Africa through research and innovation. To achieve its goals, the Department provides leadership, an enabling environment and resources for science, technology and innovation.

The Department's mission is to "provide leadership, an enabling environment, and resources for science, technology and innovation in support of South Africa's development" (Our Vision, Mission and Corporate Values (dst.gov.za)).

The DSI derives its recent mandate from the 2019 White Paper on Science, Technology and Innovation. The White paper emphasises inclusivity, transformation, partnerships to address policy coherence, the development of human capabilities, knowledge expansion, innovation performance and increased investment that will result in the economic, socio-political and intellectual benefits of STI being enjoyed by all South Africans.

It is important to emphasise that South Africa traditionally had a pluralistic system of national innovation. It is only recently that the 2019 White Paper on ST&I aims at transforming the system into a co-ordinated one.

The two Departments have signed a Memorandum of Understanding (MoU) (2018) for cooperation in the development and utilisation of scientific, technological and innovation activities for development purposes. The parties agreed that they will work "in collaboration with each other and agree that with respect to those areas of their work which are closely related, they will ensure that the respective roles and responsibilities, and the resource contribution of each department are clearly indicated and that their respective work will be supportive and aligned".

In more detail the MoU states the following objectives:

Support the development of institutional capacity and collaboration required to develop sustainable human settlements according to the principles outlined in the Comprehensive Plan and the implementation of the new strategic management model of national science and technology system;

Provide support to the Parties in addressing key problems areas by seeking solutions aimed at improving housing delivery, the development of functioning human settlements and other key problem areas regarding science and technology system;

Contribute towards wider research and development initiatives to build and nurture centres and networks of excellence that will positively influence the housing policy and the way in which housing and settlements are delivered;

Establish a shared understanding of sector development objectives, government position (policy & strategy), roles and responsibilities of each department and areas of joint action;

Jointly develop medium term action plans for sector-specific science and technology interventions, infrastructure and capacity building; and

Establish structured cooperation frameworks and/or terms of reference for the implementation of science and technology actions through agreed upon pilot projects and projects utilising the Parties' entities including the attached agreed upon terms of reference with DST entities.

The DSI has created a separate directorate –Sustainable Human Settlements- "to use knowledge, evidence and learning to inform and influence government policy on human settlements and technology choices for the creation of human settlements."

3.3.2.2. Notable Initiatives of the Directorate Sustainable Human Settlements

The Directorate Sustainable Human Settlements has established a number of projects, which are:

Innovation Partnership for Rural Development Programme (IPRDP)

This initiative addresses the problems of South Africa's rural areas with the country's poorest and least advantaged citizens. The initiative is funded by the European Union's General Budget Support programme. Focus is placed on the provision of potable water, effective sanitation and electricity.

The technologies tried currently include:

- The Corrective Action Requests Report System, which can be used by ordinary citizens to report incidents such as water leaks, water supply disruptions and water quality issues
- Algae wastewater treatment technologies, a low-power solution to the wastewater problems of small rural towns
- Low pour flush technology, which centres on the provision of decent toilets in rural areas without the waterborne sewage systems typical of better-off urban areas
- Point-of-use water purification project, which promotes robust and easy-to-use domestic water filters
- Small-scale hydropower project is testing the use of small-scale hydroelectric plants in suitable locations
- Smart geysers, which harness modern digital technology to the patterns and requirements of a particular household

Hydrogen Fuel Cells

A project to develop a 2.5 kW off-grid primary power hydrogen fuel cell prototype for rural applications is undertaken in North-West

ICT-enabled Agricultural Extension and Advisory Services

A pilot project to explore business opportunities for young unemployed agriculture graduates in the provision of extension services is under way using a mobile app developed by the Agricultural Research Council (ARC). The project currently supports approximately 560 farmers through the provision of technical know-how, market insights and research updates.

Technology for Rural Education and Development

The programme tests the extent to which new technologies and technologies that have been applied in other contexts may improve education in a rural context. The initial pilot was demonstrated in the Eastern Cape, Cofimvaba District, in 26 schools. The technologies demonstrated were information and communication technologies, alternative sanitation technologies, renewable energy, e-health and nutrition.

South African Sanitation Technology Demonstration Programme

A partnership between the DST and the Bill & Melinda Gates Foundation to pilot various innovative and affordable sanitation technologies identified through the Bill & Melinda Gates global Reinvent the Toilet Challenge.

Spatial and Temporary Evidence for Planning in South Africa

The initiative is aimed at enhancing the national capability to profile and simulate the spatial implications of growth and development in cities and towns in support of high-impact and sustainable public investment and effective governance.

Sustainable Human Settlements Landscape Survey

The project aims to develop an STI database for the collation of information on key small and medium enterprises (SMEs) that are involved in the creation of sustainable human settlements using various STI products or practices.

System for Collecting Information on DSI Proxy Indicators

The system developed by the CSIR Modelling and Digital Science Division makes it possible for information on proxy indicators to be extracted from a variety of documents, so that it can be analysed and interpreted to measure progress in achieving the goals specified in the DST's Strategic Plan (2015-2020).

Innovative Building Technology

The initiative is demonstrating that STI can reduce the cost of utilities (water, electricity and waste removal) for the tenant, the municipality, and the nation as a whole, while also improving the environmental quality of the housing unit, the complex and the surrounding community.

3.3.2.3. THE LESSONS

The objective of this case study was to describe the way the DSI collaborates with the DHS. It is important to notice that the collaborative effort started in 2018. The effort lasted three years and this includes the corona virus 2019 period.

Discussions with the relevant officials revealed that identification of mature, promising technologies initiate the discussions for the application of the particular technology. Discussions with the multiple stakeholders clarify further the concept and its application. Certain projects have been evaluated.

The positive points are as follows:

- The two Departments have legalised their agreement to collaborate by signing an MoU.
- The effort has further been institutionalised by the DSI establishing the Directorate Sustainable Human Settlements.
- The targeted beneficiaries are the country's poorest and least advantaged citizens.
- The two Departments were able to raise partially, funding from international funders.
- Discussions among the stakeholders protects the projects from wrong decisions.

4 PRIMARY RESEARCH: SURVEY OF GOVERNMENT DEPARTMENTS

The survey investigated relevant issues in 12 Government Departments (Table 1). A questionnaire was developed (Appendix 3) and was reviewed and approved by the ASSAf and DSI committee. The questionnaire was emailed to the Director General's office of the 12 Departments on 31 May 2021 and their secretaries were copied in the communication. The questionnaire was accompanied by a letter of reference signed by the President of the ASSAf Council (Appendix 3). The DSI also sent a letter from the DSI Director General, Dr Phil Mjwara to the DGs of the 12 Departments encouraging them to respond to the questionnaire.

The Departments did not respond on time, therefore, multiple follow ups through e-mails and phone calls were conducted. COVID-19 lockdowns made the situation even more challenging as officials worked only on particular days during the week. Responses were eventually received from all Departments. Five out of the twelve Departments preferred to respond in an interview. These were: Agriculture, Land reform and Rural Development; Cooperative Governance; National Treasury; Trade and Industry and Competition and Mineral Resources and Energy.

It was interesting to note that all participants gave the same response, when responding to the questionnaire and in the interviews to the question: "In your opinion, do you think science, technology and/or innovation is relevant in your Department's policies and work plans?". All participants agreed that STI was important for their policies and activities.

The responses to the questionnaire and the interviews are summarised below:

1. To your knowledge, has your department integrated or adopted any science, technology and /or innovation aspects in its policies or planning framework? **A related question was "Do you monitor the incorporation of STI into your policies and planning and if yes please rate the monitoring mechanism (1 least effective; 5 most effective)**.

Do you monitor the incorporation of STI into your policies and planning?	Seven Departments mentioned that they were monitoring the incorporation of STI into policies and planning. (Basic Education; Human settlement; Treasury; Water; Public Works; Agriculture; dtic). Five Departments answered that they did not monitor the incorporation of STI into policies and one official answered that he was not sure. Only three responses covered rating of performance. The values were 3, 4 and 5. (Average to excellent).
What are the constraints in incorporating STI in your policies? (e.g. expertise; budget; other please define)	There were a number of answers. Four departments mentioned budget/cost (4); three departments mentioned technical skills (3); two departments mentioned lack of capacity/resources (2). Other issues that were mentioned include implementation in lower government sphere; IT silos within Departments and lack of interdepartmental collaboration Examples were offered by the Department of Health; Department of Basic Education; Department of Human Settlements; Treasury; Water and Sanitation and Public Works and Infrastructure.

2. To your knowledge, has your department integrated or adopted any science, technology and/or innovation aspects in its work plan such as programs, activities or interventions?

Yes	Nine government Departments declared that they had a dedicated unit working on STI programmes or activities. The Departments did not identify the specific programs/evidence; whether they monitored the incorporation of STI in these programs, neither did they mention any constraints in doing so.

3. To your knowledge, has your Department integrated or adopted any aspects of South Africa's science, technology and /or innovation policies (e.g. 2019 White Paper on Science, Technology and Innovation) in its policies, planning framework or work plan?

Government department	**Feedback**
Basic Education	Integrated National Strategy for Mathematics, Science and Technology (MST) 2019-2030, a National Implementation Plan and nine Implementation Plans for each of the Provincial Education Departments. This new strategy was developed in co-operation with the Departments of Higher Education &Training and Science & Innovation. The goals of the National Development Plan are a National Policy that finds expression in the DBE's implementation of the Three-Streams Curriculum Model as well as Curriculum Policy documents that provide for Technology subjects and other technology-related disciplines. This includes subjects such as Information Technology and Coding & Robotics. Every subject has its own, highly specific Curriculum and Assessment Policy Statement (CAPS). These CAPS are required to be approved by Cabinet as national policies. The DBE has developed a guideline framework for the establishment and management of Focus Schools. They form a legislatively distinct category of school, along with Special Schools for scholars with barriers to learning (Special Schools) and Public Ordinary Schools which constitute the vast majority of schools in the Basic Education sector. These schools provide for learners with exceptional aptitudes and talents in particular fields of endeavour. Most Focus Schools established to date offer Science and Technology oriented subjects. The MST Conditional Grant forms part of policy implementation by the DBE.
Health	The Department has a research policy which provide an enabling framework for the conduct of research that improves human health and wellbeing in South Africa.
Human Settlements	The Department has adopted the use of alternative building technologies (ABT) in Construction of houses. The DORA grant framework makes a provision for a percentage of funding to be used on inclining block tariffs (IBT).
National Treasury	• NT ICT Policy • Corporate Governance of ICT Policy Framework and Charter

Government department	Feedback
	• Project Management Framework • Change Management Framework • ICT Strategy • ICT Implementation Plan • ICT Operational Plan The above listed documents address the formal documents that mandate principles and standards that apply to the governance of ICT within the National Treasury, which is essential to the efficiency of business operations and initiatives. Technology initiatives that have been launched include but not limited to the following: • Cloud computing technology • Web Portals • Infrastructure Technology (Network, Internet, Hosting, etc.) • Security Management • Unified Communication Services and Technology • Business Intelligence capability tools • Digital Signatures • Call Management System • Enabling work from anywhere Innovation initiatives that have been launched include but not limited to the following: • Enterprise Content Management • Cloud based collaboration and management • Enterprise Architecture • Business Automation initiatives

Government department	Feedback
	• Professional Services • Systems Development
Public Works and Infrastructure	The following entities of the Department provides for such: • Construction Industry Development Board (CIDB) has Centres of Excellence and BRICS projects support Building Information Modelling (BIM). A 4IR technology and plans are underway to support the introduction of Drone Technology training for use in the construction industry. • Agrément South Africa (ASA) Act and Green Building policy and Programme.
Water and Sanitation	• Draft Mine Water Management (MWM) Policy – the Department is currently developing the Mine Water Management Policy which aims to provide a coherently integrated approaches across government, the private sector and civil society for the sustainable management of mine water by; building on existing legislative frameworks; addressing gaps or weaknesses; and capitalising on opportunities identified in relation to mine water management, including AMD. The policy specifically provides for among others; that the selected technologies for mine water impact management are situation-specific, cost-effective, sustainable and involve equity in water resources management through adoption of appropriate funding mechanisms such as the polluter-pays and/ or user-pays-principle. • 2016 National Sanitation Policy (NSP) – Cabinet approved a National Sanitation Policy following a review of all previous policies including the White Paper on Water Supply and Sanitation (1994); the White Paper on a National Water Policy of South Africa (1997) and the White Paper on Basic Household Sanitation (2001). The NSP seeks to strengthen equity and dignity of all South Africans by enhancing previous sanitation policies. It goes beyond the policies that were mainly focussing on redress to deal with imbalances of the past in terms of access to basic sanitation levels of services across society by being forward looking in terms of improved levels of services, innovative and appropriate technology to ensure sustainability and improving the lives of the poor. The specific policy positions relating to this aspect are as follows: - POSITION 19: Research and Innovation for sanitation services - POSITION 24: Appropriate sanitation technologies

Government department	Feedback
	• Draft MWM Policy - It is /will be the case consistently so considering that evidence depicts that supplying South Africa's growing population with clean, safe drinking water is a significant challenge. Not only is the country's water infrastructure in need of refurbishment in some places and entirely absent in many others, but access to sufficiently large quantities of potable water is increasingly becoming a challenge. Acid mine drainage often contains toxic heavy metals and radioactive particles or is acidic and can be extremely harmful to the health of humans, animals and plants. However, situated in the Witbank Coalfields in the Mpumalanga Province of South Africa, the eMalahleni Waste Water Reclamation Plant uses reverse osmosis to desalinate mine-impacted underground water, and provides potable water that is used to benefit local needs. It should be noted that whilst reverse osmosis is the front runner for most treatments, there is a plethora of other treatments and technologies that can be used. Other technologies also become more appropriate when considering natural environmental protection objectives. • NSP Policy – The policy identifies research and innovation for sanitation services as crucial to achieving both national and international imperatives of water conservation and demand management, water security and the public health benefits of sanitation therefore making it a consistent stimulus for the sanitation sector to move towards sustainable services. The policy further highlights the need to address the issue of appropriate technology with a view to change preconceived notions of sanitation from either waterborne in urban areas and dry systems in rural areas to one where the most appropriate technology is provided to an area. It does this by advocating for technology choices that are based on resource availability within a settlement area, through (1) developing a formal process for certification and accreditation of appropriate sanitation technologies and (2) developing regulations for new developments to use greywater in waterborne sanitation systems, minimising impacts on water resources.

4. Does your Department have a dedicated budget towards science, technology and / or innovation related programmes? Please indicate approximate amount for R&D and separate amount for innovation.

Ten departments declared that they had science budgets although two of those emphasised that the resources available were limited

5. Does your Department have dedicated unit /personnel working on science, technology and/ or innovation programs or activities?

Nine government Departments declared that they had a dedicated unit working on STI programs or activities.

6. Does your Department have human or infrastructural capabilities to incorporate science, technology and/ or innovation in your policies and work plan?

Nine departments mentioned that they had structures and three that they did not (Department of Communication and Digital Technologies; Cooperative Governance; Human Settlements).

7. Does your Department monitor local policies and international good practice (e.g. implementation of innovation roadmaps)?

Four Departments declared that they did not monitor local policies and international good practice (Department of Communication and Digital Technologies; Cooperative Governance, Mineral and Energy; Department Trade, Industry and Competition) and eight departments declared monitoring activities.

8. In your opinion what policies can improve coherence in the policies and programmes of your Department with the innovation policies and programmes of the Department of Science and Innovation?

Three departments mentioned the Ministerial Clusters as possible approach to improve coherence.

Another three suggested R&D.

Two departments mentioned collaboration policy

Two suggested that there will be coherence if they follow their own policies.

Other approaches that were mentioned were: The Intergovernmental Relations Framework Act 2005; impact assessments; best practise; research on evidence and ICT.

The variety of solutions suggested may be indicative of the complexity of the concept and the lack of consensus.

5 FINDINGS AND DISCUSSIONS

The objectives of the research study were to: *Assess how national and provincial government departments' policies are open to innovation uptake; and ascertain how policies and different institutional programmes have integrated STI and instilled the innovation culture within and across the departments.* The study used the following tools to collect the data: *desktop literature review; policy documents analysis; case studies; and a survey of Departments*.

The **literature review** looked at: the importance of research, development and innovation; policy coherence and failures; the organisational structures of research systems; and the South African National System of Innovation. The review highlights that:

i. The pervasiveness of research and innovation for economic growth needs a re-think and government intervention is needed across the board.
ii. Policy coherence is challenging to assess in pluralistic systems, and South Africa is currently considered as such. Policy coherence is about acknowledging the interdependence and interrelations between different policies. Two dimensions of complexity are distinguished in STI policy: the policy-mix and multi-level governance. The relevant literature identifies a number of coordination mechanisms, e.g. the creation of centralised agencies, coordination councils, super-ministries, leadership at the cabinet level, intermediary agencies, collaboration programmes, lead organisations, standards setting bodies, etc.
iii. South Africa's research systems is currently a pluralist system, in that government departments and their agencies initiate and manage their own research activities.
iv. The South African National System of Innovation recognises the importance of science and technology for economic growth and development. There is emphasis on the intensions of the White Paper on Science, Technology and Innovation of 2019 to establish a **coordinated system** of Science and Technology (STI) and that STI should become the responsibility of all government structures.

The **document analysis** was conducted to identify the frequency of certain concepts as an indication of the existence of that concept in the particular Department. Below is a summary of the frequency of each concept in the selected documents per Department (findings in Table 3 and Appendix 1).

Table 5: Summary of the frequency of each concept in the selected documents

Government Department (number of documents analysed)	Number of keywords searches in selected policies/strategies						
	Research and development	**Science / scientists / scientific / scientifically**	**Technology / technologies / technological / technologically**	**Innovation / innovated / innovative / Innovators**	**Fourth / 4th industrial revolution**	**Smart**	**DST/ Department of Science and Technology / DSI/ Department of Science and Innovation**
Agriculture, Land Reform and Rural Development (5 documents)	0	6	28	8	0	0	4
Basic Education (6 documents)	10	43	94	16	0	0	1
Department of Health (6 documents)	1	19	74	48	4	4	3
Communications and Digital	9	7	132	103	0	4	3

Technologies (1 document)							
Cooperative Governance (2 documents)	0	0	4	7	0	0	0
Human Settlements (2 documents)	1	0	6	9	0	0	0
National Treasury (1 document)	1	1	49	13	0	1	1
Public Works and Infrastructure (2 documents)	0	0	8	7	0	0	0
Water and Sanitation (3 documents)	1	1	15	1	0	0	0
Mineral Resources and Energy (2 documents)	24	20	56	7	0	0	2
Social Development (1 document)	0	4	7	0	0	0	0
Trade, Industry and Competition (1 document)	2	5	25	17	8	12	2

Investigation of 32 policies identified the following with regards to the concept "***innovation***":

- Eleven policies (34%) do not mention the word 'innovation' at all
- Four documents (12.5%) refer to innovation only once
- One document refers to innovation twice and three documents mention innovation 3 times each.
- Two documents contain the word "innovation" 4 times
- Two documents mention the word innovation 5 times
- One document 6 times and one document 7 times.
- Two documents have the word innovation 9 times each
- Two documents 13 times each
- There is one document with the word innovation 17 times (Re-imagined Industrial Strategy 2019)
- One document with the word appearing 26 times (National Digital Health Strategy for SA 2019-2024)
- One document with the word appearing 103 times (The last document is the "National Integrated Information and Communications Technology (ICT) Policy White Paper" (2016) of the Department of Communications and Digital Technologies.)

Eleven out of the 12 Departments use the concept of 'innovation' to a 'certain extent'. It is apparent that the South African Government Departments are aware (to a certain extent) of the importance of the concept of 'innovation' for policy. The only government department that didn't have the keyword related to "innovation" is the Department of Social Development based on selected policies. (The Department of Social Development's documents didn't feature the term innovation).

In order to create a basis for comparisons, the study identified the number of times the word 'innovation' appears in the White Paper on Science, Technology and Innovation (2019). The word

appears in the DSI document 448 times. The DSI document examines 'innovation' in depth while the other policies are only tangential to the concept.

Overall,

- Keywords related to "**technology**" are most used in the selected policies, many accounting to the ICT governance used to support the organisation.
- Seven out of the twelve departments acknowledge the role of the Department of Science and Technology / Science and Innovation in their policies which is encouraging.
- Some of the Departments do not have their policies readily available online (from their website or a google search) and so they could not be accessed for the study.

The **case on China** shows that, China for example, succeeded in developing its economy and society based on science, technology and innovation. South Africa, although has recognised the importance of science and technology by creating a separate Department, has not been able to raise S&T to an adequate level with R&D expenditures as percentage of GDP remaining around 0.8%. Probably the challenges for South Africa and other countries are: how to co-ordinate Ministers and Government Departments to be coherent and committed in the field of science, technology and innovation; and should political parties also be targeted in efforts to improve appreciation of S, T and I.

The **survey** highlighted:

1. That South African government departments are aware and agree on the importance of the concept of 'innovation' for policy.
2. With regards to the *adaption and integration* of STI in departmental programmes, policies and frameworks: six departments offered examples, and nine departments declared that they had a dedicated unit working on STI programmes or activities. The following constraints were identified - namely budget/cost (4); technical skills (3); and lack of capacity/resources (2).
3. The area of *monitoring* coherence and incorporation of STI in departmental policies: seven departments declared monitoring activities; three departments mentioned the Ministerial Clusters as possible approach to improve coherence and another three suggested R&D; two departments mentioned collaboration and other policies.

The **findings** confirm that STIs are critical drivers for social and economic development. The broad findings appear to show that STI can be accommodated in most of the investigated departments, but clarifications should be provided on what is expected from possible amalgamations/ incorporations.

6 RECOMMENDATIONS

Further analysis of the Departments (Appendix 2) seems to confirm that STI can be accommodated in the majority of the investigated departments, but clarifications should be provided on what is expected from such amalgamations/incorporations.

The process of determining the level of adoption and integration is qualitative and aims to cover as many elements as possible that may indicate integration and adoption of STI by a government department. The level of adoption and integration is determined as follows – (1) the extent to which key search words are found in the selected policies particularly the explicit mention of the Department of Science and Technology / Science and Innovation; (2) a state entity reporting to the particular Department on implementation of STI activities; (3) responses from the survey questionnaire and interviews; (4) STI related organisational functions within the Department; and (5) using the information extracted from National Treasury Full Estimates of National Expenditure 2021 (Tables 6 and 7). The levels of integration are determined as such that the integration is at its minimal if lower than 5 (< 5), average if equal to 5 (=5), and greater if higher that 5 (>5) (Table 8).

The following recommendations were developed on the basis of the literature review, above factors, challenges identified and suggestions from the participants.

Using the existing infrastructure/mechanisms can be among the first actions.

1. The cluster approach was mentioned by a number of participants. Government clusters are groupings of government departments with cross-cutting programmes. The main functions of clusters are to:
    - Ensure alignment of government-wide priorities
    - Facilitate and monitor the implementation of priority programmes
    - Provide a consultative platform on cross-cutting priorities and matters being taken to Cabinet.

The DSI belongs to Economic cluster. The cluster consists of 20 government Departments. Hence, the **first recommendation is for the DSI to consider submitting the issue of STI Coherence to the economic cluster in their next meeting**.

2. An additional and complementary approach is to activate the Intergovernmental Relations Framework Act (IRFA) for the establishment of a national intergovernmental forum. According to the legislation "A national intergovernmental forum established in terms of section 9 is a consultative forum for the Cabinet member responsible for the functional area for which the forum is established- (a) to raise matters of national interest within that functional area with provincial governments and, if appropriate, organised local government and to hear their views on those matters; (b) to consult provincial governments and, if appropriate, organised local government on- (i) the development of national policy and legislation relating to matters affecting that functional area; (ii) the implementation of national policy and legislation with respect to that functional area; (iii) the co-ordination and alignment within that functional area of- (aa) strategic and performance plans; and (bb) priorities, objectives and strategies across national, provincial and (iv) any other matters of strategic importance within the functional area that affect the interests of other governments; and (c) to discuss performance

in the provision of services in order to detect failures and to initiate preventive or corrective action when necessary". The advantage of IRFA is that it mobilises Provincial and local Government officials as well. In the above context **DSI should engage the department of Cooperative Governance as a means to influence lower levels of Government**.

3. **DSI to consider the establishment of the Government Institute for Science, Technology and Innovation (GIST).** The Institute will undertake ex ante impact assessments of issues with high impact in society and will inform the relevant authorities. The OST in the USA and the POST in the UK are successful examples of similar efforts abroad.
4. **ASSAf to consider establishing a National Programme for Appreciation of Science and Technology in Government.** The programme will aim to improve the appreciation of science and technology among government officials. The program will develop and present STI information to government officials in a way that they can appreciate it.
5. To **expand the investigation to cover all government departments** at National and Provincial levels.

7 REFERENCES

Ang, J. and Madsen, J. (2011). Can second generation endogenous growth models explain the productivity trends and knowledge production in the Asian miracle economics? *The Review of Economics and Statistics.* **93(4):** 1360-1373.

Bonvillian, WB. (2014). The new model innovation agencies: An overview. *Science and Public Policy.* **41 (4)**: 425–437.

Bouckaert, G., Peters, BG., and Verhoest. K. (2010). *The coordination of public sector organisations: Shifting Patterns of Public Management*. Basingstoke: Macmillan.

Bowen, GA. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal*, **9(2):** 27-40. DOI 10.3316/QRJ0902027.

Briassoulis, H. (2004). Policy integration for complex policy problems: what, why and how. *Greening of Policies: Interlinkages and Policy Integration*, Berlin: pp. 3 - 4.

Brickman, R. (1979). Comparative approaches to R&D policy coordination. *Policy Sciences.* **11(1).** August.

Burdman, M. (1995). China declares science to be the top productive force. *EIR* **22(27).** June 30 1995

Chataway, J., Chatuverdi, K., Hanlin, R., Mugwagwa, J., Smith, J. and Wield, D. (2009). *Technological Trends and Opportunities to Combat Diseases of the Poor in Africa* (Chapter 2). In: Kalua, FA., Awotedu, A., Kamwanja, LA. and Saka, JDK. (eds). *Science, Technology and Innovation for Public Health in Africa*. Monograph, NEPAD Office of Science and Technology, Republic of South Africa, Pretoria, South Africa.

CNBC (2019). *Global CFO Council* available at: 1 in 5 companies say China stole their IP within the last year: CNBC.

Coe, DT., Helpman, E. and Hoffmaister, AW. (1995). *North-South R&D Spill overs*. Centre for Economic Policy Research, UK.

Department of Science and Technology (DST). (2012). *Ministerial Review Committee on Science, Technology and Innovation Landscape in South Africa: Final report*. Pretoria.

DSI (2019). *White Paper on Science, Technology and Innovation*. Department of Science and Innovation, Pretoria.

Freeman, C. and Huang, W. (2015). *China's "Great Leap Forward" in Science and Engineering*. NBER Working Paper Series No. 21081.

Freeman, C. (1987). Technology and Economic Performance: Lessons from Japan, Pinter, London.

Ganea, P. and Pattloch, T. (2005). *Intellectual Property Law in China 3*. (Christopher Heath ed., 2005); Gabriel. supra note 21, at 327-28.

Government Gazette No 27898. (2005): *Intergovernmental Relations Framework Act*. Pretoria.

Hsieh, HF. and Shannon, SE. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research*. **15(9):** 1277-1288.

Ilori, TA. (2002). *Promoting technological innovation for the industrial development of Africa*. NISER Monograph Series No 6. NISER: Ibadan.

Kohen, G. (1978). *Karl Marx's theory of history: A defence*. New Jersey: Princeton University Press.

Kumar, U. (2014 ed). *50 Breakthroughs: Critical scientific and technological advances needed for sustainable global development.* Institute for Globally Transformative Technologies. Lawrence Berkeley National Lab. Berkeley, California 94720.

Lindner, R. (2012). Cross-sectoral coordination of STI-policies: governance principles to bridge policy-fragmentation. In Fraunhofer ISI (Ed.), *Innovation Systems Revisited: Experiences from 40 years of Fraunhofer ISI Research* (pp. 275-287). Stuttgart, Fraunhofer Information.

Magro, E., Navarro, M., Zabala-Iturriagagoitia, JM. (2014). Coordination-mix: the hidden face of STI policy. *Review of Policy Research.* **31(5):** 367-389.

Mansfield, E. (1991). Academic research and industrial innovation. *Research Policy.* **20(1)**: 1-12.

Mathews, J. (2009). China, India and Brazil: Tiger technologies, Dragon multinationals and the building of national systems of economic learning. *Asian Business & Management*. **8(1):** 5-32.

Mathews, J. and Cho, DS. (2000). *Tiger technology: The creation of a semiconductor industry in East Asia.* Cambridge: Cambridge University Press.

Murphy, K. and Topel, R. (2003 eds). *Measuring the gains from medical research: An economic approach.* Chicago: University of Chicago Press

NACETEM. (2010*). Assessment of innovation capability in the manufacturing sector in Nigeria*. Monograph Series No 4: NACETEM: Ile-Ife.

National Planning Commission. (2011). *National Development Plan*. *Our future – make it work*. Pretoria Executive Summary. National Planning Commission, Pretoria.

NEPAD. OST. (2006). *Africa's science and technology consolidated plan of action*. NEPAD OST: Pretoria, South Africa.

OECD. (1997). *National innovation systems*. Paris. France

OECD. (2008). Reviews of innovation policy. Paris. France

OECD. (2010). *Regional development policies in OECD countries*. Paris. France

OECD. (2009). *Policy responses to economic crisis: Investing in innovation for long-term growth*. Paris. France

OECD. (2012). *Innovation for development.* Paris. France

Peters, BG. (2018). The challenge of policy coordination. *Policy Design and Practice.* **1(1):** 1-11

Pouris, A. and Pouris, A. (2011). Patents and economic development in South Africa: Managing intellectual property rights. *South African Journal of Science*. **107(11/12):** 1-10

Prusak, L. (1996). The knowledge advantage. *Planning Review*. **24(2):** 6–8.

Romer, P. (1990). Endogenous technological change. *Journal of Political Economy.* **98(5):** 71-102.

Ronayne, J. (1984). *Science in government*. Edward Arnold, Gaulfield, London.

Rothschild, Lord. (1971). *The organisation and management of government R&D.* Cmmd 4814. HMSO, London.

Senate Special Committee on Science Policy. *(1977). A Science policy for Canada.* Queen's Printer, Ottawa.

TYIP. (2007). *Ten-year innovation plan*. Department of Science and Technology. Pretoria.

Wikipedia. (2021). *History of science and technology in the People's Republic of China*. Accessed during 2021

APPENDIX 1: WORD SEARCH OF POLICIES OF SELECTED GOVERNMENT DEPARTMENTS

Government Department	Policy	Number of keywords searches in the policies selected						
		Research and development	**Science/scientists /scientific/scientifically**	**Technology/Technologies/Technological/Technologically**	**Innovation/innovated/innovative/Innovators**	**Fourth/4th industrial revolution**	**Smart**	**DST/Department of Science and Technology/DSI/ Department of Science and Innovation**
Agriculture, Land Reform and Rural Development	Poultry Master plan 2010	0	0	0	0	0	0	0
	Agricultural Land Holdings Policy Framework (2013)	0	0	2 Adoption of technology and the effect of economies of scale would influence profitability in certain types of enterprises Efficiency gains are often achieved through introduction of new technologies	1 Some of the broad functions of such an office should perform analyses for development, innovation and upgrading	0	0	0
	Department of Agriculture, Forestry and Fisheries (DAFF) Agro-processing Strategy (2012)	0	6 Council for Scientific and Industrial Research Department of Science and Technology	21 (highlighting few words only) The agro-processing industry covers a broad area of postharvest activities, comprising artisanal, minimally	0	0	0	4 DST Department of Science and Technology

			It is premised on some of the key departure points of the IPAP 2, and adds a number of interventions in rural development, agriculture, science and technology, education and skills development, labour, mining and beneficiation, tourism, social development and other areas. DAFF will collaborate with, among others, the Department of Science and Technology (DST), Agricultural Research Council (ARC), and Council for Scientific and Industrial Research (CSIR) in the provision access to technology for agroprocessors.	processed and packaged agricultural raw materials, the industrial and technology-intensive processing of intermediate goods and the fabrication of final products derived from agriculture The term encompasses particular types of firms which are mostly labour intensive but remain largely heterogeneous in terms of their organisational and marketing capabilities and technology Supply-side constraints (skills, technology, infrastructure, etc.) According to Mather (2005), concentration itself has been identified as a consequence of two main factors namely, historical agricultural marketing legislation, and the technological barriers to entry, which are inherent in food processing				DAFF will collaborate with, among others, the Department of Science and Technology (DST), Agricultural Research Council (ARC), and Council for Scientific and Industrial Research (CSIR) in the provision access to technology for agroprocessors. Other roles include supporting the implementation of the strategy by providing services that departments have comparative advantage in, for example, the Department of Science and Technology (DST) specialises in creation and provision of

			Other roles include supporting the implementation of the strategy by providing services that departments have comparative advantage in, for example, the Department of Science and Technology (DST) specialiees in					technology for business development, among others
	Rural Development Framework (2013)	0	0	3 This phase is largely driven by the revitalisation of old and revamping of new social, economic and Information, Communication and Technology infrastructure. Growth in green technology is an integral part of the strategy Implementation of other rural development schemes that support micro-enterprises, self-employment, effective linkages, capacity	3 It is equally important to add to these the flow of ideas, flow of information and flow of diffusion of innovation The significance of this Chinese experience does not only lie in the fact that the household is clearly critical to adaptation and innovation Chile's transition to democracy has produced considerable reductions in absolute poverty through Government's pro-growth economic agenda combined with	0	0	0

				building, infrastructure, technology, access to credit and marketing	progressive social policies and innovative institutional reforms			
	The Integrated Sustainable Rural Development Strategy (2000)	0	0	2 Unlike the larger commercial farmers, these producers do not have the financial capacity to assume additional costs or to adopt alternative technology. Social capital is therefore seen as contributing to development in a manner similar to more orthodox assets, such as human capital (education, health, and training), physical capital (tools and technology), and financial capital (savings, credit and investment).	4 Such programmes will be replicated in the local development nodes where appropriate, to maximise the multiplier effect and facilitate service delivery, to avoid identified weaknesses, and to find new and innovative delivery mechanisms. The outcomes of the co-ordinated long-range planning will translate into innovative, special integrated services and programmes. Cascading partnerships and participation formations to all levels of implementation, while simultaneously ensuring that innovative models which are relevant to the context, are developed	0	0	0
Basic Education	White Paper on Education and Training (1995)	6 National Open Learning	29	14 (highlighting some relevant words only)	4 The developmental initiatives which are	0	0	0

		Agency (NOLA)would undertake research and development on open learning, help build a network of public and private open learning institutions and practitioners, and facilitate their efforts to translate open learning principles into effective practice. The partnerships are expected to undertake planning, arrange public advocacy, sponsor research and development, and mobilise financial resources for the programme.	(highlighting some relevant words only) Access to technological and professional careers requiring a strong basis in mathematics and science is denied to all but a fraction of the age cohort, largely because of the chronic inadequacy of teaching in these subjects. An appropriate mathematics, science and technology education initiative is essential to stem the waste of talent, and make up the chronic national deficit, in these fields of learning, which are crucial to human understanding	In response to such structural changes in social and economic organisation and technological development, integrated approaches toward education and training are now a major international trend in curriculum development and the reform of qualification structures The quality of South Africa's diploma, degree, postgraduate and research output has created and sustained the country's sophisticated modern economic and financial infrastructure, industrial, business and communications technology, medical, legal, media, cultural and other professional services. In these respects South Africa compares well with other industrialising countries and seeks to match itself with the world's best. Access to technological and professional careers	described below anticipate several important structural and institutional innovations. In a time of transition it may appear that change takes on a momentum of its own. One institutional innovation which the Ministry wishes to see investigated with some speed is the idea of Community Learning Centres. The centre of gravity of professional innovation, and the major responsibility for provision, will not lie with government departments but with non-government, community-based and private providers, resource and training agencies, operating within appropriate national and provincial guidelines Establish and maintain a national Education Management Information System (EMIS), collaborate with the			

		In undertaking these preparations, the Ministry will give full attention to the substantial volume of research and development work which has already been done in connection with the National Training Board's National Training Strategy Initiative, and the multi-stakeholder National Investigation into Community Education (NICE) Establish and maintain a national Education	and to economic advancement. Special criteria will be needed to prepare students for subjects in short supply, particularly science, mathematics and technology	requiring a strong basis in mathematics and science is denied to all but a fraction of the age cohort, largely because of the chronic inadequacy of teaching in these subjects. Special criteria will be needed to prepare students for subjects in short supply, particularly science, mathematics and technology.	Department of Labour and other departments in extending the system to cover information on training provision and performance, and manage an appropriate research and development programme, in order to determine national needs, encourage and evaluate innovation, and monitor delivery and performance;			

		Management Information System (EMIS), collaborate with the Department of Labour and other departments in extending the system to cover information on training provision and performance, and manage an appropriate research and development programme, in order to determine national needs, encourage and evaluate innovation, and monitor delivery and performance; It will be responsible for the						

		research and development of national norms and standards for educational programmes across the spectrum at all levels. There is an unanswerable case for investing in research and development on the appropriateness of distance education strategies for different learning goals, including the use of study guides, videos, computers, newspapers, etc						
	White Paper on e-Education (2004)	3 The research and development community	3 Telkom Foundation, together with Telkom's strategic	74 (highlighting some relevant words only)	9 (highlighting some relevant words only) Digital literacy refers to the ability to appreciate	0	0	1 The Department of Education, in collaboration the Departments of

		must continuously assess current practices, and explore and experiment with new technologies, methodologies and techniques that are reliable and will support teachers and administrators in e-Learning and e-Administration To this end, Government must bring together teachers, researchers and the ICT industry in an action-oriented research and development forum, to evaluate and develop leading-edge	partner Thintana, has committed over R200m to support education and training in the areas of ICT, mathematics and science. Priority areas for national rollout include South African history, technology, mathematics, sciences and the biology of, and social behaviour associated with, HIV/AIDS. This will be done in conjunction with relevant government departments and the providers of further education and training programmes, as well as higher education institutions that have computer science programmes	Information and communication technologies (ICTs) are central to the changes taking place throughout the world. The challenge of providing modern technologies to schools in order to enhance the quality of learning and teaching will require a significant investment. Through appropriate technologies, it is hoped that South Africa will leapfrog into the new century, bypassing the unnecessary adoption cycle, and implement a solution that works now, and has the capacity to handle future developments It is no use having state-of-the-art technology unless it can be sustained. Beyond the issue of access, there is a gap in the ability of learners and teachers to use these technologies effectively, to access high-quality and	the potential of ICTs to support innovation in industrial, business, learning and creative processes. The objective is to build digital and information literacy so that all learners become confident and competent in using technology to contribute to an innovative and developing South African society Assessment is an important driver in education and, if not well-managed, can become a barrier to innovation. The following key elements underpin the use of ICTs in teaching and learning without constraining the teachers, learners and learning organisations in creativity, problem-solving and innovation innovation - prepared to develop entirely new learning environments that use technology as a flexible tool, so that			Communications and Science and Technology, the teaching profession, higher education institutions and research agencies, will formulate a research agenda on ICTs for e-Learning.

		applications for learning identification of research frameworks for academic research and development, for research bodies and institutions to solicit funding for research in e-Education		diverse content, to create content of their own, and to communicate, collaborate and integrate ICTs into teaching and learning e-Education will connect learners and teachers to better information, ideas and one another via effective combinations of pedagogy and technology in support of educational reform.	learning becomes collaborative and interactive. Technology is integrated as a flexible tool for whole-school development.			
	The National Policy Framework for Teacher Education and Development in South Africa (2007)	0	0	0	0	0	0	0
	Policy Document on Adult Basic Education and Training (2003)	1 to identify issues in regard to the relationship between materials, curricula and qualifications as they emerge for inclusion into policy debates	9 Use science and technology effectively and critically, showing responsibility towards the environments and health of others These are the twelve broad	5 develop an understanding of the world of science and technology. The Department of Education believes that to ensure good quality provision, training and capacity building programmes in the following areas should be	3 The Department will provide leadership on the provision of low-cost, innovative and well designed materials for ABET. Other Directive Principles stated in the Act are the encouragement of lifelong learning;	0	0	0

		and research and development programmes.	categories of organising fields of learning adopted by SAQA, namely: - Law, military science and security - Health sciences and social services - Physical, mathematical, computer and life sciences The AET directorate of the national Department of Education has selected eight learning areas for which ABET unit standards should be developed. These learning areas are drawn from the twelve organising fields of learning. The ABET learning areas are: - Mathematical literacy,	made available to educators, field supervisors and administrators at provincial level as well as regional/ area/ district/ circuit ABET specialists: -- planning, curriculum development, in-service training, subject advisory services, information technology, examinations, administration and finance Use science and technology effectively and critically, showing responsibility towards the environments and health of others. These are the twelve broad categories of organising fields of learning adopted by SAQA, namely: - Manufacturing, engineering and technology The ABET learning areas are: - Technology	achieving an integrated approach to education and training within the National Qualifications Framework; cultivating skills, disciplines and capacities necessary for reconstruction and development; recognising the aptitudes, abilities, interests, prior knowledge and experience of learners; encouraging independent and critical thought; enhancing the quality of education and educational innovation through systematic research and the development of education; The Directorate believes that while innovation and new initiatives invariably are expensive, we must not have our vision clouded in terms of understanding the cost-savings the policy outlined above has for our country in the medium to long-term - and these savings cannot be measured in monetary terms alone.			

			Mathematics and Mathematical sciences - Human and Social sciences - Natural sciences - Economic and Management sciences develop an understanding of the world of science and technology.					
	Plan of Action Improving access to free and quality basic education for all (2003)	0	2 In 1994, a Government elected by the people of our country could at last set that schooling system on a more normal course, where institutions could nurture our youth in an environment of peace, and could produce the scientists,	1 The efficacy of the current post provisioning approach, district-level deployment of educators, school-level time management, the role of SGBs, class size, classroom technology, and systems of support, reward and punishment for educators are some of the issues that should receive attention.	0	0	0	0

			teachers, voters, mothers, fathers, politicians and business people of the next generations, Secondly, educators with specialisations that are scarce, for instance educators with a mathematics or a science specialisation, must be paid more, at least in the interim, in order not to loose those educators to other sectors of the economy					
	The National Policy for an equitable Provision of an Enabling School Physical Teaching and Learning Environment (2010)	0	0	0	0	0	0	0
Health	White Paper for the	0	0	3	0	0	0	0

	Transformation of the Health System in South Africa (1997)			Health Technology: Directorate - Responsible for the evaluation, regulation and registration of health technology. Responsible for providing financial advice and ensuring that expenditures incurred are in accordance with the various programme descriptions; rendering and maintaining information technology services within the Department; and advising the Department on the procedures to be followed to obtain goods and services				
	National eHealth Strategy, South Africa 2012/13-2016/17	1 Strengthen Research and Development	0	30 (highlighting some relevant words only) This strategy aims to support the strategic objectives of the Department of Health in a way that is comprehensive, pragmatic and innovative. It defines eHealth as a broad domain which includes mHealth,	5 Telemedicine attracts considerable interest and innovation among academics, researchers, private enterprise and health professionals. While the HIS environment is characterised by numerous fragmented computerised systems and several vertical	0	2 This work is coordinated by the SABS and the local standard will be referred to as SANS 828-2 Health informatics – Health smart (HS) card.	0

				telemedicine and all information communication technologies (ICTs) used to promote, support and strengthen healthcare. The World Health Organisation defines eHealth as "the use of information and communication technologies (ICTs) for health to, for example, treat patients, pursue research, educate students, track diseases and monitor public health. This results from the lack of technology regulations and a lack of policy frameworks for all aspects of infrastructure delivery. A lack of cooperation between various groups resulting from lack of a clear understanding that eHealth includes all ICTs for health such as mobile technologies, telemedicine and electronic patient records. This lack of cooperation prevents	programs, South Africa is also innovating in mHealth and telemedicine solutions. Establish innovative methods of early detection of noncommunicable and chronic diseases. This involves developing career paths, training and skill retention strategies in order to build up a workforce that can innovate, develop, deploy, maintain and support all eHealth interventions, especially health information systems and health management information systems.		In December 2010, the National Health Council (NHC) technical task team approved the Tiered ART Monitoring Strategy comprising of a paper-based register (the ART register), non-networked electronic register (TIER.net) and a networked disease specific EMR system (SMARTER39) for HIV/ART patient monitoring in line with the WHO's 3 Tiered ART M&E strategy	

				urgently needed progress in using eHealth as an enabler. To strive for closer collaboration with the private and non-profit sectors in information and communication technologies, in order to further public services for health.				
	The National Health Promotion Policy and Strategy 2015 - 2019.	0	0	1 Physical Environment and Infrastructure Burden of disease, climate and seasonality, transportation and communication networks, access to health care facilities, access to water, sanitation, household technologies, etc.	3 This could be improved by national coordination with civil society, and particularly through the sharing of innovative approaches, standardising monitoring and evaluation and ensuring that resources are efficiently applied by preventing duplication. Lead and implement effective and innovative change management. Lead and implement innovative health promotion approaches.	0	0	0
	National Policy Framework and Strategy	0	7 A well-functioning health system	4 Lack of facilities to train current health	1 Lack of facilities to train current health	0	1 Palliative care to be included	0

	on Palliative Care 2017 - 2022		ensures equitable access to essential medical products, vaccines and technologies of assured quality, safety, efficacy and cost-effectiveness, and their scientifically sound and cost-effective use Taking into account the United Nations Economic and Social Council's Commission on Narcotic Drugs' resolutions 53/4 and 54/6 respectively on promoting adequate availability of internationally controlled licit drugs for medical and scientific purposes while preventing their diversion and abuse, and promoting adequate availability of	professionals in service. Consider e-learning with support, telemedicine and innovative technology to support training Medical products and Technologies: Medicines products and technologies (MT) A well-functioning health system ensures equitable access to essential medical products, vaccines and technologies of assured quality, safety, efficacy and cost-effectiveness, and their scientifically sound and cost-effective use	professionals in service. Consider e-learning with support, telemedicine and innovative technology to support training.		in all in-service training with recognition of training through certification and recorded on HR records and other platforms (e.g. Skills Smart).	

			internationally controlled narcotic drugs and psychotropic substances for medical and scientific purposes while preventing their diversion and abuse; Acknowledging the special report of the International Narcotics Control Board on the availability of internationally controlled drugs: ensuring adequate access for medical and scientific purposes, Affirming that access to palliative care and to essential medicines for medical and scientific purposes manufactured					

			from controlled substances Noting that the availability and appropriate use of internationally controlled medicines for medical and scientific purposes Noting with appreciation the efforts of nongovernmental organisations and civil society in continuing to highlight the importance of palliative care, including adequate availability and appropriate use of internationally controlled substances for medical and scientific purposes, as set out in the United Nations international drug					

			control conventions					
	National Digital Health Strategy for South Africa 2019 - 2024	0	6 The departments of science and technology and telecommunications and postal services; Participation in the workshop was from a broad stakeholder group including the national and provincial health departments, the Department of Science and Technology as well as the Department of Telecommunications and Postal Services. Other stakeholder groups who participated included the statutory councils, research institutions, development partners, universities and	30 (highlighting some relevant words only) South Africa has fully embraced the potential of digital health technologies to improve the quality and coverage of healthcare, increase access to services and skills, and promote positive changes in health behaviours to prevent the onset of acute and chronic diseases This, combined with emerging technological advances sets the scene for digital health to have a larger contribution to our health and well-being more than ever before. These developments, alongside a rapidly changing technology landscape within the context of the fourth industrial revolution present great opportunities for innovation.	26 (highlighting some relevant words only) Develop leadership capacity for digital health innovation and adaptive management These developments, alongside a rapidly changing technology landscape within the context of the fourth industrial revolution present great opportunities for innovation. It is embodied in the five strategic principles of a person centred focus, expanded access, innovation for sustainable impact, digital health workforce for economic development and a whole-of-government approach. The strategy is underpinned by five strategic principles of a person-centred focus,	4 Effective collaboration between public and private sector stakeholders will be crucial in order to build cost-effective digital health solutions, reduce data costs and build better digital health infrastructure within the aspirations of the fourth industrial revolution. The release of the new strategy is timely, following the establishment of the Presidential Commission on the Fourth Industrial Revolution by President Cyril Ramaphosa [1], announced during the February 2019 State of the Nation Address.	1 The latest developments led by the WHO have moved from eHealth to digital health, which has an emphasis on digital consumers, with a wider range of smart-devices and connected equipment being used, together with other innovative and evolving concepts such as that of Internet of Things (IoTs) and the more widespread use of Artificial Intelligence (AI), big data	2 The departments of science and technology and telecommunications and postal services; Participation in the workshop was from a broad stakeholder group including the national and provincial health departments, the Department of Science and Technology as well as the Department of Telecommunications and Postal Services. Other stakeholder groups who participated included the statutory councils, research institutions, development partners,

			Non-Governmental Organisations (NGOs) Firstly, hard components, such as skills in ICT sciences, health sciences and workforce management and development. It will include establishing technical resources such as cloud infrastructure and an environment for supporting sophisticated data science activities. Establish a data science capability to secure technologies such as big data, AI and predictive analytics for enhanced benefits of the digital health ecosystem, particularly more	"…assess their use of digital technologies for health, including in health information systems at the national and subnational levels, in order to identify areas of improvement, and to prioritise, as appropriate, the development, evaluation, implementation, scale-up and greater utilisation of digital technologies, as a means of promoting equitable, affordable and universal access to health for all, including the special needs of groups that are vulnerable in the context of digital health". Digital health technologies provide opportunities to strengthen health systems, transforming the way health services are provided and the way in which people engage with those services. The strategy will benefit patients seeking access to healthcare services, healthcare workers to	expanded access, innovation for sustainable impact, digital health workforce for economic development and a whole-of government approach. Digital health innovation focal points will be established at universities and parastatals	Participate in global and national digital health dialogues to exploit the fourth industrial revolution for UHC. Adequate bandwidth provides opportunities for sharing connectivity with employees and clients, via free WiFi and other methods, which will be transformative and support citizens to embrace the opportunities of the fourth industrial revolution. .	and analytics. [3]	universities and Non-Governmental Organisations (NGOs)

			sustainable health systems approaches and evidence-based clinical decisions	provide better services, and health systems managers to fulfil their role, empowering all citizens to better navigate their personal health journeys using digital technologies.				
	National Health Research Strategy: Research Priorities For South Africa 2021-2024	0	6 The research questions proposed should cover a whole spectrum of research for Health, including clinical, basic science, social, health systems, and policy research. Research questions should cover a whole spectrum of research for Health, including clinical, basic science, social, health systems, and policy research.	6 How infectious is the 501Y.V2 variant, using aerosol sampling technology? Ensure adequate supply of investigational? Therapeutics showing efficacy (address? Cost/affordability, equitable access, production capacity and technology transfer Service and benefit packages: designing and evaluating the benefit package (services included) for UHC; evaluating the approach towards benefit package design and health technology assessment; core services we need to deliver; how to expand	13 Innovative research to develop low-cost screening and intervention approaches as well as medicines and vaccines is needed Health Systems Innovation as outlined in the NSI White Paper Research translation and rollout of innovations Leadership and capacity for digital health innovation and adaptive management Innovative research to develop low-cost screening and intervention approaches as well as medicines and vaccines is needed	0	0	1 References: South African Department of Science and Innovation (2019). White Paper on Science, Technology and Innovation March 2019.

			Research questions should cover a whole spectrum of research for Health, including clinical, basic science, social, health systems, and policy research. References: Human Sciences Research Council. Human Sciences Research Council Strategic Plan 2016/2017 – 2020/2021. South African Department of Science and Innovation (2019). White Paper on Science, Technology and Innovation March 2019.	these; and cost implications Explore individual and combinations of interventions to generate community demand for quality, including dissemination of locally relevant information and innovations that use new technologies Continuing education and information updates on technological advances relevant to the field South African Department of Science and Innovation (2019). White Paper on Science, Technology and Innovation March 2019.	Test the effect of innovations in the preservice education of health professionals on delivery of competent and respectful care Explore individual and combinations of interventions to generate community demand for quality, including dissemination of locally relevant information and innovations that use new technologies Test management innovations and intrinsic and extrinsic approaches to motivate providers References: South African Department of Science and Innovation (2019). White Paper on Science, Technology and Innovation March 2019. Motaung S. Gauteng health research and innovation summit 2019. South African Journal of public health 2019 3:56 SAMRC (2020).			

					Strategic health innovation partnerships, request for application (RFA): Eastern Cape Health priorities.			
Communications and Digital Technologies	National Integrated Information and Communications Technology (ICT) Policy White Paper (2016)	9 Investment: Policy must promote and stimulate domestic and foreign investment in ICT infrastructure, manufacturing, services, content, and research and development. Advising the Ministry on areas for future research and development and planning. Unassigned spectrum may be assigned on a short - term basis for test or research and	7 The Departments of Telecommunications and Postal Services, Science and Technology and the Meraka Institute will coordinate programmes to roll-out support mechanisms for the technology hubs to be established in various centres of the country Key departments involved in the ICT sector include the Department of Telecommunications and Postal Services, Department of Science and Technology, Department of	132 (highlighting some relevant words only) The Departments of Telecommunications and Postal Services, Science and Technology and the Meraka Institute will coordinate programmes to roll-out support mechanisms for the technology hubs to be established in various centres of the country Information and Communication Technologies (ICTs) can play a key role in facilitating all the objectives of the NDP Chapter Ten meanwhile focuses on the need to increase the amount of local content available over digital platforms as means to drive uptake of digital technologies.	103 (highlighting some relevant words only) To establish new innovative mechanisms to blend private and government funding and support for universal service and access, in line with recommendations in South Africa Connect This White Paper outlines the overarching policy framework for the transformation of South Africa into an inclusive and innovative digital and knowledge society. Interventions to reinforce fair competition and facilitate innovation in the converged environment including approaches to addressing horizontal and vertical integration across the value chain	0	4 This White Paper includes interventions to address infrastructure challenges in the ICT sector. Use of smart technologies can also assist in facilitating sustainable infrastructure development across all sectors by, for example, providing early warning systems to alert of maintenance issues. The diagram below, drawn from ITU international best practice,	3 Key departments involved in the ICT sector include the Department of Telecommunications and Postal Services, Department of Science and Technology, Department of Trade and Industry Notwithstanding interventions such as the Department of Science and Technology's ICT Research, Development and Innovation Roadmap, a great deal still needs to be done to position South Africa as one of the leading

		development purposes Contribute to research and development on new deployment methods Aligning key state interventions such as ICT policy development and regulation, Research and Development, Funding, Efforts to promote local and Foreign Direct Investment Promoting research and development, innovation and local manufacturing	Trade and Industry, Notwithstanding interventions such as the Department of Science and Technology's ICT Research, Development and Innovation Roadmap The Industrial Policy Action Plan (2014-2017) expresses concern about the inadequate levels of coherence and coordination in prioritisation and agenda setting for science and technology innovation by, and between, government, business, academia and civil society An ICT RDI Investment and Planning Advisory Council including	Use of smart technologies can also assist in facilitating sustainable infrastructure development across all sectors by, for example, providing early warning systems to alert of maintenance issues. Technology Neutrality: Regulatory interventions should as far as possible be technologically neutral in order to stimulate innovation and facilitate the development of innovative new product and service offerings. To introduce a flexible evidence-based framework to respond to changes in technology and ensure new digital divides do not emerge.	E-learning and innovative use of ICTs in the education sector can assist in addressing inequalities in education in schools across South Africa, and facilitate ongoing improvement of educator skills. Innovation and Competition: Innovation, fair competition and equitable treatment of all role players must be facilitated to ensure a range of quality services are available to end-users and audiences. Where necessary, put in place proportionate remedies that address the needs of users and promote innovation, investment, affordability and quality of service		identifies the different types of interventions necessary to address the different categories of access gap (obligations to increase market efficiency, once off smart subsidies and on- going support for particular users) This section of the White Paper focuses on addressing the "true access gap" through development support and subsidies and the "smart subsidy zone" The term the "Internet of Things" refers to connecting	nations in new innovations arising from its own research and development programmes. The ICT RDI Investment and Planning Advisory Council will be Co-Chaired by the Departments of Telecommunications and Postal Services (DTPS); and Science and Technology (DST)

		Industry growth involves multifaceted interventions that cut across many government departments. Key activities in the value chain include: - Research and development; Notwithstanding interventions such as the Department of Science and Technology's ICT Research, Development and Innovation Roadmap, a great deal still needs to be done to position South Africa as one of the leading nations in new	senior officials from various government departments, as well as industry and research institutions (Universities and Science Councils) and civil society representatives, The ICT RDI Investment and Planning Advisory Council will be Co-Chaired by the Departments of Telecommunications and Postal Services (DTPS); and Science and Technology (DST) The Departments of Telecommunications and Postal Services, Science and Technology and the Meraka Institute will coordinate programmes to roll-out support mechanisms for the technology				objects and devices (called "smart" objects or devices) over the Internet (including, for example, household appliances) allowing them to communicate with each other, with other applications or to people.	

		innovations arising from its own research and development programmes IP protection provides much-needed incentives for innovation and creativity by enabling enterprises to recoup their investments in research and development and to fund future innovation.	hubs to be established in various centres of the country					
Cooperative Governance	Policy process on the system of Provincial & Local Government (2007)	0	0	1 How and in what circumstances can municipalities tap into alternative technology and innovations to enhance service delivery?	1 How and in what circumstances can municipalities tap into alternative technology and innovations to enhance service delivery?	0	0	0
	The White Paper on Municipal Service Partnerships	0	0	3 MSPs may also permit municipal councils to reduce their expenses for	6 There may be occasions when it is difficult or undesirable to completely	0	0	0

	(2004)			equipment rental, lease costs, initial purchase costs and technology licensing arrangements Over time, municipalities can save on the capital costs of infrastructure expansion and technology upgrades The suitability of a technical proposal for local needs, the reliability of the proposed technology and its ease of maintenance, and the proposed logistical arrangements for maintenance and support	specify the services required and the form of contract, for instance where a municipality wishes to encourage private sector innovation. The White Paper on Local Government recommends that municipalities look for innovative ways of providing and accelerating the delivery of municipal services. Enhancing the capacity of municipal councils to identify, evaluate and implement a broader, more innovative and feasible range of service delivery options; A key innovation of the Systems Act and its amendments is the idea of service provision through municipally owned entities termed "municipal entities". There may be occasions when it is difficult or undesirable to completely specify the services required and the form of			

					contract, for instance where a municipality wishes to encourage private sector innovation. Where innovation is desired, but the scope for error is large, municipalities should consider some form of intermediate process of inviting low-budget "concept proposals" in order to be able to firm up their ideas and subsequently issue a clear specification of services required, in a formal tender			
Human Settlements	Department of Housing White Paper A New Housing Policy and Strategy for South Africa (1994)	1 research and development activities around the promotion and facilitation of credit provision in the country, both at the wholesale (funding) and retail levels.	0	3 Technology Choice and Infrastructure Costs Significant work has already been done in this area and it is suggested that chapters 6 to 10 of the so- called "Red Book" produced by the Division of building Technology of the CSIR, be used as a basis for determining these standards.	9 The country's extremely wasteful approach to land will have to change, allowing for higher densities and innovation in its use. South Africa has a relatively well developed infrastructure as a basis upon which future housing policy can develop: - technical capacity and innovation.	0	0	0

				impact of technology choice on the environment	It is only by mobilising and harnessing the full diversity of resources, innovation, energy and initiative of individuals. communities. In addition to the project based subsidy programme already in place, Government will introduce a range of specifically designed lump sum subsidy instruments to support a broad and 3innovative housing delivery process in the country. Government believes that it has a significant role to play in actively developing and supporting new and innovative approaches to social housing, It will, however, be imperative to allow maximum flexibility with regard to provincial and local innovations in the application of the subsidy, provided that no hidden subsidies should be provided in the process.			

					Various parastatal and non-Governmental organisations involved in the provision of housing credit, play an important role in the provision of credit and especially in developing innovative new approaches to such provision. The need for special purpose lending vehicles as pioneering and innovating institutions is, however, recognised and programmes to ensure the sustained growth and expansion of this sector are envisaged to be part of the mandate of the National Housing Finance Corporation. As agency of Government: - the identification, encouragement and support of viable, people-driven, innovative approaches to mobilisation of savings and credit.			
	Towards a Policy Foundation for the Development	0	0	3 Light industrial areas making use of new technologies can be safely	0	0	0	0

	of Human Settlements Legislation (2016)			considered for integration with other uses provided that they meet the necessary health and safety standards. New technologies to limit pollution exist that need to be applied Efficient construction methods and materials: this will be accomplished by improving capital productivity via better construction, value engineering, procurement excellence, industrial construction, and promoting development of cost-effective, quality approved building materials and technologies with a view to bringing down the cost of affordable housing submarket.				
National Treasury	Economic Transformation, Inclusive Growth, and Competitiveness: Towards an Economic Strategy for South Africa (2019)	1 The authors argue that the technological sophistication, research and development (R&D), sophisticated packaging,	1 The National Treasury is working with the Departments of Small Business Development and Science and Technology on the design and	49 (highlighting some relevant words only) In a skills-constrained economy, the bias towards skills-intensive employment driven by technological advancement has the	13 (innovation - highlighting some relevant words only) Barriers to entry distort product markets and reduce the incentives for productivity and	0	1 Around the world, large dominant electricity producers have restructured to cope with technological	1 The National Treasury is working with the Departments of Small Business Development and Science and Technology on the design and

		temperature and disease control, and computerised logistics that go into producing a fresh orange ready for consumption in a foreign market can outstrip the technology and manufacturing transformation required, say, to produce a carton of orange juice. References: Schaffer, M.E., A. Steenkamp, W.T. Flowerday, and J.G. Goddard (2018). Innovation Activity in South Africa: Measuring the	implementation of a small business ideation and early start-up fund to address some of the shortcomings of the current funding landscape.	unintended consequence of raising wage premiums, which further entrenches inequality and contributes to rising unemployment. Agriculture and services, especially the tourism sector, are conduits for labour-intensive growth. Increasing competition in global value chains has forced domestic manufacturers to increase their competitiveness through investments in new technologies and upskilling their workforces. Technologically sophisticated exports, in particular, are crucial to structural transformation as they enable the economy to move from low- to high-productivity activities. These wage trends are partly explained by skills biased technological change but are also the result of an uneven and underperforming basic education system.	innovation, which directly inhibit growth. A small business and innovation fund is being created to focus on the ideation and start-up phases of a business where the market failure in small business finance is most binding. Second, enhanced competition can be a lever for inclusive growth and economic transformation by encouraging the growth of smaller firms, the entry of new firms, and growth in innovation and productivity. Export orientation sustains competitive pressures and forces innovation, and export sophistication through a focus on productivity and innovation is key to sustainable long-run growth (Cherif and Hasanov 2019).		changes such as the rise of smart meters, micro grids, self-generation, and small modular power plants (International Renewable Energy Agency 2015)	implementation of a small business ideation and early start-up fund to address some of the shortcomings of the current funding landscape

		Returns to Research and Development. Washington, DC: World Bank		These influence investments in physical and human capital, the incentive to innovate and develop new technology, and how production is organised. Global economic realities and demand are changing rapidly with technological changes in the electricity space (Makgetla 2017).				
Public Works and Infrastructure	Government-wide immovable asset management policy (2005)	0	0	0	0	0	0	0
	White Paper Public Works towards 21st century (1997)	0	0	8 (highlighting some relevant words only) Public works will play a major role in this, not only through employment creation but through managing public assets and major investments in economic infrastructure, electrification, telecommunication and information technology As highlighted in the National Public Works	7 (highlighting some relevant words only) The strategic framework for transforming the Department of Public Works is being established within the context of government's primary socio-economic objectives, as well as with tire aims of increasing efficiency and innovation And major innovations will be pursued, such as the Ten Point Plan for	0	0	0

				Programme, both direct and indirect effects of DPW activities will be critical for the introduction and promotion of labour-based technology in development and maintenance of state assets and it has used excessively capital-intensive (and import-intensive) technology	enhancing emerging entrepreneurial activity through the procurement process Promoting innovation Innovation and best practice Innovation and conformance with international property best practice			
Water and Sanitation	White Paper on Basic Household Sanitation (2001)	0	0	1 An aim of the national sanitation policy is to promote the environmental sustainability of sanitation systems. To ensure that sanitation systems are designed, constructed and operated in such a way that contamination caused by sanitation systems is restricted to acceptable levels throughout the life cycle of the system, regardless of the chosen technology option.	0	0	0	0

	The Strategic Framework for Water Services (2003)	1 There are many other role-players involved in the water services sector. These include any organisation providing water services, all consumers and households using water services, all employees in these organisations and their related representative structures, education and training institutions, professional bodies, contractors, non-government organisations, the manufacturing industry, business and other	1 Other role-players. These include science councils such WRC, CSIR & HSRC, academic institutions, water services authorities, SALGA, water utilities and service providers, non-governmental bodies, consultants and professional organisations such as the Cities Network, the Water Institute of South Africa (WISA), the Institute of Municipal Financial Offices (IMFO), and the Institute of Municipal Engineering of Southern Africa (IMESA)	14 DEAT has a role to play with regard to water and sanitation services insofar as environmental impact assessments are required for water services infrastructure projects, and in participating in joint ventures that promote conservation, cleaner technologies and waste minimisation. Choice of technology. The definition of a basic sanitation service (see section 6.3.1) does not define the technology to be used in providing such a service. This decision, made by the water services authority, is the key to success in providing free basic sanitation services in a sustainable manner. The selection of technology is strongly dependent on settlement conditions. Water services authorities must typically address the following situations: In intermediate areas (for example, peri-urban areas or rural areas where settlement densities are	0	0	0	0

		organisations involved in supporting activities such as research and development		high), a water services authority must decide on an appropriate technology which is financially viable and sustainable. Ideally, the subsidy for operating costs should be calculated as a subsidy per household per month for each settlement type and technology used. Water services authorities must then decide on the appropriate technical solutions, allocate subsidies between households based on settlement type and technology (see subsidy arrangements above) and work out what consumer charges will be necessary to sustain the service over time. In the choice of technology, a trade-off must be made between effectiveness, affordability, capacity to operate and maintain, life-cycle costs, consumer acceptability and environmental impact. Water and sanitation technologies should be considered together.				

				Technology. National norms and standards are not prescriptive in the specific choice of technology to be used to achieve a specified or desired outcome Choosing appropriate sanitation technologies This will assist water services authorities to examine the full suite of options available before deciding on a particular technology for delivery of water and sanitation.				
	National Water Policy Review (NWPR) Approved Water Policy Positions (2014)	0	0	0	1 Mechanisms for partnerships: - there is an opportunity to explore innovated and new mechanisms to encourage water use efficiencies within and between the various water use sectors of the country	0	0	0
Mineral Resources and Energy	White Paper A Minerals and Mining Policy for South Africa (1998)	17 (highlighting a few relevant words only)	16 (highlighting a few relevant words only)	26 (highlighting a few relevant words only) Undoubtedly some of the older mines are reaching	2 Innovative solutions have been developed by the established mining houses and research institutions.	0	0	0

		The last section focuses on research and development infrastructure conducive to the optimal development of the country's resources. Institutional research and development in respect of all the aspects of mineral development and exploitation relevant to small-scale mining is required, as well as the transfer of this technology to small-scale miners Research and development in the mineral industry needs to	Research and development in the mineral industry needs to conform to the development of a comprehensive science and technology policy that will address the country's needs. Science Councils and Government departments will endeavour to establish joint-venture research and training programmes with universities and the private sector in order to produce the necessary skilled and productive manpower required for mineral beneficiation developments. The Science Councils form part of the technology bridge between	the end of their lives, leading to job losses and the other attendant negative effects of downscaling, but these problems are being tackled energetically within the sector, through restructuring of mining groups, technological advances and innovative methods of improving productivity. Management of deposits that will be brought to account in the future requires a long-term perspective attuned to changes in technology and markets that is more likely to be found in the private sector. Institutional research and development in respect of all the aspects of mineral development and exploitation relevant to small-scale mining is required, as well as the transfer of this technology to small-scale miners. Access to finance and technology	Undoubtedly some of the older mines are reaching the end of their lives, leading to job losses and the other attendant negative effects of downscaling, but these problems are being tackled energetically within the sector, through restructuring of mining groups, technological advances and innovative methods of improving productivity.			

		conform to the development of a comprehensive science and technology policy that will address the country's needs Policy in this regard is set out in the Science and Technology White Paper and tackles issues such as directing the country's research and development effort towards addressing the needs of its citizens, the balance between applied and fundamental work, redressing past discrimination in access to	mining operations and available science, engineering and technology. It is here that the State's contribution is greatest. Co-operation between the various mining and mineral processing research and development institutions will be encouraged to make best use of existing facilities, to promote collaborative research efforts, to promote technology transfer and to ensure that minerals-related research and development is conducted in accordance with the country's science and technology policy and national	The Department of Minerals and Energy (DME) will co-ordinate needs-driven research by the Science Councils and ensure that this information and technology is accessible to the small-scale mining sector These include large-scale and capital-intensive operations like smelting and technologically sophisticated refining as well as labour-intensive activities such as craft jewellery				

		training related to research and development and the methods of funding these activities. A relatively large number of stakeholders representing a variety of disciplines perform research and development activities for the minerals and mining industry and these efforts need to be synergistic and complementary. The State is involved in research and development both as part of the national scientific and	objectives for the minerals industry.					

		technological effort and on behalf of the industry through the CSIR, Mintek and the Council for Geoscience as well as at universities and technikons. In instances where mining houses have identified advantages they have cooperated on research and development activities. Mining companies remain committed to research and development on process cost reduction and customer satisfaction, which serves						

		their own interests and is funded by themselves, whilst recognising the potential contribution of user influenced public sector research for common interests.						
	A Beneficiation Strategy for the Minerals Industry of South Africa (2011)	7 Side stream refers to infrastructure (e.g. power, logistics etc.), research and development, human resource development and inputs such as capital goods, consumables and services They are also chosen to demonstrate intrinsic,	4 Glossary: Department of Science and Technology the successful implementation of this strategy depends on intensive co-ordination across a range of government departments, particularly the Departments of Mineral Resources, Economic Development,	30 (highlighting some relevant words only) From 5,000 years ago, when beeswax formed the pattern, to today's high-technology waxes, refractory materials and specialist alloys, the castings allow the production of components with accuracy, repeatability, versatility and integrity in a variety of metals and high performance alloys. It also aims to expedite progress towards knowledge based	5 Research and Development: South Africa's limited exposure to break-through research and development programs thwarts the prospects of innovation in creating new products for beneficiation Additionally, the Coal-To-Liquid technology in South Africa further augments the need for investment in research and technology for prospects of discovering innovative means of optimising utilisation of mineral	0	0	2 Glossary: Department of Science and Technology The Department of Science and Technology outlines the legislative provisions as well as processes for R&D tax incentives in the Income Tax Act, 1962 (Act 58 as amended) and South African Council for Natural Scientific

		multi-tier value proposition benefits for South Africa, including creation of new jobs, development of requisite skills, investment in research and development, economic growth, sustainable development and cost-effective support for the broader policies of government. Research and Development: South Africa's limited exposure to break-through research and development programs thwarts the prospects of innovation in	Trade and Industry, Science and Technology, Public Enterprises, Energy and National Treasury as well other key mining stakeholders, including business and labour. Align beneficiation R&D requirements (both current and recurrent) to the national ten year plan for science and technology The Department of Science and Technology outlines the legislative provisions as well as processes for R&D tax incentives in the Income Tax Act, 1962 (Act 58 as amended) and South African Council for Natural Scientific	economy and contribute to an incremental GDP growth in mineral value addition per capita in line with the vision outlined in the NGP, NIPF and the Advanced Manufacturing Technology Strategy (AMTS) Additionally, the Coal-To-Liquid technology in South Africa further augments the need for investment in research and technology for prospects of discovering innovative means of optimising utilisation of mineral resources for the benefit of the country This leverage will attract investment, technology and skills to expedite growth in the sector. However, based on South Africa's historical mineral industry strength, there is a potential to attract and develop technological excellence in mineral related industries to support side-stream and downstream value addition	resources for the benefit of the country Research and Development: South Africa's limited exposure to break-through research and development programs thwarts the prospects of innovation in creating new products for beneficiation The company should provide competition for existing producers, helping to hold down prices for downstream activities, identify innovative activities and projects, and mobilise private as well as public resources to develop the mining value chain. Investment in R&D to find innovative means for beneficiation (recycling) of gases emitted in the generation electricity.			Professions Act, Act No. 16 of 2004.

		creating new products for beneficiation Limited exposure to Research and Development Opportunities exist for research and development to be directed at finding an alternative approach, such as potential of recycling the use of captured gases in the process of energy generation for re-generation of electricity as well as other uses (beneficiation), Investment in research and development initiatives,	Professions Act, Act No. 16 of 2004					

		which will be aimed at unlocking the intrinsic value of South Africa's minerals through finding new products and/or technologies in support of local beneficiation						
Social development	Framework for Social Welfare Services (2013)	0	4 It contributes to evidence-based practice that promotes the consistent use of scientifically validated information and effective interventions in social welfare service practice. Evidence-based practice can be thought of as a process undertaken by professionals where the scientific status of	7 (Information Management and Technology = 6 words) Developing and strengthening the partnership requires the inclusion of public sector objectives in line with government's programme of action (aligning strategies with common goals) and ensuring the provision of resources (human, financial, infrastructural and technological) to facilitate collaborative interventions by the welfare sector as a whole	0	0	0	0

			potential interventions is investigated and a thorough explication of the results is shared with clients so that practitioner and clients together can select the most appropriate steps for addressing a specific need. A national framework for research in the social welfare services sector is needed to guide the application of scientific approaches and methodologies in conducting research. The theoretical framework for service integration permits practitioners to apply the scientific basis of their interventions to	These service enablers include appropriate human resources (social welfare service practitioners), sufficient and equitable funding for services and programmes provided by collaborative partners, infrastructure (office space and facilities), and information management and technology equipment.				

			all activities they undertake					
Trade, Industry and Innovation	Re-imagined Industrial Strategy (2019)	2 Contribute to investment to boost greater demand in the renewable sector – particularly solar, municipal waste, biomass, biogas and wind – to support rural development, localisation, research and development, small enterprises and co-operatives. The universities in Mpumalanga and Northern Cape should be encouraged to offer academic programmes	5 Designation of the Bojanala SEZ in North West; Science and High-Tech SEZ in Ekaindustria; SEZ in Northern Cape Science, Technology & Innovation SA has strong capacity in pharmaceuticals, medical devices, treatment, medical aids, R&D, waste disposal, nuclear medicine & also in animal health / veterinary sciences Build Capability: Train 1 million youth on FIR skills (data science, 3D printing, AI, robotics, cloud computing, etc)	25 (highlighting a few words only) Innovation: Digital economy, developing and diffusing new technologies Continue to support the use of renewable technologies in the country's energy mix to reduce the cost of energy, decrease greenhouse emissions, build the local industry through increased localisation and create jobs, while recognising the reality that we have large coal reserves that can provide cheap energy that can also assist with affordable prices Investigate the cost-benefit of introducing solar panels in state buildings and mandate new commercial and residential developments in the medium term to use renewable energy	17 (highlighting a few words only) Ensure a legal and regulatory framework for promotion of innovation. Increase spending on innovation and aim for more technological break-through critical to the country's development through support for research Open opportunities for young people to develop new software and applications, devices and equipment through specialised start-up support programmes for use by all spheres of government and society. A digital innovation centre will be established for this purpose within the next three years. Local procurement allows us to leverage and expand exports in the region - big ARV tender recently given	8 4IR is critical in pushing the economy beyond its current limits and harnessing opportunities to support our industrialisation programme Leveraging the 4IR-Key Initiatives 4IR Special Economic Zone Neither in Training or Employed -ICT SETA spend and Skills Levy to develop 4IR skills Basic Education:- Curriculum Innovation at basic education, to include 4IR skills Under consideration is 4IR Innovation	12 (highlighting a few words only) Smart Youth Centres, Business Centres & Incubation Hubs, and Priority will be given to effective use of new technologies for public infrastructure as we build smart public schools and smart health facilities and smart community policing to fight crime. Smart use of incentives, coupled to target	2 DST Research Coordination: Alignment to sector strategies (DST, DTI, DTPS, academia, research councils

		in renewable energy. Defence and aerospace industry - Potential Impact: High export growth, strong research and development as well as capability development transfer	Finalise designation and implementation plans/finance of the Bojanala SEZ in North West; the Automotive SEZ in Tshwane; Science and High-Tech SEZ in Ekaindustria;	technologies to reduce utility costs Develop domestic capability to manufacture new green technologies including batteries for autos and the grid, expand solar geyser repair and maintenance, and create an infant industry fund to support commercialisation of new technologies.	to India has taken jobs & innovation from SA Work with stakeholders to ensure that innovators and artists are justly rewarded for their labour in the digital age and protect the copyrights of artists.	Corridor (Innovation Hub with strong linkages with other SEZs, Industrial Parks, ICT Hubs) Inter-Ministerial Commission on 4IR Digital Economy/4IR	outcomes (reciprocity)	

APPENDIX 2: DEPARTMENTAL ANALYSIS

Department of Agriculture, Land Reform and Rural Development

The Department of Agriculture, Land Reform and Rural Development is one of the few departments with a Directorate on Research and Technology Development dedicated to research, technology development and technology transfer. Of the five keywords selected emphasis is on the keyword "research and development". There is no surprise that there is specific reference to the keywords "Department of Science and Technology" in the *Department of Agriculture, Forestry and Fisheries (DAFF) Agro-processing Strategy* (2012). The specific mention of the DSI entities such as the Council of Scientific and Industrial Research (CSIR) and Agricultural Research Council (ARC) shows integration of the STI in both government departments.

Department of Basic Education

The Department of Basic Education (DBE) incorporates STI by integrating science, technology, engineering and mathematics in the curriculum programmes. DSI and the Department of Higher Education and Training (DHET) have been merged as one department and at some point, one would expect to see more streamlining among the three departments in school curriculum (basic education), higher education and STI skills required in the future workforce. On Basic Education, the Department had a document called 'The Science Engagement Strategy' which addressed public indicatives that could be put in place and ways to excite the public about science, technology, and innovation. DSI also engages with young people through the South African Agency for Science and Technology Advancement (SAASTA) which fell under the NRF. There are about 30 basic education science centres in provincial and regional areas across the country with programmes designed with the DBE to popularise science, technology and innovation to young people. The annual DSI National Science Week also works involves with DBE in getting young people across the country to participate in STI activities. The word searches on the six selected policies revealed that there is significant mention of words related to "science" and "technology" and to some extend "innovation". There is also an explicit mention of "collaboration with the Department of Science and Technology on the teaching profession, higher education institutions and research agencies, will formulate a research agenda on ICTs for e-Learning". There is some level of integration of STI by DBE.

Department of Health

The COVID-19 pandemic necessitated the need for stronger collaboration between DSI and the Department of Health (DoH) particularly in the role of vaccination the areas of research and innovation in support of COVID-19 required collaboration between for example DoH's

National Health Laboratory Service (NHLS) and the DSI's Council for Scientific and Industrial Research (CSIR) biosciences laboratory. The industrialisation of the National Ventilator Project (NVP) for COVID-19, which produced ventilators for SA and neighbouring countries also required collaboration between the two departments. DSI also has strategic health initiative partnership project sin all provinces as part of its infrastructure projects. In analysing the word search in the six selected policies, there is significant mention of the words related to "innovation" and the latest strategy National Digital Health Strategy for South Africa 2019 – 2024 explicitly mentions words related to smart" and "fourth industrial revolution" and recognises the role of the DST/DSI. There is definitely an integration of STI

within the DoH in addition to having a unit within the Department dedicated to research and development.

Department of Communications and Digital Technologies

The Department of Communications and Digital Technologies (DCDT) is in the process of finalising the ICT and Digital Economic Master Plan. The Master Plan makes explicit mention of the collaboration with DSI on strengthening the digital economy e.g. reforming South Africa's IP policies and patent grant system. The DSI in partnership with DCDT have established the World Economic Forum Centre for the Fourth Industrial Revolution. The core focus of the Centre will be technology governance. DSI's CSIR Meraka Institute plays a critical role in ICT research, development and innovation roadmap. The interview did not reveal much on the collaboration however the only policy selected *National Integrated Information and Communications Technology* (ICT) Policy (2016) has significant use of all the concepts "research and development", "science", "technology", "innovation", "smart" and acknowledges the role of the "Department of Science and Technology" except "fourth industrial innovation".

National Treasury

Analysing the results of the interview, National Treasury highlights its institutional mechanisms that are in place to strengthen its governance such as ICT strategy and its implementation plan. They've also introduced some innovations in updating their delivery of work. The National Treasury is responsible for the annual publication – Estimates of National Expenditure. This can give an indication of which government department have allocated line budget items targeted for science, technology and innovation.

Table 6: Budget line items highlighted in the 2021 Estimates of National Expenditure

Government Department or Entity	Budget line item (word search relating to above) (2021/22 to 2023/24)
Agricultural Research Council	• Number of peer-reviewed scientific publications per year
Basic Education	• Maths, science and technology grant
Communications and Digital Technologies	• Digital terrestrial migration and technology
Employment and Labour	• Research, innovation and statistics
Environment, Forestry and Fisheries	• Biodiversity science and policy advice
Health	• Health technology assessment
Higher Education and Training	• National Institute for the Humanities and Social Sciences • Sefako Makgatho Health Sciences University • Number of awards (scholarships, fellowships and grants) by the council to MSPhD and postdoctoral candidates, and early career scientists per year • Number of awards (scholarships, fellowships and grants) by the council to female MSc, PhD and postdoctoral candidates, and early career scientists per year
Human Settlements	• Council for Scientific and Industrial Research

Mineral Resources and Energy	• Council for Geoscience: Operations • Council for Geoscience • Council for Geoscience: Economic • Council for Geoscience: Expanded public works programme
Police	• Forensic Science Laboratory
Public Service and Administration	• Centre for Public Service Innovation
Sports, Arts and Culture	• Human languages technologies projects (Council for Scientific and Industrial Research) • United Nations Educational, Scientific and Cultural Organisation
Trade, Industry and Competition	• Council for Scientific and Industrial Research: National Cleaner • Council for Geoscience • Council for Scientific and Industrial Research • Council for Scientific and Industrial Research: National Foundry • Technology Network • Intsimbi future production technologies initiatives • Support programme for industrial innovation
Water Research Co mmission	• Innovation and impact

Source: 2021 Estimates of National Expenditure

Table 7: Programmes and sub-programmes highlighted in the 2021 Estimates of National Expenditure

Government Department / Entity	STI related Sub-programme
Agriculture, Land Reform and Rural Development	• *Technology Research and Development* develops and adapts innovative and app ropriate technologies in rural areas. • *Onderstepoort Biological Products* prevents and controls animal diseases that affect food security, human health, and livelihoods through continued development and the efficient manufacturing of innovative animal-related pharmaceuticals (including vaccines) and related products.
Basic Education	• Curriculum Implementation and Monitoring supports and monitors the implementation of the national strategy for learner attainment to monitor the quality of teaching, and improve the quality of mathematic s, science, technology and language education from grades R to 12 in all public schools.
Communications and Digital Technologies	• Information Society Development supports the promotion of a digital society by facilitating the adoption and use of digital technologies. • Knowledge for innovation Programme
Corporate Governance	• Information Technology, Intelligence and Information Management Systems guides the development of a comprehensive information management and communications system, and establishes integrated communication channels with all disaster management role players. In collaboration with the relevant disaster management stakeholders, this subprogramme also provides early warning messaging systems for severe weath er and other hazards
Health	• Innovation and Technology Programme • Forensic Science Laboratory funds forensic science laboratories, which provide s pecialised, evidence-related technical analysis and support to investigators.

Defence	• Technology Development provides for establishing and sustaining selected science and technology capabilities in the defence industry.
Environment, Forestry and Fisheries	• Biodiversity Monitoring Specialist Services provides support services for intergo vernmental and legislative biodiversity and science policy; and monitors, evaluates, analyses, negotiates and advises on national and international biodiversity conservation statuses and trends. This sub-programme also catalyses international and national negotiations through the p rovision of the best available scientific and policy information.
Mineral Resources and Energy	• *Nuclear Energy Management* provides overall management to the programme and oversees the national liaison office of the International Atomic Energy Agency; and is responsible for managing the African regional cooperative agreement for research, development and tra ining related to nuclear science and technology. • *Economic Growth, Promotion and Global Relations* promotes economic growth and investment in the sector. This sub-programme also makes transfers to the Council for Geoscience and the Council for Mineral Technology and Research (Mintek) • *Nuclear Safety and Technology* manages and implements all matters related to nuclear safety and technology as required by legislation and international agreements; implements nuclear energy policy in line with therequirements of the integrated resource plan; and administers all mat ters related to nuclear technology, safety, liability and emergency managementwith the aim of improving the governance of the nucl ear sector. This subprogramme also makes transfers to the South African Nuclear Energy Corporation, the National Nuclear Regulator and the National Radioactive Waste Disposal Institute and is responsible for paying membership fees to international organisations.
Public Service and Administration	• *Knowledge Management and Innovation* manages, develops and monitors the implementation of policies and programmes for knowledge mana gement and innovation. • *Research and Development* establishes the knowledge base in support of the programme to inform the selection and development of potential innovative models and solutions. • *Enabling Environment* nurtures and sustains an enabling environment to entren ch a culture and practice of innovation in the public sector through innovative platforms and products
Rural Development	• *Technology Research and Development* develops and adapts innovative • and appropriate technologies in rural areas.
Social Development	• *3* provides for the coordination, incubation and innovation of departmental and social cluster initiatives such as the expanded public works programme.
Statistics SA	• *Business Modernisation* improves data and information management across the department by modernising the way business is conducted • and supported by technology. • *Innovation and Research* conducts statistical research, and innovates statistical methods, practices and processes for improved efficiency and agility.
Trade, Industry and Competition	• *Macroeconomic and Microeconomic Policy* evaluates and develops macroeconomic and microeconomic policy options to promote decent work outcomes, productivity, entrepreneurship and innovation
Companies and Intellectual	• Innovation and creativity promotion

Property Commission	
Transport	• *Research and Innovation* ensures research and innovation in, and monitoring of the transport sector for sustainability.

Source: 2021 Estimates of National Expenditure

Department of Human Settlements

The DSI signed a collaboration agreement with the Department of Human Settlements in 2018. The overall objective is "aimed at facilitating the leveraging of resources and capacity in the Parties respective Departments to build a critical mass of knowledge in their respective areas of responsibility and to augment the institutional capacity of the Parties in research and implementation of innovations to support such policy priorities." On the 22nd of June 2021, the DST launched the Science Technology and Innovation for Sustainable Human Settlements Roadmap. This was not mentioned by the Department of Human Settlements in their interview or anything relating to the roadmap. The roadmap is aimed to deploy innovations and technology to achieve green, smart and sustainable human settlements in the context of 4th Industrial Revolution. The roadmap also includes the Department of Water and Sanitation. The Minister of Human Settlements, Water and Sanitation is responsible for the Department of Human Settlements; and the Department of Water and Sanitation. This is a clear integration of STI by three government department in developing smart settlements. The interview only mentioned the use of alternative building technologies in housing construction. Of the two policies selected for the Department of Human Settlements, the *Department of Housing White Paper a New Housing Policy and Strategy for South Africa* mentioned the word "innovation" significantly (9 times), considering the policy was adopted in 1994. The other policy, the *Towards a Policy Foundation for the Development of Human Settlements Legislation* (2016) only mentions the concept "technologies" and no other concepts. The implementation of the roadmap seems to be ongoing, led by the Council of Scientific and Industrial Research. Integration in this area seems to be in good progress.

Department of Social Development

Interpreting the results of the interview, the Department does invest in the technical infrastructure to support its work and continuously engages in research in areas of priority. The Department is not directly engaging with the STI activities relating to the DSI. This argument is supported by the word search on the one policy was selected: *Framework for Social Welfare Services* (2013) which only mentions words "science" and "technology".in reference to supporting their technical and infrastructure needs. The DSI is doing work on social innovation and the collaboration with the Department of Social Development could have far reaching impact. There are no clear projects on social innovation highlighted from the interview and this is a gap that can be considered for integration. Social innovation here can be interpreted as innovative ways to tackling systemic social problems through new products, service, processes or organisational approaches.

Department of Cooperative Governance

Based on interviews, the Department of Cooperative Governance does not seem to integrate STI policies in its policies and institutional mechanisms. Of the two policies selected for the keywords search: *White Paper on Municipal Service Partnerships* (2004); and the *Policy process on the system of Provincial & Local Government* (2007), there appeared to have no mention of the concepts "research and development", "science", "Fourth Industrial Revolution", "smart" and "Department of Science

and Technology". The *White Paper on Municipal Service Partnerships* mentions words "technology" and "innovation" three and six times, respectively. The *Policy process on the system of Provincial & Local Government* only mentions the words "technology" and "innovation" once. The department does acknowledge the use of technology and identifying "innovative ways of providing and accelerating the delivery of municipal services". The Department is at the coal face of service delivery. The Department needs to consider putting into action ways of aggressively introducing public service delivery innovation and adopting new trends in the Fourth Industrial Revolution. Collaboration with institutions such as the Centre of Public Service Innovation under the Department of Public Service and Administration could assist the Department integrating some practical aspects of STI in its policies and institutional mechanisms.

Department of Public Works and Infrastructure

In August 2020, DSI unveiled seven hydrogen fuel cell systems which are being used as the primary power source for the field hospital established at 1 Military Hospital in Pretoria as part of the government's response to COVID-19. The project is a public-private partnership between the DSI, the Department of Public Works and Infrastructure (DPWI), the Department of Defence (DoD), local companies Bambili Energy and HyPlat, and international companies PowerCell Sweden, Horizon Fuel Cell Technologies (Singapore) and Element 1 Corporation (United States). Two selected policies do not show significant keywords and indicate minimal integration between the two departments as also emphasised by the interview.

Department of Water and Sanitation

The DSI's Water Research Commission ensure integration between the DSI and the Department of Water and Sanitation (DWS). The DWS has dedicated structure unit on research and has budget for research and development. DSI is collaborating with the DWS and the WRC to develop a Water Research, Development and Innovation Roadmap. The three policies selected do not reflect the level of integration between the two departments however the interview does highlight the details of integration of STI by DWS.

Department of Mineral Resources and Energy

The institutional role in enhancing integration is also highlighted here where South African National Energy Development Institute (SANEDI) plays a role in the implementation of the hydrogen strategy. SANEDI will also fund projects to take intellectual property created through the Hydrogen SA (HySA) centres of competence to market in partnership with the private sector. There's the DSI's Council for Mineral Technology Research (Mintek) which provides research, development and technology that fosters the development of business in the mineral and mineral products industries. There is also the Rock Innovation Programme developed in conjunction with the Department of Mineral Resources, CSIR, the Council for Geoscience and Mintek. South Africa's geosciences and mining research and development (R&D) environment was investigated by the CSIR's Centre for Mining Innovation and a subsequent programme was developed, which took into consideration South Africa's research needs, as well as the outcomes and recommendations proposed by various appropriate DST-funded studies. There seems to be significant integration of STI by the Department of Mineral Resources and Energy at an institutional level. This is supported by the fact that the two policies selected mention most of the concepts searched to a large extent.

Department of Trade, Industry and Competition

Possible collaboration with Department of Trade, Industry and Competition on the development of green hydrogen economy. DSI has already made strides in research and development of fuel cell which is a fundamental input in this hydrogen economy. DST has adopted the National Hydrogen and Fuel Cell Technologies Research, Development and Innovation (NHFCT RDI) strategy and has three Hydrogen South Africa (HYSA) centres of competence (CoCs). Minister Patel announced in his budget vote that dtic's Industrial Development Corporation (IDC) would lead the commercialisation of green hydrogen efforts, working with the DSI. Even though the dtic has two separate units on innovation related work, there is little evidence of explicit collaboration with the DSI. There is little evidence of practical collaboration however the intention is expressed in the newly adopted dtic's Re-imagined Industrial Strategy (2019).

Table 8: Summary on level of adoption and integration of STI into government policies and planning framework

Government Department		Entities playing a role in integration	Summary							Level of integration < 5 means Minimal = 5 means average > 5 means Greater
			Words: Research and development	Word: Science/ scientists/ scientific/ scientifically	Word: Technology/ Technologies/ Technological/ Technologically	Word: Innovation/ innovated/ innovative/ Innovators	Word: Fourth/ 4th industrial revolution	Word: Smart	DST/ Department of Science and Technology / DSI/ Department of Science and Innovation	
1.	Agriculture, Land Reform and Rural Development	Agricultural Research Council	0	6	28	9	0	0	4	> 5
2.	Basic Education	DSI South African Agency for Science and Technology Advancement	10	43	94	16	0	0	1	= 5
3.	Health	National Health Laboratory (NHLS) DSI's Council for Scientific and Industrial Research (CSIR) biosciences laboratory	1	19	74	48	4	4	3	> 5
4.	Communications and	DSI CSIR	9	7	132	103	0	4	3	= 5

	Digital Technologies									
5.	Cooperative Governance		0	0	4	7	0	0	0	< 5
6.	Human Settlements	DSI CSIR	1	0	6	9	0	0	0	> 5
7.	National Treasury		1	1	49	13	0	1	1	< 5
8.	Public Works and Infrastructure		0	0	8	7	0	0	0	< 5
9.	Water and Sanitation	Water Research Commission	1	1	15	1	0	0	0	> 5
10	Mineral Resources and Energy	Mintek Council for Geoscience	24	20	56	7	0	0	2	= 5
11	Social Development		0	4	7	0	0	0	0	< 5
12	Trade, Industry and Competition	CSIR	2	5	25	17	8	12	2	< 5

APPENDIX 3: QUESTIONNAIRE

Dear Sir/Madam

Quantitative Evidence Research Consultancy Services cc has been appointed as a service provider by the Academy of Science of South Africa (ASSAf) to assess how national and provincial government departments have integrated Science, Technology and Innovation (STI) in their policies and institutional programmes.

The White Paper on Science, Technology and Innovation focuses in particular, on the use of STI to accelerate inclusive socio-economic growth and transformation, and to respond to the global technological advancement, such as 4th industrial revolution (4IR). The Department of Science and Innovation (DSI) is committed through the establishment of the Inter-ministerial Committee on STI, be chaired by the Minister of Higher Education, Science and Innovation, to ensure that STI is integrated into the planning of relevant government departments and STI programmes. The White Paper therefore, seeks to ensure that all departments working in areas that affect STI are open to innovation uptake and that there is policy coherence across the National System of Innovation (NSI).

The research primarily aims to cover the following key areas:

1. Identification of the capabilities and constraints of departments in incorporating STI in their policies;

2. Assessment of the linkages and potential implementation gaps between government departments and policies to ensure that there is policy coherence across; and

3. Identification of current effectiveness of current mechanisms used by government departments to track and monitor the incorporation of STI in policies and planning.

A brief questionnaire, see below, has been prepared based on the key areas to be completed by the relevant officials to provide insight on whether there has been any integration of STI in their policies, planning framework and programmes/activities.

If there are any questions regarding this matter, or clarity on the questionnaire, please do not hesitate to contact me, Prof A Pouris apouris@icon.co.za / 083 630 5996, or Mrs AEM Thirion andronikip@hotmail.com / 076 260 3025. It would be appreciated to receive the responses to the questionnaire **on/or before 11 June 2021**.

I would be grateful if you could confirm that you have received the request. Thank you for your time and consideration.

Please complete Respondent Information:

Name of Government Department	
Programme/Division/Branch in the Department	
Name & contact numbers of person completing the form	

Please respond to the following questions by placing an "x", where applicable, and elaborate as appropriate.

3. To your knowledge, has your department integrated or adopted any science, technology and /or innovation aspects in its policies or planning framework?

Yes	
No	
If Yes, please identify the policy and elaborate on the approach and the integrated or adopted science, technology and innovation aspects (e.g. evidence)	
If Yes, please elaborate on whether this was a once off or it's consistently so	
Do you monitor the incorporation of STI into your policies and planning?	Yes Effectiveness of mechanism 1 2 3 4 5 (tick one 5 excellent) No
What are the constraints in incorporating STI in your policies? (e.g. expertise; budget; other please define)	

4. To your knowledge, has your department integrated or adopted any science, technology and/or innovation aspects in its work plan such as programs, activities or interventions?

Yes	
No	
If Yes, please identify program and elaborate on the approach and integrated or adopted science, technology and innovation aspects (e.g. evidence used)	
If Yes, please elaborate on whether this was once off or it's consistently so	
Do you monitor the incorporation of STI into your programs, activities or interventions?	Yes Effectiveness of mechanism 1 2 3 4 5 (tick one 5 excellent) No
What are the constraints in incorporating STI in your programs, activities or interventions?	

9. To your knowledge, has your Department integrated or adopted any aspects of South Africa's science, technology and /or innovation policies (e.g. 2019 White Paper on Science, Technology and Innovation) in its policies, planning framework or work plan?

Yes	
No	
If Yes, please describe /elaborate on those aspects of South Africa's science, technology and /or innovation policies. (e.g. introduced R&D funding).	
If Yes, please elaborate on whether this was once off or it is the case consistently so	

10. Does your Department have a dedicated budget towards science, technology and / or innovation related programmes?

Yes	
No	

11. Does your Department use a dedicated budget towards research and development programmes? Please indicate approximate amount for R&D and separate amount for innovation.

Yes	
No	

12. Does your Department have dedicated unit /personnel working on science, technology and/ or innovation programs or activities?

Yes	
No	
If Yes, please elaborate on the dedicated unit /personnel e.g. name; approximately size etc.).	
If Yes, please elaborate on whether this was once off or it is the case consistently so	

13. Does your Department have human or infrastructural capabilities to incorporate science, technology and/ or innovation in your policies and work plan?

Yes	
No	
If Yes or No, please elaborate on the capabilities	
If Yes, please elaborate on whether this was once off or it is the case consistently so	

14. Does your Department monitor local policies and international good practice (e.g. implementation of innovation roadmaps)?

Yes	
No	
Please elaborate (include the M&E framework tracking)	

15. In your opinion, do you think science, technology and / or innovation is relevant in your Department's policies and work plans?

Yes	
No	
Please elaborate	

16. In your opinion what policies can improve coherence in the policies and programmes of your Department with the innovation policies and programmes of the Department of Science and Innovation?

1	
2	
3	

Thank you for your participation in this national effort!

A Copy of the letter of reference signed by the President of the ASSAf Council.

ASSAf
ACADEMY OF SCIENCE OF SOUTH AFRICA

Applying scientific thinking in the service of society

19 May 2021

TO WHOM IT MAY CONCERN

RE: **NATIONAL AND PROVINCIAL GOVERNMENT POLICY RESEARCH STUDY**

Dear Colleague

The Department of Science and Innovation (DSI) has commissioned the Academy of Science of South Africa (ASSAf) to conduct a Policy Research Study on behalf of the Department. The objective of the study is to assess how national and provincial government departments' policies are open to the uptake of innovation; how they have integrated Science, Technology and Innovation (STI) in their policies and different institutional programmes; and instilled the innovation culture within and across the departments.

It is anticipated that the outcome of the study will inform the DSI on how government departments have embraced innovation. This will thus enable the Department in creating enabling environments to engage with stakeholders to formulate policy interventions that accelerate the realisation of the value of STI in public service and society in general, in line with the 2019 White Paper on Science, Technology and Innovation.

ASSAf has contracted Quantitative Evidence Research, led by Professor Anastassios Pouris, to conduct this study on behalf of the Academy. **ASSAf would highly appreciate your assistance in this national effort to assist Prof Pouris when your participation is requested for collection of information and opinions, in a form of an interview, questionnaire, expert consultations etc.** Should you have any questions, please contact Professor Anastassios Pouris on apouris@icon.co.za or anastassios.pouris@up.ac.za.

Yours sincerely

Prof Jonathan Jansen
President: Academy of Science of South Africa (ASSAf)

1st Floor Block A, The Woods, 41 De Havilland Crescent, Persequor Park
PO Box 72135, Lynnwood Ridge 0040, Pretoria, South Africa
Tel: +27 12 349 6600, Fax: +27 12 349 5461, Email: info@assaf.org.za
www.assaf.org.za