STI4CE Strategy for South Africa

Deliverable 3: STI Analysis Report - Ecosystem and Opportunities

Final Draft

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Development of an STI-led cross-sectoral Circular Economy Strategy for abating GHG emissions in South Africa

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0 Executive Summary

In support of the UN Climate Technology Centre and Network (CTCN), the Department of Science and Innovation (DSI) is in the process of developing a Science, Technology and Innovation Circular Economy (STI4CE) Strategy that aims to support South Africa's transition to a more circular economy (CE) through Science, Technology and Innovation (STI). The South African government recognises the potential of the CE to address growing resource challenges; achieve national climate and sustainability commitments; and create new socio-economic opportunities through greening existing sectors and unlocking new circular businesses and business models.[1] The CE approach aligns to the goals of the National Development Plan (NDP) and a number of national industrial, developmental and environmental policies, and can be seen as a direct response to Government's STI Decadal Plan 2022-2032, which recognises the critical catalytic role of STI in the CE as a cross-cutting opportunity.

DSI has embarked on a process to facilitate positioning the CE at the centre of economic development in South Africa (SA) through a STI based approach within the mandated responsibilities of the department. This report represents Deliverable 3 – STI Analysis report that establishes an overview of the existing STI ecosystem, including internal structures, processes and budget lines within the key implementing department (DSI), of the STI policy landscape, its development and implementation mechanisms as well as important STI initiatives, tools and instruments. Based on this analysis and outcomes of D2, opportunities have been derived by DSI mandate (Human Capacity Development, Research and Development, and Innovation and priority sectors).
DSI is a separate government department that was established to ensure greater coordination, integration and better management of 'all government funded science and technology institutions' while providing a rounded review of public expenditure on science and technology. Its inner structure and their operations are influenced by DSI's goals, objectives and mandates, while on the other hand, outcomes and budget lines determine temporary focus areas. The department has 5 Programmes[2], that are listed below and their relevance in the introduction section: **Programme 1: Corporate Services and Institutional Planning support**; **Programme 2: Technology Innovation**; **Programme 3: International Cooperation**; **Programme 4: Research, Development and Support**, and **Programme 5: Socio-economic Innovation Partnerships**.

These 5 programmes are represented by 6 branches of the department, with their relevance to the STI4CE strategy included in the introduction section, namely: **Institutional Planning and Support**, **Corporate Services**, Technology, **International Cooperation and Resources**, **Research Development and Support, and Socio-Economic Innovation and Partnerships**

The DSI programmes are supported by eight entities or implementation agencies, which are: Academy of Science of South Africa (ASSA), Council for Scientific and Industrial Research (CSIR) , Human Science Research Council (HSRC) , National Advisory Council on Innovation (NACI), National Research Foundation (NRF) , South African Council for National Scientific Professionals (SACNSP), South African National Space Agency (SANSA), and the Technology Innovation Agency (TIA). The CSIR, TIA and NRF play the biggest role in CE and STI, with the CSIR leading in the CE research and has published work on various sectors of the economy where CE has the most impact. With the funding of students, the NRF contributed to the human development through producing the number of PhD's needed by the economy and the various Centers of Excellence. TIA supports innovation through partnering and funding innovative SME's and that contributes to the de-risking of the projects through to commercialisation.

The overall budget within DSI was R9.1 billion within the 2022/2023 budget cycle, of which 97% has been spent. The internal funding allocation ranges between 2-55%, with the largest part (55%) going to Research, Development and Support. The budgeting, same as the planning, monitoring, and reporting are highly influenced by the National Development Plan 2030, Medium Term Strategic Framework 2019-2024, DSI STI Strategy and the Decadal Plan. According to the DSI Strategic Plan[3], current budget allocation to various Programmes withing DSI is based on a historic and incremental budgeting method. The Plan highlights the need for a change in this budget allocation method, to meet the changes in priorities brought about by the policy shifts.

The Policy landscape journey leading up to the development of this STI4CE strategy started in 1996 with the Promulgation of the White Paper on Science and Technology. Developments over the last 27 years have included

numerous Science and Technology driven outputs and developments to address challenges such poverty, food security and energy and to create an enabling environment for circular economy.

Other important guiding policy documents that shall inform the planning, implementation and monitoring of the yet to be developed STI4CE Strategy, with their relevance highlighted in the introduction section, include: **The National Development Plan (NDP) 2030**, the **Medium-Term Strategic Framework 2019-2024**, **5-year Strategic Plan 2020-2025 of the National Advisory Council on Innovation (NACI)**.

For these elements to synthesis and effectively inform the STI4CE Strategy, **appropriate links and collaboration has to be established between the mentioned bodies**. In particular, between NACI and the DPME to help integrate STI into transversal government planning by the DPME, and to support funding prioritisation by the DPME and National Treasury (e.g. via the annual Budget Mandate Paper). Additionally, the involvement and integration between DSI and NACI has to be increased, that is tasked to prepare reports on the implications of geopolitical and demographic shifts, technological changes, environmental sustainability imperatives and other megatrends for government STI planning. Lastly to highlight is the importance of a **strong integration of Local and Provincial Governments in the higher-level planning and coordination**. Given that provinces and municipalities are the once integrating the national strategic frameworks, a more effective way, in contrast to a 'top-down' approach, is the consequent and systematic integration of representatives of Provinces and Local Government in the process that also allows feedback from the bottom-up channel.

DSI is driving important and enabling initiatives aimed at improving coordination and integration amongst the various ministries and government departments with linkages to CE and STI. These play an important role in shaping the institutional arrangements and governance chapter in the STI4CE Strategy, working towards effective implementation and alignment. They include, **Circular Innovation South Africa (CISA), CE Inter-ministerial Steering Committee, CE Working Group (inter-departmental), Circular Innovation Platform; and CE STI Forum.** The M&E reporting and auditing on performance aspects related to DSI functions and the STI4CE Strategy is embedded in a range of reference documents, their relevance highlighted in the introduction), including: **STI Indicators Report**, **DSI Annual Report**, and **CSIR Annual Report.**

It is imperative for the DSI to have a consolidated database of ecosystem role-players within the STI space, including those operating within different cycles of the circular economy. These actors include tertiary education and research centres, government departments and entities, private sector entities both large and small, civil society mobilisers and organisations, and a set of intermediary organisations. The focus of these actors ranges from very specialised focus on a single material supply chain or single sector association, to broad systems views with an aim to support systems integration. For effective production and uptake of STI for CE, investment is required in both the specialised skills and institutions, as well as in the intermediary organisations who draw linkages and provide 'translation' services that support in making research and innovation either policy- or implementation-ready. DSI is well positioned to serve as intermediary by providing several brokering roles between the creators, users and beneficiaries of STI. This linkage role has been articulated along four needs and elaborated under the introduction section, (1) **Supporting public sector coordination for meaningful uptake of circular economy ideas, (2) Connecting research and practice; (3) Facilitate the uptake of new IP and (4)**, **Facilitating new skills development required for CE transitions.**

As part of the STI ecosystem, several initiatives, instruments and tools exist that shape the STI4CE landscape. The South African government is committed to supporting the transition to a circular economy. It has many initiatives in place to promote both circularity and STI. These initiatives are focused on developing and implementing policies and regulations, supporting research and development, and promoting the adoption of circular economy practices by businesses and consumers. Relevant instruments include legislation, policies or institutional arrangements, such as the Carbon Tax, EPR Regulation 2021, or the National Waste Management Strategy. Available tools to support the CE transition from the STI perspective include strategic reports and frameworks, such as the Medium-Term Strategic Framework or the STI Indicator Report.

Based on previous conversations with CSIR contemplating different ways to priorities sectors, it was agreed that the STI4CE Strategy should align with ongoing departmental initiatives and rather complement them instead of duplicating. This implies looking at those sectors where only little STI initiatives are taking place or no STI roadmaps exist, but obviously also on those sectors with promising CE opportunities as identified in D2. Sectors where many STI initiatives or the presence of a roadmap have been identified are: water, waste, construction,

energy and agriculture[7]. To summarise result of D2, the sectors with the highest CE potential are water, mobility, mining, energy, agriculture and industry/manufacturing. Based on these considerations, proposed/preliminary priority sectors for the STI4CE Strategy are: **Energy**, **Industry and manufacturing (incl. textiles, plastics and e-waste)**, **Mining**, and **Mobility.**

Overall, SA has a lot of strengths that can be attributed to this growing body of policies and strategies. However, most opportunities are determined by a lack of implementation force and coordination. On the one hand, stakeholders are often working in their own corners without cross-departmental collaboration or (at least) communication. On the other hand, there is no aligned understanding of the scope of and requirements for CE. This ultimately represents a threat limiting the positive impact of existing STI and CE initiatives, and further the future STI4CE Strategy. The synthesis of major STI-related gaps and opportunities have been grouped into six interrelated themes under the three stated goals of DSI, namely Human Capacity Development, Research and Development and Innovation through Private Sector Engagement and Entrepreneurship. The needs, challenges and opportunities under these themes are presented in the table in Section 4.1. The gaps and opportunities in the proposed priority sectors are summarised in the table under Section 4.2.

1 Introduction

This report is the third deliverable (D3) under this project, in which the science, technology and innovation (STI) ecosystem and opportunities related to enhancing CE in South Africa are presented. The findings and opportunities identified represent the foundation for the measures to be proposed under the STI4CE Strategy as well as its components (next deliverable, D4).

The content of this deliverable is based on desk research, literature review and specifically the stakeholder consultation through targeted interviews with different departments, incl. DSI, as well as the second workshop that engaged different stakeholder groups on identifying gaps and opportunities for STI support for CE.

The report is structured in the following parts:

- In the first part of the report, the project team elaborates the **existing structures, processes and budgeting lines within DSI** which is fundamental to ensure that the STI4CE Strategy is well embedded into the given DSI system and proposes improvement potentials where possible.
- The second chapter introduces the **policy landscape and ecosystem of STI for CE**. It provides an overview of most important strategic frameworks and processes informing the STI4CE Strategy as well as different stakeholders with relevant mandates and those that act in the field through diverse initiatives and tools.
- The third chapter is based on D2 and **highlights the most important sectors to include in the STI4CE Strategy** – "most important" meaning high-impact sectors with large CE potential combined with the fact that there are no STI-related initiatives ongoing yet.
- The last chapter **summarises gaps and opportunities** throughout chapter 2 and 3 structured by DSI mandates and sectors.

1 Existing strategic intent, structures, processes and budgeting lines within DSI

This chapter aims to understand the DSI mandates, structures, processes and budgeting lines. It is a foundational exercise to enable proper integration of the future STI4CE Strategy into the existing environment and inform a design for impact and relevance by, for instance, taking advantage or leveraging existing processes.

1.1 DSI Structure and Agencies

DSI is a separate government department that was established to ensure greater coordination, integration and better management of 'all government funded science and technology institutions' while providing a rounded review of public expenditure on science and technology.

Unfolding their Impact Statement ('South Africa's sustainable and inclusive development enabled and enhanced through science, technology and innovation'[1]), DSI upholds the following Vision, Mission and Values, as stated in DSI's most recent Annual Report:

- **Vision**: Increased well-being and prosperity through science, technology and innovation.
- **Misson**: To provide leadership, an enabling environment and resources for science, technology and innovation in support of South Africa's development.
- **Values**:
    - Professionalism: The Department is professional and delivers high quality performance to both internal and external stakeholders.
    - Innovation: The Department is innovative in solving problems and enhancing effectiveness and efficiency.
    - Ethical behaviour: The Department and its employees are consistent in their actions and accountable and transparent in dealing with public funds and other resources.
    - Knowledge sharing: The Department and its employees share and use knowledge constructively to ensure that it contributes to the building of a robust and productive knowledge economy.[2]

The department has 5 Programmes spanning from internal affairs such as corporate governance, to technology and innovation[3]. These include:

- **Programme 1: Corporate Services and Institutional Planning support** - Even though this has no direct relevance to the strategy, it gives administrative support to the department such as Finance, HR, and Legal. That support will also include the support needed by the strategy
- **Programme 2: Technology Innovation** – This programme is relevant to the strategy because it focuses on innovation and technologies. The components/focus areas for the programme are critical for the growth of SA economy, key to these is hydrogen and energy, considering the energy problems we are experiencing, the importance of energy in the growth of the economy and the Hydrogen Corridor that has been identified.
- **Programme 3: International Cooperation** - With the current budget cuts due to the strained fiscals, international partnerships become important areas to mobilise additional funding and learning best practise when it comes to STI. DSI is already an entry point for International STI funding into the country, that needs to be enhanced to form more partnerships and mobilise more funding.
- **Programme 4: Research, Development and Support** – R&D is key in developing new local technologies and adopting international technologies. With industry research funding dwindling, the R&D support is

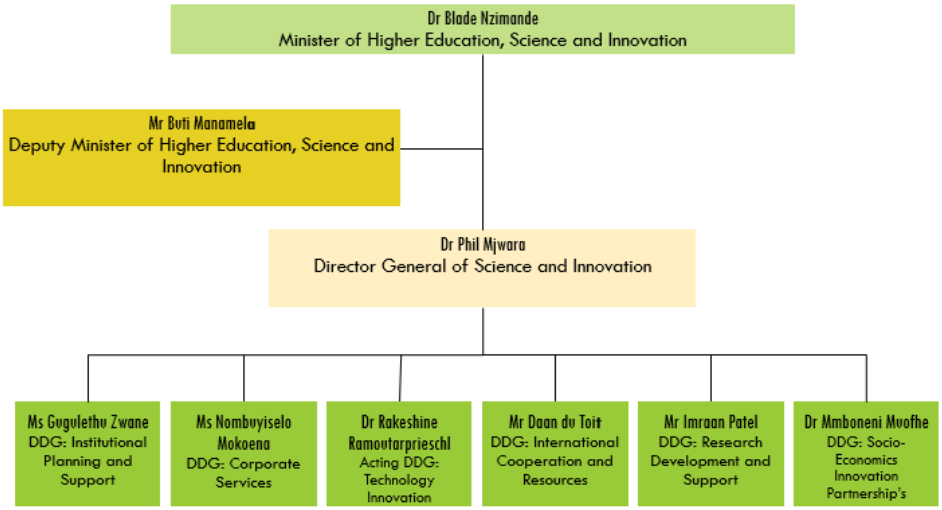
[1] DSI (2020) Strategic Plan 2020-2025
[2] DSI (2023) Final Annual Report
[3] DSI (2011) Corporate services and institutional planning and support

needed where relationship between private sector and NSI is improved, and private sector uses more local HEI's and science councils to solve SA industrial problems

- **Programme 5: Socio-economic Innovation Partnerships** – This is where it all comes together, STI interventions must finally benefit society to improve socio-economic conditions of the country. Benefits of STI need to trickle down to all communities and lead to improved lives and livelihoods and tackling poverty, unemployment and inequality.

These 5 programmes are represented by 6 branches of the department (program 1 is split into 2 separate branches, one of Corporate Services and one for Institutional Planning). The following organogram depicts the six DDG's in relation to the DG of Science and Innovation, who is accountable to the Minister of Higher Education, Science and Innovation, and the Deputy Minister.

Figure 1-1 Organogram of DSI Directorates



Source: own table

There are various Chief Directorates reporting to each DDG:

1. **Institutional Planning and Support**
   1.1 The Ministry and Office of the Director-General
   1.2 Enterprise Risk Management
   1.3 Policy, Planning, Governance, Monitoring and Evaluation Internal Audit Activity (IAA)
   1.4 Science Communication

2. **Corporate Services**
   2.1 Finance
   2.2 Human Resources
   2.3 Legal Services
   2.4 Information Systems and Knowledge Management
   2.5 Auxiliary Services

3. **Technology Innovation**
   3.1 Bio-innovation
   3.2 Hydrogen and Energy
   3.3 Space Science and Technology
   3.4 Innovation Priorities and Instruments
   3.5 The National Intellectual Property Management Office (NIPMO)

4. **International Cooperation and Resources**

4.1 International Resources
4.2 Multilateral Cooperation and Africa
4.3 Overseas Bilateral Cooperation

5. Research Development and Support
5.1 Human Capital and Science Promotion
5.2 Basic Sciences and Infrastructure
5.3 Science Missions
5.4 Astronomy

6. Socio-Economic Innovation and Partnerships
6.1 Technology Localisation, Beneficiation and Advanced Manufacturing
6.2 Sector Innovation and Green Economy
6.3 Innovation for Inclusive Development
6.4 Science and Technology

The following table has been developed to provide additional information about the purpose and various chief directorates of each branch, along with their potential role in future roll-out of the STI4CE strategy.

Table 1-1 The Six Branches of the DSI along with their purpose, components, and potential links to STI

Programme/Branch	Purpose	Components/ Chief Directorates	Relevance to STI4CE
1A: Institutional Planning and Support	Geared towards supporting the high-level policy prioritization	• The Ministry and Office of the Director-General • Enterprise Risk Management • Policy, Planning, Governance, Monitoring and Evaluation • Internal Audit Activity (IAA) • Science Communication	Gives administrative support to all projects within the department including STI4CE. Supports coordination with other government departments that are relevant to CE through Inter-Governmental Steering Committee and Circular Economy STI Forum
1B: Corporate Services	Responsible for the overall management of the Department and providing centralised strategic and administrative support, and an essential strategic partner in the Department's governance, administration and programme delivery	• Finance • Human Resources • Legal Services • Information Systems and Knowledge Management • Auxiliary Services	Gives administrative support to all projects within the department including STI4CE. Supports coordination with other government departments that are relevant to CE through Inter-Governmental Steering Committee and Circular Economy STI Forum
2: Technology Innovation	Aims to enable research and development (R&D) in strategic and emerging focus areas (space science, energy, biotechnology, nanotechnology, robotics, photonics, and indigenous knowledge systems) intellectual property management, technology transfer and technology commercialisation in order to promote the realisation of commercial products, processes and services from R&D outputs through the implementation of enabling policy instruments.	• Bio-innovation • Hydrogen & energy • Space Science and Technology • Innovation Priorities & instruments • National Intellectual Property Management Office (NIPMO)	This Chief Directorate has several programmes that have an impact on food security, energy security, and managing IP. Development of new technologies and CE based innovation is supported here. Bio-economy strategy, Forest Products under DALRRD together with ARC and CSIR are some of the initiatives for CE with DSI. DMRE with MMP, SANEDI and Mintek support the Hydrogen Roadmap and modernising mining.

3: International Cooperation	Aims to strategically develop, promote and manage international relationships, opportunities and S&T agreements that strengthen the national system of innovation (NSI) and enable an exsite2016 of knowledge, capacity and resources between South Africa and its regional and international partners. The Programme also supports South African foreign policy through science diplomacy.	• International Resources • Multilateral Cooperation and Africa • Overseas Bilateral Cooperation	Best practice on CE is learned and shared with international partners within the continent and outside. Through these relations human capital required for CE is developed
4: Research, Development and Support	Aims to provide an enabling environment for research and knowledge production that promotes strategic development of basic sciences and priority science areas, through science promotion, human capital development, the provision of research infrastructure and relevant research support, in pursuit of South Africa's transition to a knowledge economy.	• Human Capital and Science promotion • Basic Sciences and Infrastructure • Science Missions • Astronomy	Development of SET human capital required for CE. Basic infrastructure relevant for our context is developed. Hydrogen, Waste RDI, and Water RDI Roadmaps have been developed and people with the right skills will be needed to implement these, NRF and TIA through their funding of students and supporting entrepreneurs respectively play a key role.
5: Socio-economic Innovation Partnerships	To enhance the growth and development priorities of government through targeted science and technology-based innovation interventions and the development of strategic partnerships with other government departments, industry, research institutions and communities.	• Technology Localisation, Beneficiation and Advanced Manufacturing • Sector Innovation and Green Economy • Innovation for Inclusive Development • Science and Technology Investment	STI4CE Projects and the Waste and Water Roadmaps falls under this programme. New economies will be developed through improved local beneficiation and localizing technologies for CE. DTIC has Advanced Manufacturing Strategy as a priority and the TIA Technology Stations Programme supports the development of CE based technologies. Green Economy forms part of this under DFFE as custodians of CE in the country currently

Source: own table

The DSI's programmes are supported by 8 entities or implementation agencies, listed in the figure below.

Figure 1-2 The 8 entities of the DSI

Note: The National Intellectual Property Management Office (NIPMO) is part of one of TIA)

These structures and their operations are influenced by DSI's goals, objectives and mandates, on the one hand, while on the other hand, outcomes and budget lines determine temporary focus areas. The next sub-chapter will shed more light into the latter element. The CSIR, TIA and NRF play the biggest role in CE and STI, with the CSIR leading in the CE research and has published work on various sectors of the economy where CE has the most impact. With the funding of students, the NRF contributed to the human development through producing the number of PhD's needed by the economy and the various Centres of Excellence. TIA supports innovation through partnering and funding innovative SME's and that contributes to the de-risking of the projects through to commercialisation.

The Decadal Plan, which aims to address the need to develop South Africa's innovation capacity, build and transform STI human resources, strengthen and transform the research enterprise, and expand partnerships and linkages through science diplomacy is the key driver the key driver of the STI4CE strategy[4]. The imperatives of this for the implementation of Circular Economy drives the future strategy and its implementation plan.

1.2 Funding allocations within DSI, by programme and DSI entity

This chapter provides additional information about DSI entities, their mandates and their linkages to the outcomes and budget.

The overall budget within DSI was R9.1 billion within the 2022/2023 budget cycle, of which 97% has been spent and the largest part (55%) going to Research, Development and Support. The internal funding allocation to the 6 programmes is shown in the table below.

Table 1-2 DSI funds distribution by programme

Programme/Branch	Budget 2022/2023 [R']	Share of total budget [%]
1: Institutional Planning and Support	3435 174	4
2: Corporate Services		
3: Technology Innovation	1 897 725	20
4: International Cooperation	165 687	2
5: Research, Development and Support	4 983 051	55
6: Socio-economic Innovation Partnerships	1 755 624	19
Total	**9 145 262**	**100**

Source: own table based on the most recent 2022/23 Annual Report[6]

[4] NRF (2022) Decadal Plan
[5] NRF (2022) Decadal Plan
[6] DSI (2023) Final Annual Report

According to the DSI Strategic Plan[7], current budget allocation to various Programmes withing DSI is based on a historic and incremental budgeting method. The Plan highlights the need for a change in this budget allocation method, to meet the changes in priorities brough about by the policy shifts.

The following table provides an overview of the DSI entities, their programme expenditure, along with their Mandates and links to the 6 DSI outcomes listed in the DSI Strategy[8].

Table 1-3 DSI entities, their mandates, links to the 6 DSI outcomes and budget

Name of Public Entity	Mandate	Outcomes	Programme and 2022/23 expenditure
National Research Foundation (NRF)	To support and promote research through funding, human resource development and the provision of the necessary research facilities in order to facilitate the creation of knowledge, innovation and development in all fields of science and technology, including indigenous knowledge, and thereby to contribute to the improvement of the quality of lives of all the people of South Africa.	A transformed, inclusive, responsive and coherent NSI Increased knowledge generation and innovation output Human capabilities and skills for the economy and for development	Research and Development Support R99 740 800 Socio-Economic Innovation Partnerships R40 000 000
Council for Scientific and Industrial Research (CSIR)	To foster, in the national interest and in the fields which in its opinion should receive preference, industrial and scientific development, either by itself or in cooperation with principals from the public or private sector, and thereby to contribute to the improvement of the quality of life of the people of South Africa, and to perform any other functions that may be assigned to it by or under the Scientific Research Council Act.	Knowledge utilisation for economic development (a) in revitalising Existing industries and (b) in stimulating R&D led industrial development Increased knowledge generation and innovation output Innovation in support of a capable and developmental state	Socio-Economic Innovation Parentships R1 002 269 000
Technology Innovation Agency (TIA)	To support the state in stimulating and intensifying technological innovation in order to improve economic growth and the quality of life of all South Africans by developing and exploring technological innovation.	Knowledge utilisation for economic development (a) in revitalising existing industries and (b) in stimulating R&D led industrial development Increased knowledge generation and innovation output Innovation in support of a capable and developmental state	Technology innovation R458 370 000 Socio-Economic Innovation Partnerships R72 400 000 International Cooperation and Resources R114 613 785
Human Sciences Research Council (HSRC)	To initiate, undertake and foster strategic basic and applied research in the human sciences, and to gather, analyse and publish data relevant to developmental challenges in South Africa, elsewhere in Africa and in the rest of the world, especially by means of projects linked to public sector oriented collaborative programmes To inform the effective formulation and monitoring of policy and to evaluate the implementation of policy	Innovation in support of a capable and developmental state Increased knowledge generation and innovation output Knowledge utilisation for inclusive development	Socio-Economic Innovation Partnerships R321 098 000

[7] DSI Strategic Plan reference
[8] dst.gov.za/images/2020/DST_2020_2025_STRAT_PLAN_FINAL_JULY.pdf

	To stimulate public debate through the effective dissemination of fact-based research results To help build research capacity and infrastructure for the human sciences in South Africa and the rest of Africa To foster and support research collaboration, networks and institutional linkages within the human sciences research community To respond to the needs of vulnerable and marginalised groups in society by researching and analysing developmental problems, thereby contributing to the improvement of the quality of their lives To develop and make publicly available new datasets to underpin research, policy development and public discussion of the key issues of development, and to develop new and improved methodologies for use in their development		
Academy of Science of South Africa (ASSAf)	To promote common ground in scientific thinking across all disciplines, including the physical, mathematical and life sciences, as well as the human, social and economic sciences. To encourage and promote innovative and independent scientific thinking. To promote the optimum development of the intellectual capacity of all people. To provide effective advice and facilitate appropriate action in relation to the collective needs, opportunities and challenges of all South Africans. To link South Africa with scientific communities of the highest levels, within the SADC, the rest of Africa and the rest of the world.	Increased knowledge generation and innovation output. Innovation in support of a capable and developmental state	Research and Development Support R33 839 000 International Cooperation and Resources R2 000 000
South African National Space Agency (SANSA)	To promote the peaceful use of space. To support the creation of an environment conducive to industrial development in space technology. To foster research in space science and technology, communications, navigation and space physics. To advance scientific, engineering and technological competence and capabilities through human capital development outreach programmes and infrastructure development. To foster international cooperation in space-related activities.	Increased knowledge generation and innovation output Innovation in support of a capable and developmental state Knowledge utilisation for economic development (a) in revitalising existing industries and (b) in stimulating R&D led industrial development	Technology Innovation R16 439 000
National Advisory Council for Innovation (NACI)	To advise the Minister for Science and Technology and, through the Minister, Cabinet, on the role and contribution of science, mathematics, innovation and technology, including indigenous	A transformed, inclusive, responsive and coherent NSI	Not specified

	technologies, in promoting and achieving national objectives, namely, to improve and sustain the quality of life of all South Africans, develop human resources for science and technology, build the economy, and strengthen the country's competitiveness in the international arena.	Innovation in support of a capable and developmental state	
South African Council for Natural and Scientific Professions (SACNASP)	To administer the registration of professional, candidate and certificated natural scientists, and related matters.	A transformed, inclusive, responsive and coherent NSI Human capabilities and skills for the economy and for development	Not specified

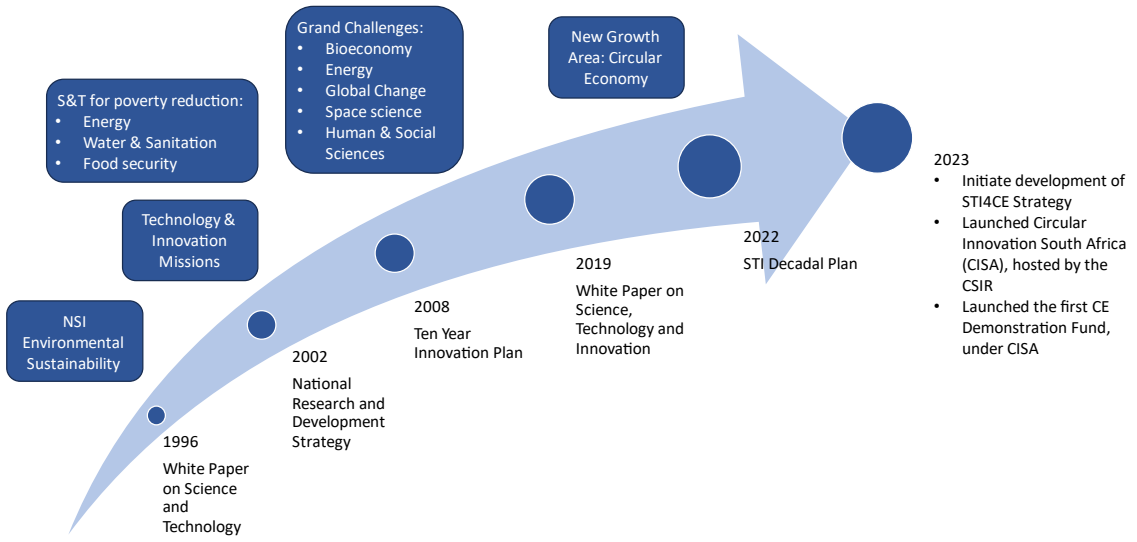
Source: 2022/2023 Annual report

2 STI (for CE) Ecosystem and Indicators

2.1 STI Policy Landscape

The local, South African STI policy landscape includes a complex array of Acts and Regulations, administered across multiple Government Departments and affiliates. The Policy landscape journey leading up to the development of this STI4CE strategy started in 1996 with the Promulgation of the White Paper on Science and Technology. Developments over the last 27 years have included numerous Science and Technology driven outputs and developments to address challenges such poverty, food security and energy and to create an enabling environment for circular economy. The following diagram provides a broad overview of the Policy landscape journey leading up to this STI4CE strategy process.

Figure 2-1 Policy development leading up to the STI4CE Strategy



Source: Slides from Henry Roman

In addition to the elements, there are additional policy initiatives which have given effect to the STI4CE Strategy. The following table provides a complete overview most relevant policy initiatives and provides an indication of their relevance to the emerging STI4CE Strategy. Some do inform the STI4CE Strategy more from a content perspective, such as the RDI Waste Roadmap and alike, while others provide an important framework related to planning and implementation, such as the MTSF.

Table 2-1 Relevance of existing relevant policies to STI and STI4CE Strategy

Policy	Focus	Relevance to STI4CE
STI White Paper 2019	The paper represents the commitment to using STI to support the development of South Africa, in line with the NDP.	It sets the medium- and long-term policy direction for the South African government to ensure a growing role for STI. The White Paper is the Policy framework of the Decadal Plan which sets the focus of the STI4CE strategy. In the absence of the CE policy in the country, this policy white paper and the Decadal Plan for implementation will give guidance to priority areas for CE impact. Mining, agriculture and manufacturing are some of those priority areas with the Bio-Economy Strategy already in place, Advanced Manufacturing Strategy with the DTIC and DMRE already looking at Hydrogen

		as a source of energy and identified the Hydrogen Corridor.
Decadal Plan 2022-2032	It outlines principles to be applied for targeted interventions which include waste and pollution reduction, regenerative systems and sustainable materials management. Eight Social grand challenges are identified that are aimed to be tackled: o Climate change and sustainability; o Education, skills and the future of work; o ICTs and Smart Systems; o High-technology industrialisation; o Nutrition security; o Water security; o Health innovation; and o Sustainable energy.	The focus sectors of the STI4CE strategy stem from this plan, which identifies manufacturing, agriculture and mining as STI and innovation priorities. CE is profiled as an opportunity for socio-economic development and environmental preservation. The plan is intended to be implemented as a master plan for collaboration between other departments such as Departments of Agriculture, Land Reform and Rural Development; Mineral Resources and Energy; Health, and Trade, Industry and Competition. STI for CE priorities are viewed from a broader sustainable materials management perspective, aimed at an overarching resource productivity improvement in the targeted resource-intensive sectors.
National Development Plan (2012)	The NDP is the key driver of all Policy directives, which need to align to the following ambitions: • eradicate absolute poverty to zero by 2030, • reduce unemployment by creating 11 million new jobs by 2030, and • significantly reduce inequality.	STI4CE strategy must align to NDP & it's implementing Framework (MSTF below). Countries that tackle poverty effectively are characterised by strong STI. (Focus on poverty, inequality and unemployment)
Medium Term Strategic Framework (2019–2024)	A five-year implementation plan and an integrated monitoring framework of the NDP. Focuses on the seven priorities and related interventions in particular those relating to poverty, inequality and unemployment.	STI4CE can influence the next 5- year planning cycle of MTSF 2025-2030.
Bioeconomy Strategy (2013)	The Bio-economy strategy was developed to provide a strategy and economic advancement of science-based "bio-solutions" such as biopharmaceuticals and vaccines; produce biofuels; improve and adapt crops; remedy industrial and municipal waste. The first sector specific strategy developed by the DSI in 2013, ahead of the White Paper of 2019.	Observe lessons and similarities with STI4CE - A **biotechnology platform** was formed: a strategic need/gap in the innovation value chain by offering world-class technical services and expertise to external stakeholders - Need for assessment of **performance and impac**t 10 years later of this Strategy - whose vision (and impact) includes similar ambitions to the proposed STI strategy, including contribution to GDP. - Three sectors have been identified for interventions and they are agriculture, health, and industrial and environment. For example, in agriculture, intervention that look at biocontrol and biofertilizers, water resource management, aquaculture, and soil conservation already align with CE
Roadmaps: - Solar Energy Technology Roadmap (2010)		STI4CE can unlock opportunities to develop roadmaps for all key sectors including:

- ICT Research Development & Technology Roadmap (2013) - Waste RDI (2015) - Research Infrastructure Roadmap (2016) - Water RDI (2018) - Sustainable Human Settlements (2021) - Hydrogen Society (2021)	Roadmaps are strategic guides for planning and provide vision and a structure to assist in the implementation and sustainability.	- Energy - Mobility - Mining Under Green Economy Waste RDI Roadmap is ready, DFFE as a custodian and NRF through funding students will ensure correct skills are available for implementation. Equally under Water and Sanitation Department and DMRE there are Water RDI Roadmap and Hydrogen Roadmap respectively and these can already be leveraged on for this strategy's implementation.
National Advisory Council on Innovation Act (1997)	Allows for NACI to advise the Minister on the role and contribution of science, mathematics, innovation and technology, including indigenous technologies, in promoting and achieving national objectives, namely -to improve and sustain the quality of life of all South Africans, - develop human resources for science and technology, -build the economy, and - strengthen the country's competitiveness in the international sphere.	STI4CE will be aligned to the same national objectives Need to strengthen links between NACI and DPME As an advisory body to the minister and having programmes such as STI Portal, and Community of Practice NACI ensures that correct policy decisions are taken and implemented, STI initiatives and programmes are well coordinated. These can be brought to the CE STI Forum.

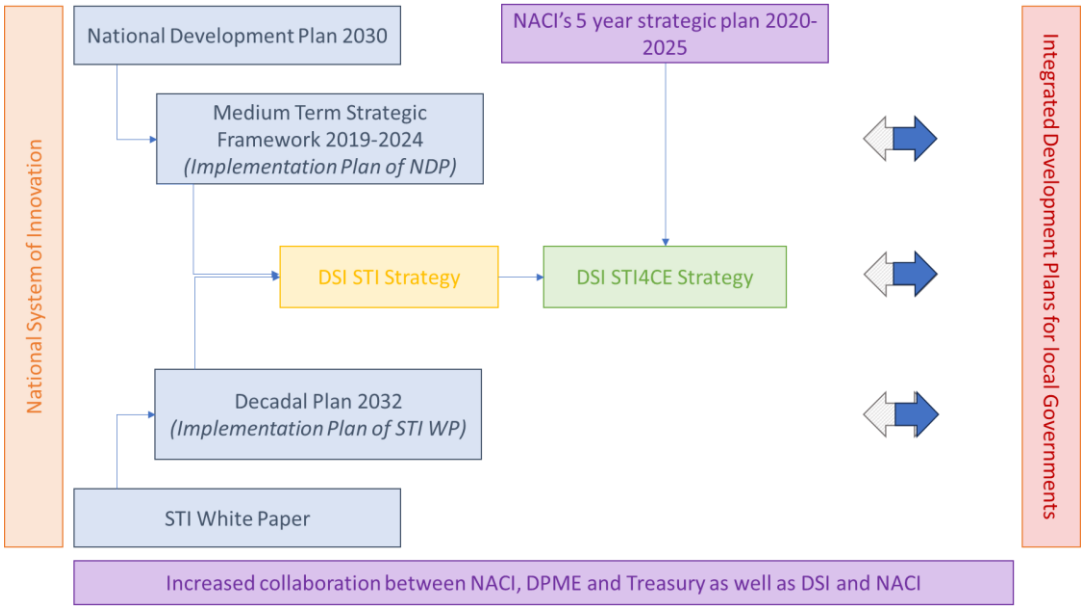
Source: own table

Planning, implementation and monitoring framework for the STI4CE Strategy

Moving forward in steering the STI focus towards CE, it is important to narrow down more and to identify the key guiding policy documents informing and representing the environment for the STI4CE Strategy, operating and shaping the National Innovation System (NSI)[9] and influencing budget allocation. The figure below (Figure 2-2), combines (i) highlighting the most important policy initiatives and (ii) suggest how they would *ideally* inform the STI4CE Strategy as well as the overall planning process, e.g. strengthening the integration of Local Governments or aligning with NACI's 5-yeat strategic plan. For the STI4CE Strategy, relevant mechanisms, procedures and indicators of these documents will be synthesised in a dedicated chapter.

[9] An NSI can be understood as a set of functioning institutions, organisations and policies that interact constructively and optimally in the pursuit of a common set of social and economic goals and objectives, seeking to promote change through the introduction of innovations. The White Paper highlighted that such a system, in its broadest conception, is the means through which a country seeks to create, acquire, diffuse and put into practice new knowledge that will help that country and its people achieve their individual and collective goals. A well-functioning, coordinated and efficient NSI that helps in the achievement of national development priorities remains an ideal for which South Africa continues to strive. (NACI 5-year strategic plan 2016-2021).

Figure 2-2 Relationship between STI4CE Strategy and existing implementation frameworks



Source: own illustration

Note: This diagram illustrates the relationship between existing implementing and guiding frameworks and the STI4CE Strategy within the NSI. The MTSF is the implementation plan for the NDP and directly informs the DSI STI Strategy. The same applies for the Decadal Plan being the implementation plan of the STI White Paper. All these documents, channelled through the DSI STI Strategy, lay the content and procedural foundation for the STI4CE Strategy. In addition to these, the NACI 5 year strategic plan also requires recognition in the STI4CE Strategy. For the final implementation, it is key to leverage on the existing Integrated Development Plans for local Government and ensure that the objectives and actions in the STI4CE Strategy are contextualised and tailored to the local levels. Finally, this all demands increased collaboration between NACI, DPME, Treasury and DSI.

From the DSI and STI perspective (also see Figure 2-1), two significant policy outcomes are the key drivers of the DSI STI Strategy and respectively the development of the STI4CE Strategy:

- **The STI White Paper of 2019** identified CE as a new source of growth for RSA and recognises that this is a systemic approach. It sets the long-term policy direction for the South African government to ensure a growing role for STI; and
- **The STI Decadal Plan (2022-2032)** is the implementation plan of the White Paper and outlines principles to be applied for targeted interventions which include waste and pollution reduction, regenerative systems and sustainable Materials Management. It is driven by the philosophy to continue building the NSI, while at the same time pivoting the NSI to have a greater impact on addressing South Africa's national priorities.

From a broader but not less relevant perspective, there are two more higher-level documents that provide the overarching framework for development priorities and shape budget allocations, relevant to the DSI STI Strategy and the STI4CE Strategy:

- **The National Development Plan (NDP) 2030** sets the long-term vision for South Africa of eliminating poverty and reduce inequality. It identifies the role of different sectors and stakeholders on this journey based on strong leadership, effective government and active citizens). It may play a critical role in streamlining implementation and coordination processes as well as monitoring and evaluation, and capacity building.
- The **Medium-Term Strategic Framework 2019-2024** is the implementation plan of the NDP and outlines an outcomes-based monitoring framework. It aims to address the challenges/pillars of unemployment, inequality and poverty.

The last principal document that should inform and consider the STI4CE Strategy is the **5-year Strategic Plan 2020-2025 of the National Advisory Council on Innovation (NACI)** that plans the support of NACI to the

Minister of Science and Technology in e.g. develop human resources for science and technology and build a competitive economy. It identifies strategic outcomes to contribute to the realisation of the National Development Plan (NDP) and the 2019 White Paper on Science, Technology and Innovation (STI).

For these elements to synthesis and effectively inform the STI4CE Strategy, **appropriate links and collaboration has to be established between the mentioned bodies**. In particular, between NACI and the DPME to help integrate STI into transversal government planning by the DPME, and to support funding prioritisation by the DPME and National Treasury (e.g. via the annual Budget Mandate Paper). Additionally, the involvement and integration between DSI and NACI has to be increased, that is tasked to prepare reports on the implications of geopolitical and demographic shifts, technological changes, environmental sustainability imperatives and other megatrends for government STI planning.

Lastly to highlight is the importance of a **strong integration of Local and Provincial Governments in the higher-level planning and coordination**. Given that provinces and municipalities are the once integrating the national strategic frameworks, a more effective way, in contrast to a 'top-down' approach, is the consequent and systematic integration of representatives of Provinces and Local Government in the process that also allows feedback from the bottom-up channel (further discussed in Chapter 2.2).

2.2 Development planning and implementation of DSI policies

The South African Government sees development planning as a means to achieve national development goals. In South Africa, all three spheres of Government conduct development planning, which includes setting of measurable targets, linked to implementation plans. The National Development Plan (NDP) sets out a long-term vision for the country and provides the programme through which South Africa can advance radical economic transformation.

The Medium-Term Strategic Framework (2019-2024) sets out the implementation priorities across South Africa's national development priorities, the Provincial Growth and Development Strategies (PGDS) provides planning at a provincial level, and the Integrated Development Plans (IDP), set by each municipality to ensure effective planning and service delivery at Local Government level. The Development planning framework is supported by the Spatial Development Frameworks (SDFs) at National, Provincial and Local Government levels, which further guide development and facilitate land use prioritisation and sustainable development.

In addition to the 4 key framework documents outlined above (NDP, MTSF, DSI Strategy and Decadal Plan), budget allocation within the DSI should also consider the District Development Model (DDM) and the Service Delivery Program outlined in the DSI The District Development Model (DDM) provides an approach through which national and provincial departments allocate budgets that are geo-referenced to a particular District Municipality[10]. This approach allows for diversification in resource allocation to meet the varying needs of the difference geographical regions. The DDM approach aims to promote integration and information sharing amongst Government departments and programmes to maximise the impact, coordination and alignment of resources to improve service delivery. The DSI STI Strategy calls for the consideration of appropriate institutional arrangements and mechanisms for the implementation of the Decadal Plan in the Districts. The following committees are suggested to be established for the DDM Innovation Compact: the DDM Innovation Strategic Management Model, the DDM Innovation Fund, DDM Inclusive Innovation Programmes and the DDM Inclusive Innovation Council.

The DSI's Innovation for Service Delivery Programme and Circular Economy interventions is designed to support the demonstration of technologies addressing waste management, water and wastewater management, human settlement, sanitation, education, and energy provision. These programmes are designed to help municipalities respond to climate change through innovation and to support the SDG obligations. A call is made for circular economy and municipal waste management technology centres to promote a just transition to a low-carbon economy by districts. This recommendation is worth considering during the development of a pilot

[10] DSI Strategy Reference

implementation project for the STI4CE project. DDM interventions outlined in the Strategy have the potential to impact on the following four DSI DDM impact areas:

Figure 2-3 Impact areas of the DSI DDM model

Source: DSI STI Strategy[11]

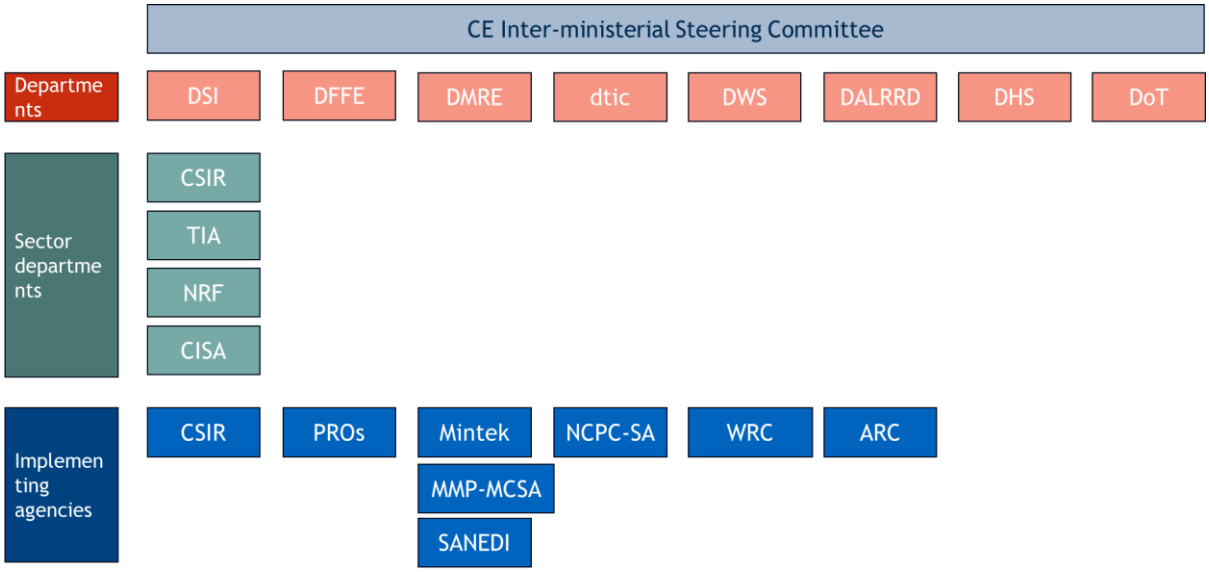
Important institutional structures to support the implementation of the STI4CE Strategy

DSI is driving important and enabling initiatives aimed at improving coordination and integration amongst the various ministries and government departments with linkages to CE and STI. These play an important role in shaping the institutional arrangements and governance chapter in the STI4CE Strategy, working towards effective implementation and alignment. In the following, they are taken note of:

- **Circular Innovation South Africa (CISA):** A portfolio management unit (PMU) established by the DSI to give effect to the circular economy intentions of the new decadal plan (2022-2032) and hosted by the CSIR. CISA is therefore a programme of the DSI, implemented by the CSIR.
- **CE Inter-ministerial Steering Committee:** This committee promotes a strong partnership between government departments and aims to guide the STI4CE Strategy. The structure has been approved by EXCO and the meeting is quarterly chaired by the DDG. The first meeting was held in April 2023, and was not attended by DARD, DHS and DMRE. Departments who attended the first meeting included:
    - Department of Forestry, Fisheries and Environment (DFFE)
    - Department of Water and Sanitation (DWS)
    - Department of Trade, Industry and Competition (DTIC)
    - Department of Small Business Development (DBSD)
    - Department of Mineral Resources and Energy (DMRE)
    - National Treasury (NT)
- **CE Working Group (inter-departmental):** This group is in the process of being established.
- **Circular Innovation Platform**: The recently launched Circular Demonstration Fund.
- **CE STI Forum:** This forum is being considered by the DSI for implementation by CISA.

[11] https://www.dst.gov.za/images/DSI_Approved_Revised_2020-2025_SP_March_2022.pdf

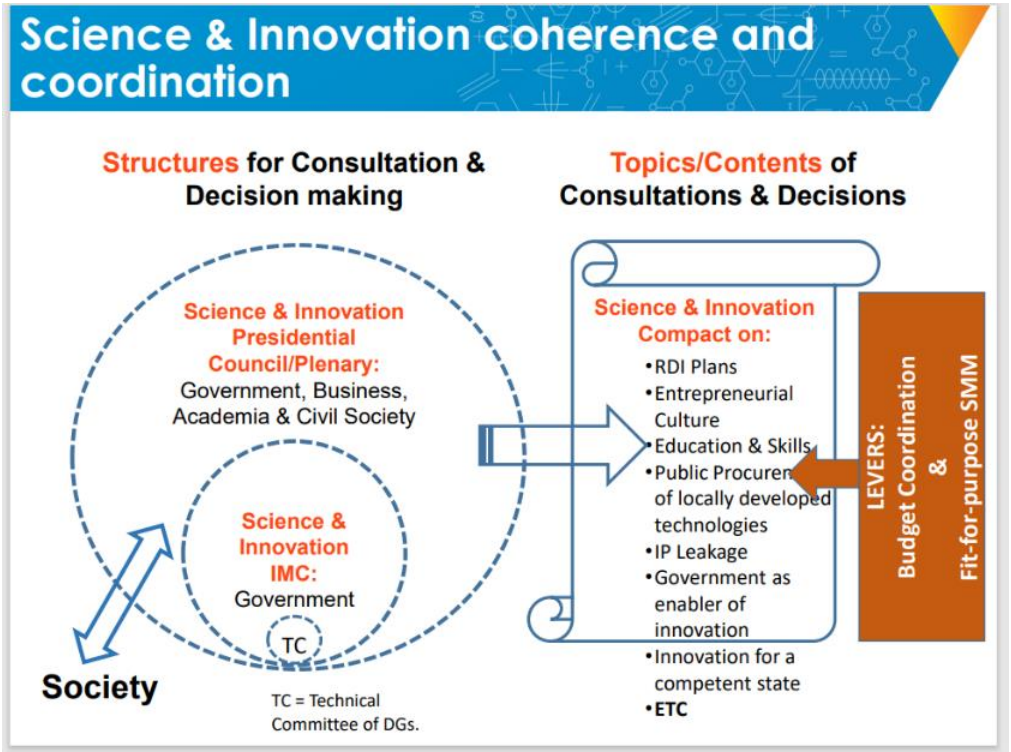
Figure 2-4 Overview of departments and implementation agencies involved in the CE Inter-ministerial Steering Committee



Source: own figure, based on slides of Linda Godfrey, CSIR

On the one hand, these bodies act as a mechanism to systematically integrate CE into the other departments and create cross-departmental collaboration but, on the other hand, they may also support the research efforts of other departments related to CE. The following diagram shows how current coordination related to STI works withing the various government departments.

Figure 2-5 Science and Innovation Coherence and Coordination



Source: NACI (2022)[12]

[12] NACI (2022) NACI Presentation DDG 2022 (presentation on the Decadal Plan by the DDG at a NACI Colloquium)

2.3 The Monitoring and Evaluation system and relevant processes

The White Paper empowers the National Advisory Council on Innovation (NACI) to monitor and evaluate South Africa's national system of innovation (NSI). The membership of NACI is broad and it is constituted with members with a wide range of expertise and experiences with regards to national and provincial interests, scientific and technological disciplines innovation the needs and opportunities in different socio-economic fields, and research and development in all sectors.

The organising framework for this DSI's Yearly Monitoring and evaluation report is derived from the National Advisory Council on Innovation (NACI) Monitoring and Evaluation (M&E) framework[13]. This framework examines inputs and enablers, flows and linkages, and outputs and impact to illustrate the current state of the country's NSI.

The Department's planning, budgeting, monitoring and reporting is done in relation to the following relevant strategic frameworks that have been illustrated in the previous sub-chapter:

- Pillars of the National Development Plan (2030)[14]
- 7 Apex Priorities of the Medium-Term Strategic Framework[15] (2019-2024)[16]
- 6 Outcomes and 19 Indicators of the DSI Strategy (2020–2025)[17]
- 8 Societal Grand Challenges and 5 System Goals of the Decadal Plan[18]

Table 2-2 provides an overview of the relevant focus areas, priorities, outcomes and indicators of the above-mentioned frameworks, driving the DSI's planning, budgeting, monitoring and reporting. The frameworks and their relations to planning and monitoring will be addressed in this chapter.

Table 2-2 Priorities of key framework documents

National Development Plan 2030 (NDP)	Medium Term Strategic Framework (MTSF) (2019-2024)	DSI STI Strategy (2020-2025)	Decadal Plan (2023 - 2032)
6 Pillars[19]	7 Apex Priorities[20]	6 Outcomes[21] and 19 Indicators	8 Societal Grand Challenges and 5 System Goals[22]
1. Mobilisation of all South Africans 2. Active engagement of citizens in their own development 3. Expansion of the economy & making growth inclusive 4. Building of key capabilities (human, physical & institutional)	1. Building a capable, ethical and developmental state 2. Economic transformation and job creation 3. Education, skills and health 4. Consolidating the social wage through reliable and quality basic services 5. Spatial integration, human settlements and local government	1. A transformed, inclusive, responsive and coherent National System of Innovation. 2. Human capabilities and skills for the economy and for development. 3. Increased knowledge generation and innovation output. 4. Knowledge utilisation for economic development in (a) revitalising existing	**8 Societal Challenges:** 1. Climate change and sustainability 2. Education, skills and the future of work 3. ICTs and Smart Systems 4. High-technology, industrialisation 5. Nutrition security 6. Water security 7. Health innovation 8. Sustainable energy **5 System Goals:**

[13] www.dsi.gov.za/index.php/resource-center/reports/strategies-and-reports/3977-south-african-science-technology-and-innovation-indicators-report-2023
[14] prelims (nationalplanningcommission.org.za)
[15] https://www.parliament.gov.za/storage/app/media/PBO/National_Development_Plan_Analysis/2022/october/28-10-2022/Policy_Brief_Performance_on_the_2019-2024_MTSF_Priority_6_Social_Cohesion_and_Safer_Communities_Part_1.pdf
[16] 2019-2024 MTSF Comprehensive Document.pdf (dpme.gov.za)
[17] DSI Strategy reference
[18] https://www.nrf.ac.za/wp-content/uploads/2023/06/STI-Decadal-Plan-2022-23-14Dec22.pdf
[19] Implementation Framework Presentation (pmg.org.za)
[20] Implementation and review of the MTSF 2019-2024 (dpme.gov.za) The MTSF 2019-2024 was developed in 2019, approved by Cabinet at the end of October 2019 and officially launched with the SONA 2020 for implementation. The 2019-2024 Medium-Term Strategic Framework (MTSF) is South Africa's second 5-year implementation plan for the NDP, and it consists of 7 priorities, 81 outcomes, 337 interventions and 561 indicators. It sets out the interventions per department or relevant government institution that will advance the seven priorities adopted by government.
[21] DSI STI Strategy, The outcomes (across all programmes) are measures against 19 indicators
[22] https://www.nrf.ac.za/wp-content/uploads/2023/06/STI-Decadal-Plan-2022-23-14Dec22.pdf

5. Building a capable and developmental state 6. Fostering of strong leadership throughout society	6. Social cohesion and safe communities 7. A better Africa and World	industries and (b) stimulating R&D led industrial development. 5. Knowledge utilisation for inclusive development. 6. Innovation in support of a capable and developmental state.	1. Building an inclusive, coherent and coordinated National System of Innovation 2. Creating an enabling environment for innovation in South Africa 3. Bolstering human resource development for STI 4. Expanding and transforming research system 5. Increasing funding for STI

Source: own table

Current monitoring and evaluation findings are reported in a complex matrix, which includes most of the elements outlined above. The following screenshot from the DSI STI Strategy document is inserted to illustrate how these elements are all incorporated, and it demonstrated the relationship between the Pillars, Apex Priorities, Outcomes and indicators. For instance, it shows how Priority 1 of the MSTF (A capable, ethical and developmental state) (refer to table 2.2) is measured in terms of various Outcomes (in this case a Transformed inclusive and responsive NSI), which have indicators, a baseline and a 5-year target.

Table 2-3 Example of a current monitoring table demonstrating the relationship between NDP Pillars, MSTF Apex Priorities, and DSI strategy outcomes

NDP Pillar 1	Achieving a more capable state		
MTSF Apex Priority 1	**A capable, ethical and developmental state**		
Outcome:	**Outcome indicators**	**Baseline**	**5-year target**
A transformed, inclusive, responsive and coherent NSI **Outcome Statement:** *Expand, transform and enhance the responsiveness of the NSI*	**Outcome Indicator 1:** Number of formalised partnerships between different category actors of the NSI that advance Decadal Plan priorities	New indicator	10
	Outcome Indicator 2: Number of STI missions introduced and adopted by Cabinet to crowd in resources and capabilities across the NSI	New indicator	5 missions introduced and adopted by Cabinet to crowd in resources and capabilities across the NSI
	Outcome Indicator 3: Percentage of STI investment support by government, domestic business, non-governmental sector and foreign/ international sources that advances GERD towards 1,1% of GDP	0.62%	1,1%
	Outcome Indicator 4: Number of approved strategies that give effect to the agreed dimensions of transformation to be effected in the NSI	New indicator	3
Innovation in support of a capable and developmental	**Outcome Indicator 1:** Number of demonstrators that have successfully introduced a new way of delivering a service	172	420

Source: Monitoring framework for DSI[23]

It is important to note that M&E reporting and auditing on performance aspects related to DSI functions and the STI4CE Strategy is embedded in a range of reference documents including:

- STI Indicators Report[24]
- DSI Annual Report[25]
- CSIR Annual Report[26]

NACI produces a yearly **STI Indicators Report** based on NACI's NSI monitoring and evaluation (M&E) framework[27]. This framework examines inputs and enablers, flows and linkages, and outputs and impact to illustrate the current state of the country's National System of Innovation (NSI). The NACI STI Indicators reports provides valuable feedback on the progress within various sectors of the NSI, and it examines investments in research, development and innovation, STI human resources, innovation in manufacturing, digital competitiveness, and the distribution of research and development (R&D) in provinces, among other indicators. The report

[23] DSI STI Strategy
[24] STI Indicators Reports – National Advisory Council on Innovation (naci.org.za)
[25] DSI 2022 23 Annual Report (dst.gov.za)
[26] https://www.csir.co.za/sites/default/files/CSIR%202022-23%20AR%20Layout%20V20.2.pdf
[27] NACI (2023) Indicators Report

furthermore identifies relative strengths and weaknesses of the national system of innovation (NSI) in comparison with other countries. It indicates progress in creating conditions conducive to the translation of innovative R&D into useful technologies with a positive impact on the economy, society and the environment.

The **DSI Annual Report** provides a record of expenditure and progress in the various programs, along with audited financials. The following screenshot provides insights into the tracking of planned and actual budget expenditure, extracted from the most recent DSI Annual Report[28]. It demonstrates the audited performance, planned targets and actual achievement of Outcomes and Outputs linked to the Technology Innovation Program, which is the third of the 6 Programmes of the DSI (outlined in Table 1-2).

Table 2-4 Screenshot of audited status of Programme 2 - Technology Innovation

Achieved						Not Achieved				
No.	**Outcomes**	**Outputs**	**Output indicators**	**Audited actual performance 2020/21**	**Audited actual performance 2021/22**	**Planned annual target 2022/23**	**Actual achievement 2022/23**	**Deviation from planned target for 2022/23**	**Status**	**Reasons for deviations**
1.	Innovation in support of a capable and developmental state	Decision-support tools	Number of decision-support tools developed and/or maintained	3 decision-support tools developed by 31 March 2021	2 decision-support tools developed and/or maintained by 31 March 2022	2 decision-support tools developed and/or maintained by 31 March 2023	2 decision-support tools were developed and/or maintained by 31 March 2023	None	Achieved	n/a
2.		SANSA and TIA oversight to ensure alignment with government priorities	Number of strategic and technical engagements with SANSA and TIA to ensure alignment with national priorities	8 strategic and technical engagements with SANSA and TIA to ensure alignment with national priorities by 31 March 2021	8 strategic and technical engagements with SANSA and TIA to ensure alignment with national priorities by 31 March 2022	8 strategic and technical engagements with SANSA and TIA to ensure alignment with national priorities by 31 March 2023	8 strategic and technical engagements with SANSA and TIA to ensure alignment with national priorities by 31 March 2023	None	Achieved	n/a
3.		SANSA Regional Space Weather Centre upgrades completed	Provision of space weather information for the aviation industry in South Africa and the African continent	SANSA Regional Space Weather Centre upgrades initiated by 31 March 2021	4 new products and/or services developed (linked to high frequency propagation and/or Global Navigation Satellite System applications) by 31 March 2022	Space Weather Centre issuing bulletins and warnings for aviation industry in South Africa and the African continent by 31 March 2023	Space Weather Centre issued bulletins and warnings for aviation industry in South Africa and the African continent by 31 March 2023	None	Achieved	n/a

Source: DSI Annual Report[29]

The **CSIR's Annual Report** is the third document to note for M&E Reporting and auditing and provides an overview of performance information, organisational highlights, governance, human capital and consolidated financial statements along with CSIR publications per program. The CSIR's performance is measured against its 5 Strategic Objectives (SO) outlined below, which are:

- SO1: Conduct RD&I of transformative technologies and accelerate their diffusion;
- SO2: Improve the competitiveness of high-Impact industries to support South Africa's re-industrialisation by collaboratively developing, localising and implementing technology;
- SO3: Drive socio-economic transformation through RD&I that supports the development of a capable state;
- SO4: Build and transform HC and infrastructure;
- SO5: Diversify income and maintain financial sustainability and good governance. [30]

The following screenshot from the most recent CSIR Annual Report demonstrates how the 5 SOs are reported on in terms of specific Key Performance Indicators. Planned targets and overall achievements for the SOs (here: SO2 - Improve the competitiveness of high-impact industries to support South Africa's re-industrialisation by collaboratively developing, localising and implementing technology).

[28] file (dst.gov.za)
[29] file (dst.gov.za)
[30] https://www.csir.co.za/sites/default/files/CSIR%202022-23%20AR%20Layout%20V20.2.pdf

Table 2-5 Extract from CSIR Annual Report to show planned targets and actual achievements of SO 2 and the associated KPI's

SO2: Improve the competitiveness of high-impact industries to support South Africa's re-industrialisation by collaboratively developing, localising and implementing technology.						
Performance Indicator	Actual Achievement 2021/22	Planned Target 2022/23	Actual Achievement 2022/23	Deviation from Planned Target to Actual Achievement for 2022/23	Comment on Deviations	Threshold/ Number
KPI 06: Number of localised technologies	14	11	16	45%	Target exceeded	≥75%/≥8
KPI 07: Number of joint technology development agreements being implemented for industry	25	27	37	37%	Target exceeded	≥75%/≥20
KPI 08: Number of SMMEs supported	99	72	116	61%	Target exceeded	≥75%/≥54

Source: CSIR Annual report[31]

Additional considerations for the M&E of the STI4CE Strategy

This section outlines M&E-related considerations, captured in key strategic documents. Future emphasis should be on integration and harmonisation of M&E activities across all sectors involved in STI4CE Strategy. Doing so, it is important to note that the M&E of the STI4CE Strategy shall measure the different objectives and actions that it will suggest with suitable indicators, considering existing and topic-related strategic frameworks containing indicators and reporting procedures.

The Decadal plan introduces a set of indicators and focus areas, to be considered in a reviewed M&E Framework, which seeks to translate the White Paper vision into reality. The Decadal Plan identifies several new outcomes and indicators for meeting the societal grand challenges. These are summarised as follows:

- Global Pharmaceutical economy: Expansion of the NSI using SA's IKS and rich biodiversity could position SA as one of the top emerging economies in the global pharmaceutical industry.
- Technology Platforms for vaccine discovery, development and production based on innovation linkages between the public sector, private sector, academia and civil society.
- Strengthen generic drug manufacturing R&D programmes aimed at technology know-how and the piloting of active pharmaceutical ingredients (APIs) through public-private partnerships, supporting technology platforms for API research and manufacturing should be for a significant and accelerated impact.
- NSI enabling a just energy transition is required.
- Affordable healthcare services through the development of RDI capabilities in new treatment and prevention. Precision medicine, digital health, use of indigenous knowledge and vaccine production.
- Investment in neuroscience research to develop methodologies that could enhance learning outcomes (AI, machine learning, virtual reality).
- Innovation to help improve competitiveness and productivity, which will ultimately contribute to the modernisation of SA's key industrial sectors.
- RDI interventions towards zero waste to landfill, as well as address climate change and adaptation.
- Increase funding of RDI capabilities in biotechnology, advanced manufacturing, space science, and ICT to drive improvement and productivity in the manufacturing/production sector, economic growth in terms of GDP contribution, new high-tech SMMEs development.[32]
- Post graduate centres funding to contribute towards a locally relevant and globally competitive workforce.

[31] https://www.csir.co.za/sites/default/files/CSIR%202022-23%20AR%20Layout%20V20.2.pdf
[32] Adapted from Decadal Plan

Other aspects for possible future consideration in M&E re-alignment extracted from the NACI Strategic Plan could include:

- Guidelines and Toolkit for the Design and Implementation of the Sovereign Innovation Fund;
- 2021 Status of Innovation in Technical, Vocational Education and Training (TVET) report;
- Facing the Facts: Women participation in STEM;
- The National Science, Technology and Innovation Information Portal (NSTIIP).

Box 2-1 Introduction and questions of NSTIIP

NATIONAL SCIENCE TECHNOLOGYAND INNOVATION INFORMATION PORTAL https://nstiip.naci.org.za/
Vision: The NSTIIP will be a single point of access for all stakeholders to draw and deposit information on measures and analyses of all aspects of the National System of Innovation (NSI), providing up to date, accurate information on the state of NSI in South Africa
Project: The National Science, Technology and Innovation Information Portal (NSTIIP) makes use of the developments in information technology to collect and curate innovation-related data and information.
STI Questions: Where does this project stand, and how is the information being used, analysed and shared?

Recommendations

- Require clear clarification of current budget allocation procedures, protocols and reporting,
- Ensure that the next MTSF (2025-2030) is informed by the STI4CE Strategy. The MTSF **sets out the interventions per department or relevant government institution that will advance the seven priorities adopted by government.**
- Planning on government needs to drill down to all levels, i.e. provinces, districts and municipalities. The high-level strategic frameworks require better contextualisation and unfolding to the local situation and circumstances.
- Updated status of DDM Model and circular economy linked interventions at District and Local Authority level.
- Revisit the District Development Model and improve indicators and guidance to Local Municipalities to ensure the STI Strategy informs planning at Local Authority level via existing instruments such is the IDP.
- **Established appropriate links between NACI and the DPME to help integrate STI into transversal government planning by the DPME, and to support funding prioritisation by the DPME and National Treasury (e.g. via the annual Budget Mandate Paper).**
- Future M&E framework must consider the extensive list of new suggested indicators developed in the Decadal Plan
- **Increase the involvement and integration between DSI and NACI, who is tasked to prepare reports on the implications of geopolitical and demographic shifts, technological changes, environmental sustainability imperatives and other megatrends for government STI planning.**
- Make sure that Local Governments are included in the planning process and have the right materials at hand for the implementation of the strategic frameworks.
- Ensure that the processes of budgeting, monitoring and evaluation do inform reporting!
- Consider a pilot project which will assist districts and municipalities to showcase CE and Just transition to a low carbon economy as per the DSI for Innovation for Service Delivery Program, which makes a call for circular economy and municipal waste management technology centres.

2.4 STI and CE stakeholder linkages

It is imperative for the DSI to have a consolidated database of ecosystem role-players within the science, technology and innovation space, including those operating within different cycles of the circular economy. An unexhaustive, but insightful list of key STI and Circular Economy stakeholders has been provided in D2: Annex E and shows a wide variety of actors who need to be engaged in a STI for CE strategy.

These actors include tertiary education and research centres, government departments and entities, private sector entities both large and small, civil society mobilisers and organisations, and a set of intermediary organisations. The focus of these actors ranges from very specialised focus on a single material supply chain or single sector association, to broad systems views with an aim to support systems integration. For effective production and uptake of STI for CE, investment is required in both the specialised skills and institutions, as well as in the intermediary organisations who draw linkages and provide 'translation' services that support in making research and innovation either policy- or implementation-ready. Such examples include Green Cape, who serve an important role in building trust between industries and between industry and government, thereby accessing private and public data and brokering effective relationships between stakeholders. Another example could be PEDI, who do the same work in building trust in communities, to support uptake of new approaches and technologies, positioning themselves as allies in development.

Through baseline research, interviews and stakeholder workshops, it has emerged that the DSI is also well poised to serve as intermediary by providing several brokering roles between the creators, users and beneficiaries of STI. This linkage role has been articulated along four needs:

- **Supporting public sector coordination for meaningful uptake of circular economy ideas:** This entails several brokering, facilitation and partnering roles for the DSI. While many government departments may allocate budget for R&D, the teams responsible for this may not be equipped to (i) take a long-term perspective to anticipate required innovation needs, (ii) articulate the R&D specifications effectively, nor (iii) find the appropriate provider of this R&D service. Here, the DSI can offer services to allay these three shortfalls; novel approaches are needed to facilitate discussion or ideation with identified departments, as the teams involved may not know precisely what they need. DSI may also be in a unique position to provide reflective space for identified government officials to come together to reflect upon project or programme successes, shortfalls and future needs, and secondly to draw linkages with the work across other departments. Presenting such meetings as R&D 'work' may enable DSI to provide open space for much needed government reflection and collective planning. Finally, along with DFFE, the national focal point for Circular Economy implementation, DSI can serve as a coordinator around STI to support government-wide uptake of systemic perspectives to CE that move beyond waste and pollution. By providing robust evidence on whole-of-life approaches, circular business models and CE demonstration projects, the DSI can serve a vital role of providing inspiration to government, practitioners and residents of the country for what the STI approaches in CE could and should mean for society.
- **Connecting research and practice:** Research processes are often misaligned from policy and budgeting processes, relying on an expectation that research may make its way into practitioner hands, rather than working to ensure that this is the case. DSI, particularly through the National Research Foundation, can support the joint articulation of research needs by researchers and societal actors, that can produce fit-for-use research outcomes, as well as to ensure that there are end-users awaiting the final research products. Supporting government departments or CE actors to put forward research needs that can be pursued by Masters, PhD, Post-doc or career researchers can contribute to timelier or aligned research that addresses societal needs. To do this, the NRF can prioritise grants and bursaries to research that promotes inter- and trans-disciplinary research processes and can place stipulations on grant provision that require *demonstrable* forms of societal impact.
- **Facilitate the uptake of new IP:** As with fit-for-use research, making IP available for actors to build upon and start new businesses can contribute to CE transitions. DSI, particularly through its entities of the National Research Foundation, Technology Innovation Agency and the National Intellectual Property Management Office (NIPMO), can support in brokering newly produced research and IP with small-, medium- and large businesses. Working with existing actors who support with development of entrepreneurial ecosystems can support more targeted uptake of South African produced innovation.
- **Facilitating new skills development required for CE transitions:** Skills for undertaking CE data collection, monitoring, and evaluation, as well as developing new technology, societal and governance processes, and business models, are very scarce in South Africa and the continent. This skills gap is reinforced by a lack of demand for such services, resulting in migration of skilled workers to geographies

where the skills are in demand. Here, DSI can serve a dual role of demonstrating the importance and value of CE-focussed skills (e.g. Life Cycle Assessment, Material Accounting) to both public and private actors, while supporting tertiary institutions and Trade Schools to invest in skills building. DSI can provide guidance on new skills required to enact circular transitions and supporting with the development of programmes and trainings that effectively equip early- and mid-career professionals to implement circular initiatives. The global burgeoning of the CE concept and the rush to develop Circular Economy Roadmaps for nations, local government and businesses lends itself to the concordant training of professionals able to do this in appropriate and effective ways.

These needs do not require DSI to take sole responsibility, but acknowledge that the institutional structure of DSI, namely as a transversal unit, gives it a unique ability to broker and support work of a wider set of public and private actors.

The above reflections are scoped to South Africa but may also have important resonance with Continental and International agendas to drive circular transitions. The Decadal Plan refers to a science diplomacy strategy focussed on the following strategic objectives:[33]

- Share in international experience and expertise: researcher training and mobility
- Leverage foreign investment in South Africa and joint investment with international partners
- Advance African agenda for science, technology and innovation (African Union / Southern African Development Community)
- Influence international science policy agenda in support of national priorities (Sustainable Development Goals)

It further articulates the following intentions with regards to the 'Africa Agenda':

- Transformative research and innovation partnerships through increased funding for co-funded bilateral R&I partnership with other African Governments
- Building human resources by increasing South African mobility to other African countries
- Strengthening and growing research infrastructure partnerships, particularly through investing in continental and regional, large-scale research infrastructures, especially cyber. Here, the African Open Science Platform offers potential.
- Promoting and enhancing STI capabilities through supporting AU and SADC programmes and investing in pan-African research and innovation funding and support programmes.
- Leveraging opportunities of the African Continental Free Trade Area to enhance creation and use of South African or African STI
- Attract foreign investment in ways that instil true co-ownership and co-responsibility in partnerships with the Global North

The STI for CE strategy will focus on the South African scope, but draw linkages to the above intentions as opportunities that can mutually reinforce South African STI development in the areas of Circular Economy.

STI Initiatives, instruments and tools

The following three sub-sections break down a selection of key initiatives, instruments and tools that currently exist within the STI4CE landscape. Initiatives represent active programmes and projects undertaken by one or more actors; instruments refer to legislation, policies and other institutional arrangements; and tools refer to tangible outcomes or products, such as reports, indices, and roadmaps.

Initiatives

The South African government is committed to supporting the transition to a circular economy. It has many initiatives in place to promote both circularity and STI. These initiatives are focused on developing and implementing policies and regulations, supporting research and development, and promoting the adoption of circular economy practices by businesses and consumers.

[33] NACI (2022) Decadal Plan Presentation by DDG

DSI has undertaken a number of initiatives, as reported in the most recent Annual Report[34]:

- Carbon dioxide to fertiliser salt: DSI partnered with EPCM, an SMME, and cement producer Pretoria Portland Cement (PPC) to launch the CoalCO2-X demonstration technology at the PPC factory in Dwaalboom, Limpopo, on 25 January 2023. The technology involves capturing carbon dioxide from flue gas emerging from a coal-fired boiler and its conversion into a fertiliser salt.
- Hydrogen and Fuel Cell Expo: DSI secured a South African pavilion at the International Hydrogen and Fuel Cell Expo held in Tokyo, Japan, from 15 to 17 March 2023.
- Plant and animal health system: DSI, through the Agricultural Bioeconomy Innovation Partnership Programme (ABIPP), is supporting interventions in diagnostics, surveillance, monitoring and early warning systems for plant and animal health and food safety.
- Energy Storage Internship Programme: DSI has secured additional funding of R2 534 437,50 from the Energy and Water Sector Education and Training Authority for training under the Energy Storage Internship Programme. This will allow more unemployed university of technology and technical and vocational education and training college graduates to be recruited for a 12-month internship programme at energy storage pilot facilities.
- Biosecurity Hub: In October 2022, DSI and the Department of Agriculture, Land Reform and Rural Development (DALRRD) supported the launch of the National Biosecurity Hub by both Ministers. The hub aims to provide sanitary and phytosanitary capacity building and information, support research services to clients in the public and private sectors, and strengthen biosecurity to meet international trade requirements.
- Biosecurity Digital Platform: In terms of modernising agriculture, ABIPP funded the development of a digital platform at Innovation Africa @UP to support the piloting of digital decision-making support systems for biosecurity for farmers and industry. This hub is in support of the Agriculture and Agro-processing Master Plan (AAMP), which is led by DALRRD.
- Innovation Fund: Since its inception, the Innovation Fund (IF) has served a critical catalytic role in strengthening the South African economy and placing the venture capital industry on a sustainable footing for the future. The IF is making good progress in mobilising further funding from various sources, which is clear from the amount of private sector investment that it has attracted in the space of two years. At the beginning of 2022/23, a total of R525,230 million was disbursed in as part of the pilot phase. The funds went to several implementation partners and initiatives. Of the total disbursed amounts, R19,715 million was allocated to the Biomanufacturing Enterprise Development and 6,032 million to the mRNA Technology Transfer Hub. Approximately 89,4% (R469,483 million invested by the DSI in the Innovation Fund.
- Innovation Bridge Portal: With respect to building the innovation ecosystem, the DSI invested R8 million in the Innovation Bridge Portal (IBP) in the year under review. The IBP is an innovation showcasing instrument that provides investment matchmaking and partnership through innovative finance. In 2022, the IBP recorded about 460 innovators and entrepreneurs and 220 investors who had become members of the IBP community.
- Youth Leadership and Technology Networks: The DSI has also invested in developing innovation management and entrepreneurship skills, targeting the youth through programmes such as the Technology Top 100 (TT100) Learnership and Internship Programme and the Technological Higher Education Network South Africa (THENSA) human capital development programme. During 2022/23, a DSI investment supported 40 unemployed youth through the TT100 programme. In addition, a R28 million investment for three years was made to THENSA, whose venture creation programme provides entrepreneurship skills training to TVETs in partnership with the industry, for 12 to 18 months, targeting 100 young people a year.
- Bio-refinery Industry Development Facility (BIDF): Located at the CSIR's Durban campus, the BIDF provides the research and development support, laboratories, analytical infrastructure and pilot facility needed to develop, test, evaluate and improve innovative biological and chemical conversion technologies and products in a range of industries. In addition to the extraction of value from waste produced by the forestry, paper and pulp industries (in support of the BRC), the BIDF focuses on the

[34] DSI Annual Report 2022/23

chemicals, pharmaceutical, manufacturing and agro-processing industries. The facility is also explicitly oriented towards assisting SMMEs in commercialising circular technologies.[35]

- Mandela Mining Precinct: The Mandela Mining Precinct (MMP)[36] is a Public-Private Partnership between the Department of Science and Innovation (DSI) and the Minerals Council of South Africa. It is an initiative aimed at revitalising mining research, development and innovation in South Africa to ensure the sustainability of the industry. The MMP has established four South African Mining Extraction RDI (SAMERDI) research centres at UP, UJ and Wits, to perform the required basic research while allowing for a number of post graduate students to obtain higher degrees. Discussions with Director Julie Courtnage have been captured into the strategic objectives of this report.

There are multiple initiatives across the country outside of the DSI through other public or private partners or collaboratives that bring an additional richness through STI to the CE landscape. These initiatives will be expanded on in an Annex of the STI4CE Strategy listing relevant both local and international STI initiatives.

Non-STI Instruments

Carbon Tax

The Carbon Tax Act in South Africa aims to reduce greenhouse gas emissions and transition the country to a climate resilient society which can feed into Green Economy. It was enacted in 2019 and is considered an instrument of climate action to stabilize global temperatures. South Africa, the only country in sub-Saharan Africa to have implemented a carbon tax, has a historically energy-intensive and carbon-intensive economy. The tax is designed to discourage the use of high carbon-emitting building materials and reduce pollution in the construction industry. However, there are concerns about the potential implications of the tax on the human rights of poor populations. The revenue generated from implementing the Carbon Tax Act should be Tax Act should be channelled toward addressing these potential adverse impacts on human rights.

Extended Producer Responsibility Regulations, 2021

The extended producer responsibility (EPR) regulations, a component of the 2008 National Environmental Management: Waste Act, reflect an established principle of environmental policy, aiming to make producers responsible for the environmental impacts of their products throughout the product chain, from design to the post-consumer phase. The goal is to reduce the burden on municipalities and taxpayers for managing end-of-life products, minimize waste destined for final disposal, and increase recycling rates. EPR systems are widely used globally, with around 400 such systems in operation. Governments should periodically review and adjust the targets of EPR policies, establish consistent means for enforcing EPR obligations, and consider financing EPR systems sustainably. Peer pressure and strict enforcement are suggested as ways to address free riding in EPR systems. The updated OECD guidance focuses on the design, governance, competition issues, design for environment incentives, and the role of the informal sector in EPR implementation.

Existing Paper & Packaging PROs in South Africa:

- The Polyolefin Responsibility Organization (POLYCO) leigh@polyco.co.za.
- PETCO Producer Responsibility Organization NPC. info@petco.co.za.
- The Glass Recycling Company (TGRC)
- Metal Packaging Association of SA (METPAC-SA)
- Fibre Circle
- The Aerosol Manufacturers' Association (AMA)

National Waste Management Strategy, 2020

The National Waste Management Strategy (NWMS) is an extension and legislative requirement of the 2008 National Environmental Management: Waste Act. Among the eight goals of the NWMS, those most pertinent to the application of STI in the CE are as follows:

- Promoting waste minimisation as well as the re-use, recycling and recovery of waste; and
- Increasing the contribution of the waste sector to the green economy.

[35] https://innovationbridge.info/ibportal/campaign/circular-economy/csir-bidf
[36] https://mandelaminingprecinct.org.za/

A major struggle in South Africa has been moving beyond a waste-centric definition of the CE. Stated otherwise, the end goal of a circular transition is to progressively move towards the elimination of waste altogether. Therefore, as much as the NWMS can be invoked to support forms of STI that minimise and otherwise re-use, recycle or recover waste, consideration should be given to whether this strategy sufficiently promotes a transition toward a post-waste economy in the country.

Significant Donor-Funded Capacity Development Programmes

Capacity development can be scaled to advance socioeconomic development and inclusive growth through large donor funded projects. A good example is the partnership between South African Local Government Association (SALGA) and European Union (EU) who are undertaking a project entitled 'Enhancing Municipalities' Capacity for Development (EMCD)'37. The project funding is EUR750,000 for a period of three years and will be implemented in 12 Municipalities in 4 Provinces. The project aims to increase capacity of municipalities to undertake responsive inter-municipal planning as well as to implement the plans and strategies to enable them to meet their developmental mandate. The scale and extent of this project could be duplicated for capacity development in STI4CE.

Tools

STI Indicator Reports

In response to global economic, ecological and social challenges, NACI was commissioned to investigate the state of STI in South Africa. The resulting report delves into R&D investments, human resources, manufacturing innovation, digital competitiveness and R&D distribution across provinces. Comparing South Africa to other nations, the report identifies strengths and weaknesses in its national innovation system. Additionally, it assesses progress in translating innovative R&D into beneficial technologies for the economy, society and environment. These reports are published every year[38]. Annexure 1 provides an overview of the

National policies and STI roadmaps (hydrogen, bioeconomy, human settlements, water and waste)

South Africa's journey towards leveraging STI unfolds on multiple levels. The overarching STI Decadal Plan 2022-2032[39] charts a course for tackling social and economic challenges through five pillars: human capital, research and development, innovation infrastructure, knowledge commercialisation, and global engagement. While not solely STI-centric, the National Development Plan 2030[40] underscores its crucial role in achieving long-term goals, highlighting sectors like advanced manufacturing, renewable energy, and ICT as engines of growth and job creation. Further depth comes from DSI-led sector roadmaps for areas like biotechnology and space science, while other government departments, like Health and Basic Education, contribute their own STI-related plans. Regionally, some provinces have crafted their own roadmaps, harnessing local strengths and opportunities. Finally, the private sector adds its voice through R&D roadmaps and investments aligned with national priorities, cementing STI's multifaceted role in South Africa's future.

Medium-Term Strategic Framework

The Medium-Term Strategic Framework (MTSF) 2019-2024 essentially serves as a roadmap charting South Africa's course towards a more just and equitable future. More than a set of goals, it is intended as a dynamic blueprint for action, consisting of seven key priorities: (1) building a capable, ethical and developmental state; (2) economic transformation and job creation; (3) education, skills and health; (4) consolidating the social wage through reliable and quality basic services; (5) spatial integration, human settlements and local government; (6) social cohesion and safer communities; and (7) a better Africa and world. Though these priority areas, the MTSF outlines the steps needed to achieve South Africa's developmental aims. The MTSF also acts as a compass, ensuring that national, provincial, and local spheres of government are all moving in the same direction. Through an integrated monitoring framework, it enables state actors to track progress through measurable outcomes, indicators and targets. The MTSF leverages the district-based delivery model, fostering better communication,

[37] Municipalities To Benefit From New Project - Business Media MAGS
[38] Naci (2023) STI Indicators Reports
[39] STI (2021) Decadal Plan
[40] National Planning Commission (2021) National Development Plan: Vision for 2030

coordination and collaboration between different spheres of government. As such, it aims to foster a united effort, supported by clear direction and consistent monitoring, towards a thriving South Africa.[41]

Technology Readiness Levels

Initially conceived by the US National Aeronautics and Space Administration (NASA), Technology Readiness Levels (TRLs) represent a method of classifying the maturity of a given technology. Using this framework, technology maturity can range from TRL 1, where initial research is conducted, to TRL 9, where technology has already been commercialised for a significant amount of time. With widespread adoption, this framework can serve as a standardised way for DSI to assess the current state of STI in service of the CE in South Africa as well as a guiding tool for determining what level of maturity a given initiative is intended to achieve within a given sector.

Municipal Innovation Maturity Index

The Municipal Innovation Maturity Index (MIMI), developed in partnership between the University of KwaZulu-Natal, Human Sciences Research Council (HSRC) and South African Local Government Association (SALGA), is a measure of a given municipality's capacity for innovation, either directly or through support of the private sector.[42] The MIMI represents a municipality's ability to learn, share and implement forms of STI for improved service delivery, products and processes. Although this index is not explicitly oriented toward the CE, it could be adapted to explicitly include circularity as a key component. By standardising our understanding of the capacity of local governments to implement STI, this tool has the potential to equip DSI with the knowledge needed to best support different municipalities across the country through the STI4CE Strategy.

SMME Innovation Support

The most recent STI Indicators Report43 tables the distribution of innovation support organisations in the various provinces. These organisations are reported to be intermediary who provide innovation infrastructure and support services, especially to SMMEs and previously marginalised communities. The overall purpose of these organisations is to improve the success of SMMEs and start-ups. Organisations include technology stations, incubators, living labs and fabrication labs. Technology stations and incubators, implemented by TIA, are the main support instrument organisations and they are sector-focused and are located at universities and universities of technology. They facilitate technology transfer between these educational institutions and small enterprises. The Small Enterprise Development Agency incubator programme (under the Department of Small Business Development) remains the largest innovation-support programme. They have a broad national presence and provide innovation infrastructure and training. University-based incubators, which are a variant of the traditional business incubator, are emerging with a focus to promote technological transfer and commercialisation.

The following table, extracted from the 2023 STI Indicators Report shows an uneven distribution of these organisations in the provinces.

[41] Department: Planning, Monitoring and Evaluation (2019) Medium-Term Strategic Framework
[42] Economic and Performance and Development Research Programme. *Municipal Innovation Maturity Index (MIMI) – Phase 2: Towards a Digital Platform*. Available: https://repository.hsrc.ac.za/bitstream/handle/20.500.11910/15295/11348.pdf?sequence=1&isAllowed=y [21 December 2023]
[43] STI-Indicators-2023-Report.pdf (naci.org.za)

Table 2-6 Number and type of innovation support organisations in the provinces

	Eastern Cape	Free State	Gauteng	KwaZulu-Natal	Limpopo	Mpumalanga	Northern Cape	North West	Western Cape	Total
Technology Stations	3	2	5	2	1	0	1	0	3	17
Incubators	8	5	22	11	5	7	3	2	7	70
Science parks	1	1	1		0	0	0		1	4
Fab Labs	2	1	2		1		1	1	1	9
Living Labs	2	1	0	3	0	0	1	2	1	10
Ekasi Labs			10							10
Innovation -Colab				1						1
University-based incubators	2	2	4	1					2	11
mLab				1						1

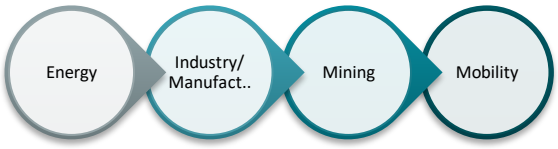
Source: STI Indicators Report

3 Suggested STI Priority Sectors

Based on previous conversations with CSIR contemplating different ways to priorities sectors, it was agreed that the STI4CE Strategy should align with ongoing departmental initiatives and rather complement them instead of duplicating. This implies looking at those sectors where only little STI initiatives are taking place or no STI roadmaps exist, but obviously also on those sectors with promising CE opportunities as identified in D2. Sectors where many STI initiatives or the presence of a roadmap have been identified are: water, waste, construction, energy and agriculture[44]. To summarise result of D2, the sectors with the highest CE potential are water, mobility, mining, energy, agriculture and industry/manufacturing. Based on these considerations, priority sectors for the STI4CE Strategy are proposed in the following.

Respectively, the priority sectors for the STI4CE Strategy, where STI guidance and instruments are missing are illustrated in Figure 3. Energy is an enabler for economic development and is demanded by manufacturing (incl. plastic, e-waste and textiles), mining and mobility.

Figure 3-1 STI priority sectors



Clean Energy

South Africa is facing an energy crisis that may last for years. The sector is at the centre of the economy due to the country's high energy intensity. South Africa has been crippled by sporadic and increasing energy shortages. Energy, particularly renewable energy, has been identified by various policies, strategies and regulations as a key enabler of [circular] economic development due to the wide array of sources that can be harnessed. These include but not limited to technologies such as biogas, natural gas, biofuels from used oils and hybrid options. As identified in D2, the opportunities are fourfold, namely utility focused, materials, business and innovation, as depicted in the table below. Under the National Energy Act on 2008, the South African National Energy Institute (SANEDI) was established in 2011 to direct, monitor and conduct energy research and development, promote energy research and technology innovation as well as undertake measures to promote energy efficiency throughout the economy. Since then, SANEDI has worked on projects across the entire economy establishing various programmes. Of importance and most relevant to the strategy is the DSI Secretariat, where the focus is on Coal CO2-X; Energy Storage; Hydrogen South Africa (HySA); and Renewable Sustainable Energy (RSE) Hub and Spokes. NSI in involved in these programmes and industry will be taking these to market, a Hydrogen site has already been identified in Coega for implementation. Work is also being done in the cleaner mobility and renewable energy spaces to reduce pollution and emission of GHG. With all of the energy research being conducted in SA, including the latest development around the Just Energy Transition Partnership (JETP), the is no real critical analysis of the sector to determine the efficacy, impact and outcome of these initiatives and this should be done to identify gaps and opportunities. The next chapter (4.2) presents STI opportunities to fill these gaps.

Table 3-1 Overview of CE opportunities in the energy sector that require STI support

Utility Focussed Opportunities	Material Opportunities	Business Opportunities	Innovation Opportunities

[44] Water Research, Development, and Innovation (RDI) Roadmap: 2015-2025, Waste Research Development and Innovation Roadmap South Africa Roadmap, Construction: Innovation Roadmap for Sustainable Human Settlements, Energy: The Hydrogen Society Roadmap, Agriculture: The Bio-Economy Strategy. Please note, athough there is a STI roadmap for hydrogen, it is yet a niche topic. Thus, there is the potential to support the transition towards CE through STI in conventional power generation, which could be potentially linked with mobility. Similarly, there is a strategy and not roadmap for the bio-economy. It includes various components of agriculture and value chain optimization which has been considered as sufficiently covered.

• Renewable energy • Energy Storage • Agrivoltaics • Green Hydrogen • New Energy Vehicles • Freshwater Substitution: desalination @ dry cooling • Waste to energy • Carbon capture, utilisation and storage • Emissions prevention • Fly-ash valorisation	• Circular design of energy technologies – reduced material and energy use • Increased efficiency, longevity of energy technologies • Recycling of energy technologies at end of life	• New business models and enabling regulatory frameworks which promotes circular economy principles in the energy sector. • Decouple economic development from energy usage & demand • Local manufacturing and recycling of solar technologies	• Incentives for innovation in energy technology (such as Solar Panels from Waste Crops) • Energy producing roads • Biochar from water hyacinth

Source: own table, based on D2

Note that this presents an overview derived for the previous D2 Report assessing the available opportunities and gaps identified and engaged with the first stakeholder workshop. The information above this table shows that some of these initiatives are being addressed at different levels, but there are still needs. The private sector is also working on a number of these but require additional STI support to mainstream opportunities.

Industry and manufacturing (incl. textiles, food and beverages and e-waste)

South Africa's manufacturing sector is linear in nature, which results in high resource demand, unsustainable production, and high wastage. The sector is also a significant emitter of greenhouse gases due to fossil-based energy use. Productivity within the manufacturing sector is low, and waste and pollution are generated in significant volumes. Although a challenge, it presents opportunities to do better. Applying circular economy principles, such as designing out waste and closing resource loops, offers a systemic approach to address these challenges and achieve resilience in the local manufacturing economy. Sub-sectors such as electronics and textiles are part of human development and products of innovation. However, opportunities for their end-of-life cycle remain untapped. By encouraging scientific, technological and innovative strategies, ecosystem role-players can research and develop these opportunities using circular principles from the technology cycle: Redesign, Remanufacture, Recycle, Repair, Refurbish, Remanufacture, Repurpose and more. Plastics and packaging are a reality that society cannot completely do without. It is thus imperative for STI to support sustainable production and consumption. R&D has catalysed innovations such as biodegradable plastics, and recycled packaging material. As identified in D2, the opportunities are fourfold, namely utility focused, materials, business and innovation, as depicted in the table below. However, up until now they miss tailored STI support. The next chapter (4.2), presents STI opportunities to fill these gaps.

Table 3-2 Overview of CE opportunities in the manufacturing sector that require STI support

Utility Focussed Opportunities	Material Opportunities	Business Opportunities	Innovation Opportunities
• Material flows and sustainable resource utilization • Product life cycle • Innovative production processes. • Additive Manufacturing • Biobased fuels /materials • Circular Business Models • Green Steel Manufacturing • Industrial Symbiosis • Material Looping • Remanufacturing • Renewable Energy Technologies • Resource Efficiency • Cleaner Production	• Innovative manufacturing enterprises • Re-industrialization and the transition to a more circular economy • Design and implement the circularity of resources • Design of products, manufacturing and production process for the entire product life cycle, including usage and end-of-life	• New business models and enabling regulatory frameworks which promotes circular economy principles in the manufacturing sector. • Exploration of business models with higher impact for the circular economy • Strengthen local manufacturing, reduce dependence on resource imports, unlock new economic opportunities. • Positioning the country for a green economic recovery • Innovative manufacturing enterprises	• Incentives for innovation • 4IR Technologies, digital technologies i.e., Internet of Things (IoT), 3D printing • Low-GWP hydrocarbon refrigerants • Additive manufacturing • Adoption of industrial robots • Construction 4.0 technologies • Digitalization of the industry

Source: own table, based on D2

Mining

The mining sector plays a significant role in the country's economy by providing minerals and metals domestically and globally. However, the sector is facing challenges such as declining productivity, increasing costs, fluctuating exchange rates, declining ore grades, and environmental issues. The circular economy is seen as a framework to promote prosperity, job creation, and resilience while reducing greenhouse gas emissions, waste, and pollution. Regarding the mining sector, there are many opportunities for rehabilitation linked to agriculture where reclaimed land can be turned into urban forests or food belts – with the help of R&D to determine suitability. Similarly, there are a multitude of options to enhance the efficacy and potential of extracting precious metals, Rare Earth Elements and other valuable mineral and metal resources for tailings and fly ash that have enormous potential to dive the circular economy of the country. There are several initiatives linked to DSI and the likes of the Mandela Mining Precinct, such as SAMERDI and their programmes in longevity of current mines, mechanised mining systems, advanced orebody knowledge, real-time information management systems and the successful application of technologies centred around people programme. Again, STI has the potential to spur these ideas into research and tangible opportunities for implementation. The next chapter (4.2) presents STI opportunities to fill these gaps. The table below present the opportunities in the sector by the following categories: utility focused, materials, business and innovation, as depicted in the table below.

Table 3-3 Overview of CE opportunities in the mining sector that require STI support

Utility Focussed Opportunities	Material Opportunities	Business Opportunities	Innovation Opportunities
• Integrate renewable/alternative energy • Green Hydrogen production • Mine water remediation and recycling • Dust suppression • Land reclamation through rehabilitation	• Reclaiming/reprocessing tailings • Repurpose mine waste and tailings to backfill or construction aggregates • Metals slag and fly ash to low-carbon cement alternatives • Move to landfill reduction or zero waste • Substitution to less toxic raw materials • Repurposing/recycling of rubber tyre and conveyor belt waste / energy recovery • Process residues and secondary materials • Urban mining	• Reduced costs in tailings and slimes dam management – better for environment too • SME development and supplier development in supply chains through waste beneficiation • Reduced energy and water costs, less impact on environment • Reduced carbon footprint facilitates continued approved/preferred export markets • ESG reporting and reduced Scope 1, 2 & 3 emissions • Develop local supply chains and improve community relations • Increased financial sustainability through Critical Raw Material extraction and management	• Ore extraction efficiency and precision mining • Innovation in acid chemicals management • Bioremediation • Carbon capture and carbon storage • Leasing mineral resources (MaaS)

Source: own table, based on D2.

Mobility

The mobility sector is a very important part of every country's economy, particularly South Africa. This sector includes sub-sectors such as aviation, road, rail, and maritime transport. It is a major polluter in South Africa regarding CO_2 generation and to offset this, the government is considering strategies to reduce air pollution. Mobility is also linked directly and indirectly to other sectors such as agriculture, particularly the role of transporting organic produce to various markets. There is an opportunity to decentralise agricultural practices

to reduce the distance travelled; bring food and agricultural supplies into cities and towns – resulting in less emissions. Linked to agro-waste in particular, biogas and biofuels can be used as a feedstock to run more public transport modes such as buses. A project of this nature is underway in the City of Johannesburg. As identified in D2, there are more opportunities that are even fourfold, structured in: utility focused, materials, business and innovation, as depicted in the table below. However, up until now they miss tailored STI support. The next chapter (4.2), presents STI opportunities to fill these gaps.

Table 3-4 CE opportunities in the mobility sector that require STI support

Utility Focussed Opportunities	Material Opportunities	Business Opportunities	Innovation Opportunities
• Investment in non-motorised transport solutions (e.g. bicycles and electric bicycles as well as related infrastructure) • Skills development in maintenance and repair of new mobility solutions • Upscaling locally developed technology and civic tech solutions for efficient public mobility (e.g. GoMetro132), to be developed alongside transit-oriented urban development • Research and development for clean fuel technologies (e.g. biodiesel, hydrogen, natural gas, propane, renewable energy)	• Developing eco-routes as an intervention and solution for energy efficiency in vehicles • Circularity in automobile sector • Management and disused end of life EV's and disused transport components	• Production and use of hybrid and electric vehicles and components for light motor vehicles, logistics, mining and manufacturing sectors, including modular design of components for maintenance and repair.	• Product as a service • Innovation in combustion and other engine development • Innovation in fuels

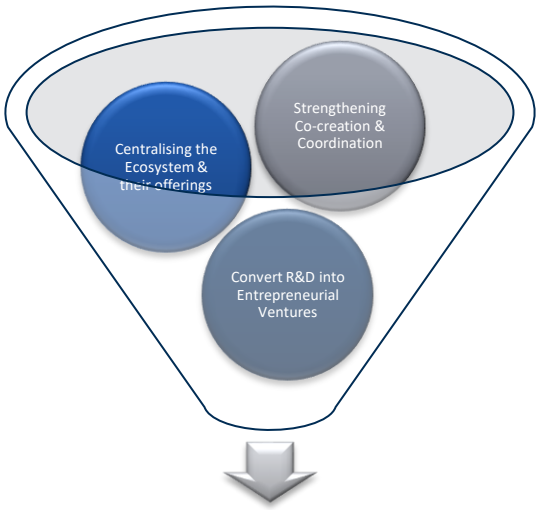
Source: own table, based in D2

4 Overview of STI4CE gaps and opportunities

Some of the best opportunities for STI supporting CE are related to collaborative ecosystems and stakeholder offerings, strengthening co-creation and coordination as well as partnerships with business for ease of taking completed research to commercialisation, which need to be translated and taken further by tangible STI programmes, as shown in the figure below.

Overall, SA has a lot of strengths that can be attributed to this growing body of policies and strategies. However, most opportunities are determined by a lack of implementation force and coordination. On the one hand, stakeholders are often working in their own corners without cross-departmental collaboration or (at least) communication. On the other hand, there is no aligned understanding of the scope of and requirements for CE STI. This ultimately represents a threat limiting the positive impact of existing STI and CE initiatives, and further the future STI4CE Strategy

Figure 4-1 Greatest overarching STI opportunities to support CE



Source: own figure

A more concrete breakdown of these higher-level opportunities is presented in the next two sub-sections. They are unpacked by DSI mandate and STI priority sector.

4.1 Gaps and untapped opportunities falling under DSI mandates

This sub-section provides an overview of the gaps and untapped opportunities surrounding the generation and uptake of STI to strengthen the CE, particularly those that could fall under DSI mandates or be realised through close collaboration between DSI and one or more other institutions. These gaps and opportunities are drawn from the outcomes of Workshop 2, which took place in November 2023 and focused on sourcing priorities from multi-sectoral stakeholders. Based on a synthesis of those outcomes, major STI-related gaps and opportunities have been grouped into six interrelated themes under the three stated goals of DSI, namely Human Capacity Development, Research and Development and Innovation through Private Sector Engagement and Entrepreneurship. These themes are introduced below, with a more comprehensive list of needs, challenges and opportunities presented in Table 4-1.

4.1.1 Human capacity development

Theme 1: Entrepreneurship

Ultimately, much of the generation and certainly the uptake of STI in driving the CE is being undertaken by the private sector with more than two thirds of investment and research and development expenditure[45]. These actors have the potential to not only implement STI with lower bureaucratic obstacles, but also generate new ideas and innovations for the betterment of society and its natural support systems. Figure 2 highlights the relationship between entrepreneurship and science and its related positive impacts. However, current policy gives limited explicit consideration to smaller companies and entrepreneurs. In fact, a narrative emerging from Workshop 2 was that those entrepreneurs present made strides in their businesses, either in spite of, or with little awareness and support by government platforms and initiatives. This points to a gulf between regulatory frameworks and those very actors that constitute the country's economy. Thus, there is yet untapped potential for an STI4CE Strategy in South Africa to empower entrepreneurs, especially SMMEs, by providing them with the guidance, support and agency they need to drive the circular transition. This requires the strategy to consider the realities of running a business and responding to market demands. A key call in the meeting was that more demand for CE goods and services are needed to help drive uptake of CE business models, which however does not fall into the mandate of DSI.

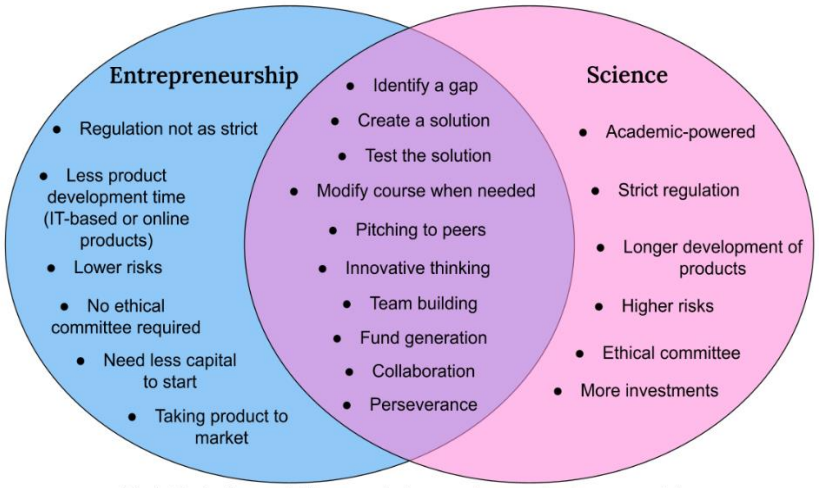


Fig 1. Similarities and differences between science and entrepreneurship.

Figure 44-2: Similarities and Differences between Science and Entrepreneurship[46]

Theme 2: Awareness, education, training and capacity building

The skills barriers facing entrepreneurs hoping to enter the CE are twofold. First, symptomatic of a deeper issue plaguing the national economy, many young people lack fundamental business skills. Second, among those that do start their own businesses, there is a lack of knowledge on how to adopt existing forms of STI and operationalise them in circular business practices. This knowledge gap extends to municipal authorities, leaving them uncertain as to how best to support and enable emerging circular businesses. The lack of sufficient technical knowledge and capacity is felt particularly acutely in South Africa's rural municipalities, which have a dearth of tertiary education institutions. There is thus significant need and potential to strengthen the linkages between the private sector and educational institutions, with the aim of more closely aligning educational programmes and associated government funding with the technical skills required for entrepreneurs to link STI with market opportunities in the CE. Doing so has the potential to create the conditions for entrepreneurs to

45 https://african.business/2023/01/trade-investment/private-sector-is-key-to-revitalising-south-africas-economy#:~:text=The%20private%20sector%20has%20a,and%20research%20and%20development%20expenditure.

46 https://www.enventure.org/posts/science-and-entrepreneurship-parallels-and-intersection

implement, iterate and potentially develop new forms of STI and drive the circular transition in South Africa in an organic manner from the bottom up.

4.1.2 Research and development

Theme 3: Research and development

Even with the necessary technical knowledge and skills, actors in the private sector require robust evidence to justify the prioritisation and implementation of different forms of STI. As it stands, the lack of such a consolidated, accessible and institutionalised evidence base has led to redundant pilot projects and a lack of guidance on the use of circular technologies in the public sector. As such, there is potential for DSI to develop a standardised, unbiased framework for reporting on the financial viability and socio-environmental impacts of different forms of circular STI, translating these to clear standards that businesses are incentivised to meet in order to most effectively achieve their own long-term goals. Doing so would provide actors in the private sector with more reliable proof of the viability of circular businesses, helping to increase confidence and secure greater funding to accelerate the circular transition. Of course, the necessary evidence informing such a framework relies on coordinated research. Thus far, however, research into STI has been disconnected from industry practices. In light of this, there is the secondary opportunity for DSI to establish a mechanism (such as a community of practice and associated forum) through which national government departments, industry associations and research bodies meet on an ongoing basis to align the objectives of research and development initiatives with the tangible needs identified in practice. Establishing such a platform is also crucial to ensuring that the findings of studies are showcased and find their way to those actors best positioned to actualise their potential.

Theme 4: Inter-governmental and sectorial collaboration

The need to better align research bodies and different industries speaks to a broader need for collaboration between the public, private and non-governmental sectors as well as academia and civil society. Although DSI is mandated to ensure that advances in STI feed into the public and private sectors, the sampling of multi-sectoral stakeholders at Workshop 2 consistently emphasised a lack of transparency and communication surrounding the work of DSI. As a result, while many initiatives currently exist across sectors to promote the generation and uptake of STI in the CE, their effectiveness is diminished significantly by the effects of poor coordination between siloed efforts. This points toward a need for more diverse and effective means of communication that better realise DSI's potential as a facilitator and coordinator. More effective means of collaboration include both within government (e.g. by identifying and regularly meeting with “innovation champions” in different departments to disseminate STI information relevant to their respective roles in promoting the CE) as well as between government and other sectors (e.g. by developing a stakeholder map and decision tree, meeting with multi-sectoral points of contact and supporting and learning from the work of intermediary organisations).

4.1.3 Innovation through private sector engagement and entrepreneurship

Theme 5: Common platform

The need for greater collaboration and aligned research creates a significant opportunity for the development of an innovative platform or shared platform for communication and information sharing that serves as an accurate reflection of the CE ecosystem in South Africa. As supported almost unanimously by stakeholders present at Workshop 2, such a platform would ideally serve as a so-called one-stop-shop for those involved in either the generation or uptake of STI in the CE. This could host various types of information, including (1) a comprehensive registry of actors in different sectors/industries and their roles within broader value chains; (2) regulatory frameworks and government support in different sectors; and (3) new research publications. By hosting some combination of these information types, a platform such as this has the potential to address many of the preceding gaps in knowledge and coordination, thus catalysing a host of further initiatives to solidify the role of STI in South Africa's circular transition. However, when deciding exactly what form this platform should take, it is important not to duplicate existing efforts or create more work without a clear understanding of who will take responsibility for it. As such, this platform could take a more decentralised form, acting as a “network

of networks" that connects various existing initiatives actors that are already best positioned to engage with their constituencies.[47]

Theme 6: Financing

Ultimately, seizing the opportunities in the generation and uptake of STI is contingent on the availability of financial resources. Within that realm, the need for greater collaboration translates into the potential for a more strategic inventory and alignment of finance within government in order to fund initiatives that will have the largest impact. However, there is also a considerable gap between entrepreneurs and potential funding opportunities. This is due to the lack of knowledge of or access to relevant government funding mechanisms as well as the high degree of perceived risk surrounding up-and-coming business in the CE because of the previously discussed skills gap and lack of evidence for the viability of circular technologies. Thus, there is a vital need for the development of new funding mechanisms that lower the barrier to entry for entrepreneurs, particularly SMMEs. Notably, such a mechanism could build on other opportunities for collaboration and integration by spanning multiple actors across sectors, such as DSI, CISA, Circular Development Fund, the Industrial Development Corporation, the dtic incentives, banks and producer responsibility organisations. To minimise risk to funders and ensure the long-term financial sustainability of emerging circular businesses, new funding mechanisms can be explicitly tied to a mentorship and/or training programme, wherein recipients gain experience from established professionals and undergo relevant up-skilling. Crucially, whatever form this new funding mechanism takes, it is crucial that it is institutionalised as part of an accessible roadmap that provides prospective recipients with clear information and steps on where and how to apply for funding.

Table 4-1 below provides more detailed points on the gaps or needs for the uptake of STI, obstacles or challenges in this uptake, as well as opportunities for STI creation and uptake that can support circular transitions.

[47] There is a potential role for Circular South Africa and the Circular Innovation South Africa initiatives - CSA is a platform development to bring the network-of-networks, but CISA is more focused on the Circular Development Fund.

Table 4-1 Gaps and untapped opportunities falling under DSI mandates

DSI Mandate	Theme	Gaps / needs	Obstacles / challenges	Opportunities for STI4CE
Human capacity development	Entrepreneurs	• An STI4CE Strategy that focuses on entrepreneurs (particularly SMMEs) • There is a gap between entrepreneurship and meaningful circular outcomes. • Understanding what STI interventions are required at different stages of business development and operation to best support entrepreneurs.	• Limited market for CE products and services. • Limited funding to catalyse CE interventions by entrepreneurs. • Incubators prioritise the number of entrepreneurs, but not the quality of business outcomes. • Capacity-building without assured resources. • Funders do not pay sufficient attention to quality indicators.	• Develop an STI Roadmap from developing technical training and support such as testing facilities for Entrepreneurs until they are ready to go to Market • Explore status and ownership of the Innovation Bridge[48] for future alignment with STI strategy implementation
	Awareness, education & training	• Greater general societal awareness of the concept of CE. • STI skills at municipal level, particularly in rural areas. • Embedding CE as a broad concept within specific sectors and fields of education, with educational mandates for specific sectors/jobs.	• CE is still a relatively new concept and not widely understood, compounded by a simplistic, 'greenwashing' understanding of CE. • Lack of financial resources to appoint sufficiently skilled personnel in rural municipalities to ensure wider reach of CE awareness EPR scheme calls for LCS analysis of products. • Long time frame and financial cost of developing new curricula at a tertiary level.	• In collaboration with DFFE, clearly define CE system and design of CE based on evidence. • Engineering institutions to require graduates to serve in rural settlements before accreditation, paired with temporary rural training programmes. • Modify existing curricula at higher education institutions by training a cohort of professors across the country's major universities to embed CE in their respective faculties. Include a requirement for Legislative Compliance Specialists to inform curriculum development.
	Awareness, education & training (cont.)	• Foundational business skills (generally) as well as knowledge on how to implement existing forms of STI in circular business models (specifically) among young entrepreneurs. • Integration of indigenous and overlooked knowledge systems in the CE. • Greater connection between the NSF and CE industries.	• Lack of knowledge or guidance on how entrepreneurs are to transition from traditional to circular business models or adopt forms of circular STI, stemming from a lack of appropriate education and training. • Difficulty of translating and codifying indigenous knowledge systems. • Lack of knowledge and understanding from NSF on the critical skills required by entrepreneurs in the CE. • Lack of knowledge among businesses of the training and educational programs funded by the NSF.	• Develop an accessible, subsidised one-year diploma that combines business and CE training for rollout across universities as well as TVET colleges. • There is room to codify indigenous knowledge further in sectors other than medicine. • Impending NSF restructuring will allow for greater autonomy. • Existing funding mechanisms in place for universities, TVET colleges, artisanal learning and work-based learning. • Pending proposal to support SMMEs.

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DSI Mandate	Theme	Gaps / needs	Obstacles / challenges	Opportunities for STI4CE
	Evidence base	• Verifiable data: strengthen the STI evidence base to better identify opportunities. • Monitoring and evaluation: describe and report on the social, economic and environmental impacts and outcomes of CE work using STI indicators • De-risking investment and fostering confidence in project development	• Financers need better levels of security • Re-aligned M&E and reporting incorporating recommendations of recent studies and reviews (	• Unbiased DSI validation: using DSI to gather information and report on the economics/viability and impacts/outcomes of STI applications in CE projects (e.g., biogas), as opposed to the service provider. • Need to measure performance in technology • Unpack material flows to identify opportunities and inform industries and entrepreneurs of where "new markets" can be strengthened. • Need to incorporate interventions to related expanded M&E policy learning capabilities of the NSI – see Annexure A
Research and development	Research & development	• Poor support for commercialisation of STI related to CE. • DSI to better lead CE STI conversations • Research is either not user-ready or perpetuates research for research's sake. • Research brokerage and the use of research does not live up to its potential. • Research is disconnected from policy and practice.	• Research institutions hold IP related to CE. • Research cycles are not matched with budgeting or policies / short review cycles.	• R&D institutions should relinquish their hold over entrepreneurs' IP, instead conducting R&D to catalyse small businesses and open new markets. • Adopt Value Analysis (VA) approaches specific to different fast-moving consumer goods (FMCG; e.g., Plastics Pact, textile, food loss and waste) oriented around supply/demand targets. These VA act as a vehicle to identify STI needs and allocate STI funding. • Living labs: areas within cities that are exempt from various regulations (e.g., Air Emission License) to expedite piloting. • DSI explicitly funding Transdisciplinary Research that has a set of user-ready recommendations. • Deal book: a portfolio of applied research and a resourced 'broker' to test those ideas and then equip an implementer. • DSI funds Technical Assistance for de-risking project proposals • Alignment NSI already undertaking R&D in CE related fields.

DSI Mandate	Theme	Gaps / needs	Obstacles / challenges	Opportunities for STI4CE
	Inter-governmental and sectoral collaboration	• An STI4CE Strategy that is practical and applicable, not theoretical, with actionable interventions. • Improved intergovernmental communication & collaboration. • Limited communication and celebration of CE opportunities. We need greater visibility of DSI's work to address private sector mistrust. • Improved relationships between DSI and non-governmental actors. • STI must be integrated in various sectors to have a greater positive impact in society through CE.	• Siloed operation of sectoral departments • The perception by other departments that STI can only be done by DSI • Businesses don't know what to do, why or how to be involved in the production/uptake of STI in the CE.	• DSI to support the development of sector-specific masterplans that include CE interventions, e.g. for TIPS. • Identify a CE "innovation champion" per department or subject in respective government departments and have STI forums to share information and best practices. • Use a communication strategy and outreach initiatives, such as hosting dialogues and providing snapshots of current research. • Multi-stakeholder implementation plans • The private sector and NGOs can support DSI to improve the communication of CE opportunities.
Innovation	Common platform	• A dynamic site functioning as a hub of curated CE information. • A platform for businesses to ask DSI questions about specific materials: regulations, support, funding, etc. • Registry of CE STI actors and roles. • An engagement mechanism (e.g. platform) for sharing information on topics such as how to engage with municipalities. • Aggregator of curated public knowledge, shared data and funding sources.	• Uncertainty regarding mandates: who will be responsible for funding, creating and maintaining the platform? • Uncertainty surrounding the uptake of information. • Lack of initiative from government and other actors. • Lack of data sharing agreements involving DCDT and a national data policy	• Big data markets • Knowledge brokering could play a role in creating and/or maintaining such a platform or disseminating information. • The platform could be maintained through public funding initially and later through membership. • Develop centralised map or database with tangible information such as key players, where in value chain they play, funding accessible at which stage (TRL), what to submit. This should be linked to other partners' websites too. • Focus on creating a "network of networks", harnessing existing institutional relationships of different organisations rather than duplicating work. • Explore status and ownership of the Innovation Bridge[49] for future alignment with STI strategy implementation

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DSI Mandate	Theme	Gaps / needs	Obstacles / challenges	Opportunities for STI4CE
	Funding	• In collaboration with dtic and IDC, ensure that SMMEs have access to sufficient funding to acquire facilities, equipment, etc. to establish their businesses. • Better coordination and transparency among departments for CE STI budgets.	• Perceived risk of funding young entrepreneurs with a lack of experience.	• Joint funding mechanism involving the DSI, IDC and PROs. • Provide funding to eligible businesses for a fixed period, subject to strict CE criteria and tied to a mentoring programme wherein DSI appoints an experienced CE practitioner to guide and pass on knowledge to an emerging SMME. • Take advantage of unused RDI budget of departments, e.g., TIA.

4.2 Gaps and opportunities in STI priority sectors

Based on Chapter 2, whose development involved stakeholder consultation and analysis of the local expert team, the table below summarizes the STI CE gaps and opportunities per STI priority sector. These will be included and further elaborated in the STI4CE Strategy. Some of the mentioned opportunities are already in the pipeline by other departments and agencies. However, they have been listed here to ensure a comprehensive overview. In the final STI4CE Strategy, those that are not yet tackled and clearly fall under the mandates of DSI will be selected and taken further.

Table 4-2 Overview of STI gaps and opportunities in priority sectors

STI priority sector	CE opportunities	STI gaps	STI opportunities
Energy	Renewable energy	Barriers to adoption of the new technologies, which includes the need for long-term land productivity certainty, market potential, just compensation, and system flexibility. There is no policy to support the facilitation of the integration of agrivoltaics into the energy sector and addressing the competition for land between solar PV and agriculture. There is a need for greater innovation in decoupling economic growth from resource consumption. Redesigning and re-engineering industrial processes and products, as well as effective capture and use of waste streams.	Develop and implement innovative technologies and solutions for renewable energy generation, distribution, and utilization. Support research and development efforts to improve the efficiency and effectiveness of renewable energy systems, as well as promote the adoption of sustainable practices in the energy sector. Facilitate collaboration between manufacturers, government, and other stakeholders to promote the growth and integration of renewable energy sources in South Africa's energy mix.
	Energy Storage		Integration of reusing and recycling at the initial design stage is crucial for achieving a more environmentally sustainable and circular outcome Develop a battery management and control system to optimize the sizing of batteries and ensure uninterrupted supply to loads within specified limits. Use of batteries as an energy storage option, its popularity and technologically maturity, makes it a viable solution for integrating renewable energy systems. R&D in energy storage innovation.
	Green Hydrogen		Aggressively pursuing research, development, and market creation for hydrogen and fuel cell technologies. Formulate specific policies for hydrogen development and enhancing hydrogen energy production, for South Africa to achieve a transition from a fossil fuel-based economy to a hydrogen energy-based economy. R&D in small-scale hydrogen production.
	New Energy Vehicles (NEV)		Transform correct theoretical knowledge into NEV products, meeting or creating new market demands and enhancing the ability of enterprises to compete. Introducing alternative vehicle technologies, such as electric and hydrogen vehicles, can have a significant impact on reducing greenhouse gas emissions in the transport sector.

	Agrivoltaics		Combining solar photovoltaic (PV) renewable energy generation with agricultural production, agrivoltaic systems will offer potential benefits for farmers and the environment. Refining the technology and developing educational, legal, and financial frameworks that support scaling. Policy support is crucial in facilitating the integration of agrivoltaics into the energy sector and addressing the competition for land between solar PV and agriculture.
	Local manufacturing and recycling of solar technologies		STI can support the financial feasibility of local manufacturing of solar panels by determining the Minimum Sustainable Price (MSP) and exploring the potential for cost reduction and just energy transition. Contribute to the selection of the most suitable battery technology for small-scale domestic PV systems, considering factors like environmental impact, circular economy compatibility, and resource supply constraint. Drive the development and implementation of circular economy practices in the energy sector, promoting sustainability and economic growth in South Africa.
	Circular design of energy technologies – reduced material and energy use		Development of lifetime extension and closed-loop recycling of photovoltaic (PV) modules, which can help reduce virgin material demand and life cycle waste. Develop a modular energy infrastructure that is reconfigurable, decoupling the life of the infrastructure from its modules and extending their lifecycle, thereby promoting circular economy principles. Adopt sustainable and renewable energy devices, such as photovoltaic/thermal collectors and phase change materials, along with the establishment of supporting infrastructure, to improve energy generation, transmission, and use efficiency.
	Increased efficiency, longevity of energy technologies		Develop and use new technologies, R&D, and innovative processes, to improve energy efficiency. Develop appropriate policies, such as differentiated price policies to support energy efficiency in South Africa and create an effective energy efficiency policy.
	Recycling of energy technologies at end of life		Develop innovative, high-value end-uses for waste streams such as organic waste and industrial biomass, as well as waste plastic, by diverting viable resources from landfills. Develop and use recycling processes, such as the recovery of secondary metals from photovoltaic structures and materials, to improve the environmental performance of renewable energy systems.

			Design of products for disassembly through modular approaches and the development of materials for substitution. Closed-loop recycling and refurbishment of Pb-acid batteries are well-established in South Africa, making them a sustainable choice for small-scale domestic PV systems. Lithium battery recycling new to South Africa, requiring additional support and development
Manufacturing/ industry	Material flows and sustainable resource utilization	Greater platforms for research, development, and innovation (RDI) to be developed. Low conversion rate of RDI into collaborations between policy-makers and implementers. Very low and complicated processes of prototyping/testing innovations as well as issues of copywriting, patenting and intellectual property. Without the above, new and circular products or services are not able to grow market (demand). Access to finance remains very low and may be attributed to financiers' understanding of how RDI can be monetised (return on investment). Poor link between policies and strategies geared at developing new markets for manufacturing.	Sustainable management of supply chains and materials, smart and lean production, and the application of modelling and simulation techniques. Research and data mapping full LCA impacts, outcomes and economic benefits of local beneficiation from extractive resources, alternative materials (construction and manufacturing), CRM and REE extraction and beneficiation locally, local valorisation of lost materials identified in MFA. Research, analysis and validated model generation for carbon offsets for alternative CE manufacturing systems to align with NDC calculations. Research into manufacturing and industrialisation benefits on decarbonisation regarding local carbon tax benefits and international market alignment: Cost benefit analyses.
	Product life cycle		Digital transformation of manufacturing firms, integrating Industry 4.0 technologies, smart data, and life cycle assessment methodology, integration of social organizational life cycle assessment.

	Innovative production processes	Need to develop STI skills and capacity in bio-engineering	Developing high-value end-uses for waste streams, such as organic waste and industrial biomass, extract high-value products from waste, such as xylose sugar and pine oils from sawdust, and high-value sugars, fibers, and nanofibrils from mill sludge. Use of low-value, non-recycled waste plastic in road construction.
	Additive Manufacturing	Lack of research on alternative materials	Integrating recycling processes into the additive manufacturing process chain. Promoting research and development in additive manufacturing. R&D into additive manufacturing using geopolymer options in built environment
	Biobased fuels /materials	Poor understanding of the technology and opportunities	Development of hybrid materials based on organic and inorganic compounds. Developing high-value end-uses for waste streams, such as organic waste and industrial biomass. Use of biobased, biodegradable plastics beyond traditional composting, providing opportunities for high-value beneficiation.
	Circular Business Models	Aligning STI to CE models and outcomes	Systematic process model for business model innovation, which includes stages like preparation, sensing, seizing, and transforming, along with recommended practices and tools. Reduce complexity and uncertainty in circular economy business model innovation by providing sectorial business model patterns that are tailored to specific manufacturing sectors, helping companies visualize the viability and feasibility of circular economy business models.
	Green Steel Manufacturing	Understanding the scale of technology options and measuring the full carbon impact. Research on impacts of water required to produce hydrogen	Adopt green primary iron production processes that use hydrogen as the reductant instead of coke. Utilizing low-cost solar photovoltaic electricity to produce hydrogen, making the process cost competitive. Exporting green primary iron from South Africa to leading decarbonizing markets. Increase the utilization of electric arc furnaces and reduce the EU's demand for clean electricity, thereby lowering total decarbonization costs. Use of big data techniques and tools can be applied in the steel industry to improve socio-economic and environmental sustainability of production cycles.
	Industrial Symbiosis		Innovative use of waste from one company as a resource for another, can be a strategy to manage resource scarcity and climate change challenges. Promoting resource efficiency and business development, industrial symbiosis can reduce carbon emissions and create sustainable solutions. Improved understanding and implementation of industrial symbiosis, including the development of resource partnerships, contextual conditions, and network strategies.

	Remanufacturing		Enhance scientific research and upgrading technological capabilities, as outlined in Sustainable Development Goal-Target 9.5 (Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries). Build advanced internal manufacturing capabilities and forging knowledge collaborations to overcome resource constraints and drive frugality in design, engineering, and manufacturing processes.
Mining	Integrate renewable/alternative energy	Enabling policy environment, including a competitive energy market structure and adequate energy infrastructure, to support the integration of renewables in mining operations. There is a need for technological advancements in waste valorization and the development of high-value end-uses for all mining waste. Financial considerations and demonstration of technical feasibility are vital for the successful transfer of technology in the mining industry. The lack of programmes and initiates to change the perception of waste and its value within the sector. The need for new value chains, technology development, and stability in regulation to speed up the transformation towards a	Incentivize exploration investment in minerals and metals that support the global transition to a low-carbon future and to build a comprehensive green industrialization strategy that connects mining to renewable energy opportunities.
	Green Hydrogen production		Develop and market creation for hydrogen, fuel cell, and water electrolysis technologies as being pursued by the South African government and mining companies, such as Anglo-American Platinum, Impala Platinum, and Lonmin. STI can develop human capital and create opportunities to address issues of resource scarcity and security through sustainable resource utilization, strengthen local manufacturing, reduce dependence on resource imports, unlock new economic opportunities, and create jobs.
	Mine water remediation and recycling		Address the challenges of acid waste waters in the coal mining sector by utilizing effluents as a source of raw materials and recovering valuable resources. University-developed waste valorization technologies can be transferred to the mining industry through partnerships with original equipment manufacturers (OEMs) and boutique waste processors. Implement the reduction, reuse, recycling, restoration, and reestablished uses (5R) of mineral residues, which present enormous potential for the mining sector. Develop innovative, high-value end-uses, such as extracting valuable materials from waste streams and developing biobased products, viable resources to divert away from landfills and contribute to a more sustainable mining industry.
	Land reclamation through rehabilitation and Reclaiming/reprocessing tailings		Develop technologies for recovering valuable minerals and converting mine waste into a resource with market value, through collaboration with researchers and universities. Partner with and identify potential commercial partners such as original equipment manufacturers and boutique waste processors to further develop and implement waste valorization technologies within the mining sector.

	Repurpose mine waste and tailings to backfill or construction aggregates	circular economy in the mining industry. Access to finance. Silos within the government, the private and public sectors, and the communities/society.	Develop innovative technologies to recover valuable minerals from mine waste and convert them into resources with market value. This will help reduce harmful environmental emissions and prevent the loss of valuable resources. Develop technologies and processes to repurpose mine waste and tailings as backfill or construction aggregates.
	Metals slag and fly ash to low-carbon cement alternatives		STI can enable collaboration and partnership with Researchers and private companies who have explored the use of solid waste resources such as fly ash, slag powder, and municipal solid waste incineration fly ash (MSWIFA) as cementitious materials. These waste materials can be used as alkaline activators to stimulate the activity of other materials like red mud and ground granulated blast-furnace slag (GGBS). Implement environmental management accounting practices (EMAP) to improve environmental sustainability in cement and mining companies. Valorization of coal processing waste and copper slag waste.
	Repurposing/recycling of rubber tyre and conveyor belt waste / energy recovery		Support the implementation of upcycling practices by businesses to close the loop within their industrial processes and production chains, leading to improved waste management and value-added products from waste material. STI can support collaborations and partnership with institutions and researchers who have developed technologies to valorize waste such as tires and conveyer belts to develop value added products.
Mobility	Production and use of hybrid and electric vehicles	Lack of skills for the maintenance and repair of new mobility solutions. There is need for novel multi-stakeholder collaborations to unlock the full potential of electric mobility's flexibility. Need for government policies, such as purchasing subsidies and tax rebates, to address the main constraint of electric vehicle price and improve the enabling environment for adoption.	Rigorous exploratory ecosystem modeling and stakeholder analysis, Skills development in maintenance and repair of new mobility solutions. Use of photovoltaic (PV) solar carports at large employers or car park owners to reduce the burden on the national grid and make electric vehicles more carbon friendly. Explore the potential impact of introducing alternative vehicle technologies and the importance of greater market penetration of electric and hydrogen vehicles.
	Non-motorised transport (NMT) solutions		STI can contribute by supporting research and development of innovative NMT infrastructure and services. Develop technologies to manufacture NMT products from waste i.e. plastic. Strengthen local manufacturing of green products to reduce dependence on resource imports.

	Management and disused end of life EV's and disused transport components	Lack of continuous supply of energy (loadshedding).	Develop transformative innovation policy, linked with complex adaptive systems and ecosystems, to guide policymaking and improve the adaptiveness and resilience of the ecosystem. The management of ecosystem projects, such as those focused on connected mobility, can contribute to the structuring of an ecosystem and the development of innovative solutions. Apply a proto-ecosystem approach and update existing tools and theories in innovation management, for stakeholders to align their interests and create a systemic offer with shared benefits.
	Circularity in automobile section		The STI ecosystem can facilitate collaboration, experimentation, and platformization to drive circular ecosystem innovation in the mobility sector. Develop an ecosystem for interactions between firms and other organizations, structured trial-and-error processes, and the use of online platforms to achieve greater circularity. Develop and apply circular business models and explore smart charging and vehicle-to-grid technologies, the STI ecosystem can unlock the full potential of electric mobility's flexibility and create resilient business models in the grid-aware mobility ecosystem.
	Eco-routes as an intervention and solution for energy efficiency in vehicles		Integrate innovative technologies and approaches, such as eco-routing transportation planning methods and vehicle-infrastructure communication systems. The use of eco-routes based on a new navigation concept called eco-route can help reduce the environmental footprints of road transport. Introducing alternative vehicle technologies, such as electric, hydrogen, and hybrid vehicles, can also contribute to reducing GHG emissions in the transport sector.
	Alternative clean fuel technologies		Research and development for alternative clean fuel technologies (e.g. biodiesel, hydrogen, natural gas, propane, renewable energy).

Source: own table based on CE opportunities (D2) and analysis conducted in D3 and after workshop 2.

Realising and tackling the identified opportunities requires improved coordination between government departments. This could be done by following this example: the DTIC, through its agency Trade & Industrial Policy Strategies (TIPS), can support DSI with information, research and masterplans they have either concluded or can prepare. The masterplans would set the tone for DSI to then develop tools that spur further science, technology and innovation. Another proposed approach would be working with DSBD to ensure its entrepreneurship and cooperative programmes are linked to sector-specific R&D or roadmaps developed. CoGCTA would then assist with capacity development and training for the local government decision-makers to purposely consider innovations across these sectors.

5 ANNEX

Annexure 1: Interventions to create an expanded M&E policy learning capabilities of the NSI

	Outcome		Implementation initiatives
1.	Improved understanding of systemic SASTI perfromance, and the contribution of STI to achieving SA's NDP goals through the adoption of multi perspective M&E Framework for the NSI	1.1	Review NACI M&E Framework for the NSI, including analysis of implementation options, standards/benchmarks, indicators and the Innovation Scorecards for South Africa
		1.2	Develop a data strategy to support the NACI M&E Framework
		1.3	Develop capacity at NACI so that it can assume its role as the NSI M&E institution charged with collating M&E information and analysis from various sources, translating it into advice on innovaiton policy across government. In time NACI should develop the capacity to oversee the implementation of the M&E Framework
		1.4	Develop NACI capability and plan for regular foresight exercises (e.g. every five years or as requested by the IMC)
		1.5	Conduct feasibility study on establishing an STI Observatory centrered around (but not limited to) the DST-NRF CoE in Scientometrics and STI Policy (hosted jointly by Stellenbosch Univesity and Tswane University of Technology). A characteristic of the proposed STI Observatory would be functional lnkhages to relevant M&E institutions in SA includng research chairs and CoEs at HEIs. ASSAf and the Cenre of STI Indicators at hte HSRC, as well as abroad (e.g. the UNESCO Global Observatory and the African STI Observatory), and the incusion of HDIs, industry associations and professioanl bodies.
2.	Increased M&E skills and capabilities for the NSI	2.1	Develop a strategy to expand the M&E capabilities aof the NSI, including increased posgraduate trainig and shorter-term executive type training,
		2.2	Establish a naitional STI M&E community of practice under the auspices of NACI and linked to existing similar initiatives, e.g. at the DPME, National Tresasury and appropriate DSI-NR CoEs and South African Research Chairs.
3.	An effective and vibrant knowledge policy interface in the NSI	3.1	Strenghthen the policy advisory mandates and capabilities of credible sources of STI inforamtions and analysis such as ASSAf, SARChI research chairs and CoEs. This will require a strategy to increase the mobility of
		3.2	Include a policy advice agenda in the general STI agenda approved by the IMC to improve the relevance and timeliness of STI policy advice
		3.3	Design strategies for a policy dialogue, with a focus on involving civil society, business associations and professioanl bodies, alongside academia and governemnt

Source: Decadal Plan

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