UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

Botswana

SCIENCE, TECHNOLOGY & INNOVATION FORESIGHT

United Nations

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Preface

The United Nations Conference on Trade and Development conducted a Science, Technology and Innovation (STI) Policy Review of the Republic of Botswana during 2021-22. As part of the STI Policy Review, a foresight exercise was undertaken to initiate a process of identifying future national priorities for STI in Botswana and discussing the future role of STI in development in Botswana with stakeholders in the country.

This report documents the foresight exercise including its purpose, methodology, activities, and findings. The foresight process included the following activities:

- Considering global trends in STI (covering areas such as markets, society, product groups, thematic science and technology areas and implications for the Botswana STI landscape) and local trends in STI (covering areas such as patents analysis, bibliometric analysis, exports by technology intensiveness, R&D expenditure and funding, and elements of the National System of Innovation (actors, STI governance, funding and support instruments).
- Preparing and conducting an STI Foresight Training Session for selected stakeholders in Botswana aimed at capacity building on foresight and building a common understanding of the foresight process.
- Designing and implementing a survey of stakeholders in Botswana to develop an initial list of STI priorities. Activities include stakeholder mapping, database development/sourcing, development of online survey tool, and development of criteria for prioritisation of suggested STI domains (such as alignment to Botswana's Vision 2036, transformative change potential and the feasibility of implementation).
- Conducting interviews with selected high-level stakeholders and private sector stakeholders.
- Designing and conducting two one-day foresight workshops with relevant stakeholders. The workshops were held in March 2022.
- Performing data collection to provide context on prioritized STI domains defined during the initial workshop, including among others bibliometrics and patent analysis (focused on appraising STI capability, and identifying opportunities and capability gaps for prioritized STI domains).
- Preparing the STI Foresight Report of Botswana integrating and summarising all foresight outputs (including executive summary, approach, local and international trends, prioritized domains and thrust areas, and separate chapters for each STI domain).

The foresight work was conducted from January through April 2022. Due to Covid-19 restrictions in Botswana, face-to-face meetings were moved online and all workshops were held virtually. In retrospect, this virtual environment did not have a significant influence on the outcomes of the foresight exercise. The only negative effect was the discontinuous presence of some participants in the workshops due to sporadic connectivity problems. On the other hand, it brought people into the discussion from a broad geographic spread without the burden of travelling and overnighting under pandemic restrictions. The foresight team was experienced with online deliberations and the facilitation of the workshops was designed with a remote environment in mind.

Acknowledgements

The Botswana Science, Technology and Innovation Foresight report was prepared by the Division on Technology and Logistics, UNCTAD, under the overall leadership of Shamika Sirimanne, Director, and the direct supervision of Liping Zhang, Chief, Science, Technology and Innovation for Development Section.

The report was prepared as part of the Science, Technology and Innovation Policy Review of Botswana by a team led by Michael Lim (project coordinator, UNCTAD). The team included consultants Anthon Botha (Managing Director, Techno Scene, Pretoria), Petrus Letaba (Senior Lecturer, University of Pretoria) and Gape Kaboyakgosi (researcher and consultant, Botswana).

Comments from stakeholders in Botswana were provided during two virtual stakeholder meetings held on 30 August 2022 and 7 October 2022, and a hybrid (physical and virtual) meeting with the Botswana Steering Committee in Gaborone on 7 November 2022. Comments were also received from Arno Hold (UNCTAD) and Matteo Ramina (UNCTAD).

UNCTAD worked closely with the Department of Research, Science and Technology (DRST) under the Ministry of Communications, Knowledge and Technology of Botswana, without whose collaboration the preparation of this report would not have been possible. Prior to the Government restructuring of May 2022, DRST was located in the Ministry of Tertiary Education, Research Science and Technology (MOTE).

Lesego Thamae (Director, DRST) led the team for the foresight exercise at DRST, with support from Oabona Monngakgotla (Deputy Director, DRST). Other members of the team at DRST assisted in the organization of and participation in diverse activities during the foresight work and worked closely with the foresight team, including Ontlametse Gaothuse and Oatumetse Seabe. UNCTAD thanks DRST for its support of this project.

High level officials in the Government of Botswana supported the review process through their participation in various meetings. UNCTAD acknowledges the participation of Douglas Letsholathebe (former Minister, MOTE), Aubrey Lesaso (former Assistant Minister, MOTE), Nelson Torto (Permanent Secretary, Ministry of Communications, Knowledge and Technology and former Permanent Secretary, MOTE) and Kekgonne Baipoledi (former Deputy Permanent Secretary, MOTE).

The foresight exercise and the foresight report benefited greatly from comments and suggestions provided by various people in Botswana. Many government officials, academics, scientists, engineers, private sector representatives and businesspeople, entrepreneurs at start-ups and civil society representatives gave generously of their time and insights to the team involved in the drafting of the report. All these contributors are gratefully acknowledged.

Caleb Halvorson-Fried and Michael Lim (UNCTAD) provided editorial support. Magali Studer (UNCTAD) designed the cover. Overall layout, graphics and desktop publishing were undertaken by the Division of Conference Management of the United Nations Office at Geneva. Malou Pasinos and Xiahui Xin (UNCTAD) provided administrative support.

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Abbreviations

4IR	Fourth Industrial Revolution
5G	Fifth Generation
AECOM	Architecture, Engineering, Construction, Operations, Management
AfCTA	African Continental Free Trade Area
AI	Artificial Intelligence
APET	African Union High Level Panel on Innovation and Emerging Technologies
AU	African Union
BCG	Bacille Calmette-Guerin
BDIH	Botswana Digital and Innovation Hub
BHP	Botswana Harvard AIDS Institute Partnership
BIDPA	Botswana Institute for Development Policy Analysis
BITRI	Botswana Institute for Technology Research and Innovation
BIUST	Botswana International University of Science and Technology
BONEPWA	Botswana Network of People Living with HIV/AIDS
BPC	Botswana Power Corporation
BTC	Botswana Telecommunications Corporation
BVI	Botswana Vaccine Institute
CEDA	Citizen Entrepreneurial Development Agency
CIPESA	Collaboration on International ICT Policy in East and Southern Africa
COVID-19	Corona Virus Disease 2019
CPS	Cyber-Physical System
CPU	Central Processing Unit
CSIR	Council for Scientific and Industrial Research
DBSA	Development Bank of Southern Africa
DRST	Department of Research, Science and Technology
EDD	Economic Diversification Drive
EO	Earth Observation
EPI	Environmental Performance Index
FMD	Foot and Mouth Disease
Gbps	Gigabyte per second
GDP	Gross Domestic Product
Gen	Generation
GHG	Green House Gases
GIS	Geographic Information System
GMO	Genetically Modified Organism
GNSS	Global Navigation Satellite System
GWh	Gigawatt hour
HEI	Higher Education Institution
HIV/AIDS	Human Immunodeficiency Virus infection and Acquired Immune Deficiency Syndrome
HRDC	Human Resource Development Council

HVAC	Heating, Ventilation and Air Conditioning
HWC	Human-Wildlife Conflict
ICT	Information and Communications Technology
IEA	International Energy Agency
IKS	Indigenous Knowledge Systems
IIoT	Industrial Internet of Things
IoT	Internet of Things
IP	Intellectual Property
IPP	Independent Power Producer
ISPAAD	Support Program for Arable Agriculture Development
M&E	Monitoring and Evaluation
Mbps	Megabyte per second
MOTE	Ministry of Tertiary Education, Research, Science and Technology
MRC	Medical Research Council
mRNA	Messenger RNA (Ribonucleic acid)
MSKS	Modern Scientific Knowledge System
NARDI	National Agricultural Research and Development Institute
NDP	National Development Plan
NRF	National Research Fund
NSI	National System of Innovation
OEM	Original Equipment Manufacturer
PBR	Plant Breeders' Rights
PV	Photovoltaic
R&D	Research and Development
rDNA	Recombinant DNA (Deoxyribonucleic acid)
SADC	Southern African Development Community
SARS-COV	Severe Acute Respiratory Syndrome – Corona Virus
SDG	Sustainable Development Goal
SME	Small and Medium-Sized Enterprise
SOLTRAIN	Southern African Solar Thermal Training and Demonstration Initiative
STI	Science, Technology and Innovation
STIP	Science, Technology and Innovation Policy
TB	Tuberculosis
TTO	Technology Transfer Office
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Program
VAR	Variable Application Rate
VLSI	Very Large-Scale Integration
VoIP	Voice over IP
WEF	World Economic Forum
WHO	World Health Organization
WIPO	World Intellectual Property Organization

Executive summary

Foresight includes innovative strategic planning, policy formulation, and solution design methods that do not intend to predict or forecast the future, but rather consider alternative scenarios. Foresight is a systematic process, cognitively supported by future thinking, is highly participatory, contains elements of future intelligence gathering and serves as a medium- to long-term vision-building process aimed at envisaging the future and strategically making decisions in the present to arrive at a preferred future. It empowers decision makers and policy planners to use new ways of thinking about, talking about, and implementing strategic plans and policies that would have a high benefit when realised. Foresight is built on the notion that the future is not predetermined but rather can be influenced or even created by actions in the present. Foresight consists of activities aimed at debating, shaping, and thinking about the future.

This foresight exercise for Botswana was prepared in the context of the broader science, technology, and innovation (STI) environment globally and at continental, regional, and local levels. This served to bring it into alignment with global trends and the Sustainable Development Goals (SDGs), and policies for sustainable development and STI in Africa, the Southern African Development Community (SADC), and Botswana. In particular, the four pillars of Vision 2036 were considered as guidelines for the foresight exercise. These pillars are: sustainable economic development; human and social development; sustainable development; and governance, peace and security.

The seven STI priority domains that emerged from the foresight exercise for Botswana include agriculture, digital economy, energy, environmental sustainability, health, manufacturing and social development. These domains are supported by selected thrusts. Five future STI scenarios were developed for Botswana in 2036, ranging from Survival, Unsustainable, Vacillation, Thriving, and Wild Card. In the *Survival* scenario, regional and global circumstances are unstable and strongly influential and despite making good decisions, isolation increases. In the *Unsustainable* scenario, slow and indecisive investment in STI due to external factors has not provided the momentum required to create a sustainable economy and social environment and short-term, ad hoc investment in STI leads only to marginal impact. The *Thriving* scenario envisions the Government taking the lead in STI support in a holistic way and the emergence of a strong and well-functioning National System of Innovation (NSI). The *Wild card* scenario is likened to desertification where in extreme abnormal and adverse circumstances, both economically and as far as global stability is concerned, society has reverted to a pace and level of economic activity of several decades earlier.

In the probable or likely future *Vacillation* scenario, which is the result if no significant strategic intervention and action is taken by government, economic collapse stares the country in the face. With insufficient investment in STI, and due to global economic stresses, there is slow progress in creating a coherent and well-functioning NSI.

In the preferred future of a *Thriving* scenario, the government takes the lead in STI support for socio-economic and environmental improvement and well-being, with a long-term strategic view driven by foresight. With the right strategic interventions, and effective and coordinated policy processes defined by agile implementation, a thriving preferred future can be crafted.

The strategic interventions required to realise the preferred future include the following:

- Coordinate and enable collaboration in the NSI.
- Build a network of excellent STI practitioners.
- Utilise effectively policy levers.
- Enable innovation and commercialisation.

- Measure and assess STI activities.
- Fund STI through a National R&D Fund (NRF).
- Develop needed skills at the post-graduate level.
- Incentivise private sector involvement in STI.
- Effect cultural change towards a knowledge and innovation society.
- Institutionalise continuous foresight.
- Equip the NSI with relevant research facilities and infrastructure.
- Empower the NSI institutions to execute clear mandates and build capacity.
- Provide inclusivity of indigenous knowledge and communities.
- Establish effective governance frameworks for STI.

These are elaborated upon in the findings and guidelines for further action discussed in the report. The findings of this report indicatethat by envisioning STI as a socio-economic driver, the country can thrive on its journey towards “achieving prosperity for all” as embodied in Vision 2036. This foresight report is a guideline and policymakers should take action to follow a trajectory towards the preferred future where Botswana is a thriving country. A strong STI policy framework can be built from recommendations of the STIP review and clarity on the future STI agenda brought about through the STI foresight exercise.

Chapter 1: Introduction and background

It goes without saying that the future is important to humans, whether that is in their personal capacity, the way they conduct business, or how they govern themselves. The future is, however, neither predictable nor predetermined. This implies one can make decisions in the present to shape the future in line with our values. Therefore, it is important to "experience" the future through future thinking and foresight and use that experience to mould strategies today to take us to a preferred future. Foresight enables us to do just that. Foresight is a process of systematically envisioning the long-term future of science, technology, the economy, and society. It is aimed at determining what the future may bring and identify areas of strategic R&D and technology likely to yield the greatest economic and social benefits. Whereas the future does not yet exist, we can nonetheless shape it through actions taken in the present with the help of foresight as a strategic planning tool.

Foresight is a methodology that can be used to facilitate strategic planning and policy design using the development of multiple future scenarios. It empowers decision makers and policy planners by offering different methods of conceiving, discussing, and implementing strategic plans and policies, as well as identifying possible futures and imagining desirable futures. Foresight is a highly participative process involving different stakeholders where open discussion among participants is encouraged. Given the far-reaching scope of foresight, stakeholders include public authorities, industry, research organisations, and non-governmental organisations, among others. Results are fed into public decision-making (for example, which research priorities deserve public funding), but they also help participants themselves to develop or adjust their strategies. Thinking, debating, and shaping the future is even more essential today because of the inherent complexity of science, technology, and society. The limited availability of financial resources and the increasing rate of scientific and technological change impose fast decision making on governments and other actors in the national system of innovation.

The ultimate purpose of this STI foresight exercise was to explore the future role of STI in Botswana and to generate a consensus on the future priorities for national investments in R&D, technology and innovation. The lack of clearly defined national priorities has contributed to fragmentation in the National System of Innovation, a key finding of the STI Policy Review. It was initially designed as an activity that included the collection of existing information about STI in Botswana and Africa as a whole. This was followed by critical analysis and creative synthesis to support the foresight methodology. The following additional objectives were set:

- Provide a future dimension to strategic planning.
- Provide guidance on channelling public research funding into limited areas of high excellence in STI practices.
- Provide an opportunity for STI experts to create awareness of and gain a common understanding of foresight and to build a community able to think about the future together.
- Come to an agreement of what a preferred STI future looks like.
- Align STI with socio-economic needs.
- Support centres and networks of STI excellence to prepare for the future.
- Identify new generation STI solutions for the market.
- Contribute to meeting the SDGs.
- Expose industry to opportunities to become world-class competitors in selected economic scenarios.
- Derive economic, environmental and social benefits from future STI.

- Ensure the next generation is capable of facing future challenges.
- Help to align STI activities in Botswana with its Vision 2036[1] and National Development Plan (NDP11)[2].
- Enable the Botswana Vision 2036 through STI contributions.

Cognisant of the development challenges faced by Botswana, **this foresight exercise was guided by Botswana's Vision 2036**, a government agenda that aims to "achieve prosperity for all" and that is based on four pillars:

- Sustainable economic development.
- Human and social development.
- Sustainable development (environmental sustainability).
- Governance, peace, and security.

By grounding the foresight exercise on Vision 2036 and thereby making use of an existing and accepted vision for the country, the foresight project could be undertaken within a short period. This exercise used a rapid foresight process that required much less time than many national foresight exercises, which can take up to two years to complete. The foresight exercise, like the STI Policy Review, is placed in the broader international context of the SDGs, the continental viewpoint as portrayed in Agenda 2063 for Africa, supported by the SADC vision 2050, and the values conveyed within important national level policy documents in Botswana (see Annex 1 for a list of policy documents consulted). The foresight was an integrated activity within a wider project to review the whole Botswana STI policy framework.

Throughout the foresight exercise, cognisance was given to the fact that Botswana is a small country in terms of its population size. Small countries typically have a limited public research base and limited public resources devoted to research, since many STI areas lack sufficient 'critical mass' to keep pace with the latest developments. Small size normally implies a need for specialisation to create critical mass in specific priority areas. Policy levels are often consolidated whereby stakeholders play a range of roles and represent different, potentially competing interests at the same time. There may be more priorities to address than resources, bringing tensions to the fore. Moreover, national data is often missing or incomplete.

The STI foresight in Botswana is aimed at helping to set an R&D agenda and eventually an R&D strategy. This refers to the process by which problems related to STI and the linkages between STI and both society and the economy come to the Government's attention. Policy formulation should be aided by the outcomes of the foresight, strengthening the process by which STI policies are developed by the government. The foresight outcomes will not themselves be the critical decisions to make, but they should enable decision-making through which the Government adopts a particular course of action (or non-action). Policy implementation, the process by which the government executes STI policy, should also benefit from foresight. Policy evaluation, the process by which the results of STI policies are monitored and evaluated by the state, societal, and private sector actors over time, should also benefit from foresight through the identification of relevant outputs, outcomes, and impacts.

[1] Vision 2036, Achieving Prosperity for All (2016) Prepared by the Vision 2036 Presidential Task Team, https://library.wur.nl/ojs/index.php/Botswana_documents/article/view/16023, [accessed 29 June 2022].

[2] National Development Plan 11, Volume 1, April 2017 – March 2023 (2017) https://www.cabri-sbo.org/uploads/bia/Botswana_2017_Planning_External_NationalPlan_MinEcosFin_SADC_English.pdf, [accessed 1 July 2022].

Typical foresight outcomes include:

- An understanding of global changes and challenges and their local impact.
- STI futures based on global trends and local priorities.
- Estimating the demand for new skills and capabilities, reflecting on the type of areas where young people should be educated, trained, and skilled to meet the future needs of the country.
- Making sense of future behaviour of innovation systems.
- Determining future innovation landscape trends and events that may present potential risks or opportunities.
- The ability to make preferred STI future choices.

Policy actions that should respond to these foresight outcomes include:

- The development of long-term national and regional strategies.
- Prioritising STI domains (clusters of STI or spheres of knowledge) and thrusts (specialised and expert technology areas that act as drivers or strategic activities for the domain).
- Identifying and supplying/adopting critical technologies.
- Drawing up sectoral economic strategies.
- Budget optimisation.
- Establishing technology platforms.
- Creating innovation environments and programs.
- Providing research and innovation infrastructure support.
- Identifying and institutionalising education for future professions and competencies.
- Building centres and networks of excellence within the national system of innovation.
- Supporting small business development through innovation-based public procurement.
- Continuously implementing structural reform of the STI system as driven by market dynamics.
- Giving balanced attention to both social and commercial innovation.

This foresight report documents the methodology and the processes followed to undertake foresight in Botswana, indicating the future scenarios for STI and the priority STI domains and thrusts based on a process including pre-study, customisation of the foresight exercise to Botswana's innovation ecosystem, consultation, debate, scientometrics, filtering and validation. It addresses each of the STI domain priority areas in terms of a situational analysis, identifies STI thrust priorities, and discusses capabilities within each sector. Finally, recommendations on strategic interventions are provided and policy alignment to the future landscape is identified. The report contains several annexes with detailed information used in the foresight exercise.

Chapter 2: Science, technology and innovation foresight methodology and outcomes

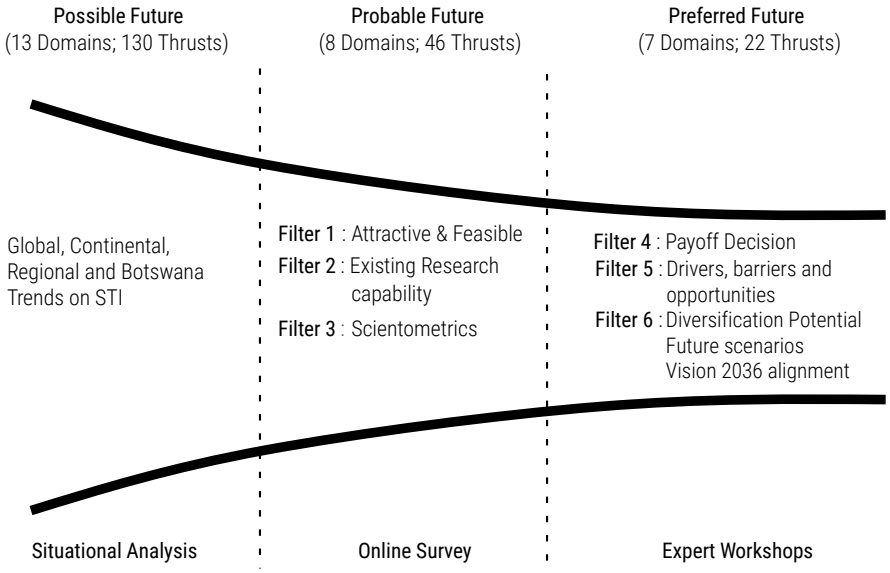
This foresight exercise employed a tailor-made methodology and tools designed to achieve a comprehensive analysis within a relatively short time. The methodology and outcomes are discussed together in this chapter. The following are the main activities that took place during January to April 2022:

- Foresight launching and training.
- Media campaign to create awareness and invite participation.
- Online survey to solicit expert opinion on domains and thrusts.
- Prioritisation workshop to reduce the number of domains and thrusts.
- Future thinking and Vision 2036 alignment workshop.
- Follow-up workshop with health and social development sectors.
- Workshop with business stakeholders.

The STI foresight training, which also served as a platform for the launching of this exercise, was aimed at preparing participants to think about a future STI agenda. The foresight exercise involved thinking at the country level, and from the onset was aimed at reaching as many stakeholders in Botswana as possible and practical. With this in mind, the DRST undertook a publicity campaign that included radio, television broadcasting, and social media to make interested parties aware of the exercise and to invite them to participate. The process adopted for this foresight exercise was structured according to three phases, namely the possible future, the probable future, and the preferred future, as shown in Figure 1.

Figure 1

Botswana STI foresight process.



Source: UNCTAD.

The possible future was determined through situational analysis of the global, continental, regional, and local trends related to STI (see Annex 1 for sources used). A list of 13 domains and 130 thrusts was drawn up. In cases where these thrusts are very broad, sub-thrusts were introduced, as noted in Chapter 3. It was assumed that any of the trends analysed could be possible.

To narrow down to the relevant trends for Botswana, a second phase was introduced to determine a probable future through an online survey of stakeholders in Botswana and by using three filters. The first analysed the attractiveness (perceived as having the most benefit) of pursuing investment in specific domains and thrusts, as well as their feasibility (high likelihood of successful implementation). The views on attractiveness and feasibility were obtained from a broad base of survey respondents. The second filter evaluated whether a domain or thrust represented an existing or new research capability in the country. The last filter employed a scientometric analysis of Botswana's publication activity in the identified thrusts. By applying these three filters, the list of domains was narrowed down to 8, with 46 thrusts in total.

To arrive at a preferred future, three additional filters were employed during discussions in expert workshops. First, a pay-off decision was made based on the length of time it will take for value to be realised by operationalising a thrust, as well as its ease of fulfilment (implementation complexity). Second, barriers, drivers, and opportunities were discussed for each domain to clarify the restrictions placed by some historic views on each domain that might impede its development, the current momentum of STI activity in a domain that drives it forward ("push" factors) and the opportunities in the future that provide a "pull" factor for the domain. Third, the diversification potential of domains was established based on the newness or exiting status of thrusts within each domain and the utility of the domain with respect to new or existing applications. A final list of 7 domains and 22 thrusts was established to guide thinking on future scenarios and alignment of the STI preferred future for Botswana with its Vision 2036.

A. Approach to deduce a possible future for STI in Botswana

A possible future is one that could happen and is anticipated for STI based on current trends. For this exercise a situational analysis was conducted based on an examination of global, continental, regional (SADC) and local STI trends and prioritisation (see Annex 2).

Global priorities

Annex 2 summarises some of the top emerging technologies as identified by various organisations globally. The emerging technologies in Annex 2 were selected based on:

- Reputation of the organisations that generated them.
- Relevance to the Botswana national system of innovation (e.g. mining, agriculture, and water purification technologies).
- Breadth of technologies covered.
- Publication date (generally within the past 1-2 years).

Most of the technologies in Annex 2 are related to the Fourth Industrial Revolution (4IR), e.g. Internet of Things (IoT), artificial intelligence, robotics, nanotechnology, big data, biotechnology, 5G, digitisation, quantum computing, autonomous systems, etc. Furthermore, renewable energy, the green economy, and space technology such as Global Positioning Systems (GPS) and Global Earth Observation (GEO) Systems, as well as medical diagnostics and modelling, are also of great importance to Botswana.

The Sustainable Development Goals (SDGs)[3] strongly influence the prioritisation of STI activities. Some SDGs for which STI play an important role include SDG 3 (Good Health & wellbeing), SDG 4 (Quality education), SDG 6 (Clean water & sanitation), SDG 7 (Affordable & clean energy), SDG 9 (Industry, innovation & infrastructure), SDG 11 (Sustainable cities & communities), SDG 12 (Responsible consumption & production) and SDG 13 (Climate action).

Regional priorities

The SADC Industrialisation Strategy and Roadmap 2015 – 2063[4] emphasises strongly the need to revitalise the manufacturing sector, with objectives such as an increase in the share of medium and high technology production and an increase in the share of manufactured exports to at least 50% of total exports. Some of the strategic priorities of the SADC Regional Indicative Strategic Development Plan 2020 – 2030 (RISDP)[5] include industrial development; social and human capital development; peace, security, and good governance; infrastructure development; and cross-cutting issues such as gender, youth, environment, and climate change, as well as disaster risk management.

The South Africa Foresight Exercise for Science, Technology and Innovation 2030 (NACI, 2019) also lists a series of STI domains and thrusts. Items that have particular relevance for Botswana were noted.

Local Priorities

At the local level, the overarching priorities are based on the four pillars of Vision 2036[1], namely:

- Sustainable economic development.
- Human and social development.
- Sustainable development (environmental sustainability).
- Governance, peace, and security.

The analysis of global, regional and local STI trends and priorities led to a candidate list of STI domains and thrusts for Botswana, as shown in Annex 3 (with definitions of the STI thrusts in Annex 4). The selection of these candidate STI domains and thrusts was based on factors such as frequency of occurrence in the analysed STI-related documents, relevance of these priorities, dominant global trends on STI, and a situational analysis of Botswana. The 13 domains and 130 STI thrusts that were selected were mapped. This map served as the first pass, initial set of potential options in terms of selecting STI priorities for Botswana based on expert opinion solicited through a web-based survey.

B. Approach to deduce a probable future of STI in Botswana

A probable future is one that is likely to happen and can be estimated based on using certain filters and maps. In this foresight exercise, the probable STI future was described based on feedback from the expert opinion survey and with the first three filters described above. In applying Filter 1, analysis of the respondent data showed that most respondents were inclined towards prioritising most thrusts as attractive and feasible. In making the selection to narrow down

[3] Sustainable Development Goals (2015) Department of Economic and Social Affairs, Sustainable Development, United Nations, https://sdgs.un.org/goals, [accessed 29 June 2022].

[4] SADC Industrialization Strategy and Roadmap 2015 – 2063, (2015), https://sadc-eu.sardc.net/resources/RISDP/SADC-Industrialisation-Strategy-and-Roadmap-2015-2063.pdf, [accessed 29 June 2022].

[5] SADC Regional Indicative Strategic Development Plan (RISDP) 2020 – 2030 (2020). https://www.sadc.int/files/4716/1434/6113/RISDP_2020-2030_F.pdf, [accessed 29 June 2022]

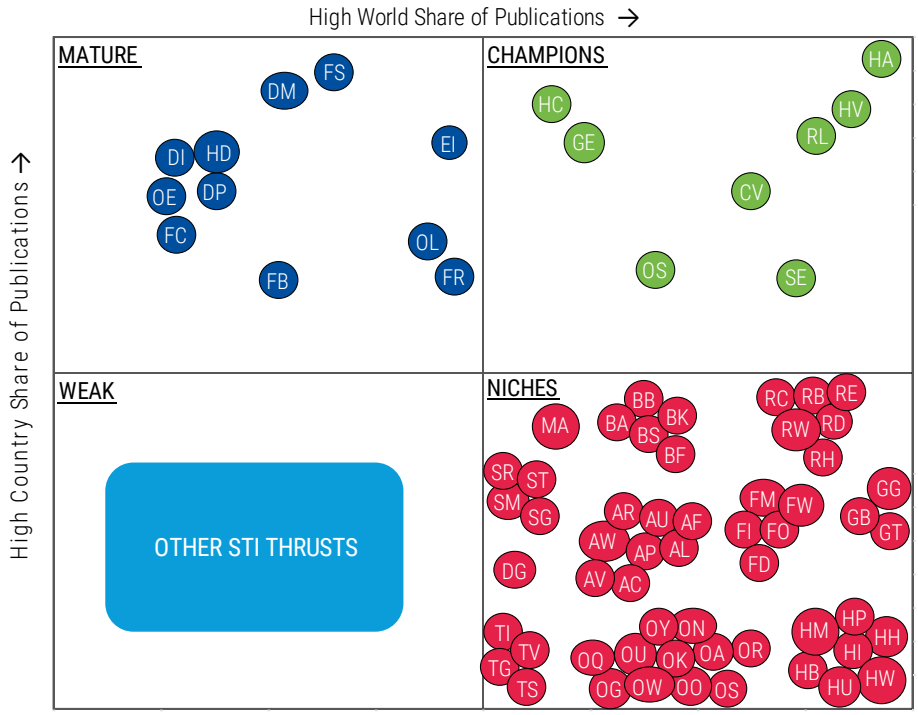
the number of thrusts, only those STI thrusts that scored high in terms of attractiveness and feasibility were considered for further investigation. A total of 89 out of 130 STI thrusts passed this criterion.

Filter 2 entailed an understanding of the level of newness of each thrust within a selected domain. This led to a view of newness of a domain in the form of a ranked list of thrusts from currently existing to requiring many new activities.

Finally in applying Filter 3, scientometrics were used to further narrow down the STI thrusts. Keywords were identified for each STI thrust to build a search string used to compute the number of scientific publications per STI thrust. The percentage of publications in Botswana (country share of publications) for thrusts between 2011 and 2021 was computed from the Web of Science (Core Collection). An arbitrary cut-off point of 2% was used to distinguish between a "high" and "low" share of country publications. The world share of publications (publications from Botswana as a percentage of total publications in the world within the same thrust) was computed using the publications number of a specific STI thrust and the number of publications of those thrusts for all countries. A cut-off point of 0.03% (Botswana's share of total world population) was used to distinguish between a "low" and "high" share of world publications. Figure 2 shows a summary of the results from this categorisation. The champions (high country and world share of publications), mature (high country share and low world share) and niche areas (low country share and high world share) were considered suitable to proceed to the next stage of prioritisation. STI thrust codes and descriptions can be obtained from annex 4. A total of 81 STI thrusts met this criterion.

Figure 2

Classification of STI thrusts based on Botswana's country and world share of publications



Source: UNCTAD, based on Web of Science data.

To further reduce the number of STI domains, the number of survey responses and number of publications as shown in figure 3 and figure 4 were used.

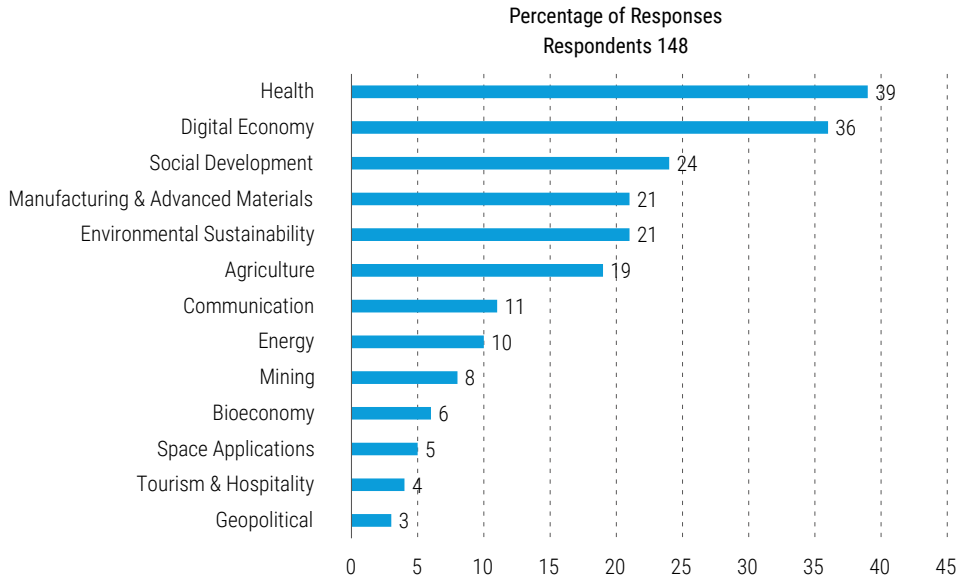
After applying all three filters, eight domains were considered important for both the foresight purpose and as an input to the STI policy formulation processes. The initial eight selected domains were as follows:

- Agriculture.
- Communication.
- Digital Economy.
- Energy.
- Environmental sustainability.
- Health.
- Manufacturing.
- Social development.

By taking into consideration all of the filters, only 46 STI thrusts met both the criteria of publications performance as well as attractiveness and feasibility. It should be noted that in addition to these 46 STI thrusts, two thrusts were not prioritised through the survey but rather classified as champions in the publications analysis and needed further investigation. These were the *HIV/AIDS* (HA) and *Climate & society* (OS) thrusts.

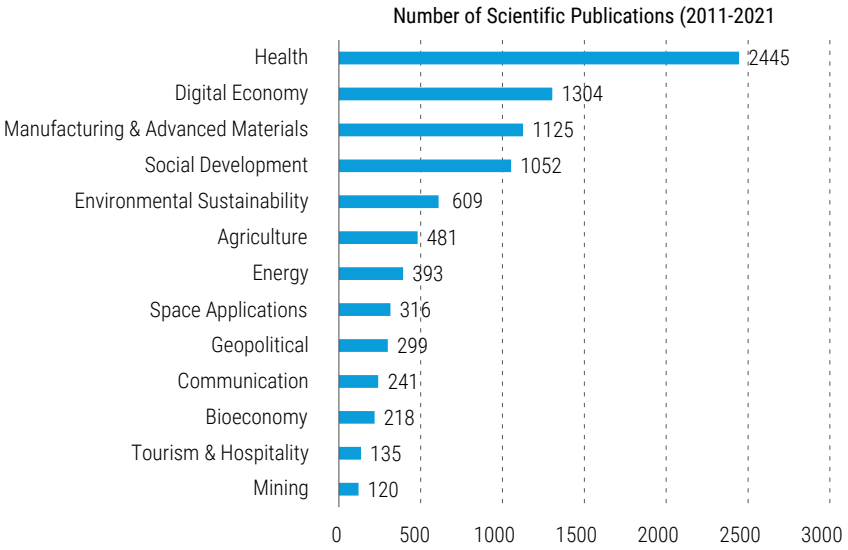
Figure 3

Number of online survey responses per STI domain that was main area of interest



Source: UNCTAD, based on online survey results.

Figure 4
Number of publications by Botswana researchers per STI domain, 2011-2021



Source: UNCTAD, based on Web of Science data.

C. Approach to deduce a preferred future of STI in Botswana

A preferred future is one that is desirable, and which should be promoted by making appropriate decisions on what should be pursued.

Four workshops were organised to facilitate the selection of the final STI priorities, to build future scenarios of how the innovation system in Botswana might evolve, and to discuss the alignment of the selected priorities with Vision 2036 and the needs of various sectors. The first two workshops were intended to focus holistically on the preferred STI future in Botswana.

A dedicated workshop was organised for the *Health* and *Social development* domains, as their importance scored very high in both the survey and scientometric analysis. This workshop focused on setting priorities for each thrust, reviewed the future landscape for health and social development, looked at the diversification potential of the two domains, and extracted recommendations related to future strategy and implementation.

The foresight workshops were used to provide more context and further rationalize the selection of domains and thrusts that would guide a preferred future by looking at Filters 4 to 6 discussed above.

The payoff decisions in Filter 4 considered the ease of fulfilment and value potential for the long list of possible STI thrusts. Only those consideredd to have a high pay-off in terms of having a high value and relatively easy implementation were selected.

Filter 5 judges how easy it would be to take a domain into the future based on the competing forces of historical precedent, drivers from current activities, and future opportunities envisioned. The following barriers, drivers, and opportunities were considered:

Barriers

- Too much regulation.
- Limited collaboration efforts.
- Conflicting strategies.
- Power struggles in government.
- Need to build public/private trust.

Drivers

- Resolving current disease issues.
- Creating an appropriate policy environment.
- Funding of research.
- Building public health programmes.
- Inclusivity in health programs.
- Increased awareness of need for technological foresight due to the Covid-19 pandemic.

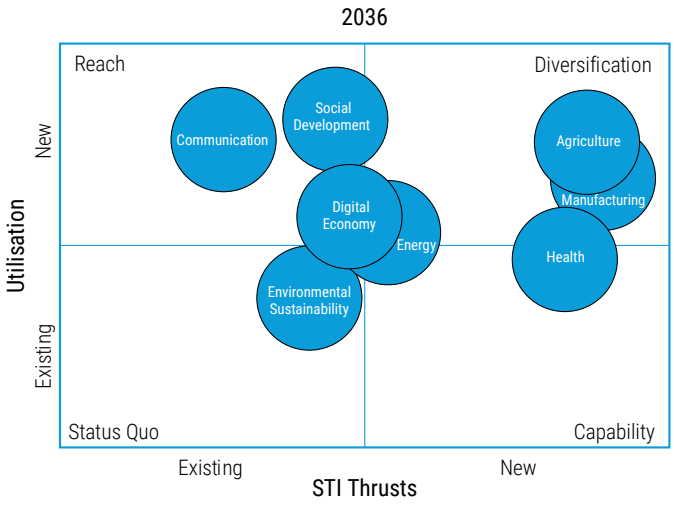
Opportunities

- Enhancing local training.
- Increasing local manufacturing capacity.
- Health technology.
- Digitisation of health.
- Need for advanced healthcare.

The diversification potential was considered only at the level of STI domains in Filter 6. A preference for increasing economic diversification was motivated by heavy natural resource dependence (see chapter 1 of the STIP review). According to Lall (2000), even though resource-based products tend to be simple and labour-intensive (e.g., simple food and leather processing), there can be activities using capital-, scale-, and skill-intensive technologies (e.g., petroleum refining or modern processed foods). It should be considered whether an STI domain can result in new utilisations (adding new value in an existing market or opening new markets) or if new capabilities (in the form of new STI thrusts that have not been available in the past) can be added by 2036 (the terminal date of Vision 2036). Figure 5 shows the categorization of the eight domains as determined by discussions among stakeholders during the workshop.

Figure 5

Domain prioritisation matrix based on the diversification potential



Source: UNCTAD.

After passing through filters 4, 5 and 6, seven prioritised domains and 22 thrusts were selected. The domain of communications had the lowest possibility of diversification as shown in Figure 5, and was therefore excluded. Communication as considered in the analysis consists mainly of telecommunications and ICT infrastructure that is in place, being maintained, or being rolled out steadily according to a long-term plan.

Lastly, a fourth workshop was held with business stakeholders to validate the identified priorities and to discuss a preferred future in the context of the business sector. The contribution of this last workshop was mainly in terms of government-business interaction and is taken up in Chapter 5.

Chapter 3: Priority STI domains and thrusts for Botswana

This chapter outlines in detail the STI domains and thrusts that were identified for STI in Botswana following the application of the six prioritisation filters. The priority domains are also analysed in terms of their context in the economy, STI capability, value added, and trade. The scientific research in each sector is highlighted with an indication of the number of scientific publications that pertain to the sector. This indicates how the priority STI domains and thrusts align with the economic sectors where they can best assist in driving Botswana towards the preferred thriving scenario.

A. Recommended STI domains and thrusts

The seven priority STI domains and 22 thrusts for Botswana are summarised in Table 1.

Table 1
Recommended STI domains and thrusts

Recommended STI domains	Recommended STI thrusts
Agriculture	• Food Security • Water Security • Vaccine Manufacturing • Precision Agriculture
Digital Economy	• Digital Government • Digital Science and Technologies
Energy	• Biomass • Advanced Energy Storage
Environmental Sustainability	• Circular Economy • Biodiversity Conservation • Climate Change • Natural Resources Management
Health	• High-Tech Holistic Medicine • Community Health
Manufacturing	• Bio-manufacturing • Industrialisation • Specialty Chemicals • Advanced Materials
Social Development	• Smart Communities • Resilient Built Ecosystems • Social Inequality & Instability • Early Childhood Development

This prioritisation exercise aimed at developing a preferred STI future aligned with the four pillars of Botswana's Vision 2036. Consequently, the prioritised domains feature significant parallels with such pillars:

- The *Sustainable Economic Development* pillar includes Agriculture, Manufacturing and the Digital Economy (ICT).
- *Sustainable Environment* includes Environmental Sustainability and Energy.
- *Human and Social Development* is associated with Social Development and Health
- *Governance, Peace and Security* is aligned with Digital Government

The STI priorities for a preferred future for Botswana will influence the future of the country. The STI domains and thrusts given in table 1 are further expanded below, focusing mainly on situational analysis, STI capabilities, context and linkages.

B. Agriculture

The agricultural sector in Botswana has been a major economic driver since before independence. This sector can be strengthened by several of the STI activities that have been prioritised for the future.

Situational analysis of the agricultural sector

Botswana is a net importer of food and agriculture contributes to approximately 2% of GDP, with 80% of agricultural GDP consisting of livestock production (Cross Border Road Transport Agency, 2018). Being a semi-arid country, the agricultural sector has unique challenges that impact negatively on agricultural productivity. As noted by researchers from the University of Arizona[6], "Prone to drought and with scarce water resources, agriculture in arid and semi-arid regions has unique characteristics and demands. Specific techniques, management practices, and techniques can be used to adapt to the presence or lack of water and moisture for growing crops". These techniques include precision agriculture, remote sensing of soil moisture, optimised irrigation systems, and crop water use efficiency.

According to the National Development Bank, the Integrated Support Programme for Arable Agriculture Development (ISPAAD) was launched in 2008 to address the challenges facing farmers and the inherent low productivity of the arable sub-sector. This programme envisaged support to raise value added by farmers through establishing Agricultural Service Centres and acquiring the requisite inputs. This subsidy programme has been shown to contribute positively to the income of small-scale farmers (Motlhwa, James and Yunxian, 2019).

Due to the major role played by livestock production in the agricultural sector of Botswana, animal health and veterinary vaccine manufacturing are very important to the sector's growth and sustainability. Indeed, due to the key role of agriculture in exports before the discovery and exploitation of minerals[7], the Botswana Vaccine Institute (BVI) was established in 1979 to produce foot and mouth disease (FMD) vaccines, to provide biological safeguards, to protect Botswana's livestock industry from the negative consequences of the disease, and to bolster exports of animals and animal products.

[6] Arid and semi-arid agriculture, University of Arizona, https://environmentalscience.cals.arizona.edu/research/arid-and-semi-arid-agriculture, [accessed 6 July 2022].

[7] Botswana Vaccine Institute, Devex, https://www.devex.com/organizations/botswana-vaccine-institute-bvi-69210, [accessed 6 July 2022].

STI capability within the agricultural sector

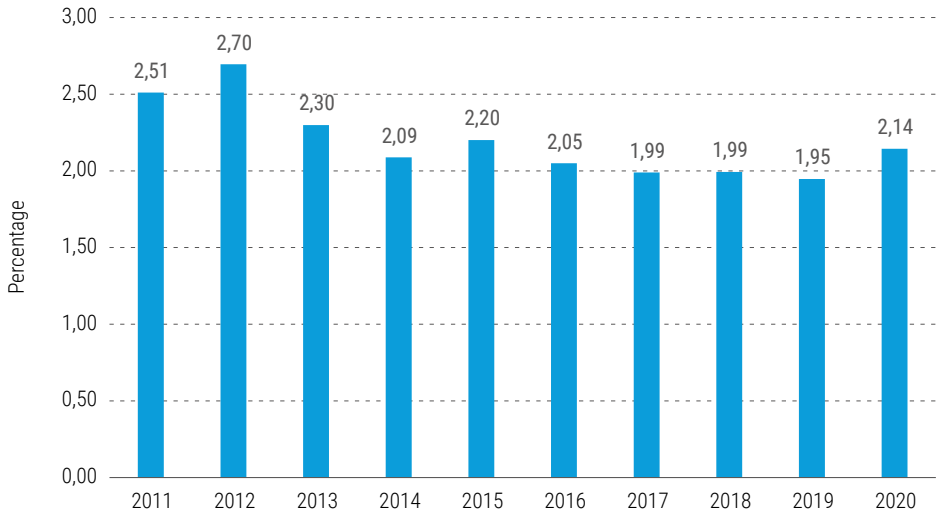
One method used to protect knowledge created for new plant species is Plant Breeders' Rights (PBRs). Botswana has no system for the protection of PBRs, but recently signed a SADC Protocol for Protection of New Varieties of Plants[8]. In the absence of PBRs statistics, this section therefore focuses on agricultural sector value added, trade statistics, as well as knowledge generation (using scientific publications as a proxy).

Value-added and trade within the agricultural sector

As figure 6 shows, the value-added of the agriculture, hunting, forestry, and fishing sector of Botswana as a percentage of GDP has been on a gradual decline from 2.70 percent in 2012 to 1.95 percent in 2019. Covid-19 seems to have reversed this trend, and in 2020 the share increased to 2.14 percent. It should be noted that this sector used to contribute to about 39 percent of GDP during the 1970s.

Figure 6

Agriculture, hunting, forestry and fishing sector value-added as percentage of GDP, 2011-2020
(percentage)



Source: UNCTADStat.

Indeed, Table 2 shows that Botswana is a net importer of food although it both imports and exports food. Agricultural machinery is also imported on net, but trade volume is much lower in percentage terms relative to that of agricultural raw materials as well as food and live animals.

[8] Plant Breeders' Rights Developments in Africa, (2021), Spoor & Fisher, https://spoor.com/plant-breeders-rights-developments-in-africa/ , [accessed 6 July 2022].

Table 2

Product export and import contribution of selected Botswana agricultural products, 2016-2020

	(Percentage value)	2016	2017	2018	2019	2020
Agriculture raw materials	% of product exports	0.10	0.07	0.08	0.10	0.10
	% of product imports	0.65	0.81	0.77	0.82	0.71
Food and live animals	% of product exports	1.70	1.47	1.63	1.50	1.93
	% of product imports	8.99	9.58	9.06	9.49	9.99
Agriculture machinery (excluding tractors) & parts	% of product exports	0.01	0.02	0.01	0.01	0.03
	% of product imports	0.15	0.18	0.14	0.14	0.19

Source: UNCTADStat.

Scientific research in agriculture-related fields

The number of publications, country share and world share of Web of Science scientific fields related to the agricultural sector are shown in table 3. Most areas have few annual publications, although some are internationally competitive (e.g. water resources, soil science, agronomy and multidisciplinary agriculture).

Table 3

Scientific publications in fields related to agriculture, 2017-2021

Web of science fields		2017	2018	2019	2020	2021
Plant sciences	Number	5	7	7	8	15
	Country share (%)	0.80	1.01	0.89	0.96	1.69
	World share (%)	0.02	0.02	0.02	0.02	0.03
Water resources	Number	12	23	13	16	14
	Country share (%)	1.91	3.33	1.66	1.92	1.57
	World share (%)	0.06	0.11	0.06	0.06	0.05
Food science and technology	Number	12	11	3	10	9
	Country share (%)	1.91	1.59	0.38	1.20	1.01
	World share (%)	0.04	0.03	0.01	0.02	0.02
Soil science	Number	4	3	2	3	3
	Country share (%)	0.64	0.43	0.25	0.36	0.34
	World share (%)	0.07	0.05	0.03	0.04	0.04
Agricultural engineering	Number	1	1	1	4	3
	Country share (%)	0.16	0.14	0.13	0.48	0.34
	World share (%)	0.02	0.02	0.02	0.06	0.05
Agronomy	Number	4	4	10	6	11
	Country Share (%)	0.64	0.58	1.27	0.72	1.24
	World Share (%)	0.03	0.03	0.06	0.03	0.05
Agriculture dairy animal science	Number	3	2	6	8	4
	Country share (%)	0.48	0.29	0.76	0.96	0.45
	World share (%)	0.03	0.02	0.04	0.05	0.03
Agriculture multidisciplinary	Number	7	2	7	10	4
	Country share (%)	1.12	0.29	0.89	1.20	0.45
	World share (%)	0.07	0.02	0.06	0.07	0.03

Source: UNCTAD, based on Web of Science data.

In relation to the selected STI thrusts for the agriculture domain, the disciplines that relate directly to food security include both food science and technology and agronomy. At the same time, water resources directly contribute to water security, while agricultural engineering relates directly to precision agriculture. Other disciplines such as soil science and plant science also contribute to precision agriculture.

Priority thrusts for agriculture

Vision 2036 envisages an agricultural sector that is sustainable, technology-driven, and commercially viable. Sustainable agriculture integrates three main goals: environmental health, economic profitability, and social equity (Brodt *et al*., 2011). Therefore, commercial viability is also incorporated as a part of sustainable agriculture. To achieve these objectives, the foresight exercise identified four relevant STI thrusts:

- *Food security.* As articulated in Vision 2036, a competitive agricultural sector is necessary to ensure food security, since many people in Botswana live in rural areas where agricultural activities predominate. Food security is achieved if everyone has, at all times, both physical and economic access to sufficient food to meet dietary needs for a productive and healthy life.
- *Water security.* A country should be water efficient and water secure. Irrigated agriculture is, on average, at least twice as productive per unit of land as rainfed agriculture, thereby allowing more production intensification and crop diversification.[9]
- *Vaccine manufacturing.* Botswana has an established veterinary vaccine manufacturing capability, implemented mainly through the Botswana Vaccine Institute (BVI). These vaccines are critical to combat economically devastating livestock diseases.[10]
- *Precision agriculture.* This is a critical area to achieve the goal of technology-driven agriculture and is in line with the Fourth Industrial Revolution. In the future precision agriculture is expected to make use of technologies such as Global Positioning Systems (GPS), Global Navigation Satellite Systems (GNSS), the Internet of Things (IoT), wireless sensors, variable rate irrigation systems, robotics, artificial intelligence (AI) and modelling.

C. Digital economy

As part of Vision 2036, Botswana has a clear strategy regarding the use of ICT as a catalyst for diversification of the economy and to transform from a middle-income to a high-income country. However, the use of ICT should be aligned with a much broader concept of digitalisation. Digitalisation is defined as the mass adoption of connected digital services by consumers, enterprises and governments, and is a key economic driver that accelerates growth and facilitates job creation (Randall *et al*, 2018). Therefore, the digital economy is not limited to the information technology industry but rather cuts across all sectors and industries.

[9] Water in Agriculture, https://www.worldbank.org/en/topic/water-in-agriculture#1, [accessed 4 July 2022]

[10] Botswana Vaccine Institute, https://bvi-bw.com/ , [accessed 4 July 2022].

Situational analysis of the digital economy

Botswana, being more geared towards trade in minerals and mining products, has recently launched an e-Commerce Strategy.[11] This strategy identified the following eight key e-commerce pillars to lay the preliminary foundation for e-commerce growth:

- ICT infrastructure, telecom and related services such as electricity.
- Logistics and trade facilitation, including postal services.
- Legal and regulatory environment.
- E-payments.
- Electronic platforms.
- Skills development and talent building.
- Raising awareness, including consumer awareness.
- e-Procurement.

It is anticipated that through the initiatives suggested in this strategy, by 2026 Botswana will better harness the power of the private sector, the talent and capabilities of the people of Botswana, a mastery of ICTs and a vibrant e-commerce sector to produce world class products and services. This is critical to realise economic diversification in the country.

According to Collaboration on International ICT Policy in East and Southern Africa (CIPESA), despite policy reforms and investments in ICT in Botswana, some of the challenges related to realising Botswana's ICT and knowledge economy visions include the lack of expected income from ICT-related foreign direct investment and of innovative local investors preparing to build local digital platforms and offer new creative services (Dunn, 2021).

STI capability within the digital economy

To assess the STI capability of Botswana in areas of the digital economy, scientific publications in related fields and trade data are used. It should be noted that no patents from Botswana could be located for the past decade in technology development areas such as telecommunications, digital communication, basic communication technology, and IT methods for management.

Scientific research in digital economy-related fields

Research in scientific disciplines related to the digital economy are not dominant in Botswana, as the country share of publications in these disciplines is low (see table 4). The information systems field had a country share of publications above 2% in 2017 and 2018 but has since dropped below 2%. This field contributes to *digital economy* thrusts such as *digital government*, *ICT in tourism* and *border control*. A low percentage of the country share of publications in fields such as artificial intelligence, automation control systems and remote sensing indicates that Botswana still needs to build considerable R&D capability to be competitive in areas like digital mining and earth observations. The automation control systems and remote sensing research fields should be further nurtured as they have a potential to be strong niches.

[11] National ICT policy review and e-commerce strategy for Botswana, UNCTAD, https://unctad.org/webflyer/national-ict-policy-review-and-e-commerce-strategy-botswana, [accessed 6 July 2022].

Table 4

Scientific publications in fields related to the digital economy, 2017-2021

Web of science fields		2017	2018	2019	2020	2021
Artificial intelligence	Number	8	5	5	5	8
	Country share (%)	1.28	0.72	0.64	0.60	0.90
	World share (%)	0.01	0.01	0.01	0.01	0.01
Automation control systems	Number	8	2	3	6	11
	Country share (%)	1.28	0.29	0.38	0.72	1.24
	World share (%)	0.02	0.00	0.01	0.02	0.04
Cybernetics	Number	0	0	3	0	1
	Country share (%)	0.00	0.00	0.38	0.00	0.11
	World share (%)	0.00	0.00	0.03	0.00	0.01
Information systems	Number	16	14	15	18	14
	Country share (%)	2.55	2.03	1.91	2.16	1.57
	World share (%)	0.03	0.02	0.02	0.02	0.02
Remote sensing	Number	3	1	2	6	7
	Country share (%)	0.48	0.14	0.25	0.72	0.79
	World share (%)	0.02	0.01	0.01	0.04	0.04
Robotics	Number	1	0	2	0	3
	Country share (%)	0.16	0.00	0.25	0.00	0.34
	World Share (%)	0.01	0.00	0.02	0.00	0.03
Software engineering	Number	4	2	2	0	2
	Country share (%)	0.64	0.29	0.25	0.00	0.22
	World share (%)	0.02	0.01	0.01	0.00	0.01
Telecommunications	Number	7	7	12	10	10
	Country share (%)	1.12	1.01	1.53	1.20	1.12
	World share (%)	0.01	0.01	0.02	0.01	0.02

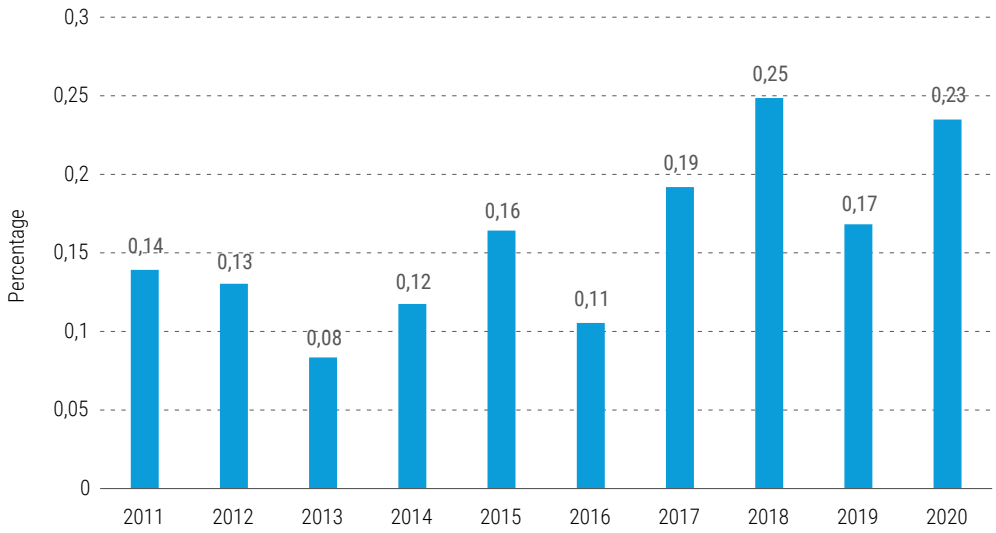
Source: UNCTAD, based on Web of Science data.

Trade statistics for the digital economy

ICT goods contribute marginally to the economy of Botswana as can be seen by the low share as a proportion of total goods trade in figure 7.

Figure 7

Trade in ICT goods as percentage of total goods trade, 2011-2020



Source: UNCTADStat.

However, a benchmarking in table 5 shows that the low share of ICT trade as a percentage of total trade in Botswana is similar to, and in some cases much higher than, that of select countries categorised by UNCTAD as exporters of minerals and mining products.[12]

Table 5

Benchmarking of Botswana ICT goods trade as percentage of total goods trade (percentage)

Botswana	0.23
Democratic Republic of the Congo	0.01
Guyana	0.03
Kyrgyzstan	0.27
Namibia	0.28
Zambia	0.04

Source: UNCTADStat.

Similarly, Botswana is competitive in exports of digitally deliverable services (see table 6) in comparison to the averages for Africa and Southern Africa, but lags behind the selected exporters of minerals and mining products, upper middle-income countries, and the world average.

[12] Developing economies of which, from 2018 to 2020, exports of ores, metals, precious stones and non-monetary gold (SITC (27 +28 + 68 + 667 + 971) on average accounted for more than 50% of their total exports (SITC 0-9) and more than 0.01% of the world total exports of ores, metals, precious stones and non-monetary gold.

Table 6

Benchmarking of Botswana's exports in digitally deliverable services as percentage of all services exports, 2011-2019
(percentage)

	2011	2012	2013	2014	2015	2016	2017	2018	2019
Botswana	30.40	16.23	24.46	27.52	21.93	23.25	26.01	27.72	25.22
World	47.98	48.20	48.62	49.57	50.32	51.17	50.91	51.18	51.79
Africa	20.48	21.37	21.34	20.23	24.09	24.91	23.66	23.08	23.52
Southern Africa	22.80	21.90	22.97	22.91	24.55	25.70	25.93	26.20	25.02
Upper-middle-income economies	30.13	30.19	30.22	32.00	30.97	31.45	31.12	32.89	33.50
Selected exporters of minerals and mining products	24.03	27.24	25.25	26.44	28.29	27.64	27.81	28.15	28.25

Source: UNCTADStat.

Priority thrusts for the digital economy

Digitalisation is a key economic driver that accelerates growth and facilitates job creation (Randall *et al*, 2018). Although the digital economy is often associated with the Fourth Industrial Revolution (4IR), digitalisation is part of the Third Industrial Revolution, in which electronics and information technology are used to automate production. Vision 2036, under the Sustainable Economic Development pillar, aims to leverage ICT as a key contributor to economic growth and employment while also supporting an efficient private and public sector. The foresight exercise identifies two main thrusts within this domain:

- *Digital government*: This includes ICT devices, such as computers and the Internet, to provide public services to citizens and other persons in a country or region. Digitalisation of government services has a wide range of potential applications such as eGovernance, border control, and technology-enabled trade.
- *Digital science and technology*: This thrust has wider application in areas such as digital mining, tourism, earth observations, bioinformatics and artificial intelligence. Digital transformation for the mining industry consists of adopting new digital tools and technological innovations that alter the mining process. The applications seen most often in a digital transformation for mining productivity include the automation of material management, machinery maintenance and performance monitoring. Vision 2036 aims to have a sustainable, vibrant and diversified mineral sector that is integrated with other sectors of the economy. IT-enabled tourism includes different aspects such as direct booking, easy payment for the end users, business to business trading for product providers, travel agents and resellers, and utilising eCommerce platforms. Digital data gathered through earth observation can be used to monitor and assess the status of, and changes in, the natural and manmade environment. Bioinformatics entails computation tools and analysis to capture and interpret biological data. Artificial intelligence is a cross cutting technology that supports the digital economy broadly.

D. Energy

The energy industry typically includes broad activities including the electricity sector, oil, coal and natural gas sectors. **This section focuses mainly on the electricity generation and distribution sector, which is an area where there is a potential to make use of STI to diversify energy sources.**

Situational Analysis of the Energy Sector

Botswana produces most of its electricity, but also relies on imports (mainly from South Africa) to meet its local demand. The Botswana Power Corporation (BPC) has four power stations, namely: Morupule A Power Station (based in Palapye), Morupule B Power Station (based in Palapye), Orapa Power Station (based in Orapa) and Phakalane Power Station (based in Phakalane). The first two are coal powered, with a capacity of 132 MW and 600 MW respectively. Morupule B Power Station was commissioned to replace the aging Morupule A Power Station, but has not delivered as expected, although there have reportedly been recent improvements, with the power station operating at 81% capacity.[13]

The Orapa Power Station with a 90MW capacity was commissioned in 2011 to address the increasing electricity demand within the mining sector. This plant is powered through diesel or natural gas. According to the BPC, the plant is used as an emergency power facility dispatched when the supply from conventional electricity generation sources is inadequate to meet demand.

Phakalane Power Station was built as a pilot solar plant with assistance from the Japanese government, but with a capacity of only 1.3 MW.[14] The Botswana government is making use of the lessons learned through this power plant to expand their capacity to produce electricity from solar. This effort is primarily through the public-private partnership as a policy framework has been adjusted to attract Independent Power Producers (IPPs).

STI Capability within the Energy Sector

Most energy sector innovations in Botswana are expected to be related to renewable energy, in support of Vision 2036 and in fulfillment of climate change mitigation commitments. With the presence of global IPPs such as Tesla, new technologies are not expected in this space but rather the application of technologies that have been proven to work in other countries. However, globally there remains the challenge of advanced energy storage solutions, which will be key to accelerating the adoption of renewable resources such as solar and wind.

Electricity supply and demand

As table 7 shows, most of Botswana's electricity production comes from its coal power stations (97.3% in 2020). There was a drastic increase in electricity production from oil in 2020 since coal power stations reduced their output significantly during the COVID-19 pandemic. Solar PV electricity generation capacity remained constant between 2016 and 2020 at 5 GWh. The country has been reducing a proportion of electricity supply coming from imports by increasing its domestic production.

As in 2020, electricity production from Solar PV constituted only 0.23% of domestic electricity production, and there is significant scope for an increased contribution of electricity production from renewable sources.

[13] Botswana cancels plans to sell troubled power plant to Chinese firm (2018), Reuters, https://www.reuters.com/article/botswana-power-idUSL5N1TB0FE, [accessed 6 July 2022].

[14] SOLTRAIN welcomes new Project Partner from Botswana, Soltrain (2017) https://soltrain.org/news/soltrain-welcomes-new-project-partner-from-botswana, [accessed 6 July 2022].

Table 7

Botswana's electricity production and imports, 2016-2020
(in GWh)

	2016	2017	2018	2019	2020
Coal	2 680	3 012	3 433	3 227	2 122
Oil	6	8	8	8	54
Solar PV	5	5	5	5	5
Total production	2 691	3 024	3 446	3 240	2 181
Imports	1 673	1 289	840	1 101	–
Domestic supply	4 364	4 313	4 286	4 341	–

Source: International Energy Agency.[15]

The electricity consumption pattern in table 8 can be understood in terms of the country's economic growth trend. A recent slow-down in economic growth has resulted in a significant reduction in the share of electricity consumed by industry (from 39.7 percent in 2016 to 28.8 percent in 2019). This has resulted in an increased proportion of the electricity consumed by others such as residential use. Botswana's GDP growth rate was 4.3 percent in 2016, 2.9 percent in 2017, 4.5 percent in 2018 and 3.0 percent in 2019.[16]

Table 8

Botswana's share of electricity supply to different users, 2016-2019
(percentage)

	2016	2017	2018	2019
Industry	39.7	33.4	29.1	28.8
Residential	27.5	31.2	33.2	34.0
Commercial & public services	23.5	25.9	27.8	27.4
Agriculture/Forestry	5.5	5.7	5.9	5.9
Other non-specified	3.8	3.9	4.0	4.0

Source: International Energy Agency

Scientific research in energy sector-related fields

The STI community in Botswana can increase its capacity for electricity generation from renewable energy through further research on innovative solutions such as advanced energy storage.

As table 9 shows, there is very little activity in renewable energy research as indicated by a low share of world publications in areas such as solar energy as well as advanced energy storage. However, it is worth mentioning that there is a notable R&D activity in biomass.

[15] Electricity, IEA, https://www.iea.org/fuels-and-technologies/electricity, [accessed 6 July 2022].

[16] World Bank "Development Indicators".

Table 9

Scientific publications in fields related to the energy sector, 2017-2021

		2017	2018	2019	2020	2021
Solar energy	Number	6	9	7	10	8
	Country share (%)	0.96	1.30	0.89	1.20	0.90
	World share (%)	0.02	0.03	0.02	0.03	0.02
Wind energy	Number	1	1	4	2	6
	Country share (%)	0.16	0.14	0.51	0.24	0.67
	World share (%)	0.01	0.01	0.03	0.01	0.04
Advanced energy storage	Number	1	6	3	5	3
	Country share (%)	0.16	0.87	0.38	0.60	0.34
	World share (%)	0.00	0.02	0.01	0.02	0.01
Biomass	Number	15	19	31	24	36
	Country share (%)	2.39	2.75	3.95	2.87	4.05
	World share (%)	0.04	0.04	0.06	0.04	0.06

Source: UNCTAD, based on Web of Science data.

Priority thrusts for energy

Through Vision 2036, Botswana intends to be energy secure, to have diversified safe and clean energy sources, and to be a net energy exporter. The two prioritised STI thrusts include traditional biomass energy and advanced energy storage solutions.

- *Biomass*: Biomass has numerous applications, including energy and heating, bulk chemicals and fuels, bioplastics and polymers, food and feed as well as pharmaceuticals. As a source of energy, some advantages of biomass over fossil fuels energy include its wide availability as a renewable resource, relatively low cost, and carbon neutrality (the emissions released by burning wood may be gradually offset by the carbon dioxide taken up by trees grown to replace those burned). The development of new biomass energy technologies to reduce greenhouse gas emissions and mitigate climate change is creating new opportunities in Botswana (Sekhwela and Kgathi, 2012).
- *Advanced energy storage*: Some renewable energy technologies such as wind and solar can be improved through advancements in energy storage. The five main categories of advanced energy storage solutions are:
  - Batteries: a range of electrochemical storage solutions, including advanced chemistry batteries, flow batteries and capacitors.
  - Thermal: capturing heat and cold to create energy on demand or offset energy needs.
  - Mechanical storage: other innovative technologies to harness kinetic or gravitational energy to store electricity.
  - Hydrogen excess electricity generation can be converted into hydrogen via electrolysis.
  - Stored and pumped hydropower: creating large-scale reservoirs of energy with water.

E. Environmental stability

Environmental sustainability in Botswana is a standalone pillar of Vision 2036. Its stated objective is the optimal and sustainable use of natural resources to transform the economy and to improve citizens' livelihoods. This pillar includes ecosystem functions and services, sustainable utilisation of natural resources, water security, energy security, sustainable land use and management, sustainable human settlements, climate resilience and disaster risk reduction, and pollution and waste.

Situational analysis of environmental sustainability

Environmental sustainability is one of the main four pillars of Vision 2036, and there is a huge government effort to regularly monitor environmental sustainability indicators along with climate change adaptation strategies. Statistics Botswana monitors environmental parameters through its biannual publication, Botswana Environment Statistics Digest.[17] The indicators included in this publication are as follows:

- Climate
- Land
- Human population
- Water
- Agriculture
- Wildlife
- Forestry
- Energy
- Minerals
- Natural disasters
- Waste management

Environmental sustainability in Botswana is the responsibility of the Ministry of Environment, Natural Resources Conservation and Tourism. According to the Development Bank of Southern Africa (DBSA)[18], despite existing institutional mechanisms and intergovernmental coordination mechanisms for environmental conservation, some gaps still exist. These include gaps in environmental policy formulation, inadequate integration of management, limited monitoring capability, insufficient coordination, lack of capacity to resolve differences and inadequate response capability.

Therefore, there is a role for STI to improve environmental sustainability from a capability point of view, including through the use of artificial intelligence, remote sensors, information systems and big data analytics.

[17] Key statistics, Statistics Botswana, https://www.statsbots.org.bw/, [accessed 6 July 2022].

[18] Botswana, DBSA, https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwix-gryZ7OP4AhVGTsAKHTRtAwwQFnoECAIQAQ&url=https%3A%2F%2Fwww.dbsa.org%2Fsites%2Fdefault%2Ffiles%2Fmedia%2Fdocuments%2F2021-05%2FChapter%25204%2520Botswana.pdf&usg=AOv-Vaw0TOmebHCVxs4XDvf1TmGKW, [accessed 6 July 2022].

STI capability within environmental sustainability

As is the case with most STI domains, there are no record of any Botswana patents in the environmental technology field within the World Intellectual Property Office (WIPO) database. This section focuses on Botswana's performance in the Environmental Performance Index (EPI) and scientific publications in prioritised STI thrusts related to environmental sustainability.

Performance of Botswana in environmental conservation

As table 10 shows, the country ranked 103rd out of 180 countries in 2020 on the EPI index. At the component level, environmental health ranked low (158th) in comparison to ecosystem vitality (48th). A stronger performance in ecosystem vitality is driven by areas such as biodiversity conservation (1st) and ecosystem services (31st). However, as part of ecosystem vitality, climate change is ranked low (128th). Some other poor performing indicators under climate change include the black carbon growth rate (168th), CO_2 growth rate (161st), and greenhouse gases (GHG) per capita (128th).

Most areas related to environmental health rank low, including air quality, waste management, and sanitation and drinking water. Overall, the low rankings confirm the gaps identified by the DBSA and reveal the areas where the STI community can make positive contributions.

Table 10

Ranking of Botswana in Environmental Performance Index

	2020 ranking out of 180 countries
Overall EPI ranking	103
Environmental health	158
Air quality	168
Sanitation & drinking water	136
Heavy metals	125
Waste management	130
Ecosystem vitality	48
Biodiversity conservation	1
Ecosystem services	31
Climate change	128
Pollution emissions	72
Agriculture	178
Water resources	106

Source: Yale University "2020 Environmental Performance Index".[19]

Scientific research in environmental sustainability-related fields

Most scientific research in fields related to environmental sustainability concerns climate change as seen in table 11.

This is an important area as climate change can have drastic negative consequences on citizens' livelihoods, the economy, and the environment. Moreover, climate change mitigation requires a coordinated response from many different stakeholders, including the STI community. Botswana's 1st place ranking in biodiversity conservation is aligned with a high share of global publications in this field. However, the country's share of publications in this field are on the decline. As the country

[19] Yale Centre for Environmental law & Policy, https://envirocenter.yale.edu/2020-environmental-performance-index, [accessed 6 July 2022].

ranks low on waste management, more effort is required to support circular economy research, technology, and innovation.

Table 11

Scientific publications in fields related to environmental sustainability, 2017-2021

		2017	2018	2019	2020	2021
Circular economy	Number	0	0	1	2	4
	Country share (%)	0.00	0.00	0.13	0.24	0.45
	World share (%)	0.00	0.00	0.03	0.04	0.06
Biodiversity conservation	Number	13	14	12	12	8
	Country share (%)	2.07	2.03	1.53	1.44	0.90
	World share (%)	0.19	0.19	0.14	0.13	0.08
Climate change	Number	25	46	37	49	46
	Country share (%)	3.99	6.66	4.71	5.87	5.17
	World share (%)	0.08	0.13	0.09	0.11	0.09
Natural resources management	Number	3	5	7	8	10
	Country share (%)	0.48	0.72	0.89	0.96	1.12
	World share (%)	0.13	0.19	0.23	0.21	0.22

Source: UNCTAD, based on Web of Science data.

Priority thrusts for environmental sustainability

This domain is a main priority in Botswana and a standalone pillar of Vision 2036. The eight objectives under this pillar are: 1) sustainable utilisation of natural resources; 2) climate resilience and disaster risk reduction; 3) sustainable land use and management; 4) sustainable human settlements; 5) ecosystem functions and services; 6) pollution and waste; 7) water security; and 8) energy security. The prioritised STI thrusts under this domain are aligned with Vision 2036 as seen below.

- *Circular economy*: An economy that uses a systems-focused approach and involves industrial processes and economic activities that are restorative or regenerative by design, enables resources used in such processes and activities to maintain their highest value for as long as possible, and aims for the elimination of waste through the superior design of materials, products and systems.
- *Biodiversity conservation*: This entails the protection and management of biodiversity to obtain resources for sustainable development.
- *Climate change*: Global momentum is building to achieve net zero in greenhouse gas (GHG) emissions—and to do so quicker than previously envisioned. Achieving local targets will require unprecedented levels of innovation (Chandaria *et al.*, 2021).
- *Natural Resources Management*: As envisaged in Vision 2036, the objective of this STI thrust is to manage and allocate natural resources in an efficient and environmentally sustainable manner.

F. Health

The wellbeing of a society is measured not only by its economic performance indicators, but also by the wellness of its people. A healthy population also improves the country's human capital potential. As part of the *Human and social development* pillar, Botswana seeks to ensure healthy living and long life expectancy.

Situational analysis of the health sector

The universal healthcare system in Botswana is dominated by government, which operates about 98 percent of its medical facilities. The country has 624 medical facilities, including 26 public hospitals distributed across the country, with 1.8 beds per 1 000 people available in the healthcare sector.[20] Health expenditure constituted about 12 percent of the government's total expenditure and 5.4 percent of the country's GDP in 2018.[21]

The country is burdened by diseases such as HIV/AIDS, tuberculosis, and malaria. Indeed, HIV/AIDS and tuberculosis are among Botswana's leading causes of death. As a result, the Botswana Harvard AIDS Institute Partnership (BHP) was established in 1996 as a collaborative research and training initiative between the Ministry of Health and Wellness and the Harvard T.H. Chan School of Public Health AIDS Initiative.[22] The BHP has expanded its mandate to other diseases such as tuberculosis.

STI capability within the health sector

Select health indicators are discussed in this section as well as scientific publications in relevant disciplines. There do not appear to be patents for medical technologies and pharmaceuticals originating from Botswana in the past 10 years.

Select health indicators in Botswana

With an improvement in management of diseases in Botswana, the life expectancy at birth has increased significantly in the last decade (see figure 8). Like most countries, life expectancy at birth for females is consistently higher than for males.

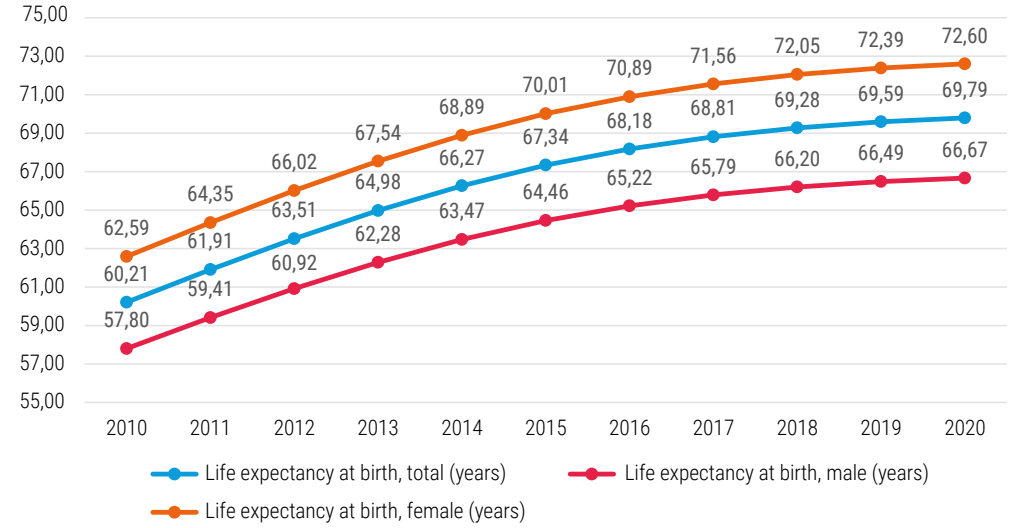
[20] Hospital beds per 1 000 people in Botswana, The World Bank, https://data.worldbank.org/indicator/SH.MED.BEDS.ZS?locations=BW, [accessed 6 July 2022].

[21] Botswana Budget Brief (208), https://www.unicef.org/esa/media/2456/file/UNICEF-Botswana-2018-Health-Budget-Brief.pdf, [accessed 6 July 2022].

[22] Botswana Harvard AIDS Institute, Partnership for HIV Research and Education, https://bhp.org.bw/?page_id=11, [accessed 6 July 2022].

Figure 8

Life expectancy in Botswana at birth, 2010-2020
(number of years)

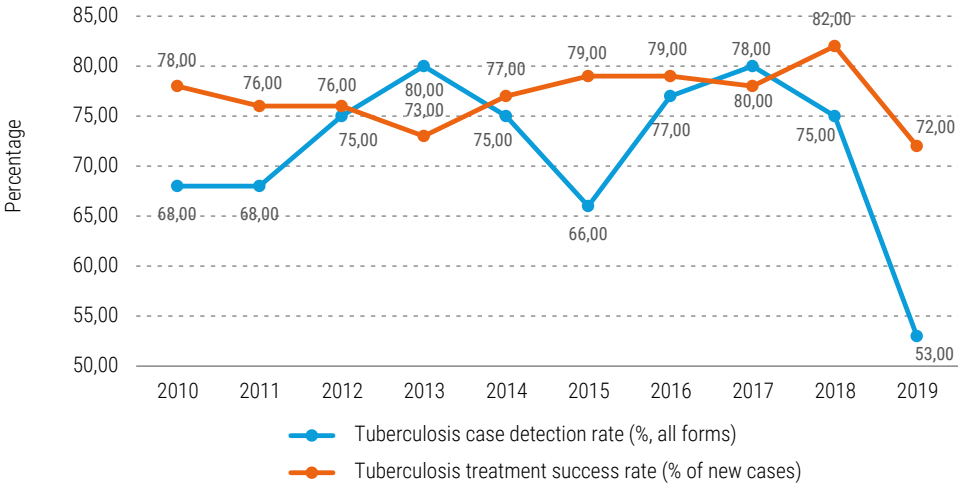


Source: UNCTAD, based on World Bank World Development Indicators database.

Figure 9 indicates that there is scope to increase the tuberculosis treatment success rate, as in 2019 it stood at 72 percent, down from 82 percent in 2018. The detection rate has fluctuated over the years and there are fears that the Covid-19 pandemic may have shifted attention away from existing diseases such as HIV/AIDS and tuberculosis. The World Health Organization (WHO) End TB Strategy[23] aims to end the global tuberculosis epidemic by 2035.

Figure 9

Success in tuberculosis detection and treatment, 2010-2019
(percentage)



Source: UNCTAD, based on World Bank World Development Indicators database.

[23] WHO Global Tuberculosis Programme, End TB Strategy, https://www.who.int/teams/global-tuberculosis-programme/the-end-tb-strategy, [accessed 2022].

Scientific research in health-related fields

Research in health and medical sciences makes up a significant share of country publications. In response to the burden of diseases, publications on infectious diseases represented about 22.5 percent of Botswana's total publication count in 2021 (see table 12). Other dominant areas include healthcare sciences and services (16.2 percent), immunology (14.4 percent), and pharmacology & pharmacy (11.4 percent).

Table 12

Scientific publications in fields related to the health sector, 2017-2021

Web of science fields		2017	2018	2019	2020	2021
Infectious diseases	Number	122	155	194	185	200
	Country share (%)	19.46	22.43	24.71	22.16	22.50
	World share (%)	0.07	0.09	0.10	0.07	0.07
Immunology	Number	83	95	137	122	128
	Country share (%)	13.24	13.75	17.45	14.61	14.40
	World share (%)	0.04	0.05	0.06	0.05	0.05
Oncology	Number	23	27	47	38	61
	Country share (%)	3.67	3.91	5.99	4.55	6.86
	World share (%)	0.01	0.01	0.02	0.01	0.02
Healthcare sciences & services	Number	100	111	116	133	144
	Country share (%)	15.95	16.06	14.78	15.93	16.20
	World share (%)	0.05	0.05	0.05	0.02	0.06
Pharmacology & pharmacy	Number	78	106	105	105	101
	Country share (%)	12.44	15.34	13.38	12.57	11.36
	World share (%)	0.02	0.02	0.02	0.02	0.02
Pathology	Number	40	48	56	64	59
	Country share (%)	6.38	6.95	7.13	7.66	6.64
	World share (%)	0.02	0.03	0.03	0.03	0.03
Nutrition & dietetics	Number	44	41	48	64	35
	Country share (%)	7.02	5.93	6.11	7.66	3.94
	World share (%)	0.03	0.03	0.03	0.04	0.02

Source: UNCTAD, based on Web of Science data.

Priority thrusts for health

The domain of health was determined to be one of the most important in Botswana through various STI foresight filters. Health and wellness fall under the *Human and social development* pillar, and the objective is to make sure that the people of Botswana will live long and healthy lives. The two identified STI priorities in this area can be summarised as follows:

- *High-tech holistic medicine*: The advantage of modern holistic medicine,a form of healing that considers the whole person, including the physiological and psychological aspects at the same time, is that it treats the human body as a complex system, akin to traditional approaches to medicine (Gannotta *et al*., 2018). It emphasises connection within the body as a system and the body is seen to be made up of interdependent parts within a complex whole. Disease and illness are considered to be manifestations of a dysfunction of the whole person, rather than an isolated event. By adding high technology, such as memory RNA (mRNA) solutions, the paradigm shift is to guide the body to heal itself by sending messages to proteins that react to anything from a virus to cardiovascular disease or to auto-immune problems.
- *Community health*: Community health consists of the combined impact of healthcare, socio-economics and social interaction. It includes the physical and mental well-being of people, not only as individuals, but also as communities. Building a strong public health system depends on solid community health programs. It further requires health promotion infrastructure, investment in health promotion, human resource training, and collaboration. Infrastructure and services for health promotion are often provided by government through educational institutions, faith-based organisations, non-governmental organisations, general medical practitioners, and private sector companies complementing government efforts (Tepera, Moseki and January, 2018).

G. Manufacturing

One objective of the *Sustainable economic development* pillar of Vision 2036 is to produce commercially viable, high value products in the manufacturing sector targeted at export markets. Therefore, manufacturing is a very important domain in which STI activities can have a tangible impact.

Situational analysis of the manufacturing sector

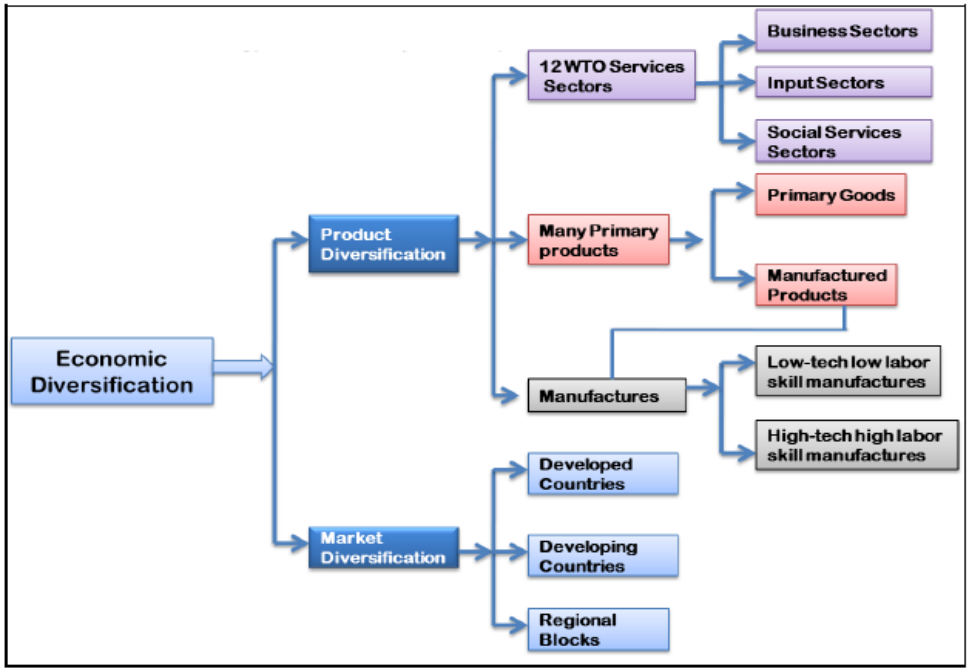
The manufacturing sector is widely considered to be a potential new source of diversification in Botswana's economy. The sector contributed about 6 percent of the country's GDP in 2021[24] and there is consensus in Botswana that it is performing below expectations. The government of Botswana has identified manufacturing as a key element to achieve the objectives of the Economic Diversification Drive (EDD)[25] as shown in Figure 10.

[24] Botswana – Manufacturing Value Added, Trading Economics, https://tradingeconomics.com/botswana/manufacturing-value-added-percent-of-gdp-wb-data.html, [accessed 6 July 2022].

[25] Botswana Economic Diversification Drive Initiative, UNDP, https://www.undp.org/botswana/economic-diversification-drive-initiative, [accessed 6 July 2022].

Figure 10

Sources of economic diversification in Botswana



Source: Botswana Ministry of Trade and Industry.[26]

As envisaged in the 2011 – 2016 EDD strategy, EDD was expected to be driven both by product and market diversification. The manufacturing sector, as part of the product diversification side, was to unlock potential of both the low- and high-tech sectors. In addition, increased beneficiation (processing) of primary products was also expected to increase competitiveness of the manufacturing sector.

As part of the EDD, approved manufacturing companies enjoy a corporate tax rate of 15 percent, compared with the standard rate of 22 percent.[27]

STI capability within the manufacturing sector

Manufacturing value-added and exports are used in this section to demonstrate Botswana's manufacturing capability. In addition, the pipeline of technologies and research are assessed through patent and scientific publications.

Manufacturing value-added and exports composition

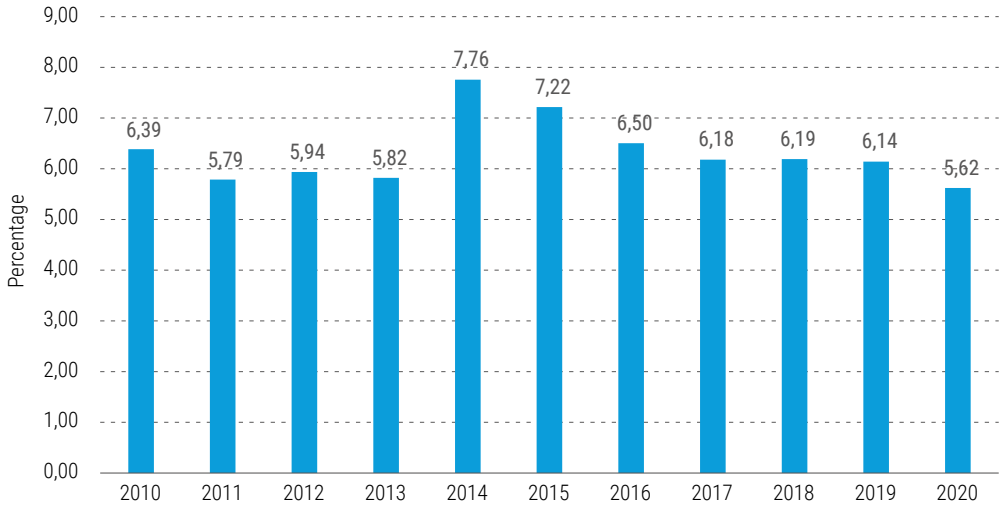
As seen in figure 11, the country's manufacturing value added as a percentage of GDP has steadily declined from 2014 to 2020 from 7.76 percent to 5.62 percent. This low contribution of manufacturing to the country's economy is not in line with the government's diversification strategy, and the STI community has an major role to play to develop innovative technological products to catalyse growth of manufactured products.

[26] Economic Diversification Drive (EDD), Ministry of Trade and Industry, https://www.gov.bw/doing-business/economic-diversification-drive-edd-registration, [accessed 6 July 2022].

[27] https://taxsummaries.pwc.com/botswana/corporate/taxes-on-corporate-income.

Figure 11

Manufacturing value added,2010-2020
(percentage of GDP)



Source: UNCTAD, based on World Bank World Development Indicators database.

Table 13 indicates that most manufactured product exports from Botswana are of medium-technology products in engineering (52.96 percent). Typical products in this category include engines, motors, industrial machinery, pumps, switchgears, boats and watches. This category also experienced the largest increase in exports between 2016 and 2020. Finally, medium-technology manufactures: process was the second largest contributor to manufactured exports in 2020 (11.21 percent), including products such as synthetic fibres, chemicals and paints, fertilisers, plastics, iron and pipes/tubes.

Table 13

Distribution of manufacturing exports, 2016-2020
(percentage)

	2016	2017	2018	2019	2020
Low technology manufactures: textile, garment and footwear	8.26	7.87	8.30	7.11	7.16
Low technology manufactures: other products	11.81	10.16	9.21	9.14	8.32
Medium technology manufactures: automotive	9.04	6.46	8.97	9.74	8.12
Medium technology manufactures: process	9.63	8.25	7.57	10.00	11.21
Medium technology manufactures: engineering	48.12	50.69	50.54	52.92	52.96
High technology manufactures: electronic and electrical	6.45	8.01	6.45	5.86	6.72
High technology manufactures: other	6.68	8.55	8.97	5.23	5.50

Source: UNCTADStat.

Technological development in manufacturing-related fields

The number of patents in technology fields related to manufacturing is very small and there is no consistency in maintaining a pipeline of inventions within a given field (see table 14). A deliberate strategy is needed to accelerate the level of technology development to support the manufacturing sector.

Table 14

Patent publications by field of technology, 2011-2020

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Electrical machinery, apparatus, energy	0	0	0	0	0	0	0	1	0	0
Computer technology	0	2	0	0	0	0	0	0	0	0
Control	0	2	0	0	0	0	0	1	0	0
Biotechnology	0	0	2	0	0	0	0	0	0	0
Basic materials chemistry	0	0	2	0	0	0	0	0	0	0
Machine tools	0	0	0	0	0	0	1	0	0	0
Other special machines	2	2	1	0	2	1	0	0	0	0
Furniture, games	0	1	0	0	0	0	0	0	0	0
Other consumer goods	0	1	0	0	0	0	0	0	0	1
Civil engineering	0	0	2	0	0	0	0	0	0	0

Source: WIPO IP Statistics Data Centre.[28]

Scientific research in manufacturing-related fields

Table 15 reveals a low global share of publications in research areas related to manufacturing (less than 0.03 percent global share). However, several research fields have a fairly high country share of publications in 2021, namely: materials science (6.41 percent), biomanufacturing (4.50 percent) and systems thinking (3.82 percent).

Table 15

Scientific publications in fields related to the manufacturing sector, 2017-2021

		2017	2018	2019	2020	2021
Materials science	Number	31	43	88	81	57
	Country share (%)	4.94	6.22	11.21	9.70	6.41
	World share (%)	0.01	0.01	0.01	0.01	0.01
Biomanufacturing	Number	17	30	34	26	40
	Country share (%)	2.71	4.34	4.33	3.11	4.50
	World share (%)	0.01	0.02	0.02	0.02	0.03
Additive manufacturing	Number	6	7	7	10	5
	Country share (%)	0.96	1.01	0.89	1.20	0.56
	World share (%)	0.02	0.02	0.01	0.02	0.01
Micro & nanosatellites	Number	0	4	1	3	0
	Country share (%)	0.00	0.58	0.13	0.36	0.00
	World share (%)	0.00	0.09	0.02	0.06	0.00
Systems thinking	Number	36	33	47	44	34
	Country share (%)	5.74	4.78	5.99	5.27	3.82
	World share (%)	0.02	0.02	0.02	0.02	0.01

Source: UNCTAD, based on Web of Science data.

[28] WIPO Intellectual Property Statistics, https://www.wipo.int/ipstats/en/, [accessed 6 July 2022].

Priority trusts for manufacturing

Under the *Sustainable economic development* pillar of Vision 2036, the manufacturing sector is envisioned to produce commercially viable high value products, targeted at export markets. Under the SADC Industrialisation Strategy and Roadmap 2015-2063,[4]a broad definition of manufacturing includes agro-processing, minerals beneficiation, as well as development and business-enabling services. The following is an articulation of the four prioritised STI thrusts under this domain:

- *Biomanufacturing*: This concerns manufacturing or biotechnology that utilises biological systems to produce commercially important biomaterials and biomolecules for use in medicines, food and beverage processing, and industrial applications.
- *Industrialisation*: This is the process by which an economy is transformed from primarily natural resource production to the manufacturing of goods. Industrialisation can be accelerated through a knowledge-based economy, one of the goals of *Sustainable economic development* pillar.
- *Specialty chemicals*: These are chemical products that provide a wide variety of uses on which many other industry sectors rely. Some categories of speciality chemicals are adhesives, agrichemicals, cleaning materials, colours, cosmetic additives, construction chemicals, elastomers, flavours, food additives, fragrances, industrial gases, lubricants, paints, polymers, surfactants and textile auxiliaries.
- *Advanced materials*: Advanced materials such as titanium, nanomaterials, and rare earth metals are at the core of high technology manufacturing. Processing and using these advanced materials within Botswana can increase the value of these advanced materials more than exporting them in their natural state.

H. Social development

This STI domain is one of the main priorities of Vision 2036, under the *Human and social development* pillar. This pillar covers multiple societal issues in areas such as health, education, culture, social inclusion and equality, spiritual well-being, strong family institutions, children's well-being and youth.

Situational analysis of social development

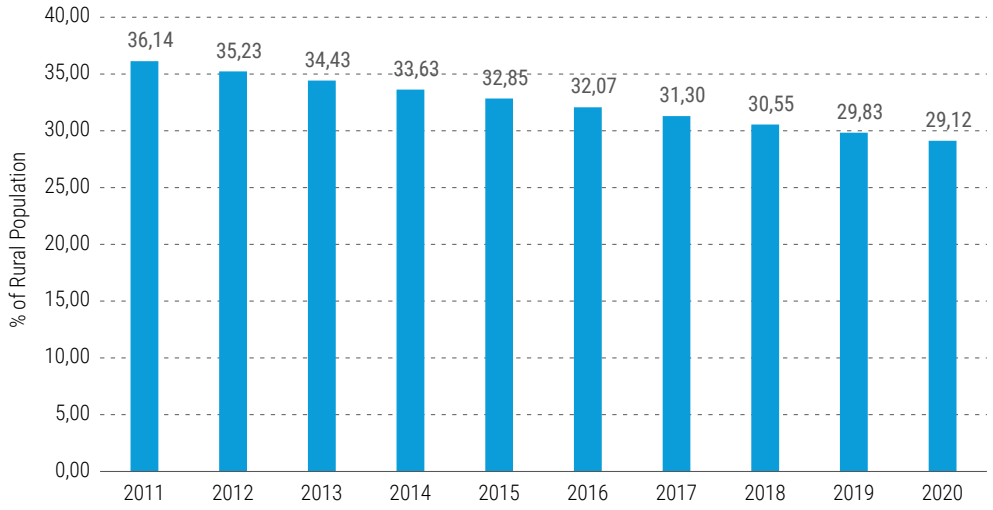
The main societal challenges in Botswana consist of poverty, inequality, HIV/AIDS (and more recently Covid-19), and high youth unemployment. These challenges are addressed within Vision 2036 through the *Human and social development* pillar. On inequality, the objectives of social inclusion and equality envision the empowerment of the marginalised population to contribute positively to the country's development, equal access to services and socio-economic opportunities for the people living with disabilities and the elderly, as well as the continued provision of social protection to support the most vulnerable members of society.

It should be noted that despite the rapid urbanisation taking place in Botswana, people living in rural areas still represent a significant proportion of the population (see figure 12). Rural planning and development are key for eradication of poverty and inequality as they are more prevalent in rural areas. In some rural areas the poverty rate is as high as 46 percent.[29] Some of the factors driving this high poverty rate include the low ownership of livestock and the high unemployment rate, especially among women.

[29] Causes of Poverty in Botswana, The Borgen Project, https://borgenproject.org/causes-of-poverty-in-botswana/, accessed 6 July 2022.

Figure 12

Rural population as a proportion of total Botswana population, 2011-2020
(percentage)



Source: UNCTAD, based on World Bank World Development Indicators database.

With respect to youth, the objective of Vision 2036 is to make relevant investments in the country's young population and reap the demographic dividend. The youth unemployment rate in Botswana has been around 37 percent during the last decade and increased to 46 percent in 2020[30] due to the Covid-19 pandemic. The youth unemployment rate is computed for individuals aged between 15 and 24.

STI capability for addressing social development

The impact pathway of STI in the Social Development domain is mainly indirect as it operates through other domains such as manufacturing, health, and environmental sustainability. Therefore, only the scientific publications data are shown in table 16. Despite increased urbanisation in Botswana, the concept of smart communities is still not dominant within the scientific community. The number of publications in this area has a low country share (0.45% in 2021) but relatively high global share of publications (0.11%). Rural planning also has a high share of global publications, followed by early childhood development.

[30] Botswana: Youth unemployment, The Global Economy, https://www.theglobaleconomy.com/Botswana/youth_unemployment/, [accessed 6 July 2022].

Table 16

Scientific publications in fields related to societal challenges, 2017-2021

Web of science fields		2017	2018	2019	2020	2021
Smart communities	Number	0	1	4	2	4
	Country share (%)	0.00	0.14	0.51	0.24	0.45
	World share (%)	0.00	0.03	0.11	0.05	0.11
Resilient built ecosystems	Number	1	3	5	4	2
	Country share (%)	0.16	0.43	0.64	0.48	0.22
	World share (%)	0.05	0.12	0.18	0.13	0.06
Early childhood development	Number	1	2	2	3	2
	Country share (%)	0.16	0.29	0.25	0.36	0.22
	World share (%)	0.03	0.06	0.05	0.07	0.04
Rural planning	Number	3	3	4	7	3
	Country share (%)	0.48	0.43	0.51	0.84	0.34
	World share (%)	0.14	0.13	0.15	0.26	0.11

Source: UNCTAD, based on Web of Science data.

Priority thrusts for social development

This STI domain proved to be one of the most important in terms of the STI foresight filters used. Indeed, also under Vision 2036, *Human and social development* is a standalone pillar with nine key objectives. The four STI thrusts prioritised for this domain can be articulated as follows:

- *Smart communities*: These are normally related to advanced urban development and often associated with smart cities. Smart community thinking includes models and projects that use advanced technology to shape economies, institutions, sustainability, and the health and wellness of citizens. However, smart communities need not only be urban and can be based in rural areas as well. Rural communities that are well-connected, have access to services and information, and thrive on their own economic endeavours can also be considered smart.
- *Resilient built ecosystem*: Resilience in this context and from an engineering point of view is a design approach that optimises both structural safety and efficient consumption. It has grown in importance as climate change threatens communities and their built environment, and it is often referred to as green engineering. Green engineering involves the design, building, commercialisation, and use of processes and products to reduce pollution, promote sustainability, and minimise risk to human existence. From an ecological perspective, it refers to the ability of an ecosystem to maintain its normal patterns of nutrient cycling and biomass production after subjected to damage caused by an ecological disturbance.
- *Social inequality and instability*: Social inequality is the uneven distribution of resources in a society, influenced by knowledge, power, religion, kinship, prestige, race, ethnicity, gender, age, sexual orientation, and class. Inequality, whether political, educational or economic may increase the risk of instability in behaviour, discipline, and peaceful existence.
- *Early childhood development*: This includes a comprehensive approach to programs and policies for children from birth to seven years of age. The rights of children are protected to enable them to develop their full cognitive, emotional, social and physical potential.

Chapter 4: Future science, technology and innovation scenarios for Botswana

A scenario is a story about a future state of existence normally expressed as a narration. A scenario is a plausible destination in the future and contains elements of barriers of the past (holding back progress), drivers of the present (pushing forward based on current strengths), and opportunities (pulling into the future). Since multiple futures should be considered, scenario planning provides a method to envisage those futures based on background information collected during a foresight exercise. By telling a story, a very complex environment can be communicated to the user, and both discrete aspects of foresight (practical aspects to act on), and future thinking (cognitive aspects of the foresight) are integrated. It is through the imagination of the scenario user that decisions are made about moving towards a preferred future. By considering one's own and others' opinions, and sticking to the facts arising from a situational analysis, scenarios can gain credibility. However, in an STI context, their main determinants are the technologies that will be employed in innovative ways in the future, as well as the ways people will behave in the market or social space with regard to social innovations and inside STI organisations, as well as the influence of external events, which may be of geopolitical, natural, economic or social origin.

A. Scenario planning process and outcomes

To support the foresight process, a customised scenario planning technique based on known tools was used to form a view on STI futures in Botswana. This technique considered the amount of control the country will have over its STI interventions, the behaviour of its people who deal with STI, and the level of uncertainty over the period of foresight. For Botswana, this period was taken as the 14 years remaining ,until Vision 2036 is to be realised.

Scenario planning was informed by the prioritisation of STI domains and thrusts. This thinking is assisted by looking at various dimensions (or depths) of the future,[31] where the current and transformed world of STI in Botswana over the foresight period is considered. One purpose of this type of thinking is to arrive at a metaphor to make scenario planning easier. This outcome is summarised in table 17.

The current state of STI was summarised from the workshop discussions and inputs from participants. Participants were then asked to provide their opinion on what the future or transformed state of STI in Botswana should look like. This is also summarised in table 17.

[31] Adapted from Inayatullah, S. (2017).

Table 17

Dimensions of understanding the future of STI in Botswana

Dimension	Meaning	Current state of STI (2022)	Transformed state of STI (2036)
The obvious, visible view	The day-to-day future, the commonly accepted headlines of the way things are or should be. Solutions to problems at this level are usually short term.	• STI activity is fragmented. • New technology trends are not capitalised enough. • Good international support is experienced. • No national research fund has been institutionalised yet. • Problems are experienced with engagement of the private sector. • Grassroots development is taking place. • R&D translation models are not optimal.	• Good coordination of STI exists government-wide and over industrial sectors. • Strong collaboration is taking place among the R&D sectors and its beneficiaries. • More R&D leads to innovation and commercialisation. • There is significant private sector investment into R&D. • There is a transition from R&D only having a local footprint to making a global impact.
The underlying system	Focus on the social, economic, and political causes of the issue	• Appropriate government structures for STI prioritisation or implementation are weak or missing. • Good training facilities exist for STI. • Policy instruments are still under development. • Better implementation of STI and related policies is required. • Monitoring and Evaluation (M&E) tools for STI are incomplete. • Better research coordination is required. • Competition takes place in the STI sector for limited resources. • Non-localised procurement systems do not support STI-based businesses preferentially. • Inadequate Full-time Equivalent (FTE) human resources exist in the STI sector.	• A strong national system of innovation (NSI) has been established and is working optimally. • Strong governance ensures that good STI decisions are made in a timely manner. • Gross expenditure on R&D has increased to beyond 1% of GDP. • Strong M&E measures are in place and practiced regularly to ensure good performance of the STI sector. • Active private sector participation in STI ensures solid partnerships in the STI ecosystem. • Good implementation of policies has resulted in cohesive STI efforts that have a positive socio-economic impact. • Strong coordination has led to a high level of complementarity and focused spending of STI funds. • Responsive procurement systems have been adopted by government, encouraging innovation and local supply, with the resultant positive impact on small business creation.

Dimension	Meaning	Current state of STI (2022)	Transformed state of STI (2036)
The world view	The big picture, the paradigm that informs what we think is real or not real, the cognitive lenses we use to understand and shape the world.	• R&D is a catalyst for economic growth	• A knowledge- and innovation-led economy utilising R&D is in place
Metaphor[a]	The unconscious story shaping our association and perception that drives understanding	• A desert	• A forest

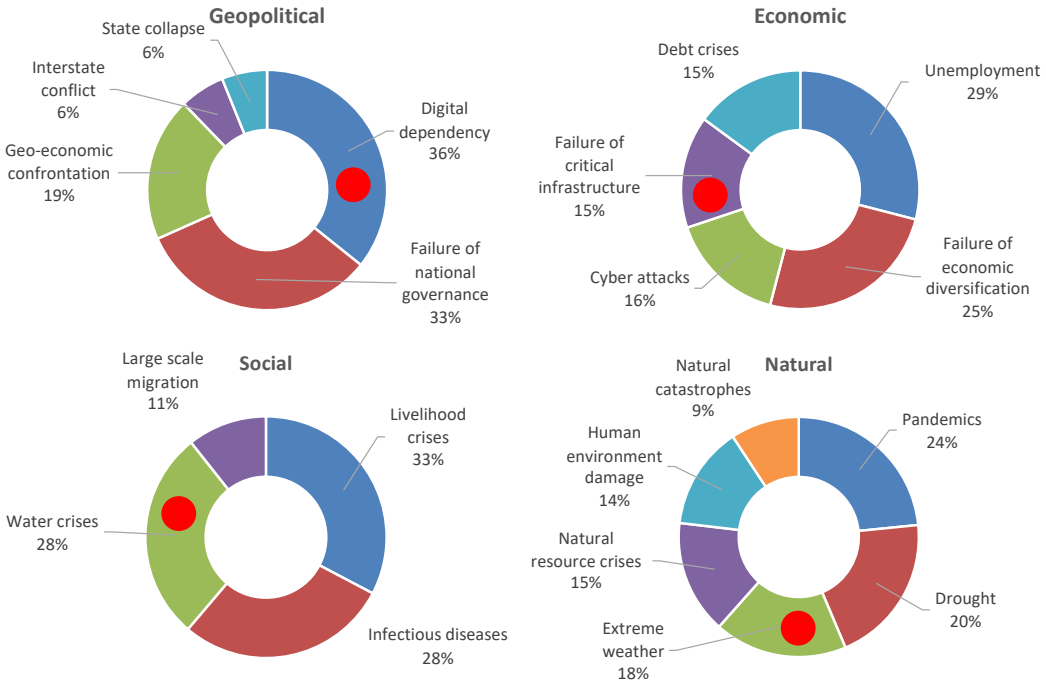
Source: UNCTAD, based on workshop discussions.

Notes: [a] The metaphor of a forest was derived from a discussion in the scenario workshop, suggested by participants. It was proposed because a forest that is healthy provides numerous benefits to all species that interact with it, in contrast to a desert. The thinking is that the country should operate its STI activities in a receptive and stimulating environment rather than one where survival remains a struggle. The metaphor of a forest chosen by the workshop participants was also used to name the scenarios.

The metaphor is now used to think about multiple futures that may arise depending on the degree of control the STI community in Botswana has as well as the level of uncertainty as indicated by a macro-environment risk analysis. Control is determined by the choice of STI activities and the skills of people who work in the STI ecosystem. Uncertainty is normally driven by risks, and as part of the online survey, the respondents were asked to rank a set of risks, informed by the World Economic Forum (WEF) global risks (Morris, 2022) in 2022 in terms of their likelihood of occurrence (see figure 13). The relative percentages were calculated from the survey responses. The red dot on the graph indicates the most important risk for each risk category as determined by the scenario workshop participants.

Figure 13

Global risks as ranked by STI survey respondents and most important risk per category (red dot) as determined by scenario workshop participants



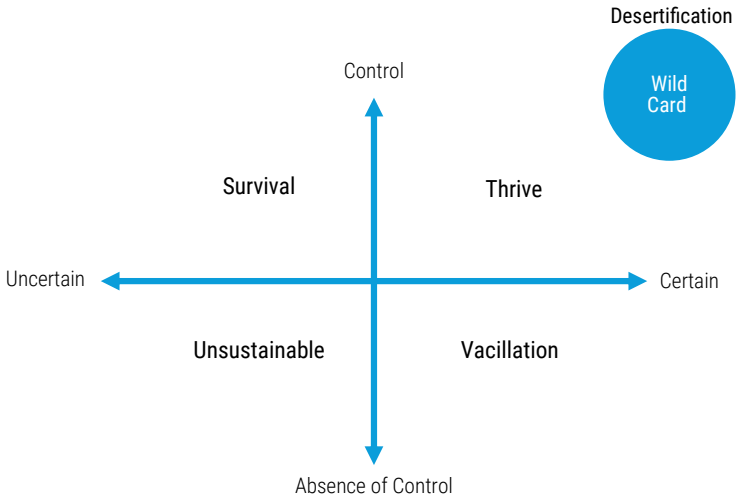
Source: UNCTAD, based on workshop discussions.

These rankings were used during workshops to facilitate discussion around uncertainties that have potential to affect the STI future in Botswana.

Five scenarios were developed for STI in Botswana as shown in figure 14. Four are described by the vectors of control and certainty, and a fifth, the so-called wild card scenario, is a possible outlier. Below is a brief description of each scenario.

Figure 14

Five scenarios for STI futures in Botswana



Source: UNCTAD, based on workshop discussions.

- *Low level of control and low level of certainty*: With no control, as in, for example, ownership of the forest, health of the trees, maintenance of forest-supporting infrastructure, and with no certainty as in, for example, natural disasters that could affect the forest or the economic devaluation of forest products, the forest will be **unsustainable.** No decisions about its contribution to useful products and low concern about its continued existence will lead to an unsustainable situation, where the forest will no longer continue to be cared for. It may disappear and will not be missed by anyone.
- *High level of control and low level of certainty*: A forest will be in **survival** mode when there is control (e.g., growth and health), but uncertainty about its existence is threatened by, for instance, deforestation, natural diseases, fire risk, drought and human settlement conflict.
- *Low level of control and high level of certainty*: When there is no control over, say vegetation health, nurturing, conservation measures, etc., a forest will be under threat, despite certainty of climate behaviour or protection against deforestation. This may lead to **vacillation**, a state where firm decisions are not made on the well-being and economic support of the forest. The forest may be left to its own destiny, since no interventions are made.
- *High level of control and high level of certainty*: To **thrive**, a forest must be exposed to an environment that is conducive to growth, protected, cared for, and it must be ensured that vegetation is healthy, where everything is under control. External circumstances that are known, such as climate change patterns, deforestation trends, economic value of the forest, etc., will determine the level of certainty as to how long a forest can remain thriving.
- A wild card future scenario is one where the forest disappears through **desertification**. Not only is the forest destroyed, but its neighbouring environment has been affected to such an extent that it has also changed its character totally. The chances of ever planting a forest again, or for a natural forest to grow again are slim. The environment has been destroyed.

B. Five scenarios for STI in Botswana

The scenarios deduced from metaphoric thinking are now projected on the future of STI in Botswana. The following narratives translate five possible futures for STI. The stories are set in 2036 with simple titles that characterize the overall scenario.

Unsustainable

The country is on the verge of economic collapse and resultant socio-economic impacts are becoming a reality. The world has not managed to find a reasonable outcome to a raging war that has now reached almost World War III levels. It is only a blessing that nuclear weapons have not been used and that large superpowers have refrained from sending the world on a path to Armageddon. Not by their own doing, but as a result of redirection of funding to build up military deterrence, less foreign direct investment has entered developing countries from the developed world. Africa as a continent, including Botswana, is now struggling to maintain sustainable livelihoods for its people.

The ambitious plan that the government had to invest in a new era driven by STI products, services and solutions was put on hold as funds were required to sustain food security and provide health services. National investment in R&D as a percentage of GDP remains stubbornly below 0.5%. The outbreak of SARS-COV-3 after the Covid-19 pandemic had a devastating impact on health care budgets and building digital healthcare solutions at the community level proved impossible.

The world is falling back on hard commodities and investing in diamonds as an alternative to gold in uncertain times. This has benefitted the country, as most STI investment is focused on mining, local manufacturing of scarce goods like pharmaceuticals, and basic health care. High energy prices have contributed to inflation, making life difficult for everyone, especially the poor. Among the uncertainty of war and the management of the new pandemic, tourism has ground to a halt. The lack of influx of foreign capital has been felt in the conservation sector. Although government and industry formed a partnership to do the best for the country under these circumstances, it is realised that the ability to maintain the standard of living at the level of the early 2020s will be difficult. The decision not to continue investment in new STI-based solutions at the planned rate is seen as pragmatic. The fragmentation of the national system of innovation and unaligned policy landscape identified in the 2020s now have a knock-on effect of not having reached critical mass with STI based solutions in a timely manner.

The financial burden placed on the manufacturing sector has also resulted in less attention to environmental stewardship and climate change. The circular economy did not materialize. Increased pollution in water resources have become a threat to humans and wildlife, and pristine natural environments are under significant pressure to remain attractive for future tourism. Taken by surprise with respect to how quickly the world was thrown into chaos by conflict, the silos that were identified at the same time could not be removed. STI is still fragmented, burdened by a lack of funding for new innovation.

Large retrenchments were seen in the R&D sector, given such budgetary constraints. Researchers became despondent and left the profession to pursue entrepreneurial ventures to benefit their families. The 2022 foresight priorities of new industrialisation, building a digital economy, providing food and water security, developing renewable and affordable energy sources and resilient built ecosystems have proved unattainable.

Social inequality and instability have not improved, and the country has slipped from its proud status of being a middle-income developing economy. Foreign investment in R&D through which the country championed STI in HIV/AIDS, climate and social studies has ceased, given the shift in global priorities. It is becoming uncertain if there will be sustainability of livelihoods as envisaged in Vision 2036.

Faster adoption of STI in prioritised areas, especially to modernise products, processes and services through digitalisation following the first foresight in 2022 could have placed the country in a stronger position. Fragmentation of the national innovation system should have been addressed faster, and partnerships based on common good for the economy and the people could have eased the current level of unsustainability. However, the complex nature of the world and the co-occurrence of many unfortunate circumstances was difficult to envisage. As in any complex system, rather than understanding exact causes and effects, trends must be recognised and proactively addressed.

History has shown that economic growth and decline take place in long waves over time. During eras of breakdown, new innovations emerge to reverse the trend and lead economies into growth again. Peace will inexorably follow war, and prosperous times will be seen again. The challenge is to focus on positive aspects where STI can turn the country around. The past establishment of a thorough awareness in the Botswana government of STI and its impact on people and economies will now start to play the catalysing role of elevating the country to the heights envisaged by Vision 2036.

Survival

The country has initiated successful STI policies following an era during which foresight became the norm in long range strategic planning. There is good alignment of policies to support the socio-economic growth envisaged by Vision 2036. A good working relationship has been developed between government, business, and society. The selection of the most rewarding STI domains and thrusts during a foresight exercise in the early 2020s has paid off. The national system of innovation has been strengthened and strong governance has been put in place. Monitoring and evaluation have become essential elements of strategic management and with good data and decision support, the country has chosen wisely on investments in industrial sectors that were targeted to grow fast. Entrepreneurship is encouraged and incentives like preferential procurement and

the alignment of supply side and demand side have led to a vibrant and successful small business sector, with many companies arising thanks to innovative solutions based on science and technology.

The institutionalisation of foresight has also resulted in a clear view of major events that could be detrimental or beneficial for the country. However, the impact of investment in new industry sectors beyond agriculture, mining, manufacturing and tourism has not been fully realized. Expenditure on R&D as a percentage of GDP is just over 1 percent. Not fully embracing a new era of digitalisation and its role in modern industrialisation and not addressing natural resource and conservation conflict, have slowed economic benefits, especially in rural areas. Little progress has been made to link citizens to services like broadband, health and education. Smart societies are not developing quickly enough, with the result that cities still present the most attractive job opportunities. The high rate of urbanization hampers the ability of many rural areas with potential to be included in the mainstream economy.

Relationships with neighbours remain difficult, as free trade zone discussions have not been concluded. Reluctance of visitors and immigrants to use modern digital identification for border control has resulted in weakly controlled and inefficient cross-border movements.

The world has changed dramatically. Even though proper horizon scanning had been introduced through a national foresight initiative, the devastating impact of SARS-COV-3, which followed five years after the Covid-19 epidemic, could not be pre-empted. The second pandemic in a decade rolled rapidly over Africa, resulting in isolation from the rest of the world. It is clear that not enough was learned about global pandemic management.

The drawn-out conflict leading to war in Eastern Europe in 2022 played a role in increased uncertainty. The crippling combination of conventional, economic, and cyberwarfare, as well as the threat of a nuclear war, led to fears of a potential World War III. Economic activity has slowed, putting strain on many developed economies. Internal protests observed in many western countries have threatened political stability.

Strong international relationships are now rare and the global impact that Botswana hoped to make through export orientation and becoming a role model for developing countries could not be achieved. Due to increased global isolation and little control over dramatic changes in the world, the country could not implement its Vision 2036 as planned. Domestic advantages from STI were visible, but often disappeared in the noise of world politics. Even as a neutral country, it was difficult to maintain the economic stability citizens were accustomed to in the early 2020s, as no economy can survive in isolation. STI focus has shifted from making the country a global player with high economic potential, to an inward focus on survival and maintaining the status quo.

Many countries declare that there is a need for a new world order. Developed economies face new challenges and a new belief is emerging that they can also learn from successful developing economies. The country has the opportunity to play a leadership role with respect to how mastery of STI can assist domestically and regionally, helping initiate a new era of regional and world peace, and resurrecting faith in humans being central both to technology as well as international law and governance. While there is a serious need to do what is necessary for survival, the country is now looking at how it can contribute to a new world order where human dignity plays an essential role in democracies.

Vacillation

The country has provided clear inputs to a STI-driven economy and wealth creation. It has adopted the process of horizon scanning and foresight, but on an irregular basis. The process was repeated every five years, with very little attention in between, resulting in little control and hesitation in the choice of options. Despite following Vision 2036 as a general guide, continuity of investment has been neglected in many new STI domains that were identified in the early 2020s. Monitoring and evaluation were instituted, but only during major strategy and policy revisions.

The world has changed faster than the decision processes to support STI's impact on the economy. This out-of-phase cycling of interventions led to short term decisions mostly focused on immediate problems. Longer term opportunities were largely unaddressed.

The global economy stabilised after the conflict in Eastern Europe in the beginning of the 2020s, which ended with a negotiated solution resulting in regional peace between superpowers. The world adapted to a post-Covid-19 era by learning from experiences during the pandemic to move forward, while simultaneously protecting the health of its people. Even the subsequent outbreak of SARS-COV-3 was less of a threat to global economic growth and social progress than Covid-19.

Nonetheless, the government was very conservative in their implementation of STI policy. While significant investments were made, with expenditure on R&D as a percentage of GDP at nearly 1 percent, they were based on a conservative outlook that favoured the established market sectors of mining, agriculture, and tourism. This was made easier by the sense of certainty that a stabilised international situation brought about. New market opportunities in digital health and government, alternative energy generation, smart communities and precision agriculture were moderately supported to maintain a knowledge base, but not for aggressive development and market leadership. When external signals were observed that the circular economy would become just as important a global initiative as climate change, investments were made, but it was too little, too late and the country performed poorly in its first international ranking of the green economy.

GDP growth has been stable but under the set targets. This ensured that the country can maintain its status as a medium income developing nation. Innovation was predominantly driven by stepwise improvements as radical innovation was seen as too risky. The relative geopolitical calm has improved African consumer spending power and has spurred continental markets. Attractive returns for investors are a result of a growing young clientele, resulting in increased demand for mostly imported smart technology-based products.

There is still significant migration to cities, resulting in limited rural economic growth. Major envisioned socio-economic development breakthroughs in rural areas did not take place. Remote learning, digital tourism and hospitality business in remote areas did not materialise. Rural healthcare is still provided in underequipped clinics. This is evidence of the sporadic investment in new STI deemed high risk. The rural population has voiced that they are not being supported according to expectations as envisaged in Vision 2036.

Easy and open access to information has resulted in more demanding customers and citizens. Regional news reporting the benefits of a more progressive STI approach and more effective harnessing of frontier technologies in neighbouring countries has played a role in setting higher expectations. While political stability is maintained, there is risk of brain drain to neighbouring countries that have successfully aligned to a stabilised world with an improved long-term outlook compared to decades before.

The decision in the mid-2030s to rapidly address the lag in domestic STI adoption at all levels has resulted in new signs of hope for STI practitioners and beneficiaries alike. The need for strong leadership and decision making may have come very late, but there is hope for the potential to leapfrog and join the frontline of STI practices in the region. The development of a well-designed national system of innovation has high potential payoff for the country.

Thrive

The country has transformed into a STI-driven future where good coordination and strong collaboration is the norm. It has full control over its STI supporting policies and is certain about its ability to handle foreseen and unforeseen events due to its flexible and forward-looking management style. Most negative impacts have been anticipated in an ongoing foresight initiative, conducted by government, business, and society. Future opportunities of economic and social benefit to the country are recognised early and preparations are made in advance to maximise the potential benefits of applying STI.

R&D is targeted at commercialisation. The country has shifted from a net importer of goods to a healthy export contender with regional and global recognition of its competitiveness, especially in its identified priority STI domains. The benefits of investment in R&D and adoption/development of specific technologies have become clear and the government and private sector are now partnering to uplift its manufacturing base and obtain premium yield from its mining and tourism sectors. National investment in R&D measured as expenditure as

a percentage of the GDP is approaching 2 percent and continues to increase due to steadily rising industry participation. The country's embrace of renewable energy has led to an emerging manufacturing sector based on new energy technologies such as green hydrogen, solar and wind. A significant transformation of industrialisation was brought about by 4IR where small, specialised manufacturing plants are now linked via hyper-connectivity. Focus is on the customisation of products and services that challenge economy of scale norms and prices. Human-centric design principles make use of the latest technology to provide better quality of life to citizens where they become part of a technology ecosystem. The risks associated with adopting new technologies are being actively assessed and addressed through ongoing foresight and technology assessments along with participation in regional and international collaborative initiatives.

Agriculture has undergone significant digitalisation and fresh products for domestic markets are available with a strong drive to export surpluses to neighbouring African countries. Beef exports, in particular, have become a strong contributor to the economy, thanks to initiated animal health programs and improvements in local vaccine manufacturing. Access to water, even in arid regions, and intelligent water harvesting systems, have supported food security. The country has become a global showcase for precision agriculture, utilising satellite navigation systems and earth observations. Most successes are forthcoming owing to a clear view of the future.

Digital government was embraced, and effective e-governance has made strategies and policies and their implementation transparent, with strong support from the private sector. The country is widely considered a safe place to live and conduct business. Border control has been modernised with e-passports, electronic scanning, and reliable Radio Frequency Identification (RFID) for freight. Technology-enabled trade has linked the economy with SADC countries in a free trade agreement that has started to benefit all participants. Many of the disadvantages of being geographically land-locked have disappeared as the country is now an active trade hub with its aviation gateway close to Gaborone and fleets of air freight carriers owned by home-based entrepreneurs.

Tourists are streaming into the country since the human-wildlife conflicts, that often threatened conservation areas, were resolved and managed properly partly through the successful application of STI. There is a good environmental balance between exploration, energy resources and nature, and more and more national parks are receiving recognition from UNESCO as world heritage sites. Climate change is still an issue in the world, but Botswana is continuing to stay well under its carbon emission targets. It also has a strong and effective mitigation program for farmers and the community at large.

Through universal connectivity, people can stay in touch with family, and work and conduct their businesses using the Internet. In remote areas, new mothers take part in early childhood development programs, health services are readily accessible, students learn remotely when necessary and have access to modelling and simulation facilities supported by high performance computing centres. The Internet of Things, smart sensors and edge computing have become embraced technologies to conduct business in new ways. The data science era has dawned in the country and decisions are quickly supported by evidence and complexity reduction. The digital divide is narrowing quickly and the chasm between rich and poor is also narrowing. Smart communities generate local work that has helped to address the unemployment and rural-urban migration issues the country had in the past. Secure networking and payment systems have made trading in cyberspace a popular way of doing business. The wisdom to invest in a STI-enabled socio-economic environment has paid off, and the country is becoming a rising star, serving as a role model to other upcoming developing economies.

Following the four scenarios discussed above, there is always the possibility of a wild card scenario. It is one that is driven by a highly disruptive event or chain of events. Even though a wild card may seem apocalyptic, there may still be a turnaround. The desertification scenario that follows describes such a situation:

Desertification

The old male lion stretches before he gets up with the last light of the setting sun glimmering on his mane. Further down the dune his pride starts to move. The winter cold is already joining the dusk to make him feel the years in his bones. For a long time, he has not seen people, neither conservation workers nor tourists. The night belongs to the pride, and he will feast before morning.

The grandmother in Mopipi squints into the raging sun. The Boteti has dried up after several years of drought and the people are hungry. No crops could be grown, not even in the rainy season, which was short and dry this year. The people from Moremi tell her that large parts of the swamps have dried up and the usually reliable waters from Angola did not arrive this year.

The nurse in the field hospital in Gweta looks at the lifeless body of a child on the bed. She tried her best. A weary doctor walks into the ward and writes out the death certificate.

In a hotel room in Gaborone, an investor from the Middle East watches a report on the evening news about the conflict which has now almost reached the village where his family lives. The world as it was known is no more. The superpowers believed that the only way World War III could be ended was with nuclear weapons. Now the war is over.

But, unlike the post-apocalyptic Hollywood movies, the result was not only scorched earth. Nature soon started to resurrect itself. There would not be unsustainable human interference for a long time, and the Okavango will rise again, the thunder will rumble over the acacia trees and a young lion will lead the pride in Central Kalahari.

The grandmother will move to Gaborone to stay with her children who became successful diamond cutters and traders. Her grandson has acquired land and will start growing fresh produce to be sold locally, and one day will be exported to neighbouring countries. The cattle are still fed on her brother's farm but will soon be grazing free once it starts to rain.

The nurse will become a clinic manager close to her hometown of Khudumelapye. She has seen the digital health equipment developed during the war for the soldiers in the field. Wearable systems, checking vitals and providing advice on the best nutrition, could change the lives of people. Fewer children will die, and schools will reopen with remote education by the best tutors in the country and the world.

The doctor will move to an academic hospital and teach medical students how to build a high technology holistic health system based on longitudinal data and data science.

The international investor will decide that Botswana is a safer and a more stable country to live and work in than his own and start the process of immigration. He will direct the digitalised industrialisation phase that will supply the world with new smart materials and intelligent manufacturing processes to reconstruct damaged infrastructure after the war.

As he crosses the dune, with a soft roar the young lion will warn his pride about a vehicle full of tourists ahead of them. They are admiring the yellow Kalahari flowers blooming in the red sand after the first rain…

A summary of these scenarios and their impact is provided in table 18:

Table 18
Scenarios summary

Survival	Thrive
Government has done all the right things for implementing STI supporting policies and funding. However, regional and global circumstances are challenging, and the country finds itself becoming isolated as a result of shifts in investment priorities and geopolitical instability. Its export orientation shifts to an inward-looking regime.	Government takes the lead in STI support for socio-economic improvement, environmental sustainability and well-being. Good coordination over the entire national system of innovation takes place. STI policy and programmes are proactively planned and rapidly and effectively implemented. Foresight is institutionalised and practiced on a continuous basis. The country is well on its way to achieving Vision 2036. The world is a stable place for collaboration and business.
Unsustainable	**Vacillation**
Economic collapse stares many countries in the face since geopolitical conflict has not receded. Natural disasters are aggravating the situation. Very little action could be taken to boost STI investment to counter these negative external impacts. International financial support by some large economies is redirected from developing economies to bolstering the home country. Slow and indecisive progress in STI policy and programmes, ineffective action to strengthen the national system of innovation, and low investment in STI by the government and the private sector have not provided the momentum required for creating a sustainable economy and social and environmental well being.	Although the world economy has stabilised following conflict in the early 2020s and regional relationships are good, government has not given enough attention to implementing STI policy and foresight in a holistic way. Selective support was provided, some of it in areas that are now being side-lined by the dynamics of international markets. After a few cycles of interventions that were short term and ad-hoc, the impact of STI in the country remains marginal.
Desertification	
In extreme abnormal circumstances, economically and as far as global stability is concerned, life has reverted to a pace and level of economic activity of decades before. Knowledge of and access to selected STI is the only hope to build an economy and living conditions resembling that of the early 2020s.	

Source: UNCTAD.

The foresight workshop found that the most likely outcome, if the current state of STI is maintained, is that the country will move to an *unsustainable* future. This was judged as most likely based upon discussion among stakeholders participating in the workshop. With the right strategic interventions, a preferred transformed future of STI contributing to a *thriving* Botswana could be possible.

C. Strategic interventions

Strategic interventions that will lead to the shift from the likely unsustainable future to the preferred, thriving future were identified through stakeholder discussions. These are listed in table 19 below.

Table 19

Suggested strategic interventions and actions to reach the preferred *thriving* future

Strategic intervention level	Action required
Governance	• Effective governance frameworks for STI policy must be in place.
Coordinate and collaborate	• Facilitate coordination across the national system of innovation • Encourage strong collaboration at a multidisciplinary level.
Network	• Build effective networks of excellence.
Policy	• Utilise policy levers to optimise STI impact.
Innovation and commercialisation	• Translate R&D into innovation and commercial and social benefit through development of models for selecting projects that will lead to commercialisation. • Utilise an Innovation Fund to take R&D through to innovation. • The NSI must be visible and well defined, supportingR&D, technology adoption/development and innovation. • Position intellectual property (IP) frameworks to protect STI that could lead to commercialisation and business creation.
Measurement and assessment	• Timely monitoring and evaluation (M&E) of outputs, outcomes and impacts. • Prioritise and institutionalise M&E at all levels. • Objective self-assessment for reducing vulnerabilities in the STI ecosystem. • Standardisation and metrology facilities must play a role in the new uses of STI.
Funding	• Set a national research agenda and fund it. • Activate the National R&D Fund (NRF).[32]
Skills development	• Provide post-graduate support for training and R&D skills development.
Incentives	• Develop innovative incentives for the private sector to become involved in R&D (distinguish between large and small companies).
Culture	• Encourage a culture change towards a knowledge and innovation society.
Foresight	• Establish a national foresight initiative and do continuous foresight, potentially including technology assessment. • Regularly scan external environment for risks and opportunities.
Equipment and infrastructure	• Provide necessary research and innovation infrastructure and facilities. • Standardisation and accreditation of research facilities.
Empowerment	• Empower institutions in the STI ecosystem (National System of Innovation) to execute, provide clear mandates and build institutional capacity.
Inclusiveness	• Acknowledge, protect and incorporate indigenous knowledge and community participation.

Source: UNCTAD.

In conclusion, the scenario exercise provided guidance on multiple futures that depend on the level of control internally and the handling of uncertainty. It indicated that decisiveness and fast implementation of STI in priority domains and thrusts will strengthen the country and enable it to face potential adverse threats and ensure it does not drift towards an unsustainable future. With the proactive interventions identified, the *likely* unsustainable future could be transformed into a *preferred* thriving future where STI will help enable the country to thrive and successfully achieve its Vision 2036.

[32] Botswana setting up a Research Fund, Botswana Guardian, Thursday March 24, 2022, https://guardiansun.co.bw/News/botswana-setting-up-a-research-fund, [accessed 4 July 2022].

Chapter 5: Main findings and way forward

This chapter spells out the main findings of the foresight exercise and provides guidelines for further action. The STI foresight exercise done in Botswana as part of the STI Policy (STIP) Review was the first ever STI foresight initiative in the country and aimed to identify future national priorities for STI (see STIP Review section 3.5). It achieved its objective of creating a platform where stakeholders, including government, parastatals, higher education and business could build awareness as a joint community for discussion about the future of STI in the country. The foresight exercise yielded a common view of STI activity required for a thriving future, and conversations were initiated about the future of STI acknowledging social development and economic needs. An overview was achieved on the role of the NSI as an STI ecosystem to ensure a thriving future for Botswana. At the same time, a decision support base was created for government to fund STI in the future by identifying priority STI domains and thrusts. A view of a joint way forward for government and business was created, with both parties agreeing that close collaboration and joint initiatives will be required for a successful STI future. Emphasis was placed on the critical importance of forming the young minds of the future that will take the country forward, thereby alerting the Higher Education Institutions (HEIs), government ministries and relevant agencies, as well as business, to focus on preparing STI practitioners for the future of work. These achievements were possible in the short time the foresight exercise was conducted by using Vision 2036 as the major driver of the country into the future.

After a structured foresight process, consisting of situational analysis, an electronic survey among STI experts, workshops with STI experts, filtering of priorities, studying the state of sectors in terms of performance and STI capability, and scenario creation, several conclusions and recommendations emerged from discussions with stakeholders during the workshops. These are captured here as the main findings of the foresight exercise and highlighted by some guidelines for further implementation.

A. Prioritised STI domains and thrusts

Priority STI domains and thrusts have been identified for further development, which helps to meet one of the recommendations of the STIP Review (see section 3.5). The filtering, and especially the diversification potential of STI domains have ensured that a good balance exists between extending existing, and introducing new, STI thrusts. While the priorities are compatible with Vision 2036 for Botswana, synergies and commonalities among the STI domains and thrusts and how they affect the future are addressed. The scenarios developed indicate the possible landscapes upon which the STI priorities may be developed in the future.

B. Towards a knowledge-based and innovation-driven society

It is time to broaden the view and rely on more than traditional sectors of the economy. Mining, agriculture and tourism will remain economic drivers and should be strengthened through the STI activities that have been identified by the foresight. Techno-economic drivers for new sources of economic value should be identified and pursued to diversify economic production. Digital and smart mining, precision agriculture, new methods of vaccine manufacturing and new digital tourism experiences can expand these existing dominant sectors in the economy. The identified STI domains and thrusts should be cultivated to expand and diversify the economy, which will contribute to meeting the diversification challenge outlined in chapter 1 of the STIP Review. These include the following:

- **Agriculture** has and will remain an economic driver for Botswana (see chapter 6 of the STIP Review on agriculture). It is supported by the STI thrusts of food security, water security, vaccine manufacturing and precision agriculture.
- **Digital economy** addresses digital government with e-governance, smart border control and technology-enabled free trade (see chapter 5 of the STIP Review on new technologies). Digital sciences will enable digital mining and ICT and Geographic Information Systems (GIS) in tourism and will be drivers of the digital economy. This will be supported by earth observations, bio-informatics and artificial intelligence.
- Existing **energy** solutions should be broadened by focusing on biomass and advanced energy storage. This includes new battery technology and the use of bio-energy. Advanced energy storage and battery technology has the potential to enable the diffusion and wider usage of renewable energies like solar and wind.
- **Environmental sustainability** is achieved through the implementation of circular economy principles, biodiversity conservation, climate change and natural resources management (see chapter 11 of the STIP Review on environmental sustainability). This is supported via sustainable tourism, an understanding of the interaction between climate and society, and green technology applications.
- **Health** will largely be driven through high-tech holistic medicine, and community health initiatives (see chapter 7 of the STIP review on health). Recognition of indigenous medicine, continuing the development of a TB vaccine, and precision medicine are three important components of future health in Botswana. The recognition of research performance on HIV/AIDS, TB vaccine discovery and cancer diagnostics and prevention should be used as a base to establish community health programs and build a strong healthcare system. Nutrition remains an important field in health. It is also crucial for food security.
- Several **manufacturing** initiatives are made possible by embracing new manufacturing technology (see chapter 10 of the STIP Review on mining and industrialization). Even though achieving economies of scale (a high enough volume of production to achieve a low per unit cost of production) may not be possible in all areas, design and manufacturing for economies of scope (low volume high price) through custom-made solutions to knowledgeable clients may form the basis of 4IR approaches. A strong industrialisation drive will be required. Bio-manufacturing, speciality chemicals and advanced materials are important thrusts that have been identified. The need for speciality chemicals is driven by mining, agriculture and manufacturing. Manufacturing will be supported by agricultural biotechnology, additive manufacturing and housing and building materials. Systems thinking is important to establish a manufacturing base, since complex manufacturing systems, logistics and market channels need to be integrated. Manufacturing should also consider the water-energy nexus in terms of sustainability. Micro- and nano-satellites are beginning to dominate space applications and the country should participate in regional programmes that develop such devices and their applications.
- **Social development** can be addressed by employing knowledge and innovation supported by technology to form smart communities, resilient built ecosystems, early childhood development, expand the current initiatives for rural planning and address social inequality and instability (see chapter 8 of the STIP Review on inclusive growth and social development). Community participation is a crucial element of social development.

C. A national research agenda

The STI priorities envision a clearer STI landscape that enables a more focused research agenda, a need identified in the STIP Review. Coordination structure is key to the success of future STI, and although a consensus on future direction may be difficult at this stage, the direction provided by the foresight exercise will assist in the convergence of many different opinions. The Government expected the foresight exercise to provide guidance on R&D funding. There should be better clarity after the foresight exercise on what areas have been identified as in some sense meriting funding in the future based on stakeholder views and quantitative analysis. Nevertheless, the STI priorities set by foresight will provide guidance to government, as well as R&D partners and industry, to make better investment (or funding) decisions for R&D. In addition, they will also provide direction for foreign (donor- or foundation-) supported R&D. Donors should indicate how the national research agenda can benefit from their involvement. Although donor funding for R&D in STI is a manifestation of confidence in the STI capability of a nation, it can also distract from real domestic needs. Therefore, a fine balance is required between reacting to the direction set by donor funding and addressing pressing domestic priorities set by foresight and national policy documents.

It is of utmost importance that the entire government structure should benefit from the STI foresight outcomes. Although STI is the direct domain of the DRST, it forms a crucial aspect of all ministries, and STI should be embraced by government, the business sector, communities and individuals to make its recommendations most effective.

The foresight process has indicated the need to align R&D outputs to desired socio-economic outcomes and impacts required for a preferred thriving future. This implies alignment of R&D to creating that future, and it will require that R&D outcomes aim to create markets, address real opportunities, and produce benefits to the economy and local communities. Priority should be given to targeted R&D projects, and extended R&D value chains must include piloting and prototyping to utilize R&D through innovative local solutions. Finally, it is imperative that R&D be translated into actual innovation through commercialization or use of R&D outputs to create economic, social or environmental impact, a challenge identified in the STIP Review (see section 3.5 for specific recommendations on how to achieve this).

D. The NSI and an STI-driven future

The National System of Innovation (NSI) operates within an STI ecosystem of government, parastatals, higher education institutions, research instutions, industry, and communities as key actors operating in a policy environment. In its current state, the NSI is fragmented and performing suboptimally (see STIP Review sections 3.4 and 3.5). Fragmentation results in NSI actors working independently with little interaction, hindering the positive effects of STI to propel the country into the future. The NSI is currently characterised by broad-based R&D and technology activity with funding spread very thinly across most activities at the individual level. However, the NSI needs to be aligned with platforms for STI to get most benefit. If the NSI is not supporting harmonisation of STI activity and the policy environment, it may negatively affect implementation of the STI foresight recommendations. The STI priorities can be aligned to Vision 2036 by empowering institutions in the STI ecosystem to execute their unique contributions based on clear mandates, and to build institutional capacity.

It is essential to provide the necessary research and innovation infrastructure and facilities to successfully implement the foresight recommendations. This includes the entire research infrastructure spectrum, from well-founded laboratories to analytical facilities through higher value chain innovation infrastructure including piloting and prototyping facilities. The existing standardisation and metrology facilities in Botswana will play an important role in new utility of STI (see section 4.3.7 of the STIP Review on technical standards). Standardisation and accreditation of research facilities will also be required. There is a need for role clarity along the value chain from idea through R&D to demonstration, prototyping and piloting, into commercialisation.

An investigation should be undertaken on how intellectual property (IP) frameworks and dedicated IP law could advance the deployment of a strong NSI (see section 4.3.4 of the STIP Review on the IP policy framework). Robust advocacy is needed to establish awareness among policy makers and researchers about benefits of IP and commercialisation, with the aim of building a knowledge-based economy. There is a need for technology transfer offices (TTOs) and IP services in the NSI. It is important to revisit and redefine incentives based on Intellectual Property Rights (IPR) in R&D institutions to establish a shared benefits approach that lets researchers benefit financially from their IP contributions.

Finally, the role that a Botswana Public Health Institute could play in establishing STI in the health sector should be investigated, given that the establishment of a Medical Research Council (MRC) in the country could improve health research governance. The relationship between an MRC and a possible National Research Fund should also be investigated.

E. Higher education and the future of work

The higher education sector and technical and vocational education and training (TVET) should align with the future STI priorities to provide the skills for the next generation of practitioners that will take STI forward (see chapter 2 and section 4.3.7 of the STIP Review on higher education, and section 2.5 for specific recommendations). Higher education and TVET must provide the right education and skills development, but also ensure employability of graduates and post-graduates, in line with future challenges and opportunities. There should be a strong knowledge base to support innovation in future priority STI areas. Companies in the private sector should indicate skills required and support students to study along these lines. Private companies should also be able to influence curricula in the education sector to enhance synergies between school and market (industry) needs regarding skills. University-industry collaboration is crucial to identify the skills required for future work and to create employment take-up for skilled STI graduates and post-graduates. In addition to the academic knowledge required to take the country into the future, life skills are required to operate in future markets. It is essential that new venture creation and entrepreneurship around STI be encouraged and supported so young people can create their own STI-based businesses and thrive in industry (see section 3.5 of the STIP Review).

F. STI foresight and decision making

The STI foresight outcomes do not represent definitive decisions on suggested priorities. They constitute a set of guidelines for government on the future. These guidelines will contribute to adequate and expedient decision-making processes in government that are aligned with real business and social needs and opportunities. Although the STI priorities revealed by foresight provide significant focus to ensure effective implementation, they may still address too many options for STI funding. The guidelines from the foresight exercise should be used as an input to policy making and government prioritisation through targeted funding. The decision is ultimately dependent on the national strategies developed to take the country forward to its desired state outlined by Vision 2036. Decision making, especially in government, must be done at the appropriate levels and must be linked with real needs and government provisions, and address the issues of responsibility and accountability. Delegation of decision making regarding STI support and deployment should be at the level where the largest impact can be established. The following issues, among others, should be taken into account in deciding the final list of priorities for implementation:

- There should be a balance between the priorities that have a potential for short-, medium-, and long-term impact. Priorities that have an immediate impact at the onset can help to build the required momentum. These include domains such as health and social development. The promising niche innovations within the country can serve as ideal pilots for immediate implementation and for potential upscaling and diffusion to the broader society and economy.

- An opportunity for technological leapfrogging should be considered in Botswana to escape the middle-income trap and to catch up with the technologically advanced countries (see chapter 1 of the STIP Review on the middle-income trap in Botswana).
- Not all prioritised STI domains and thrusts should be mission oriented STI. There is a need to also focus on blue sky, fundamental or basic research, with a balance between the two (see section 3.5 of the STIP Review). This is important to the development of frontier technologies.
- There should be cross-sectoral considerations in order to realise the benefit of multiplier effects across the sectors/areas.
- The budget implications should be considered to ensure successful implementation of the STI plan (see sections 2.5 and 4.12 of the STIP Review on financing and funding of STI). Funding availability should be in line with the short-, medium- and long-term priorities.

G. STI foresight and policy

Policy fragmentation, as identified by the STIP Review, poses a risk to efficient implementation of polcies and programs relating to the prioritised STI activities. The policy landscape and resultant strategies should benefit from the future landscape for STI revealed by the foresight and facilitate STI implementation. Multiple policies (for education, health, agriculture, energy, environmental, conservation, human settlements, manufacturing, mining and minerals, etc.) should be considered for reinforcement of STI. Coherence among various policies and programs in government is required to contribute to effective STI deployment (see section 4.12 of the STIP Review on policy coherence and using both explicit and implicit STI policies). In order to track the implementation of the policies, the appropriate quantitative targets should be established and the baseline indicators should be measured (see 2.5 and 3.5 of the STIP review on data and M&E). Beyond the influence of the STI foresight results to the policy, this foresight report should also be used to inform the sectoral plans and the planning activities of other stakeholders such as the business sector.

H. Business and STI

Large companies, like those in the mining sector, have internal funding for R&D, which is mostly done at the internal departmental level. There is often centralisation of R&D, but is also conducted through sister companies. Businesses may be amenable to piloting their in-house proprietary solutions in partnership with R&D and academic institutions to benefit from a broader knowledge pool. Many R&D needs of business can be addressed by the identified priorities in this STI foresight exercise, and it would be wise to develop some STI priorities further in partnerships with the business sector. Businesses have the potential to optimise R&D outcomes and create new processes through R&D partnerships.

In general, companies in the retail sector do not do R&D per se, but they often get their service innovation insights from customers through the marketing channel. They then respond to these direct customer requirements. Such a need established from direct customer contact is then distributed to procurement, which sources solutions. This customer-driven solution reflects service innovation approaches that do not always rely on in-house R&D. It introduces the notion of innovating *with* the user, and not *for* the user. This is an important approach, also for customer-centric development which is becoming important in new industry processes for manufacturing and service provision.

The business sector can assist with the development of industry-ready graduates. This can be achieved via partnerships between the private sector and specific educational institutions to prepare youth for technology-based careers. Internships can expose students to industry to assist them in making study or career choices.

Problem solving in industry is often done with R&D support from Original Equipment Manufacturers (OEMs), where businesses rely on their own data. Industry STI practitioners need an ecosystem of partnerships (vendors) and academic input on the latest developments, to decide what problems to solve and agree on funding models to do the R&D to solve them. There is often lack of understanding on how to incubate solutions, leading to long lead times for practical outcomes from R&D.

It must be clearly understood how to introduce frontier technologies, like those belonging to the 4IR (see chapter 5 of the STIP Review on new technologies). This is best done when objectives are technology-based. Frontier technology adoption can be led by improving existing processes, e.g., safety. It is then considered how new technology can assist in improving the process. For example, in mine or factory operations, it has to be established how atificial intelligence (AI) can assist in human/machine proximity monitoring. This is followed by conceptualising solutions, setting up technology on site and testing. If it does not work the first time, alternatives are sought out and the solution is optimised. Use cases for efficacy of technology are to be investigated. Above all, it should be remembered that people are an integral part of any new technology adoption.

I. Government and business

A forum should be supported between government and business to suggest practical and implementable solutions focused on futures training and R&D. This could contribute to STI implementation to realise Vison 2036. There is also a need to involve businesses in government supported R&D processes to solve real problems, while the private sector must give special attention to young people and the technologies they need for the future of work. There are only very limited direct links with youth at present, and students should be exposed to processes and technologies used in business. For instance, the Botswana Digital and Innovation Hub (BDIH) can play a facilitating role. (see section 3.2.3 of the STIP Review on the BDIH).

A rigorous citizen employment program is necessary, an activity that government, businesses and the financial sector should address jointly. Emphasis should be given to assist women in business. Also, this employment plan should address all levels, with specific recognition of artisan programs.

Efforts must be synergised for STI development and adoption by both government and business at the national level. Individualisation of STI that may lead to duplication of effort should to be avoided. This collaboration should be part of developing and creating a functional STI ecosystem, and joint responsibility for the R&D sector should be encouraged and incentivised. The sharing of benefits that accrue from joint STI development by business and government should be considered and defined, and this can be best achieved by aligning priorities of government and the private sector. Finally, business should involve international vendors to attract R&D to the local environment and encourage joint projects with the local R&D sector.

The entry point for business and government relationship building starts with bringing stakeholders together, making communication more open, structuring the conversation to attract as many participants as possible, identifying “pain points” and focussing on them. This will require a broadening of scope and increased dialogue between business and government. Business Botswana, a business association of employers representing employers in all sectors of the Botswana economy, facilitates collaboration and can play a leading role in establishing such a communication forum.

The corporate sector in Botswana has the ability to build scale and can make STI solutions viable for broader markets. Operating in a small economy, businesses should extend their capability and reach by looking across borders for export opportunities. This can strengthen export promotion initiatives by government.

J. Data

Data and its use should be properly understood over the whole spectrum of STI. It will be critical in the future to share data among STI practitioners, be it government, higher education or the private sector. However, duplication of data should be avoided, and clarity on the problem and its solution addressed by R&D is needed. It must be ensured that the data to solve the problem are on right level of detail and accessibility. The role of open and proprietary data should be very clear in business-government interaction. Access to shared data, especially government generated data, is essential to strengthen business and government relations. It would be advisable to investigate whether the country has a national data policy in place, and whether it needs one. A number of data centres are being built, led by the BDIH. The Data Protection Act is in place and will form an important component of such an investigation (see 2.5 of the STIP Review on data and 3.5 on national data policy).

K. STI and Vision 2036

Strategic interventions were identified to take the STI future from probably unsustainable if STI activity is not promoted through the adoption of foresight recommendations to a preferred thriving future (see STI scenarios and strategic interventions). To address the alignment of these strategic interventions with Vision 2036, good coordination and strong multidisciplinary collaboration are required. As pointed out in this report, there is strong convergence of the STI priorities chosen and the four pillars of Vision 2036. All identified developmental priorities in the vision are dependent on STI. Many STI priorities identified cross over all four pillars. One of the most significant is STI for the digital economy.

To receive the best from future STI activity in support of the vision, effective networks of excellence must be built. These networks, different from centres of excellence, indicate that existing and new STI practitioners should be linked so that the country can benefit from combining forces. Policy levers should be used wherever possible to reinforce the positive effects of STI on the future of the country.

R&D that can be commercialised quickly through innovation should have priority. This means that the development of multi-criteria decision models will be required for selecting projects that will lead to commercialisation and rapid benefits to the economy and communities.

No process is complete without measurement. Therefore, timely M&E to determine outputs, outcomes and impacts must be associated with all STI activities, making use of a set of criteria to drive competitiveness. It is therefore necessary to prioritise and institutionalise M&E at all levels (see section 3.5 of the STIP Review on M&E).

The impact of STI on Vision 2036 could be enhanced by dedicated R&D and innovation funding to strengthen commercialisation. The National Research Fund (NRF) has been conceptualised and should be operationalised as soon as possible to support the STI prioritisation and alignment with Vision 2036 (see section 4.12 of the STIP Review on the NRF).

The training of human resources with the knowledge and skills to drive the solutions of the future is critical to the success of STI accelerating Vision 2036. Post-graduate training and support for R&D skills are key.

The development of innovative incentives for the private sector to become involved in R&D, with the recognition of diverse needs of large and small companies, will accelerate the achievement of many of the objectives spelled out in Vision 2036 (see sections 2.5 and 4.2 of the STIP Review on R&D incentives).

L. Continuing foresight

Attaining the national vision of "achieving prosperity for all" requires regular macro-environmental (political, economic, social, technology, environmental and legal) scanning and practicing continuous foresight. This will assist with recognising opportunities at an early stage and reducing vulnerabilities through benchmarking and self-assessment. This STI foresight exercise can be seen as a first step towards creating community awareness around the future.

The need for an ongoing foresight culture has been identified. The country should consider the establishment of a national foresight body/platform that does foresight on a continuous basis and to avoid an ad hoc activation of foresight exercises. The M&E that accompanies foresight could also be synchronised with such a national foresight initiative. In designing future STI foresight exercises in Botswana, there is a need to include/focus on wider stakeholders beyond the direct STI community, especially the private sector and SMEs. Incorporating the voice of the community will also be important in future foresight exercises. The STIP Review discusses foresight in sections 3.5, 4.2, 4.12 and 5.4.

M. Epilogue

These findings of the STI Foresight exercise indicate that by valuing STI as a socio-economic driver the country can thrive in its journey towards "achieving prosperity for all" as embodied in Vision 2036. The guidelines have been set, and action can be taken by government to lead STI to support a future that will be beneficial for the country. With a strong STI policy framework built from recommendations of the STIP Review and clarity on the future brought about by the STI foresight, Botswana can become a leading country in Africa and in the world.

References

Brodt, S., Six, J., Feenstra, G., Ingels, C. and Campbell, D. (2011). Sustainable agriculture. *Nature Education Knowledge*, 3(10):1.

Chandaria, C., Duso, M., Frédau, M., Nielsen, J., Pamlin, D. and Pieper, C. (2021). *The next generation of climate innovation.* Boston Consulting Group (BCG), https://www.bcg.com/publications/2021/next-generation-climate-innovation.

Cross Border Road Transport Agency (2018). Country profile report.

Dunn, H.S. (2021). *Botswana ICT challenges: In quest for a knowledge-based society*. CIPESA, https://cipesa.org/2021/05/botswana-ict-challenges-in-quest-for-a-knowledge-based-society/.

Gannotta, R., Malik, S., Chan, A.Y., Urgun, K., Hsu, F and Vadera, S. (2018). *Integrative medicine as a vital component of patient care*. National Centre for Biotechnology Information, Cureus, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6173273/.

Inayatullah, S. (2017). Causal layered analysis – A four level approach to alternative futures. *Futuribles International*, https://www.futuribles.com/en/group/prospective-and-strategic-foresight-toolbox/document/causal-layered-analysis/.

Lall, S. (2000). The technological structure and performance of developing country manufactured exports, 1985-98. *Oxford Development Studies*, 28:3, 337-369.

Morris, M. (2022). World Economic Forum lists biggest global risks of 2022. Nasdaq, https://www.nasdaq.com/articles/world-economic-forum-lists-biggest-global-risks-of-2022.

Motlhwa, G., James, M.Y. and Yunxian, Y. (2019). Effects of integrated support programme for Arable Agricultural Development (ISPAAD) on the Income of Sorghum Farmers: Evidence from Kweneng District, Botswana. *Economia E Sociologia* (Evora, Portugal), 36:1, 1-10.

NACI (2019). South Africa foresight exercise for science, technology and innovation 2030: Synthesis report. Pretoria, South Africa, https://www.naci.org.za/wp-content/uploads/2020/07/South-African-Foresight-Exercise-For-Science-Technology-and-Innovation-2019.pdf.

Randall, L., Berlina, A., Teräs, J. and Rinne, T. (2018). Digitalisation as a tool for sustainable Nordic regional development: Preliminary literature and policy review. Discussion paper prepared for Nordic thematic group for innovative and resilient regions, https://www.nordregio.org/wp-content/uploads/2017/04/Digitalisation_Discussion-Paper_Jan-31.pdf.

Sekhwela, M. and Kgathi, D.L. (2012). Biomass potential in arid and semi-arid regions in Botswana. In *Bioenergy for Sustainable Development in Africa* (pp. 13-25), Springer, Dordrecht.

Tepera, R., Moseki, S. and January, J. (2018). The status of health promotion in Botswana. *Journal of Public Health in Africa*, 9:699, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6057722/.

Annexes

Annex 1: Policy documents consulted

1.

Transforming our World – The 2030 Agenda for Sustainable Development (Sustainable Development Goals)

2015

Department of Economic and Social Affairs, Sustainable Development, United Nations, https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf

and

https://sdgs.un.org/goals

[accessed 1 July 2022].

2.

Africa's Science and Technology Consolidated Plan of Action

2005

https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwieq_zw7Nf4AhW_if0HHQYTAuIQFnoECAIQAQ&url=https%3A%2F%2Fwww.merit.unu.edu%2Fwp-content%2Fuploads%2F2015%2F01%2FConsolidated-Plan-of-Action-CPA.pdf&usg=AOvVaw1teD_1t-kvPS_gdUEq30_9

[accessed 1 July 2022].

3.

Science, Technology and Innovation Strategy for Africa 2024

Part of African Union (AU) Agenda 2063

2014

https://au.int/sites/default/files/newsevents/workingdocuments/33178-wd-stisa-english_-_final.pdf

[accessed 1 July 2022].

4.

Agenda 2063 – The Africa we want

2015

https://au.int/sites/default/files/documents/36204-doc-agenda2063_popular_version_en.pdf

[accessed 1 July 2022].

5.

SADC Protocol on Science, Technology and Innovation

2008

https://www.sadc.int/files/3013/5292/8367/Protocol_on_Science_Technology_and_Innovation2008.pdf

[accessed 1 July 2022].

6.

SADC Industrialization Strategy and Roadmap 2015 – 2063

2015

https://sadc-eu.sardc.net/resources/RISDP/SADC-Industrialisation-Strategy-and-Roadmap-2015-2063.pdf, [accessed 29 June 2022].

7.

South Africa Foresight Exercise for Science, Technology and Innovation 2030, Synthesis Report

2019

https://www.naci.org.za/wp-content/uploads/2020/07/South-African-Foresight-Exercise-For-Science-Technology-and-Innovation-2019.pdf

[accessed 29 June 2022].

8.

SADC Regional Indicative Strategic Development Plan (RISDP) 2020 – 2030

2020

https://www.sadc.int/files/4716/1434/6113/RISDP_2020-2030_F.pdf

[accessed 29 June 2022].

9.

South African Foresight Exercise for Science, Technology and Innovation 2030

2019

https://www.naci.org.za/wp-content/uploads/2021/03/STI-Foresight-Synthesis-Report-Annexures.pdf

[accessed 29 June 2022].

10.

Botswana National Research, Science and Technology Plan

2005

Prepared for the Ministry of Communications, Science and Technology

https://www.researchictafrica.net/countries/botswana/BNRST_Final_Report_2005.pdf

[accessed 29 June 2022].

11.

Botswana National Research, Science and Technology Plan, Final Report

2005

Prepared for the Ministry of Communications, Science and technology by the CSIR

https://www.researchictafrica.net/countries/botswana/BNRST_Final_Report_2005.pdf

[accessed 1 July 2022].

12.

National Policy on Research, Science, Technology and Innovation

2011

Ministry of Infrastructure, Science and Technology.

13.

National Policy on Research, Science, Technology and Innovation Implementation Plan

2012

Ministry of Infrastructure, Science and Technology

https://books.google.co.za/books/about/National_Policy_on_Research_Science_Tech.html?id=ZO8hCx0c7DoC&redir_esc=y

[accessed 1 July 2022].

14.

Mapping Research and Innovation in the Republic of Botswana

2015

UNESCO, CREST: Centre for Research on Science and Technology, University of Stellenbosch, South Africa & IRD: Institute for Research on Development, France

http://academic.sun.ac.za/crest/unesco/data/Botswana.pdf

[accessed 1 July 2022].

15.

Botswana National Survey of Research and Development Report

2014/2015

https://www.worldcat.org/title/botswana-national-survey-of-research-development-report/oclc/958937961

[accessed 1 July 2022].

16.

Vision 2036, Achieving Prosperity for All

2016

Prepared by the Vision 2036 Presidential Task Team

https://library.wur.nl/ojs/index.php/Botswana_documents/article/view/16023

[accessed 29 June 2022].

17.

National Development Plan 11, Volume 1, April 2017 – March 2023

2017

https://www.cabri-sbo.org/uploads/bia/Botswana_2017_Planning_External_NationalPlan_MinEcosFin_SADC_English.pdf

[accessed 1 July 2022].

18.

Botswana National Innovation Survey (2013 – 2016)

2020

Published by: Ministry of Tertiary Education, Research, Science and Technology, Department of Research, Science and Technology.

Annex 2: Global emerging technology trends

Top emerging technologies identified by various organisations

Mining Technology[1]	Precision Agriculture[2]	WEF Top 10 Technologies[3]	Water Technology Top 5[4]	MIT Technology Review (2021)[5]	MIT Technology Review (2020)[6]	RS WEBSOLS Top 8 Transport Technology[7]	MTS Top Health Technologies[8]
Robotics	GPS/ GNSS	Decarbonisation technologies	Nanotechnology	Messenger RNA vaccines	Unhackable internet	Next Gen GPS devices	Advanced telemedicine
Internet of things	Mobile devices	Self-fertilising crops	Acoustic nanotube technology	Natural language computer models	Hyper-personalised medicine	Driver recruiting software	New methods of drug development
Airborne gravity gradiometer	Robotics	Disease diagnosing breath sensors	Photocatalytic water purification	Data trusts	Digital money	Self-driving trucks & drones	Data-driven health care
3D imaging technology	Variable-rate irrigation system	On-demand drug manufacturing	Biomimetic membranes	Lithium metal batteries	Anti-aging drugs	Automated freight matching	Nanomedicine
Automated drilling	Internet of Things	Energy from wireless signals	Automatic variable filtration technology	Green hydrogen	AI-discovered molecules	Vehicle-to-vehicle communication	5G-enabled devices
Efficient shaft & tunnel boring system	Wireless sensors	Engineering better ageing		Digital contact tracing	Satellite mega constellations	Remote diagnosis	Tricorders
Autonomous haulage	Variable-rate application (VAR) seeding	Green ammonia		Hyper accurate positioning	Quantum computing	Vehicle to infrastructure communication	Healthcare's digital assistants
Plasma technology	Weather modelling	Wireless biomarker devices		Remote everything	Tiny AI	Internet of things	Smarter peacemakers
Copper eating bacteria	Nitrogen modelling	3D printing houses		Multi skilled AI	Differential privacy		A lab-on-a-chip
Remote operating & monitoring centres	Standardisation	Space internet of things		TikTok recommendation algorithm	Climate change attribution		Wearable devices

1 List compiled by foresight experts from various sources.

2 List compiled by foresight experts from various sources.

3 Top Emerging Technologies of 2021, Insight Report, World Economic Forum (2021), https://www3.weforum.org/docs/WEF_Top_10_Emerging_Technologies_of_2021.pdf, [accessed 1 July 2022].

4 Latest water purification technologies – top five (2021), https://www.water-technology.net/features/latest-water-purification-technologies-top-five/, [accessed 1 July 2022].

5 Ten Breakthrough Technologies 2021 (2021) MIT Technology Review, https://www.technologyreview.com/2021/02/24/1014369/10-breakthrough-technologies-2021/, [accessed 1 July 2022].

6 Ten Breakthrough Technologies 2020 (2020) MIT Technology Review, https://www.technologyreview.com/10-breakthrough-technologies/2020/, [accessed 1 July 2022].

7 Eight Technologies that are shaking up the Transport Industry (2020), (RS)Websols, https://www.rswebsols.com/tutorials/technology/technologies-transport-industry, [accessed 1 July 2022].

8 A look back at the ten hottest medical technologies for 2021 (2022), Medical Technology Programs, https://www.medicaltechnologyschools.com/medical-lab-technician/top-new-health-technologies, [accessed 1 July 2022].

Annex 3: Candidate STI domains and thrusts for Botswana

Thrusts	Domains												
	Digital	Biotech-nologies	Manufacturing & Advanced Materials	Energy	Agriculture	Space	Health	Mining	Social development	Environment	Geopolitical	Communication	Tourism & Hospitality
	Artificial intelligence	Neuro-technologies	Additive manufacturing	Solar energy	Food security	Micro- and nanosatellites	Nanomedicine manufacturing	Digital mining	Smart communities	Circular economy	Globalisation	Satellite	Robots
	Big data analytics	Organoid technology (stem cells)	Nanomaterials	Wind energy	Animal health	Deep space exploration	Bio-economy and food security	Automated ore handling	Smart cities	Biodiversity conservation	Future warfare	Terrestrial	ICT in tourism
	Blockchain	Mapping the brain	Bio-manufacturing	Advanced energy storage	Water security	Earth observation	Holistic health	Advanced exploration	Resilient built ecosystems	Climate change	National security	Mobile	Hotel of the future
	Digital government	Bioenergy	Manufac-turing for sustainability	Battery technology	Arid land technologies	Resources from space	Indigenous medicine	New applications for diamonds	Grey tech to green tech	Water resource protection	Transbound-ary aspects of water	Network virtualisation	GIS applications
	Digital finance	Agricultural biotechnology	Automation	Synthetic biology	Urban agriculture	Socio-eco-nomic development	Drinking water	Natural Resource Management	Urbanisation	Disaster management	Governance & eGovernance	Connectivity	Virtual tourism
	Digital globalisation	Genetic engineering	4IR	Biomass	Agro processing	Terrestrial surveillance	Community health	Natural resources and materials	Migration and semigration	Human-nature conflict	Free trade	Bandwidth	Sustainable tourism
	Internet of Things	Biomath-ematics	Industrialisation	Natural gas	Cooperative agriculture	Geospatial planning	Pandemic management	Advanced mineral processing	Social inequality and instability	Ecotourism	Border control	Voice, image, data, holographic transmission	Green buildings
	Computer architecture	Biobanking/ Gene banking	Labour market dynamics		Vaccine manufacturing		Cancer diagnostics & prevention	Robotics					Drones

Thrusts	Domains												
	Digital	Biotech-nologies	Manufacturing & Advanced Materials	Energy	Agriculture	Space	Health	Mining	Social development	Environment	Geopolitical	Communication	Tourism & Hospitality
	Open data	Bio-informatics	Human-machine relationships		Precision agriculture		HIV/AIDS		Sustainable water use				
	Sensing		Systems thinking		Integrated rural economy		Tuberculosis		Future of work				
	Cognitive & neuromorphic computing		Housing and building materials				Nutrition		Safety and security				
	Mathematical simulation & modelling		Water-energy nexus				Precision medicine		Future world of learning				
	Models of real-world systems		Human-centred design						Educational technologies				
	Automo-tive-digital conversion		Innovative Technological Products						Transport systems				
	Cloud computing		Speciality chemicals						Human & social dynamics				
	Cybersecurity								Rural planning				
	Machine learning								Early child development				
	Data science								Climate & Society				
	Virtual & augmented reality								Service for Economic Development				
	Serious gaming								Indigenous knowledge systems				

Annex 4: Science, technology and innovation thrusts definitions

STI domains and thrusts	Code	Description
Energy		
Solar energy	ES	This includes: 1. **Photovoltaic solar energy** - obtained by converting sunlight into electricity using a technology based on the photoelectric effect 2. **Concentrated solar energy** - generate solar power by using mirrors or lenses to concentrate a large area of sunlight onto a receiver 3. **Water heating solar energy**: heating water by sunlight, using a solar thermal collector 4. **Solar pool heating**: heating a swimming pool to a warm comfortable temperature 5. **Thermal solar energy**: a form of energy and a technology for harnessing solar energy to generate thermal energy for use in industry, and in the residential and commercial sectors
Wind energy	EW	Issues around wind energy include the installation of wind turbines and setting up wind farms both on the land and offshore
Advancede Energy storage	EA	The five main categories are: **Batteries** – a range of electrochemical storage solutions, including advanced chemistry batteries, flow batteries, and capacitors **Thermal** – capturing heat and cold to create energy on demand or offset energy needs **Mechanical Storage** – other innovative technologies to harness kinetic or gravitational energy to store electricity **Hydrogen** – excess electricity generation can be converted into hydrogen via electrolysis of water and stored **Pumped Hydropower** – creating large-scale reservoirs of energy with water
Battery technology	EB	New generation battery technologies such as: 1. Nanobatteries 2. Fuel cell batteries 3. Large scale energy storage batteries 4. Fast charging batteries 5. Long lasting batteries
Synthetic biology	EY	The emergence of synthetic biology tools and techniques offers an entirely new design paradigm that harnesses and expands the inherent abilities and chemistries of living systems to transform and store energy. The three potential technology domains in this area are: 1. Electrocatalysis 2. Electron storage 3. Ion transport materials

STI domains and thrusts	Code	Description
Biomass	EI	The five types of biomass are: – Agricultural residue – Animal waste – Forest residues – Industrial waste – Solid waste and sewage
Natural gas	EN	A naturally occurring hydrocarbon gas mixture consisting of methane and commonly including varying amounts of other higher alkanes
Digital economy		
Artificial intelligence	DA	The on-going industrial revolution towards full digitalisation of producing things, interacting with things, travelling and learning, etc. Three pillars will drive this new era: – Artificial Intelligence: Machine learning as a support for improving economic development – Cloud Robotics and Internet of Things (IoT): This is the key for Industry 4.0 revolution – Infrastructure to support digitalisation
Big data analytics	DB	Complex process of examining big data to uncover information - such as hidden patterns, correlations, market trends and customer preferences - that can help organisations make informed business decisions
Blockchain	DL	A distributed database that is shared among the nodes of a computer network. As a database, a blockchain stores information electronically in digital format. Blockchains are best known for their crucial role in cryptocurrency systems, such as Bitcoin, for maintaining a secure and decentralised record of transactions. The innovation with a blockchain is that it guarantees the fidelity and security of a record of data and generates trust without the need for a trusted third party.
Digital government	DG	The use of technological communications devices, such as computers and the Internet, to provide public services to citizens and other persons in a country or region. It is also called eGovernment.
Digital finance	DF	The impact of new technologies on the financial services industry. It includes a variety of products, applications, processes and business models that have transformed the traditional way of providing banking and financial services.
Internet of things	DO	The connection over time of almost any object and device to the Internet's network of networks
Computer architecture	DC	The power and speed of computers have increased exponentially in recent years. Recently, however, modern computer architectures are moving away from single-core and multi-core (homogenous) central processing units (CPUs) to many-core (heterogeneous) CPUs.
Open data	DP	An idea that some data should be freely available to everyone to use and republish as they wish, without restrictions from copyright, patents or other mechanisms of control. The goals of the open-source data movement are similar to those of other "open(-source)" movements such as open-source software, hardware, open content, open specifications, open education, open educational resources, open government, open knowledge, open access, open science, and the open web.
Sensing	DS	Different types of sensors are available as per the suitability and applications. The standard sensor types are position sensors, pressure sensors, flow sensors, temperature sensors, and force sensors.

STI domains and thrusts	Code	Description
Cognitive & neuromorphic computing	DN	A **cognitive computer** is a computer that hardwires artificial intelligence and machine-learning algorithms into an integrated circuit (or printed circuit board) that closely reproduces the behaviour of the human brain. **Neuromorphic engineering**, also known as neuromorphic computing, is the use of very-large-scale integration (VLSI) systems containing electronic analogue circuits to mimic neuro-biological architectures present in the nervous system.
Mathematical simulation & modelling	DM	The use of models (e.g., physical, mathematical, or logical representation of a system, entity, phenomenon, or process) as a basis for simulations to develop data utilised for managerial or technical decision making.
Automotive-digital conversion	DU	The top 6 digital transformation trends in the automotive industry are: 1. Digital sources in the car buying process 2. Autonomous driving 3. Connected supply chain and improved manufacturing 4. Predictive maintenance 5. Mobility-as-a-service 6. Data security and protection
Cloud computing	DT	The delivery of different services through the Internet. These resources include tools and applications like data storage, servers, databases, networking, and software.
Cybersecurity	DY	Cybersecurity is the protection of computer systems and networks from information disclosure, theft of or damage to their hardware, software, or electronic data, as well as from the disruption or misdirection of the services they provide.
Machine learning	DE	The study of computer algorithms that can improve automatically through experience and by the use of data. Machine learning algorithms build a model based on sample data, known as training data, in order to make predictions or decisions without being explicitly programmed to do so.
Data science	DI	An interdisciplinary field that uses scientific methods, processes, algorithms and systems to extract knowledge and insights from noisy, structured and unstructured data, and apply knowledge and actionable insights from data across a broad range of application domains.
Virtual & augmented reality	DV	**Virtual Reality** is the technology that provides almost real and/or believable experiences in a synthetic or virtual way, while **Augmented Reality** enhances the real world by superimposing computer-generated information on top of it.
Serious gaming	DW	It combines learning strategies, knowledge and structures, and game elements to teach specific skills, knowledge and attitudes.
Bioeconomy		
Neurotechnologies	BN	Any method or device in which electronics interface with the human nervous system to monitor or modulate neural activity.
Organoid technology	BO	Organoids are tiny, self-organised three-dimensional tissue cultures that are derived from stem cells. Such cultures can be crafted to replicate much of the complexity of an organ, or to express selected aspects of it like producing only certain types of cells.

STI domains and thrusts	Code	Description
Brain mapping	BM	It can be used to detect the effects of aging in the mind, either structurally or functionally, as well as to detect how drugs or other substances may induce premature aging and brain tissue.
Bioenergy	BB	A form of renewable energy that is derived from recently living organic materials known as biomass, which can be used to produce transportation fuels, heat, electricity, and products.
Agricultural biotechnology	BA	A range of tools, including traditional breeding techniques, that alter living organisms, or parts of organisms, to make or modify products; improve plants or animals; or develop microorganisms for specific agricultural uses
Genetic engineering	BG	The process of using recombinant DNA (rDNA) technology to alter the genetic makeup of an organism. It involves the direct manipulation of one or more genes. Most often, a gene from another species is added to an organism's genome to give it a desired phenotype.
Biomathematics	BS	The use of mathematical models to help understand phenomena in biology. It encompasses all of biology and virtually all the mathematical sciences, including statistics, operations research, and scientific computing.
Biobanking/ Gene banking	BK	A type of biorepository that stores biological samples for use in research. Biobanks have become an important resource in medical research, supporting many types of contemporary research like genomics and personalised medicine in human health, agriculture and wildlife conservation.
Bioinformatics	BF	The application of tools of computation and analysis to the capture and interpretation of biological data. It is an interdisciplinary field, which harnesses computer science, mathematics, physics, and biology.
Mining		
Digital mining	MD	A digital transformation for the mining industry is the process of adopting new digital tools and technological innovations that alter how the mining process occurs. The applications seen most often in a digital transformation for mining productivity include: the automation of material management, machinery maintenance, and performance monitoring.
Advanced exploration	MA	Advanced technological innovation in mineral exploration creates the opportunity for resource companies to identify prospects more quickly and fast-track projects through discovery.
New applications for diamonds	MN	Diamond also has chemical, electrical, optical, and thermal properties that make it ideal for wear- and corrosion-resistant coatings, special lenses for laser radiation equipment, heat sinks in electrical circuits, wire drawing, polishing silicon wafers and computer disk drives, and other applications.
Natural resource management	MM	The sustainable utilisation of major natural resources such as minerals.

STI domains and thrusts	Code	Description
Advanced mineral processing	MP	These include technologies such as: 1. **Plasma mineral recovery**: Application of plasmas to separate minerals 2. **Bioleaching**: The catalytic action of bacteria to accelerate chemical oxidation reactions by as much as one million times those of chemical reactions alone 3. **Electrowinning**: an electrochemical process in which a metal dissolved within an electrolyte is plated onto an electrode resulting in a pure metal 4. **Heap leaching**: a well-established mining technique enabling the processing of different ores that could not otherwise be exploited under viable economic conditions 5. **Sensor technologies**: sensing devices are critical in all aspects of the mining process. Advances in real-time sensing, data collection, and data analysis and interpretation will help to understand the characteristics of materials prior to processing and improve the efficiency and processing activities.
Robotic mining	MR	Robotics technology in mining is expected to improve safety and increase productivity. Some future technologies include robotic detonators, autonomous haulers and robotic drilling.
Space applications		
Micro- and nanosatellites	SM	Satellites can be built small to reduce the large economic cost of launch vehicles and the costs associated with construction. Miniature satellites, especially in large numbers, may be more useful than fewer, larger ones for some purposes – for example, gathering of scientific data and radio relay.
Deep space exploration	SD	The branch of astronomy, astronautics and space technology that is involved with exploring the distant regions of outer space.
Earth observations	SE	The gathering of information about the physical, chemical, and biological systems of the planet Earth.
Resources from space	SR	The unlimited solar energy, vacuum, radiation, and low gravity in space, as well as the minerals, metals, water, atmospheric gases, and volatile elements on the Moon, asteroids, comets, and the inner and outer planets of the Solar System and their moons, constitute potential valuable resources. Asteroid mining is the hypothetical exploitation of materials from asteroids and other minor planets, including near-Earth objects.
Terrestrial surveillance	ST	The applications include: 1. Earth and water surveillance 2. Spy satellites 3. Detection of new man-made objects in space 4. Predicts when and where a space object will re-enter the Earth's atmosphere
Geospatial planning	SG	One of the reasons why Geographic Information System is important in urban and rural planning is the ability to better understand current needs for a city or region, and then design to fulfil those needs. By processing geospatial data from satellite imaging, aerial photography and remote sensors, users gain a detailed perspective on land and infrastructure.

STI domains and thrusts	Code	Description
Environmental sustainability		
Circular economy	RC	An economy that uses a systems-focused approach and involves industrial processes and economic activities that are restorative or regenerative by design, enable resources used in such processes and activities to maintain their highest value for as long as possible, and aim for the elimination of waste through the superior design of materials, products, and systems.
Biodiversity conservation	RB	The protection and management of biodiversity to obtain resources for sustainable development.
Climate change	RL	Global momentum is building to achieve net zero in greenhouse gas (GHG) emissions—and to do so more quickly than previously envisioned. Getting there will require unprecedented levels of innovation.
Water resource protection	RW	Water source protection involves the protection of surface water sources (e.g., lakes, rivers, man-made reservoirs) and groundwater sources (e.g., spring protection, dug well protection, and drilled well protection) to avoid water pollution.
Disaster management	RD	The Sendai Framework for Disaster Risk Reduction[1] encourages investment in innovation and technology development in disaster risk management. It aims to achieve the substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries
Human-nature conflict	RH	Human–wildlife conflict (HWC) occurs when the needs and behaviour of wildlife impact negatively on humans or when humans negatively affect the needs of wildlife. HWC demands new and innovative solutions.
Ecotourism	RE	Ecotourism is an intrinsic, participatory and learning-based experience which is focused principally on the natural history of a region, along with other associated features of the human-land nexus. Some of the futuristic innovations in this area include eEcotourism through AI and big data
Communication		
Satellite communication	CS	In telecommunications, satellites are used to provide communication links between various points on earth.
Terrestrial communication	CT	Terrestrial radio technologies have evolved considerably over the past few decades, and new applications have emerged. They include advanced mobile broadband, intelligent transmission systems and IoT devices.
Mobile communication	CM	5G is the latest technology that is expected to significantly transform mobile communication. It is expected to deliver lightning-fast connectivity that can turn mobiles into educational tools or work gadgets.
Network virtualisation	CN	The process of combining hardware and software network resources and network functionality into a single, software-based administrative entity, a virtual network.

[1] Sendai Framework for Disaster Risk Reduction 2015–2030, United Nations General Assembly Resolution (2015) https://www.preventionweb.net/files/resolutions/N1516716.pdf, [accessed 30 June 2022].

STI domains and thrusts	Code	Description
Connectivity	CC	Network-connected device types are multiplying, bringing important implications for the ecosystem of wired and wireless technologies, products, and services that will provide a foundation for tomorrow's digital economy. This creates new demands on the suppliers of connectivity, the providers of related devices and services, and the ability of industries to use their innovations to gain competitive advantage.
Bandwidth improvement	CB	Over the last decade, top broadband speeds have increased exponentially from 16 Mbps all the way to 2 Gbps. Although 5G is expected to significantly expand the bandwidth, some futurists also predict that 10G is in the making.
Voice, image, data, holographic transmission	CV	Some future trends in this area are: 1. Holographic image high-speed processing 2. Internet of Things as enabler for increasing adoption of voice communication 3. VoIP as a future of voice communication 4. Quantum internet and networks (with exchange of quantum information, instead of classic data)
Health		
Nanomedicine manufacturing	HN	Nanomedicine manufacturing and applications effectively explores the major manufacturing techniques and applications of nanomaterial-based medicine in the areas of chemotherapy, biochips, insulin pumps, and other treatment methods.
Bio-economy & food security	HB	The emerging use of genomic information will likely increase the efficiency of the breeding process as well as enhance the health of livestock. For humans, the Genetically Modified Organisms (GMOs) have potential to produce more healthier food.
Holistic health	HH	As the world becomes increasingly digital, high-tech holistic medicine is needed for the viability of whole-person care.
Indigenous medicine	HI	With the advances in technology, the future of indigenous medicine lies with its integration to the mainstream health system.
Drinking water	HW	Some of the technologies for improving the quality and safety of drinking water include: 1. Membrane filtration (e.g., nanotechnologies) 2. Point-of-Use drinking water treatment 3. Photocatalytic water purification 4. Biomimetic membranes 5. Automatic variable filtration technology 6. Acoustic nanotube technology
Community health	HC	Universal health coverage emphasises the value of the community-based delivery of health services to ensure that underserved populations have access to health care. In areas where infectious diseases are endemic, there are often few resources and limited capacity, and the introduction of effective and accessible strategies require innovation.

STI domains and thrusts	Code	Description
Pandemic management	HP	As the pandemic affects the basic survival of humankind, organisations are focusing on continuous innovation that can save lives in troubled times.
Cancer diagnostics & prevention	HD	Early diagnosis of cancer focuses on detecting symptomatic patients as early as possible, so they have the best chance for successful treatment.
HIV/AIDS	HA	Researchers remain hopeful that they are heading in the right direction to finding a cure for HIV, the virus that causes AIDS
TB vaccine discovery	HV	Tuberculosis is endemic in Botswana and a significant health problem. There is currently no vaccine that is effective in preventing TB disease in adults, either before or after exposure to TB infection. The Bacille Calmette-Guerin (BCG) vaccine that was developed a century ago, prevents severe forms of TB in children and is widely used[2].
Nutrition	HU	Some of the topical issues with regard to nutrition are: 1. Variability in responses to diet and food 2. The impact of nutrition on healthy growth, development and reproduction 3. The role of nutrition in health maintenance 4. The role of nutrition in medical management 5. Nutrition-related behaviours 6. Food supply/environment
Precision medicine	HM	An emerging trend in precision medicine is the use of artificial intelligence and machine learning to improve the traditional symptom-driven practice of medicine, allowing earlier interventions using advanced diagnostics and tailoring better and economically personalised treatments.
Agriculture		
Food security	AF	All people having, at all times, both physical and economic access to sufficient food to meet dietary needs for a productive and healthy life.
Animal health	AA	The five technologies driving improvements in Animal Health are: 1. Remote monitoring technologies: Farmers can now tell if an animal is possibly becoming sick with the use of technologies like heat detection identification or stomach acid monitors 2. Automated dairy installations such as robotics for milking of cows and health monitoring sensors 3. Pasture and feeding technologies 4. Automated cleaning systems: to remove waste and runoff from animal enclosures 5. Animal vaccines
Water security	AW	Irrigated agriculture is, on average, at least twice as productive per unit of land as rainfed agriculture, thereby allowing for more production intensification and crop diversification.

[2] TB Elimination, BCG Vaccine Fact Sheet, https://www.cdc.gov/tb/publications/factsheets/prevention/BCG.pdf, [accessed 1 July 2022].

STI domains and thrusts	Code	Description
Arid land technologies	AL	Some of the technologies that are being investigated for agriculture in arid lands are: 1. Technologies to access water stored in shallow alluvial aquifers 2. Nano conditioning of desert soil 3. Desalination of water 4. Rainwater harvesting 5. Drip irrigation 6. Harvesting water from the air 7. Crop engineering (with GMOs) 8. Solar pumps
Urban agriculture	AU	Some innovations in this area include: 1. Vertical indoor farms to enable local production at scale 2. Hydroponics and Internet of Things-based system, to produce edible plants with little water and energy 3. The use of software and robotics to grow produce inside warehouses in and around cities 4. Mobile-based platform for renting farmland to city residents to grow organic produce 5. Data-driven, climate-controlled greenhouses in cities 6. Modular indoor farming systems
Agro processing	AP	A subset of the manufacturing sector that processes raw materials and intermediate products derived from the agricultural sector. The aim is to develop and advance new processing technologies from lab to pilot and commercial scale implementation, using tools to demonstrate product and process capability at various scales.
Cooperative agriculture	AC	This includes the innovations such as grassroots innovation and social innovation.
Vaccine manufacturing	AV	Animal/ veterinary vaccine technologies and production
Precision agriculture	AR	The future precision agriculture technologies include: 1. Global Positioning System (GPS)/ Global Navigation Satellite System (GNSS) 2. Internet of things & wireless sensors 3. Variable-rate irrigation system 4. Robotics 5. Artificial intelligence & modelling
Manufacturing & advanced materials		
Additive manufacturing	FA	This is the industrial production name for 3D printing, a computer-controlled process that creates three-dimensional objects by depositing materials, usually in layers.
Nanomaterials	FN	Manufacturing of nanomaterials is an interdisciplinary field covering physics, chemistry, biology, materials science and engineering.
Biomanufacturing	FB	A type of manufacturing or biotechnology that utilises biological systems to produce commercially important biomaterials and biomolecules for use in medicines, food and beverage processing, and industrial applications.

STI domains and thrusts	Code	Description
Manufacturing for Sustainability	FM	The creation of manufactured products through economically-sound processes that minimise negative environmental impacts while conserving energy and natural resources.
Automation	FU	Three types of automation in production can be distinguished: 1. Fixed automation 2. Programmable automation 3. Flexible automation
4IR	FR	The Fourth Industrial Revolution (4IR) is the trend towards automation and data exchange in manufacturing technologies and processes which include cyber-physical systems (CPS), IoT, Industrial Internet of Things (IIoT), cloud computing, cognitive computing, and artificial intelligence.
Industrialisation	FI	The process by which an economy is transformed from a primarily agricultural one to one based on the manufacturing of goods.
Human-machine relationships	FH	The studies on human factors in intelligent manufacturing systems often involved analyses on human–machine relationships.
Systems thinking	FA	Manufacturing is becoming more systems driven, necessitated and facilitated by customer demand and availability of technology system boundary shifting and systems getting more complex around the "enterprise" rather than "process" mass customisation.
Housing and building materials	FO	The manufacturing of building materials is a huge global industry and the use of building materials is typically segmented into specialty trades such as plumbing, HVAC systems, carpentry, insulation work and roofing.
Water-energy nexus	FW	The water-energy nexus refers to the multiple points of mutual reliance of water and energy for societal use, from extraction, to processing, through point of use (and continuing through to disposal in the case of water).
Human-centred design	FD	It is based on a philosophy that empowers an individual or team to design products, services, systems, and experiences that address the core needs of those who experience a problem.
Innovative technological products	FP	Five technological innovations are given as examples to have huge impact in shaping the future of the world: 1. Cloud native applications - everything that is made runs in the cloud 2. Internet of Things 3. 5G technology 4. Electric Bicycles (e-Bikes) 5. Blockchain
Specialty chemicals	FC	Particular chemical products provide a wide variety of effects on which many other industry sectors rely. Some of the categories of speciality chemicals are adhesives, agrichemicals, cleaning materials, colours, cosmetic additives, construction chemicals, elastomers, flavours, food additives, fragrances, industrial gases, lubricants, paints, polymers, surfactants, and textile auxiliaries.

STI domains and thrusts	Code	Description
Social development		
Smart communities	OS	A smart community leverages information, infrastructure, and communication technologies, often in combination with other technologies, to create economic opportunity and improve the quality of life for its citizens.
Smart city	OC	A technologically modern urban area that uses different types of electronic methods, voice activation methods and sensors to collect specific data.
Resilient built ecosystems	OR	The ability of an ecosystem to maintain its normal patterns of nutrient cycling and biomass production after being subjected to damage caused by an ecological disturbance.
Green tech	OG	Green tech refers to a type of technology that is considered environmentally friendly based on its production process or its supply chain.
Urbanisation	OU	The population shift from rural to urban areas, the corresponding decrease in the proportion of people living in rural areas, and the ways in which societies adapt to this change.
Migration & semigration	OM	Semigration means movement from one part of a country to another (as opposed to emigration, which is migration to another country).
Social inequality & instability	OQ	**Social inequality** occurs when resources in a given society are distributed unevenly, typically through norms of allocation, that engender specific patterns. **Social instability** can take place in the form of strikes, demonstrations and other types of civil unrest.
Sustainable water use	OW	Using water in a way that meets current, ecological, social, and economic needs without compromising the ability to meet those needs in the future.
Future of work	OF	The world of work is changing. Artificial intelligence and automation will make this shift as significant as the mechanisation in prior generations of agriculture and manufacturing.
Safety & security	OA	Safety and security of communities mean the protection and securing of residents and their property, prevention of anything that may threaten them, investigation of crimes and community participation in efforts to address causes of crime.
Future world of learning	OL	The Future of Learning focuses on the role of learning technologies in both online and face to face learning, the challenges faced and solutions to support learning, and the value that technology brings.
Educational technology	OE	Educational technology is the combined use of computer hardware, software, and educational theory and practice to facilitate learning.
Transport systems	OT	Mobility is supported and driven by transport systems that are composed of infrastructures, modes, and terminals. Some of the technologies that will influence future transportation systems are next generation GPS devices, self-driving vehicles, vehicle-to-vehicle communication, etc.
Human & social dynamics	OH	Human and Social Dynamics aim to increase the ability to anticipate the complex consequences of change; to better understand how human and social behaviour at all levels change over time, including that of the human mind; to better understand the cognitive and social structures that create and define change.

STI domains and thrusts	Code	Description
Rural planning	ON	Rural planning aims to bring about economic development, yet maintain the sustainability of renewable resources and reduce income disparities.
Early childhood development	OY	Early childhood development supports the development of children from birth to age five. It includes programmes and services that support nurturing care including health, nutrition, play, learning and protection. Its interventions address four developmental domains of a growing child - physical, cognitive, linguistic and socio-emotional development.
Climate & society	OS	Climate change is projected to increase the frequency and intensity of extreme weather events, such as heat waves, droughts, and floods. These changes are likely to increase losses to property and crops, and cause costly disruptions to society.
Service for economic development	OO	Economic development can be described as a program, set of policies, or activities that seek to build capacity for self-sustaining, long-term economic growth.
Indigenous knowledge systems	OK	Indigenous Knowledge Systems (IKS) comprises of knowledge developed within indigenous societies, independent of, and prior to, the advent of the modern scientific knowledge system (MSKS).
Creative industry	OV	The creative industries are innovation led, knowledge intensive and highly exportable, and make a larger contribution to GDP than a number of traditional industry groups.
Geopolitical		
Globalisation	GG	Globalisation helps spread knowledge and technology across borders.
Future warfare	GW	Rapid advances in unmanned systems, robotics, data processing, autonomy, networking, and other enabling technologies have the potential to spur an entirely new warfighting regime.
National security	GN	Information technology plays a significant role and will continue to strengthen the national security against future upcoming threats and cyber-attacks. Particularly, information technology can help countries to identify potential threats, share information easily, and protect mechanisms in them.
Transboundary aspects of water	GT	Some of the emerging technologies that can be used for transboundary water governance include: 1. In-situ, real-time water monitoring technologies 2. Water related indices 3. Earth Observation (EO) remote sensing technologies 4. Communication and network technologies
Governance & eGovernance	GE	eGovernance is the use of ICT in transforming and supporting functions and structures of the governance systems.
Free trade	GF	The African Union High Level Panel on Innovation and Emerging Technologies (APET)[3] is encouraging African Member States to establish and install enabling infrastructural and policy frameworks that will support the effective harnessing and utilisation of innovation and emerging technologies towards accomplishing the management and execution of The African Continental Free Trade Area (AfCFTA)[4]

[3] African Union High Level Panel on Innovation and Emerging Technologies https://www.nepad.org/microsite/african-union-high-level-panel-emerging-technologies-apet, [accessed 1 July 2022].

[4] African Union Continental Free Trade Area, https://au.int/en/ti/cfta/about , [accessed 1 July 2022].

STI domains and thrusts	Code	Description
Border control	GB	In the coming years, emerging technologies will fundamentally change border management, creating huge opportunities for industry transformation.
Tourism & Hospitality		
Robotics in hospitality	TR	Robots can play several roles in hotels, guest houses and lodges, from cleaning rooms, delivering of meals (and other essentials) and staffing the front desk.
ICT in tourism	TI	IT enabled tourism has different aspects such as direct booking, easy payment for the end users, business to business trading for product providers, travel agents and resellers, utilising eCommerce platforms.
Hotel of the future	TH	Technology innovations, changing customer demands, and new competitive threats are pushing hotels to offer increasingly personal, uniquely tailored experiences for every guest on every visit.
GIS applications in tourism	TG	The integration of tourism data and GIS data is a big challenge for the tourism industry. GIS technology offers great opportunities for the development of modern tourism applications using maps.
Virtual tourism	TV	ICT-based technologies that use digital images and sensory feedback to simulate tourist attractions available at remote destinations.
Sustainable tourism	TS	Tourism that takes full account of its current and future economic, social and environmental impacts, addressing the needs of visitors, the industry, the environment and host communities.
Green buildings	TB	Designed for the proximity of the built environment to nature, blending in with the surroundings to enhance wildlife and habitat experiences.
Drones in tourism	TD	Focusing on logistics such as food and goods delivery as well as emergency services on remote tourism spots and islands.

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