SCIENCE, TECHNOLOGY AND INNOVATION POLICY DESIGN AND IMPLEMENTATION GUIDE

TOWARDS A FRAMEWORK

A.22-00918

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Preface

Effective science, technology and innovation (STI) policies are indispensable in enabling all key stakeholders and science and technology to contribute to development. The Addis Ababa Action Agenda of the Third International Conference on Financing for Development underlined the importance of STI policies at the national level to enable STI to serve as a driver and enabler for meeting the 2030 Agenda for Sustainable Development. Similarly, in the Science, Technology and Innovation Strategy for Africa 2024, which is part of the collection of measures for the first phase of implementing Agenda 2063: The Africa We Want, of the African Union, STI policymaking is prioritized as one of the four pillars.

What constitutes effective STI policy, however, remains a subject of research and debate. This guide has been designed to help countries to appreciate the processes and key elements that may improve the effectiveness of national or sectoral STI-related policies. The guide also provides numerous examples that may be helpful in the design, implementation, monitoring and evaluation of STI policies. While the guide focuses on STI, it can be useful when planning any policy area or subject.

The guide also provides good examples and numerous tools, as well as main questions, methodologies and case studies that can help to anchor the process of policy design and implementation. The annex highlights some of the policymaking experiences of Ghana and the United Republic of Tanzania, as well as the various steps and processes that the countries use and potential outcomes.

Acknowledgements

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Asfaw Yitna and Gedion Workneh of the Technology and Innovation Section of the Economic Commission for Africa provided research support. Hidat Mebratu and Rahel Menda, administrative assistants to the Director of the Technology, Climate Change and Natural Resource Management Division, provided logistical and administrative support. The report was edited and printed by the Publications and Conference Management Section.

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Executive summary

The purpose of this document is to provide guidance to science, technology and innovation (STI) policymakers. It is not intended to be prescriptive. Rather, it introduces the reader to concepts, tools and examples of aspects that it would be helpful to consider when developing STI policy. It also provides some generally agreed principles on how best to develop STI policy in a way that can be implemented and can achieve the desired outcomes and impact. It is suggested that its sustainable success requires the development of a governance and organizational structure that provides continuity, with ongoing analysis informed by ongoing monitoring and evaluation. This governance and organizational infrastructure will be country- and region-specific and will depend on many factors, including each country or region's history and culture; level of political, social, economic and technological development; and nature of its political and economic system (liberal, centralized or mixed).

I. Context

STI policies are not developed in a vacuum. They are developed within the global and regional political and economic context of national development, and it has been consistently demonstrated that appropriate investment in STI can have a positive impact on development. The drive to improve governance, including within the context of the Sustainable Development Goals, has led to a growing interest in good policymaking for development. This guide seeks to combine learning from these two elements and apply them to STI as an integral and fully aligned component of national development.

Historical evidence suggests that there are three main phases of STI development, which correlate with similar phases of economic development. The first is the pre-industrial phase, in which local science and technology capacity needs to be built at the institutional level. During the second phase, termed the catch-up phase, local industry tries to absorb, adapt and utilize existing technologies. During this second phase, gross domestic product growth tends to outpace that of more developed countries, allowing their incomes to "catch up". Most African countries are in these first two phases, with central Government playing a strong role in coordinating STI policy and market systems still weak. The final stage is the emergence of economies. In this stage, investment is prioritized towards frontier technologies to maintain global competitiveness and there is a renewed emphasis on basic research. Traditionally, STI policy has focused on an innovation system centred on industrial growth. In recent decades, however, STI has often been extended to incorporate transformative social change, such as changes aligned with the Sustainable Development Goals.

STI, by its nature, cuts across all sectors and almost all aspects of social and economic development. A country's STI policy therefore needs to be integrated into, and coherent with, many aspects of government policy. For instance, it must be consistent with the overarching development framework and plan for the country's social and economic development. It also requires engagement with many stakeholders. STI interacts with many sectors, including associated ministries and their policies, ranging from macroeconomic policy to education, trade, health, agriculture and environmental policy. In all three areas of STI, the innovation process is interactive and iterative, involving many disciplines and players with numerous internal interfaces. Engagement is necessary with academic science institutions, professional bodies such as engineers, and other types of professionals, businesses, industries and regulatory agencies. These external and internal interfaces are often encapsulated in the literature by

reference to a triple helix of interaction between the Government, the business sector and the higher-education sector, or a quadruple helix that also incorporates civil society.

The coronavirus disease (COVID-19) pandemic has shown the interconnectedness of STI with government policy and many stakeholders across the political and economic spheres. This interconnectedness includes the basic scientific research required to inform policy on lockdowns, the repurposing of many companies to address the need for new and expanded equipment and materials, and the engagement of the pharmaceutical industry in the development of new diagnostics tests, treatments and, most significantly, vaccines in record time. The vaccine development effort has required a strong public-private interface and dialogue combined with appropriate government policies, notably pre-purchase commitments to generate the necessary private sector investment in STI.

A final contextualization of STI policy development revolves around the issues of prioritization and opportunity. Aligned with national development policy, STI policy determines where public resources are directed and which sectors are promoted and supported politically and financially. As well as determining the content of a portfolio of prioritized policy-related activities, creating STI policies provides an opportunity to think outside the box and to think big about a country's future. This can lead to radical changes. China, for example, restructured its university system, while Morocco took the innovative and daring decision to become an aeronautics and space hub, thus attracting foreign investment in manufacturing, generating substantial export earnings and creating many professional jobs. Several tools are available to support such prioritization processes. It is important that such processes and outcomes are adapted to the specific needs and comparative advantages of the country concerned and are not merely a copy, or an attempted copy, of the priorities set by other countries.

II. Steps in the development of science, technology and innovation policy

There is no single, optimal way of developing STI policy. The process depends on many factors, such as the nature and culture of the country, its level of development, and its social, political and economic systems. The purpose of this document is therefore to act as a guide and to outline issues worthy of consideration when policy is developed; it is not intended to be overly prescriptive about the process.

Based on an analysis of several institutional approaches to policy development, six generic steps are outlined to guide the STI policy process, namely:

(a) Agenda-setting;

(b) Policy analysis;

(c) Policy formulation;

(d) Policy adoption;

(e) Policy implementation;

(f) Policy evaluation.

These six steps form a cyclical process whereby policy evaluation feeds into ongoing and future policy development and individual elements may iteratively feed back to inform the

process. For example, when the policy is formulated (step 3), it may become necessary to revisit or extend aspects of policy analysis (step 2) or even the primary setting of the policy agenda (step 1).

Establishing an appropriate governance structure for the policy process is critical. There are two levels of governance related to STI policy development. The first level concerns the actual process of developing the policy and may be the only level attained if a policy is being developed for the first time or has so far been viewed by the Government as a periodic and intermittent stand-alone exercise. It is advised that a high-level steering committee, or commission, be established under a very high-level authority, with subsidiary task teams established around priority areas to undertake the detailed work. It is critical that such teams should incorporate technical experts, professionals who will have to implement the policy, and representatives of constituencies that will be affected by the policy. The second level of governance can incorporate the first level. It is associated with the establishment of institutional infrastructure, such as a dedicated national agency with a secretariat, to continuously monitor and evaluate performance in STI against the background of a policy framework. This approach provides continuity so that the cyclical policy process can better produce coherent and sustainable outputs.

Stakeholder mapping and analysis can inform the composition of the committee and teams and can ensure that all sectors, disciplines and constituencies affected by the policy are consulted. This is important, not only to produce a strong technical document, but also to ensure political buy-in of the policy as an end product as progress is made through the six-phase cycle.

A. Agenda-setting

Agenda-setting can be defined as identifying the correct issues and questions to be addressed. Albert Einstein once said, “If I were given one hour to save the planet, I would spend 59 minutes defining the problem and one minute resolving it.” The output from the agenda-setting exercise could be a problem statement stating what the desired outcomes are, what needs to be achieved to deliver them and how such achievements will be measured. Such statements can be developed both at the top strategic level, to cover the whole policy framework, and at sublevels around specific areas of proposed activity. An established governance infrastructure with a dedicated secretariat that continuously monitors STI output and outcomes and carries out appropriate policy research, in collaboration with a broad academic and stakeholder base, can greatly assist in this critical stage of the process.

B. Policy analysis

Policy analysis is driven by data to inform evidence-based policy. Existing data can be used to evaluate the performance outcomes of previous policies and thus inform future policy. New data, however, may need to be generated to inform policy development, such as through surveys. It can be particularly helpful to develop capacities to undertake community innovation surveys as a tool for innovation assessment. Foresight analysis can also be useful, since STI policy, perhaps more than any other policy area, must be forward-looking, given the continuous changes brought about by new technologies. A range of potential policy actions are documented and available to support STI across a range of categories. Appropriate analysis, for example based on past country experiences, may inform which of these is most appropriate within a national context.

Owing to limited resources and operational imperatives, prioritization is necessary and difficult decisions often need to be made. These decisions may be based on technical or political economy issues and will depend on the political philosophy and culture of the country and its developmental status. Some countries may prefer a centralized approach; others, an economic laissez-faire approach. The approach taken may inform whether financial tools focus on the supply side or the demand side of financing. The centralized approach, which may be required in countries with weak STI systems and weak market systems, may involve selecting specific institutions, technologies and sectors for support. Decisions also have to be made on whether national investment will be geared towards longer-term institutional development or shorter-term, business-led return on investment. There are several methodological approaches to prioritization (such as the Delphi approach), some more demanding than others in terms of the time and effort required. All approaches, however, need to be informed by data and opinion, especially cost-benefit analysis. Furthermore, it is vital that STI priorities be aligned and coherent with the national development agenda.

According to one commentator, the "first-order" issue behind the success of Singapore was a pragmatic action-oriented approach, which identifies the problem, formulates the policy solution and sees it through with political will. A critical lesson that can be learned from the process in Singapore is to leave some "white space" budget available to foster and support any specific new ideas and initiatives that arise during the policy period. In the European Union, smart specialization strategies were developed to foster entrepreneurial discovery, "an inclusive, evidence-based process of stakeholder engagement that produces information about the potential for new activities, thus enabling effective targeting of research and innovation policy". Once again, grants are used to encourage industry, academia and civil society to work together on new approaches that can lead to entrepreneurial innovation.

C. Policy formulation

Consensus is required when a policy is formulated to give the policy a strong chance of being adopted and implemented. During this phase, an implementation plan, an associated monitoring and evaluation framework and a budget should be prepared. The implementation plan should clearly state the desired outcomes, identify key activities, actions and milestones, specify what resources will be needed and how they will be obtained, and state which officers and institutions will undertake each task. The policy and its associated implementation plan will operate at several levels. The top level of a formulated policy and accompanying implementation plan is broad, while lower levels are increasingly more specific. An important feature of any implementation plan is a communications strategy to keep stakeholders well informed during the development and implementation stages. The steering committee and task force teams must be high level and they must be appointed by a high level, such as by presidential appointment, to ensure that financial and human resources are assigned to the policy's implementation.

D. Policy adoption

Policy may have to go through various stages before it receives ministerial or presidential approval and is thereby legally adopted. For example, it may have to go through various technical committees. A national policy is often presented as a guide, rather than as law, making it non-binding, which leads to a lack of commitment to its implementation. Thus, for some aspects of the policy, or indeed for the policy as a whole, it may be worth introducing parliamentary legislation. Whichever route is taken for policy adoption, it is critical that key

political stakeholders, as well as technical stakeholders, have been adequately consulted and briefed about the policy through a wide-ranging consultative process. If critical groups have been ignored in the process, there are many points in the policy adoption process at which opponents may delay or hinder the policy, or even cause it to be rejected. For policy to be adopted, the process that it undergoes can be just as important as its content.

E. Policy implementation

Policy implementation represents the value of a policy. Policy only has value if it is implemented. However, the implementation of a complex, multisectoral, multi-stakeholder package is not straightforward. The quality of the implementation plan and the associated monitoring and evaluation framework are crucial to the policy's success and must incorporate the capacity for learning, adaptation and change throughout the implementation process. Many issues may lead to a need for a change in direction in the implementation of the policy. Such issues range from minor operational miscalculations to major events such as financial and other crises, technological changes, or a recognition that certain critical assumptions were wrong. Successful implementation of policy, including any necessary adaptation, requires a solid governance structure that facilitates good coordination of actions and clearly assigns responsibilities for activities and the availability of adequate resources. This assignment may be to certain ministries or institutions, but within these institutions key persons with personal responsibility for specific actions need to be identified. The structure of the steering committee and task team used to develop the strategy can provide a solid foundation for the development of an appropriate implementation structure that defines authority and accountability. Policy activities, overall policy progress and policy impact must all be monitored and assessed continuously.

F. Policy evaluation

This is the final component of the policy cycle and serves to bridge consecutive policies, enabling policy developers and implementers to learn from previous policies. Although evaluation is situated at the end of the cycle, it is important for it to be part of a continuum of monitoring and evaluation throughout the cycle so that policy content is evaluated continuously, from the agenda-setting stage until policy adoption. Following adoption, policy is implemented and its impact is then evaluated. The combined learning generated from this process continuously feeds into existing policy implementation and facilitates future policy development. The monitoring and evaluation framework developed as part of the implementation plan can form the basis of policy evaluation and may incorporate a scoreboard approach to facilitate top-level impact assessment. With careful planning, data can be collected throughout the policy implementation phase to inform a rigorous ex-post (after the policy) evaluation. This may incorporate many types of methodologies, depending on the specific issues under evaluation. It is critical for this continuous approach to be integrated into the governance structure of the policy, with regular policy reviews and evaluation meetings of varying intensity taking place throughout the life of the policy. These meetings should be based around the data collected. They may culminate in the commissioning of an independent terminal review of the policy to obtain a rigorous, fully objective assessment.

III. Concluding remarks

It is hoped that this guide, and its accompanying references, will prove useful to those planning to initiate and coordinate the establishment of a national STI policy and to participants in the development of a policy. The six-phase cycle guides readers through the process and provides options on how to proceed. However, the guide is not intended to be overly prescriptive about how the policy should be developed. Each country has unique traits in terms of its character, processes and STI needs, and these traits will dictate how the process is carried out and what is ultimately contained in the policy.

STI policies need to be monitored and updated regularly because of the continuously changing technological environment. The quality of data used in policy development, implementation and evaluation is critical. A formal, ongoing and regular evaluation process is critical for the implementation of current policy and the iterative development of future policies. This evaluation process requires a high-quality implementation plan and a monitoring and evaluation framework. Stakeholder mapping, analysis and engagement are crucial for all aspects of policy-cycle management. It is crucial to have a strong governance structure with high-level authority that includes those responsible for implementing the policy and those who are affected by it. The policy process can be further strengthened if it is supported by a sustainable institutional governance structure with a dedicated secretariat to oversee and support the policy cycle. Lastly, national policy is, by nature, a political and economic construct and must reflect the political situation in the country for it to be coherent with national development policy.

To help contextualize the framework, two case studies of African policymaking approaches to STI are provided, one from the United Republic of Tanzania and one from Ghana. These case studies highlight similarities between the approach in the framework guide contained in this document and national approaches to policymaking. They also highlight historical gaps in STI policymaking in many countries, including insufficient cross-government coordination, an overemphasis on research and development rather than innovation, a lack of prioritization, the absence of an agreed implementation plan and the accompanying shortage of resource allocation and mobilization, and limited monitoring and evaluation.

1. Context

1.1 International environment

Countries will need to put in place measures to nurture and harness science, technology and innovation (STI) if the long-term development vision and goals of the African Union (African Union, 2015a) are to be achieved, namely the 2030 Agenda for Sustainable Development (United Nations, 2015a) and Agenda 2063: The Africa We Want, of the African Union (African Union, 2015). This was explicitly spelled out in the Addis Ababa Action Agenda of the Third International Conference on Financing for Development, in which countries resolved to "adopt science, technology and innovation strategies as integral elements of [their] national sustainable development strategies to help to strengthen knowledge-sharing and collaboration" (United Nations, 2015b, para. 119).

This concept has been further integrated into the 2030 Agenda through the *Guidebook for the Preparation of Science, Technology, and Innovation (STI) for SDGs Roadmaps* (United Nations inter-agency task team on science, technology and innovation for the Sustainable Development Goals, 2020; Matusiak and others, 2020). Agenda 2063 similarly underscores the importance of African countries investing in and using STI for development. It is hoped that such efforts will help Africa to obtain "the means and resources to drive its own development [with] well educated and skilled citizens, underpinned by science, technology and innovation for a knowledge society" (African Union, 2015).

The African Union has further endorsed the Science, Technology and Innovation Strategy for Africa 2024 (African Union, 2014), which can support Agenda 2063. STI policies are thus seen as key instruments for driving inclusive and sustainable development.

African countries face two major challenges as they seek to use STI to drive further social and economic development. The first is the generally low baseline for STI-related activity, especially in sub-Saharan Africa (United Nations Educational, Scientific and Cultural Organization, 2017; Cornell University, INSEAD and World Intellectual Property Organization, 2020, p. 19, box 3). The second is that there are great disparities among countries across Africa in terms of economic development and STI (United Nations Educational, Scientific and Cultural Organization, 2017; Cornell University, INSEAD and World Intellectual Property Organization, 2020, p. 31, figure 1.11; African Union Development Agency, 2019). Some middle-income countries perform well and have established quite sophisticated innovation systems, notably Egypt and South Africa, while many low-income countries have extremely poor systems. A significant number of countries are unable even to provide adequate data for international assessment. This disparity in levels of sophistication among national innovation systems needs to be considered when regional policy frameworks are developed.

Nevertheless, there are some promising developments in STI across the continent. According to the Global Innovation Index for 2020, 10 countries in Africa overperformed on innovation for their gross domestic product (GDP) level. The report labels these countries as "innovation achievers" (Cornell University, INSEAD and World Intellectual Property Organization, 2020, p. 22, table 1.3). Sub-Saharan Africa is the region with the largest number of innovation achievers.

In parallel with generic interest in the development of STI in Africa, growing emphasis is being placed on better policy development processes and there is a drive for better governance. A good introduction to sound policymaking, with an emphasis on Africa, is available in a two-hour video recording of an online workshop organized by the United Nations Department of Economic and Social Affairs in February 2021.[1] The report on a United Nations workshop on policy formulation and acceleration of the Sustainable Development Goals, on the theme of improving service delivery through effective policymaking for STI, is also useful (United Nations, 2021).

1.2 Historical perspectives on innovation and development can inform top-level policy decisions

The incorporation of the Science, Technology and Innovation Strategy for Africa 2024 coincides with increased recognition globally that the broader developmental context needs to be taken into consideration when national and regional STI strategies are developed.

Building on the work of Porter (1990) (López-Claros and Mata, 2010), the World Economic Forum classifies three phases of economic development (Global Entrepreneurship Research Association, 2017, p. 13). The first phase is "factor-driven" and is dominated by the availability of resources. The second phase is efficiency-driven, or investment-driven, and is based on the development of higher-efficiency production processes and improved product quality. The third phase is the innovation-driven phase, where businesses are more knowledge-intensive and there is a larger services sector. Most African economies are at stage 1 of this process, with some moving into stage two. None is yet in stage three. According to the Global Entrepreneurship Research Association (2017), Egypt, Morocco and South Africa were phase 2 countries in 2017.

1.2.1 Three stages of innovation linked to social and economic development

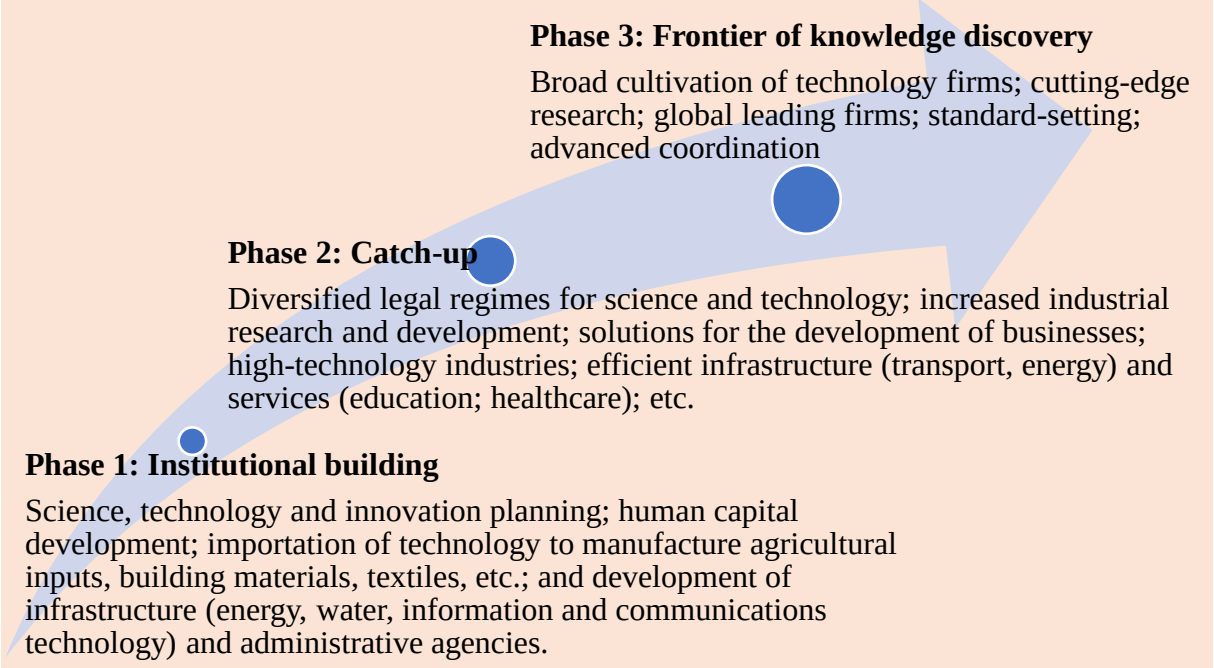
The literature on innovation and its alignment with economic development is extensive and is largely based on the work of Gerschenkron (1962) and Abramowitz (1986), who viewed economic development as a "catching-up" process, including the need to "catch up" technologically. Work on intercountry differences in technology and development reinforced this theory. This led to the identification of innovation-derived indicators that significantly correlated with economic development (Fagerberg and Godinho, 2005; Fagerberg and Srholec, 2008) and the creation of composite indices that could provide a measure of innovation capacity (López-Claros and Mata, 2010; Dutta, 2011; European Union, 2020).

In addition to the three-phase development process outlined by the World Economic Forum, a three-phase technological development process has also been identified (see figure I). The latter involves countries moving from a pre-industrial situation to a "catch-up" phase, and then to the frontier of innovation and economic development. Historic analysis (Fagerberg and Godinho, 2005; United Nations, Economic and Social Commission for Asia and the Pacific, 2018; Verspagen and Kaltenberg, 2015) indicates that the activities required to enable a country to move from the pre-industrial phase to the "catch-up" phase involve acquiring innovation capabilities in readiness for delivering innovation. This capability development

[1] The online workshop on "Sound policymaking for sustainable development" is available at www.youtube.com/watch?v=QpHxb86rn8Q.

incorporates institutional development and the creation of an enabling environment for innovation and associated economic activity, including the ability to import, absorb, adopt and adapt outside technologies for local use. This leads to the development of local businesses and brings about economic growth. The pre-industrial phase also includes making it easier to do business and strategically deciding which industries or sectors should be the focus for planned growth. During the catch-up phase, investment in businesses increases and businesses are invited to become more directly involved in research and development, either alone or in collaboration with academia. This builds on the public sector capabilities already developed during the pre-industrial phase. During the catch-up phase, there is a substantive and sustained increase in GDP growth. Finally, as the country moves from the catch-up phase to the innovative phase of development, a continued and sustained increase in research and development is needed, especially for "frontier" technologies, where a market leadership position can be developed and maintained.

Figure I
Innovation and developmental catch-up: the journey from pre-industrial to catch-up to frontier status



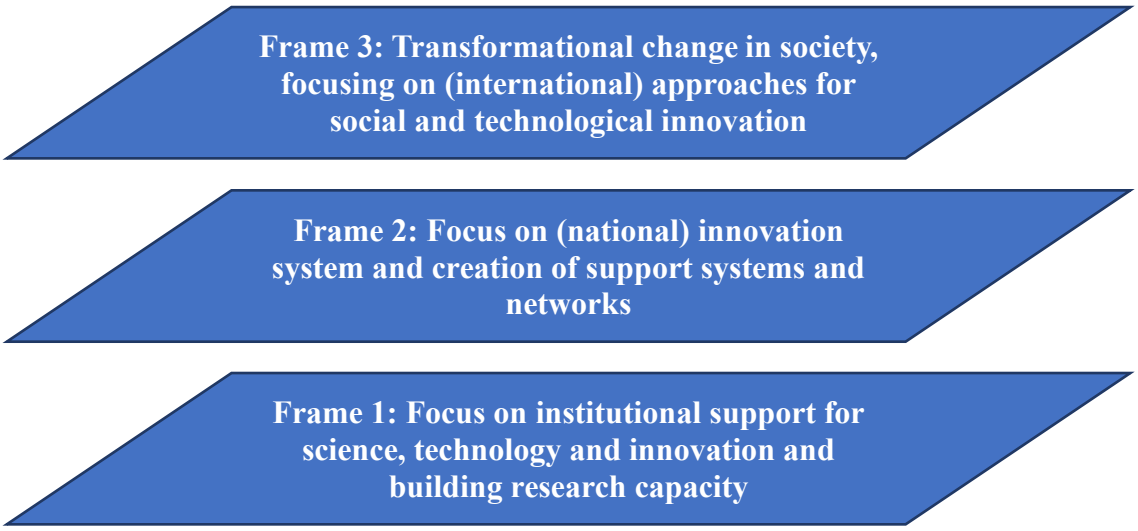
Identifying at what stage of economic and technological development a country is at may inform the types of activities required to move the country to the next phase of development.

1.2.2 Three frames for policy development, incorporating social innovation

Schot and Steinmueller (2018) outlined three frames of innovation policy developed in Western economies since the Second World War, which to some extent mirror the three phases of technology development outlined in figure II. Frame 1 reflects institutionalized government support for science and technology and associated research and development. Frame 2 represents an extension of this support to develop national innovation systems through supportive networks and laws linking innovation to entrepreneurship. Frame 3 is a more recent

development that links STI to transformative social change and is viewed within the context of emerging global needs, as set out in the Sustainable Development Goals, and the urgent need to address global warming through mitigation and adaptation. This development recognizes cutting-edge social innovation and technical innovation and acknowledges that developing countries may be able to leapfrog or bypass some technologies as they develop their STI capacity. Within the African context, this perspective may usefully be applied to Agenda 2063 and national societal aspirations for development.

Figure II
Three frames for viewing STI policy



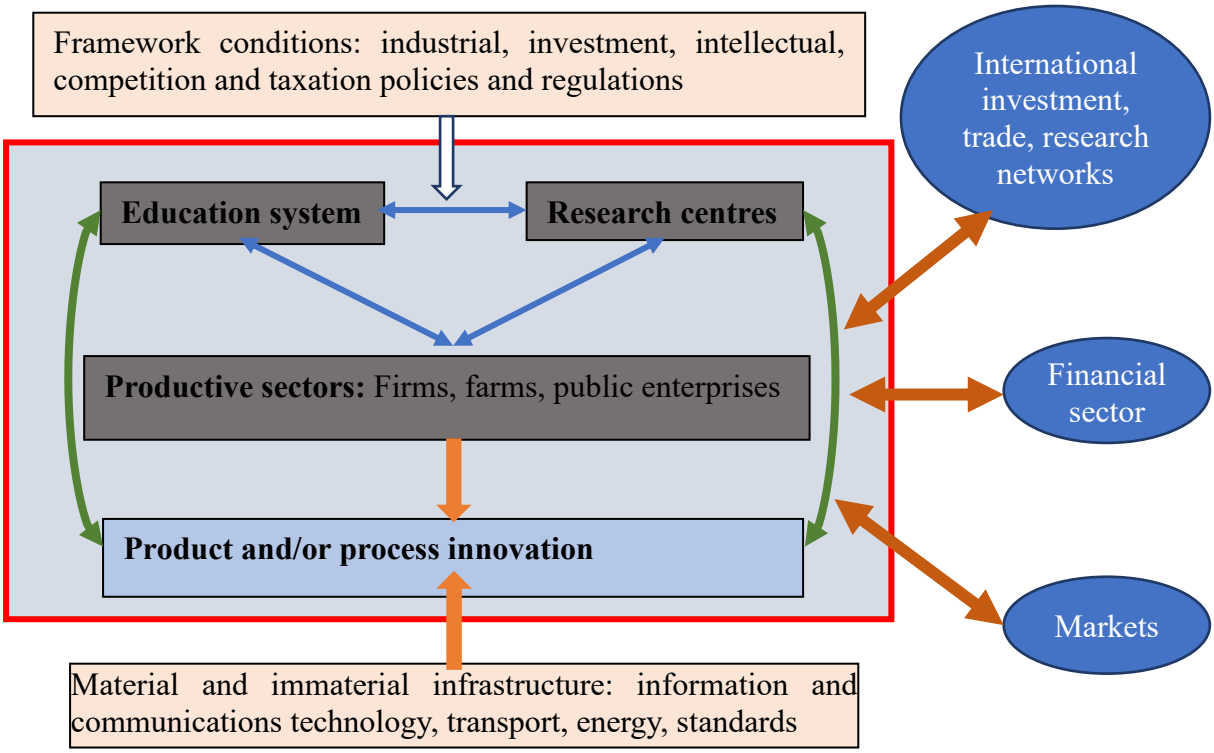
Note: Conceptualized from Schot and Steinmueller (2018).

These frames may serve to help orient policymakers and assist them in their prioritization. How policymakers view a country's immediate needs will largely depend on its level of economic, educational and business development. For example, a frame-1 perspective would focus on a straightforward process of providing financial support, such as through science and technology funds, levies, grants, loans or tax incentives to stimulate investment in research and development activity by the public sector, education centres and businesses. Frame 2 would not only provide resources, but would also enhance connectivity among sectors, such as by linking academic institutions and firms with each other, with the focus still on industrial output and economic growth. Frame 3 would shift the emphasis from the promotion of industrial and economic output to social development and well-being.

Frame 2 focuses on the establishment of a national innovation system to support, direct and generate innovation, primarily through firms and industrial enterprises. The concept of viewing innovation through a "systems" approach can be useful. A simplistic representation of a national innovation system and its various interfaces is shown in figure III, which is adapted from the approach of the United Nations Conference on Trade and Development to developing national STI policies and strategies (United Nations Conference on Trade and Development, 2011a, 2017). A frame-3 approach emphasizes social solutions as well as industrial output. For instance, Serbia has used a United Nations guide on how STI strategies can support the achievement of the Sustainable Development Goals with a focus on social and industrial outputs (United Nations inter-agency task team on science, technology and innovation for the

Sustainable Development Goals, 2020). In this approach, social, economic and environmental systems interact and collectively benefit from the STI policy.

Figure III
Elements of a national system for innovation, representing a frame-2 approach



Source: United Nations Conference on Trade and Development, 2011.

The decision on whether to take the more traditional "industrialization" approach to determining policy objectives or a more societal approach is important. Any STI policy is likely to incorporate elements from both approaches, both of which are, to some extent, manifestations of what scientists, technologists, innovators, inventors and entrepreneurs have understood over the ages. The first frame, or phase, acknowledges the benefits of sponsorship and support for science, whether from the private sector, philanthropists or the public sector. Examples of such sponsorship and support date back to Galileo, Charles Darwin's voyage on HMS *Beagle* and the work of Louis Pasteur. Similarly, the second frame builds on the creation of centres of excellence where scholars congregate and share ideas. Such initiatives date back to the creation of academies by Plato, the development of universities and the Renaissance and their impact on business, trade and, ultimately, industrial development. Frame three acknowledges that STI has always had a societal impact, whether through new concepts such as those of Isaac Newton and Albert Einstein, or new technologies such as those of the first, second, third and now fourth industrial revolutions (Schwab, 2017) and the increasing environmental impact of technological and social change.

1.3 Cross-cutting nature of science, technology and innovation policy: the need for policy coherence

STI, by its very nature, cuts across all sectors and almost all aspects of social and economic development. STI policy therefore needs to be integrated into, and coherent with, many aspects of government policy. In particular, it must be consistent with the overarching development framework and plan for the country's social and economic development. An important concept that helps to describe the cross-cutting nature of STI and its application to policy is the concept of the triple helix (Ranga and Etzkowitz, 2013), which highlights the critical interface between government, universities and industry for achieving innovation. More recently, the concept has been expanded to that of a quadruple helix, which also incorporates civil society (Leydesdorff, 2012). This section contains an overview of the interfaces that affect STI policy and the critical decisions associated with policy development and prioritization, with coronavirus disease (COVID-19) provided as an example of the need for an integrated approach to STI challenges across numerous sectors and disciplines. The need for extensive stakeholder engagement is highlighted.

1.3.1 External interfaces affecting STI policy

STI policies aim to improve the contribution of STI processes and activities to economic and social development (United Nations Conference on Trade and Development, 2017). Box 1 is an overview of policies that may need to be considered as contributors to STI policy and that may also need to be aligned with, and responsive to, STI policy. These policies provide STI policy interfaces that need to be well understood and well managed. For instance, foreign direct investment, trade, industry, entrepreneurship, education, health, and labour policies, among others, collectively create an environment that may facilitate, promote or hinder STI development through their effect on research and development, technology upgrading in businesses, investment in start-ups and innovation in businesses. If managed and developed appropriately, STI could attract foreign direct investment, drive trade and industrial development and create jobs and wealth.

Box 1
Examples of policies that contribute to and are affected by science, technology and innovation

- ✓ National development strategies
- ✓ Macroeconomic policy – tax and fiscal policies
- ✓ Digital economy strategies
- ✓ Industrial policy
- ✓ Energy policy
- ✓ Competition policy
- ✓ Education policy
- ✓ Environmental policy
- ✓ Trade policy
- ✓ Labour policy
- ✓ Policy on specific technologies (information and communications technology, biotechnology, nanotechnology, etc.)
- ✓ Investment policy
- ✓ Intellectual property policy
- ✓ Health policy
- ✓ Agricultural policy

STI policy design, therefore, cannot be limited to a single ministry or agency that is nominally responsible for housing and nurturing the science, technology and innovation portfolio. A good understanding of trends, developments, challenges and opportunities in other key sectors is required to direct STI development. Appropriate analysis may identify projects and sectors where STI investment can add value to market and developmental goals. Such analysis may also identify areas of synergy where STI can contribute to the sector and develop generic capacity in STI that is of value to the country.

For instance, a cross-cutting and formative STI strategy may be needed in a country that is seeking to grow its energy industry by developing efficient turbines (wind or hydro), alternative solar cells, energy-harvesting and scavenging devices, high-density energy-storage batteries and the growth of energy-related start-ups. Such a strategy would be affected by policies linked to the following areas:

(a) Energy policy (e.g. alternative energy sources, green energy solutions and independent power producers);

(b) Industrial policy (e.g. incentives for industry research and development and technology imports);

(c) Water and land-use policy (e.g. the roles of regulatory agencies and the length of time required to obtain approvals);

(d) Education (e.g. the availability of institutions to mobilize skilled workers and provide research support for the energy sector);

(e) Finance (e.g. interest rates, exchange rates, tax concessions and digital financial inclusion);

(f) Trade (e.g. ease of access to, and levels of priority given to, the import and export of physical equipment and knowledge products).

These issues could all have an impact on science, technology and innovation performance in general and the ability of STI to feed into the overarching objectives of the national energy strategy.

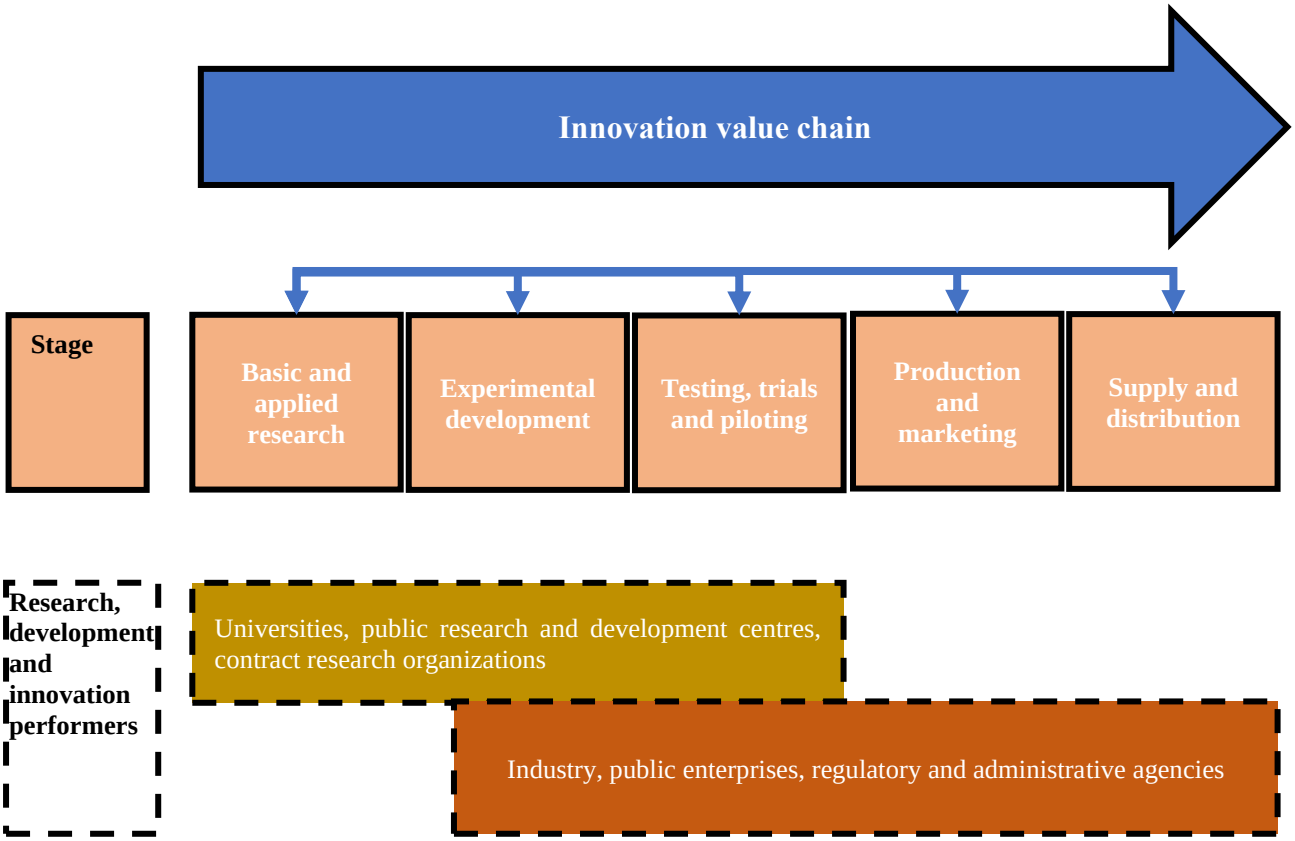
The immediate impact of such complexity in STI policy formation is the need for a well-coordinated policy process that incorporates a very broad and interactive analysis and consultation process involving many sectors and areas of expertise. The final policy must be consistent with national priorities and other sectoral policies. The high level of complexity also means that STI efforts must prioritize certain areas so that limited resources can be allocated effectively to deliver a meaningful outcome. Prioritization is especially important for low-income countries with limited resources, since they will not be able to develop STI for all areas of specialization and business development. Trade-offs will be necessary in the development of STI to support areas such as energy production; agricultural business investment; health innovation; access to water; mineral exploration, mining and exploitation of natural resources; and environmental management, the development of information and communications technology, and the fourth industrial revolution.

1.3.2 Internal interfaces affecting science, technology and innovation policy

Another aspect that adds to the complexity of the context and nature of STI policy is that it consists of three distinct areas: science, technology and innovation. Each of these areas has a distinct set of professional and technical communities, and each community has been trained in its own disciplines and spheres of experience, has its own internal and external stakeholders, uses its own financing mechanisms and financiers, and has its own culture, attitudes and mindsets. These communities increasingly need to interact with and incorporate entrepreneurship, leading to technopreneurship[2] and creating a generation of technopreneurs. Figure IV shows a summary of how the innovation value chain works through a range of different stages and processes and the roles that different entities play at different stages. It also illustrates the iterative nature of the innovation process, with various feedback loops. These feedback loops require effective interfaces and interaction platforms between the various entities involved, from academic institutions and the informal sector to development partners, the business sector and government.

[2] For additional information on technopreneurship, see https://101entrepreneurship.org/technopreneurship/.

Figure IV
A multisectoral and iterative innovation process



STI policy therefore needs to integrate three aspects. The first is the science component, which is generally concerned with the conduct and productivity of science and research systems. The overall goal of this component is to advance scientific excellence, and it is predominantly associated with academia, especially in low-income countries. Indicators to measure and assess the component in a country include the number of researchers, the number of research institutes and specialized research laboratories, the level of expenditure on research, and the peer-reviewed, indexed scientific publications that exist.

The second component is technology, which is predominantly concerned with the production, acquisition, transfer, adaptation and diffusion of new technologies and their application, such as appropriate technologies. This aspect is primarily associated with industry, but may also be linked to the informal sector and the public sector. It may, for example, involve engineers or other professional practitioners, such as health professionals and agriculturalists. The component can be measured and assessed, for example, through the volume of medium- and high-technology imports and exports, the number of utility models and patents published, and the number of fabrication labs, or fab labs, established.

The third component is innovation, the end goal of which is the effective and efficient application of existing and emerging knowledge or technologies to bring into use new and improved products (including services) and processes, or combinations thereof (Organisation for Economic Co-operation and Development and Eurostat, 2018), whether through market or non-market mechanisms. Innovation interacts substantially with entrepreneurship and business development in general. Indicators of innovation include the number of trademarks,

geographical indicators, copyrights and copylefts that are issued and the number of innovation hubs, innovation garages and innovation spaces that are established.

The roles and needs of the different communities associated with STI should be kept in mind. Academia and academic-related institutions (research and development centres, science foundations, professional associations, national academies of science, etc.) are predominantly concerned with issues such as funding for research, open access to information and ethical issues associated with research. Industry, industry associations (chambers of commerce) and entrepreneurs are interested in the ease of doing business and access to capital investment, plus regulatory standards, conformity assessments and fair competition. Governments and associated regulatory agencies are concerned with the overall impact that STI has on society and social and economic development and on ensuring that standards, including public health and safety standards, are met. Policies need to take into account the different roles and perspectives of different stakeholders and to educate them about the entire innovation pathway so that they understand and value each level of contribution. In this way, stakeholders can be encouraged to work together to collectively deliver with innovations that enter the market or public use and benefit the country's social and economic development.

1.3.3 Coronavirus disease – an example of working across interfaces

The recent COVID-19 outbreak and the resulting public health emergency have shown quite vividly how the different STI stakeholders need to interact with each other to respond to national and international needs. These stakeholders include government, academia, industry and civil society. Science has been central to government policy decisions, since it has provided models to estimate and forecast the health and economic impacts of different policy decisions and explained how the virus spreads and what the best preventive measures are. Science has also been fundamental for the development of certain biomedical interventions using medical devices and equipment, in vitro diagnostics, therapies and vaccines. Technology played a central role in immediately saving and protecting lives (ventilators, personal protective equipment, etc.), and it was technology that enabled people to telecommute and work from home. Examples of innovation include the repurposing of factories, library floors and research facilities by many teams to produce new and unique medical supplies and services; the community workers who became detectives in tracking and tracing contacts and who repurposed their activities to provide a range of social support systems; and the traders who identified innovative supply chain mechanisms and, of course, brought new products into use.

Perhaps the most high-profile example of work carried out across STI interfaces to deliver innovation has been the rapid development and roll-out of vaccines. Academic institutions and pharmaceutical companies have worked together to rapidly translate science into the technical manufacture, evaluation, production and distribution of vaccines. Their efforts were supported by huge levels of innovative financing through government policies, such as pre-purchasing commitments. They were also supported by innovative, time-saving protocols introduced by regulatory agencies. Civil society and political pressure groups, including some national Governments, have also highlighted the needs of different risk groups and influenced the prioritization of vaccine delivery to those at risk, both within countries and internationally through initiatives such as the COVID-19 Vaccine Global Access Facility.[3]

[3] For additional information on the Facility, see www.gavi.org/covax-facility.

1.3.4 Prioritization and opportunity in science, technology and innovation policy

From a policymaking perspective, decisions on the provision of resources for STI across numerous sectors and across the three distinct branches of STI (science, technology and innovation) are both complementary and competitive. Resources given to one area automatically limit the support available to another. Given the limited base of technology-intensive industries in many African countries and the low level of STI infrastructure, it is understandable that most African policies are science-heavy, focused not so much on technology and innovation as they are on researchers, research and development facilities and the capacity to conduct scientific activities. As a result, expectations among policymakers may be misplaced, since they may assume that their investment in science will automatically and rapidly enhance national competitiveness through technology and innovation, even though it is unlikely to happen in the short term.

Furthermore, where there is investment in technology through business, trade and industry pathways, the opportunity to engage academic scientists in utilizing that technology to develop home-based expertise is often missed. Such expertise could iteratively service and further develop and adapt the imported technologies for local use, but this is often prevented from happening by the boundaries that exist between technology users in industry and research scientists in academia.

In short, inappropriate prioritization and a lack of connectedness across the three branches of STI can lead to parallel, "silo-based" approaches to STI rather than a coherent and interconnected policy and strategy.

Within the academic community, perhaps more so than in business, there is the added, inherent division into different disciplines, which needs to be addressed. For example, there may be an overall emphasis on science, technology, engineering and mathematics subjects to the exclusion of social sciences, arts and business subjects and the lack of any functional interface between these subjects can be counterproductive. This has led to a move to promote science, technology, engineering, arts and mathematics, with the inclusion of engineering adding creativity and innovative design to the traditional science, technology, engineering and mathematics subjects. Sociology and psychology may not be as high profile as genomics and digital technology, but they are essential to support research and development in areas such as health, robotics and artificial intelligence. Furthermore, social, economic and business systems need to be appreciated if science and technical invention are to be translated into an innovation that is marketed and delivered for sale, for social utilization or for a combination of the two. In addition, mathematical, computing and other technical tools can enable economists, health professionals, climate scientists and businesses to model complex systems. Efforts to strike a balance academically between the "hard" natural sciences, the "soft" social sciences and indeed the "arts" may be needed to ensure a holistic approach to STI policy development.

Some countries may legitimately choose to focus more on science, others more on technology, and others more on innovation, depending on their aspirations, interests and objectives. They may also focus on certain science and technology fields that are needed most at a given time. However, regardless of the priorities set, a sense of strategic balance is critical. For instance, after 1978, China merged several of its universities, or their component units, to create comprehensive universities that were tasked with developing curricula for new and emerging technologies as part of a coherent, overarching system (Devlin, Estevadeordal and

Rodriguez-Clare, 2006). Under this endeavour, 821 universities were focused on science and technology, 242 on finance and economics, 189 on teacher training, 163 on medicine and pharmacy, 81 on agriculture, 79 on the arts, 69 on political science and law, 48 on language and literature, 30 on physical culture, 18 on ethnicity and 18 on forestry. It is important to note that, while science, technology, engineering and mathematics received the lion's share of resources, other fields were not neglected.

Prioritization within national STI policy can also provide space for a country to experiment. There is nothing to stop a developing country from deciding to become a major air traffic hub (e.g. Ethiopia), a health-care hub (e.g. South Africa), an aeronautics and space hub (e.g. Morocco), a creative film and media capital (e.g. Bollywood, in Nigeria) or an information technology hub (e.g. Mauritius). If anything, the tragedy of the STI policies of most developing countries is that Governments do not dare to dream beyond their current stage of development.

Branching out into new areas offers countries the opportunity to develop new skills and knowledge, enter new supply and value chains, tap into emerging global resources (e.g. attract new partners) and distribute their risks. In just one decade, Morocco has established itself as a major hub for the aerospace industry, attracting around 135 equipment manufacturers, exporting $1.2 billion of aeronautical products and creating 13,500 aviation professional jobs, 50 per cent of which are held by women (Chauffour, 2018; Moroccan Investment and Export Development Agency, 2018). New institutes have been built, partners have been attracted and international networks have emerged. That would not have happened if Morocco had focused only on what it already did when it developed its national strategies.

Several tools are available to assist in such prioritization processes. These are explored in section 3.5.5. It is important that such processes and outcomes rely on the specific needs and comparative advantages of the country concerned and do not merely copy, or attempt to copy, what others have prioritized.

1.4 Approaches to policymaking in science, technology and innovation

Given the range of different emphases on the economic and social priorities of countries and given the different levels of social and economic development and STI infrastructure available within countries, it is not surprising that national STI policies come in a vast array of different formats and have a wide range of stated objectives. A recently published comparative table of national STI strategies and plans (Organisation for Economic Co-operation and Development, 2016a) taken from an international STI policy survey by the European Commission and the Organization for Economic Co-operation and Development (OECD) shows some of the common features of national STI strategies, but also some of the differences in policy goals and priorities among OECD countries and key emerging economies.

In Africa, national and subregional policies need to be aligned. To date, however, of the eight regional economic communities, only the Economic Community of West African States, the East African Community and the Southern African Development Community have developed specific STI strategies. At the national level, approximately two thirds of the 54 countries in Africa have STI policies (African Capacity-Building Foundation, 2017). As is the case elsewhere in the world, the nature of these policies varies significantly from one country to another. This is further illustrated by the fact that countries also vary in the extent to which they have developed a monitoring and evaluation framework to assess their policies.

Given the vast variability in national STI policies and their formats and the array of options for policy prioritization, careful thought should be applied when STI policies are being designed. This is particularly the case in a situation where there are significant resource constraints and a policy is being developed against the backdrop of a national and global crisis, such as the financial crisis of 2008 and the COVID-19 crisis. Space for policy experimentation should nevertheless be provided and the lessons learned from such experimentation should be applied. Successful policy implementation also requires the development of targets against which success may be measured. Careful preparation of policy and careful implementation, with ongoing analysis and assessment, are important factors to minimize policy failure (Hudson, Hunter and Peckham, 2019; Bolaji, Gray and Campbell-Evans, 2015).

The need for careful policy preparation and implementation to respond to the specific and often unique needs of a country means that an overly prescriptive approach to policy development is inappropriate. This guide therefore does not specify in detail what must be done and how it must be done, and it does not provide a common format for presenting policies. Similarly, it focuses not on the specific processes used to develop an STI policy, such as public consultations, but on the critical and strategic aspects that inform the processes. The report sets out the broad questions and issues that underpin strategic policy development, such as whether policies and their objectives are clearly defined; whether they offer the best framework to achieve the desired goals; whether achievement of the goals and objectives will have a substantive impact on national development; whether technological, economic, environmental, social, political and cultural feasibility have been considered; and whether the boundaries between STI policy and other policy areas (such as education) are discernible.

2. Overview of the policymaking process

As indicated already in section 1.1, paragraph 6, a two-hour video recording of an online workshop organized by the United Nations Department of Economic and Social Affairs in February 2021 provides a useful overview of general policy development issues, with a focus on Africa.[4]

The mechanics of the policymaking process can be broken down into several distinct steps, with variations occurring among institutions. Table 1 presents the steps and terminology used by three eminent institutions, each with its own perspectives. These steps are arranged into six phases for the purposes of this discussion. It is noteworthy that there are significant similarities across the three sampled institutions, despite their different spheres of interest. For example, the Centers for Disease Control and Prevention (2019) of the United States focuses on health policies; the United Nations inter-agency task team on science, technology and innovation for the Sustainable Development Goals (2020) focuses on STI road maps for achieving the SDGs; and the Smart Policy Design and Implementation initiative of the Harvard Kennedy School (2022) focuses on government policy as an iterative process involving continuous improvement. These three examples of policymaking processes are summarized in table 1 and synthesized into six phases, which are summarized below.

[4] The online workshop on "Sound policymaking for sustainable development" is available at www.youtube.com/watch?v=QpHxb86rn8Q.

Table 1
Comparison of several institutional policy processes

Phases		*Examples*		
Sequence	*Description*	*Centers for Disease Control and Prevention*	*United Nations inter-agency task team on science, technology and innovation for the Sustainable Development Goals*	*Harvard Kennedy School*
1	Agenda-setting	Identify the problem	Define the objectives and scope	Identify pressing policy problems
2	Policy analysis	Analyse the policy	Assess the current situation	Diagnose underlying causes
3	Policy formulation	Develop a strategy and policy	Develop the vision, goals and targets Assess alternative pathways	Design high-potential, feasible policy solutions
4	Policy adoption	Enact the policy	..	..
5	Policy implementation	Implement the policy	Develop a detailed road map on science, technology and innovation for the Sustainable Development Goals	Implement and monitor proposed solutions
6	Policy evaluation	Monitor and evaluate the policy	Monitor, evaluate and update the plan	Test high-potential solutions with rigorous evaluation Refine those solutions based on continuous feedback

Phase 1: agenda-setting

The problems that arise rarely have a single root cause. Most of them are the result of a wide range of causes and issues. All problems should therefore be framed and reframed to reveal the underlying causes in a way that allows them realistically to be addressed. It is also important to develop multiple options to address such causes. For instance, inadequate funding for research and development may result in inadequate funding for research facilities, low salaries for research and development staff, limited research supplies or technology commercialization, or a lack of research and development incentives for firms. Deep and probing questions are essential to properly identify the problem that needs to be addressed so that appropriate policy action can be developed.

Phase 2: policy analysis

Policy analysis involves reviewing and, if necessary, generating data used for policy decisions. The Harvard Kennedy School specifically encourages this phase of the process to identify and diagnose the underlying causes of the policy issue at hand. There is always a danger of policy analysis focusing on the "populist" issues of the day, which might merely be manifestations and symptoms of the problems that society and the public see, rather than the root causes that need to be addressed. Those who work on this phase must be open, transparent

and honest about what the data show, which areas lack data and where various interpretations of the data are possible.

Based on existing knowledge, the policy must ultimately define a clear set of objectives or targets that help to address the problem that has been identified. Time should not be wasted on problems that it is not appropriate for the policy to address. As already stated, there may be many solutions to the same issue. For instance, through consultations, one issue that several countries identified was that they lacked the genetic engineering capacity to participate in trade in transgenic crops. Some countries opted to build their regulatory capacity (such as Zambia), while others opted to build their genetic engineering capacity (such as Egypt) (Keetch and others, 2014). These choices reflected whether each country preferred only to police the technology, or also to participate in the technology and gain the full capacity to manage it now and in future.

Phase 3: policy formulation

The third phase of the process incorporates the final drafting of the policy. This phase emphasizes the need to link the policy with a strategy aimed at delivering strategic outcomes. The resultant policy or solution should address the identified challenges to maximum effect. There are two aspects that are considered critical for successful strategy and policy development, namely:

(a) The identification of the policy route to be taken from among many potential solutions (i.e. prioritization);

(b) The development of an implementation plan, with a concomitant monitoring and evaluation framework.

In developing policy, it is important to assess many potential solutions and policy options. In the public sector in Africa in particular, policy approaches have often been over-simplistic, with courses of action sometimes taken without due consideration being given to the full variety of options available. It is also the case that any option chosen is likely to be either beneficial or detrimental to some stakeholders, some of whom would need to support the option for it to be adopted and eventually implemented.

Internet voice calls through voice-over-internet-protocol services is an example of a service that benefited the masses but was seen as a threat by telephone companies. There is currently a debate over cryptocurrencies, a service that may benefit the majority but may also disrupt existing financial set-ups and the power held by that central banks and Governments. Engaging with stakeholders and reassuring the winners and losers of certain actions may be important for policy to be adopted and implemented efficiently.

For policy to be adopted, it must be in line with, or at least seen to be supportive of, the current or emerging political, social and economic thinking. An example of such emerging issues and the impact they can have on policy occurred in the 1990s, when most African Governments were liberalizing their economies and facing budget deficits. Policies encouraging academia and government departments to create spin-off entities that could become firms and/or self-sustaining entities became the norm. Private universities, for instance, grew rapidly in number and size. As one study noted, “while political thinking favouring the application of market principles in higher education was a debatable issue in the 1980s, it

became an operational principle guiding developments in higher education in the 1990s in Africa" (Varghese, 2006).

One impact of this approach was a reduction in support for industrial research institutes in Ghana, the United Republic of Tanzania and Zambia, even though those countries' STI policies called for increased support (United Nations, Economic Commission for Africa, 2013). In Ghana and Zambia, funding and the number of researchers by 2010 had fallen below the levels seen in the 1970s. In retrospect, the policies should perhaps have repositioned industrial research institutes so that they contributed to private sector development, perhaps by collaborating with the private sector or even by merging with other research and development institutions.

The implementation phase needs to be thought out during the policy formulation and design phase and responsibilities assigned to institutions and individuals, with adequate resources provided for successful implementation of the policy. The term "resources" in this instance may refer to more than just finance. For instance, both Kenya and Zambia[5] developed mechanisms to increase funding for research and development and technical training, respectively. However, their failure to invest in building the capacity needed to manage and administer the funds (Waruru, 2019) had a negative impact on implementation. During the design phase it is also essential to properly address who and what should be prioritized for support, how the impact of that support will be assessed and how success will be measured. When there is a failure to plan effectively for implementation and associated monitoring and evaluation, ad hoc decisions and actions are taken that do not effectively lead to the desired impact in a timely manner. Many policies have been developed and presented that did not have a detailed implementation plan or monitoring and evaluation framework. Such policies had negative consequences. This was even the case for the Science, Technology and Innovation Strategy for Africa 2024. Although the Strategy has stimulated STI development across the continent, progress has been slower than intended, in part owing to this major oversight.

Phase 4: policy adoption

Enactment is a key component of the policy process but is often undervalued. For a national policy, enactment is the final stage of adoption by the appropriate technical committees, Cabinet and parliament. It represents the culmination of the previous three phases and symbolizes society's approval of the policy. If the fundamental problems in the policy have not been adequately addressed or consultations have been insufficient, the policy can easily fall at this major hurdle. Successful policy depends heavily on strong stakeholder engagement and broad societal and political agreement on the proposed policy. The successful formalization of the policy builds on the open and transparent nature of the policy development process, which will be discussed in more detail in section 3. It has been noted that a national policy is usually presented as a guide and not as a law. The non-binding nature of a policy often leads to a lack of commitment to its implementation. For some aspects of policies, it may therefore be worth considering introducing legal sanctions to ensure implementation. In some cases, the policy itself may need to be presented before parliament as a bill.

[5] The Skills Development Fund in Zambia takes 0.5 per cent from the total payroll of employers to support technical and vocational skills development and is collected through the Zambia Revenue Authority. The National Research Fund of Kenya was set up with legislation stating that it would receive and generate at least the equivalent of 2 per cent of GDP per year.

Phase 5: implementation

Implementation is the real test of a policy's relevance and value. As referred to in the section on policy formulation, it is critical that there is a detailed implementation plan associated with the policy. It is also essential that financial and human resources as well as administrative and bureaucratic support are made available to ensure and assist implementation.

Phase 6: policy evaluation

A policy's success can only be determined if a monitoring and evaluation framework is in place to assess whether the policy objectives have been met. Ongoing monitoring and evaluation during policy implementation allows for corrections and changes to be made to the implementation strategy. Regular comprehensive annual and midterm reviews may allow for more substantive insights, as they assess whether the expected outcomes and impact of the policy are being achieved. This in turn allows the fundamental assumptions behind the policy to be assessed, which may affect not only the current policy, but also related policies developed in the future. There should be a culture of regular and continuous review and refinement of a policy and its associated actions.

3. Towards a guide for policy design

This guide is not intended to serve as a template for a policy document or a detailed outline of the operational steps and processes involved in policymaking. African countries are familiar with policymaking and the structure of policy documents in their countries. Several African countries have designed, adopted and implemented at least one STI-related policy. There are also many regional and international agencies interested in supporting countries with their policy development or adapting certain approaches to the situation in certain countries. Matusiak and others (2020, pp. 14–20) outline several relevant methodologies or instruments developed by organizations for the development of an STI road map for the Sustainable Development Goals and, by inference, more generic STI policies. These organizations include the European Union, the OECD, the United Nations Conference on Trade and Development, the United Nations Educational, Scientific and Cultural Organization, the United Nations Industrial Development Organization, the World Bank and the Transformative Innovation Policy Consortium.

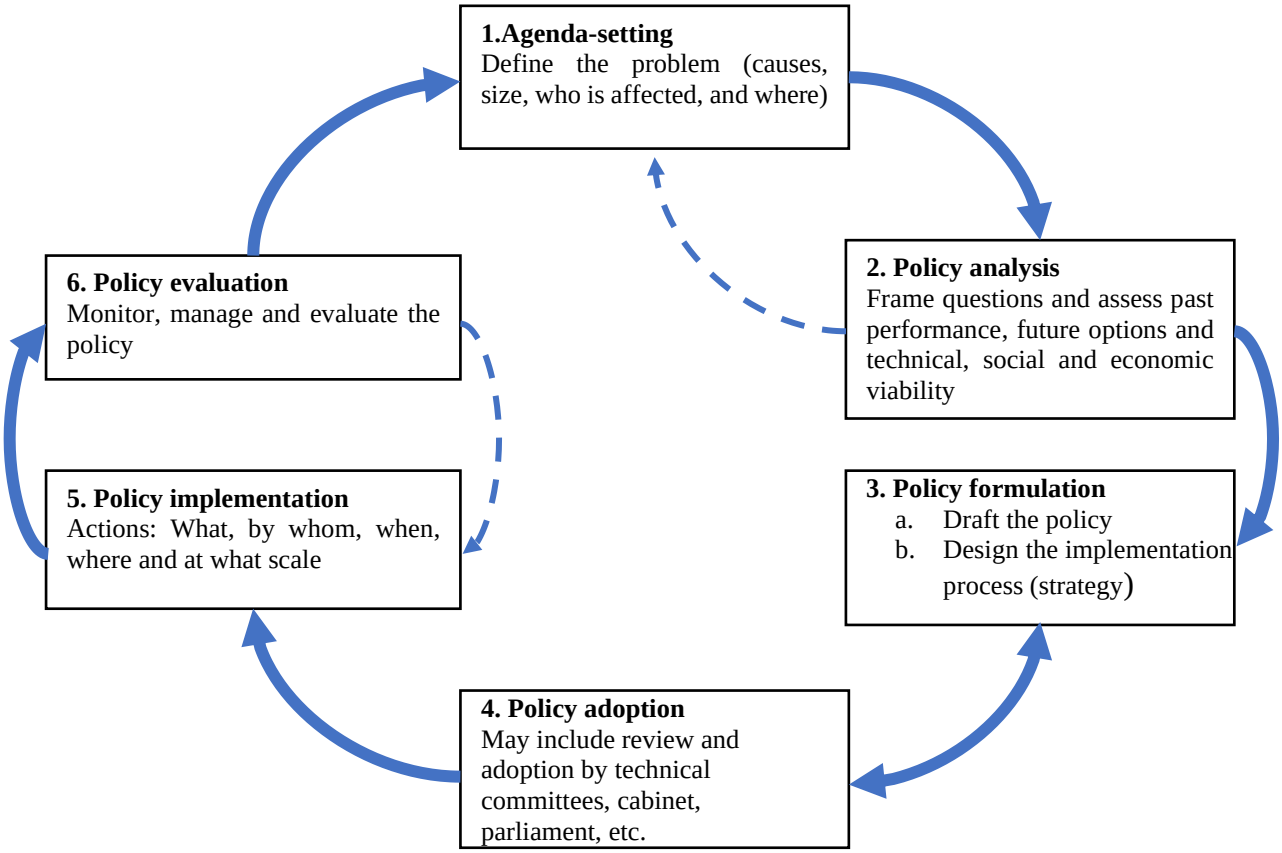
David Weimer (1992, p. 373) argued that: "Instruments, alone or in combination, must be crafted to fit particular substantive, organizational and political contexts." In the light of this principle, this guide is intended to help policymakers and decision makers to strategically address the specific challenges they face and to improve the quality of their policy design and implementation to achieve their intended outcomes and impacts. The guide therefore addresses questions and issues that are faced during policy design, implementation and evaluation to help countries to move towards more evidence-based policies that address national needs.

3.1 Composite framework

Based on the analysis of the various policy frameworks outlined in section 2, a composite framework is proposed that covers six phases, as indicated in figure V. This framework represents a cyclical process, where the experiences of one policy development and implementation process feed into the next iteration or generation of the policy. This cyclical

process incorporates feedback loops, enabling decisions made at each step to be revisited and refined as new information emerges from the process. The remainder of this section explores in more detail the issues that need to be considered at each phase of the process.

Figure V
Composite framework for STI policy design



3.2 Governance of the policy process

Establishing an appropriate governance structure for the policy process is critical. There are two levels of governance related to STI policy development. The first concerns the actual process of developing the policy and may be the only level attained if a policy is being developed for the first time or has been viewed by the Government to date as a periodic and intermittent stand-alone exercise. It is advisable to establish a high-level steering committee or a commission under a very high-level authority, with subsidiary task teams established around priority areas to carry out the detailed work. These teams need to include technical experts, professionals that will have to implement the policy and representatives of constituencies that will be affected by the policy.

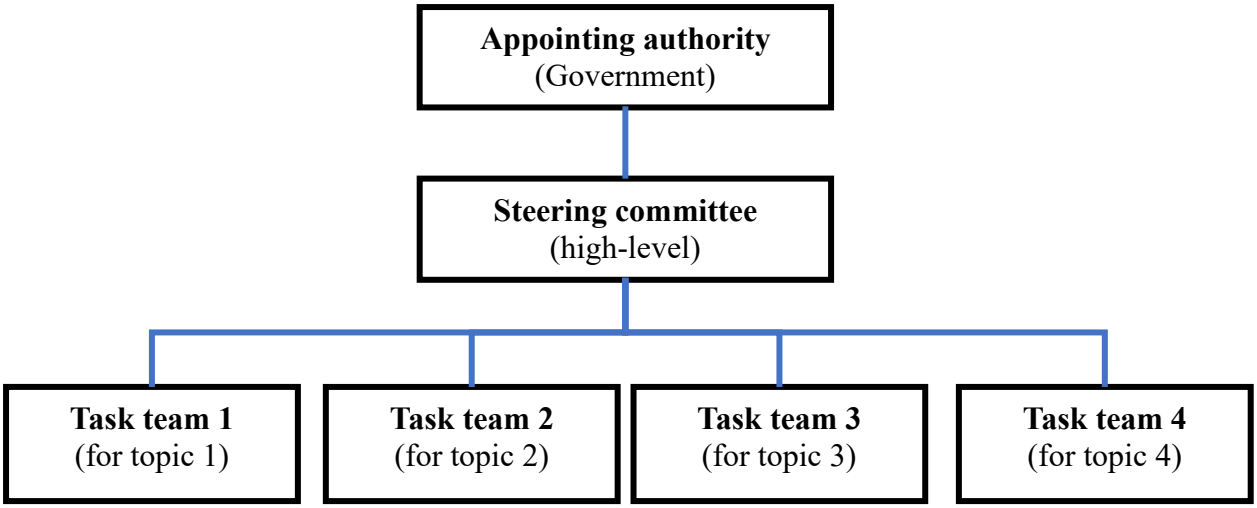
The second level of governance can incorporate the first level. It is associated with the establishment of an institutional infrastructure, such as a dedicated national agency with a secretariat, to continuously monitor and evaluate performance in STI against the background of a policy framework. This approach provides continuity so that the cyclical policy process can better produce coherent and sustainable outputs.

3.2.1 Governance of policy development

As stated in section 1.3.1, STI policy interacts with a wide range of policies from different sectors that influence and are influenced by STI performance. While a limited number of experts can help shape the policymaking process, its success may depend on incorporating people that understand, influence and benefit from the sectors likely to be affected by the policy. The process of developing STI policy therefore needs to incorporate mechanisms that allow for a wide range of input and expertise but are efficient, effective and able to deliver a policy document within a given timeline.

One approach that often works well is a steering committee formed of authoritative people with a broad overview of the STI area and its technical and political interfaces. Such a committee is often supported by task teams composed of people from the key sectors needed to achieve the end goal. For instance, when STI policies are designed to drive manufacturing, not only should the manufacturing sector be consulted, but there should be a task team composed of persons and practitioners who will be positively or negatively affected and those who will have to implement and follow its directives. Such a task team may include members from other sectors that may determine its success or failure (e.g. national bureaux of standards, importers, financial institutions, tax authorities). In short, the teams should include individuals and institutions that are likely to be part of the policy design or implementation, as well as beneficiaries and those likely to be affected, whether positively or negatively. Teams must have clear terms of reference. Figure VI is a generic diagram of a useful governance structure for the policymaking process.

Figure VI
Governance structure for the policymaking process



Note: There may be more or fewer than four task teams.

The steering committee oversees and coordinates the efforts of all the task teams. It should be a high-level team appointed by the president or the minister responsible, depending on the governance arrangement operating in the country. Each team's terms of reference should provide a direct reporting line to the appointing authority. Team members should be selected based on their expertise, passion and leadership. Members of the steering committee are members in their personal capacity, but also in their capacity as a representative of any

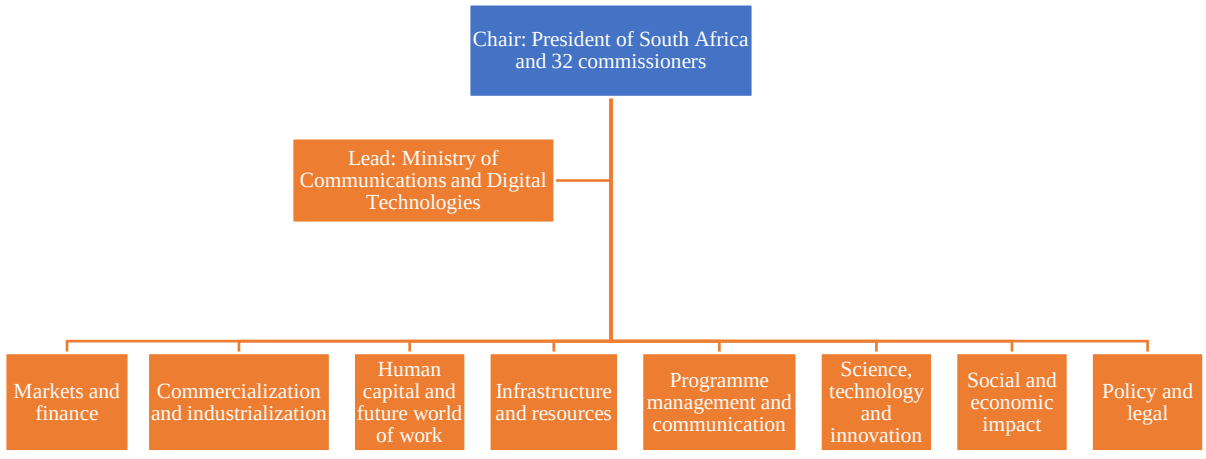
institution they represent. Continuity of discussion within the committee is necessary, and the option of seconding replacements in a member's absence should be limited or minimized. The steering committee should ideally include people who can provide or interpret information about the policy, people who are affected by the policy and people who administer resources related to the policy (Centers for Disease Control and Prevention, 2021a). For example, the committee might include experienced representatives of academia, industry, civil society, development partners and government. Gender and age should also be considered.

Task teams are the heart and soul of the process. Each team focuses on a specific policy area or outcome, such as a pillar, specialization area or technology. Members should ideally be appointed by the steering committee and should report to the same authority as the steering committee to maximize responsiveness and ensure that any necessary changes to the makeup of the teams can be done quickly. Members should be appointed strategically. Like the members of the steering committee, they should be motivated by and passionate about the desired outcome, have a vested interest in a high-impact outcome, be able to inspire team members, be respected by their peers and fellow team members to ensure accountability, collectively cover many disciplines, and provide key insights, resources or checks and balances. As is the case for the steering committee, the ability for a member to be represented by another person if they are absent should be limited.

South Africa provides a good example of how such a structure can work in practice, with its Presidential Commission on the Fourth Industrial Revolution (South Africa, 2019). As shown in figure VII, the role of the steering committee was taken by the Commission, which was appointed and chaired by the President. The Commission was formulated against the background of the country's vision for development, which is centred around addressing poverty, unemployment and inequality. The Commission consisted of eight "workstreams".

If carefully constructed, the steering committee and task teams will help to identify and clarify the issues raised under the remit of the policy and improve the policy's design, analysis, implementation and evaluation. The six phases of the composite framework outlined in figure VI are discussed in more detail below.

Figure VII
Task team and workstream structure of the South African Presidential Commission on the Fourth Industrial Revolution



3.2.2 Institutional governance and STI policy management

Section 3.2.1 outlines critical elements of how to manage the policy development process. A long-term, sustainable commitment to STI policy development and management, however, as opposed to periodic and intermittent policy development, requires a dedicated national framework and infrastructure. Among the most critical functions of such an infrastructure, however it is designed, is the continuous generation and analysis of data and indicators associated with STI, including data associated with existing policy. Indeed, if such an infrastructure does not exist, or if it exists but it is not delivering on this important function, establishing such an infrastructure or making it perform this function may be a key component of any STI policy that is under development.

A new policy is built on the lessons learned and experiences accumulated over the years and is based on solid data and evidence that emerge from research. The need for certain data to be acquired for policy development should, to the extent possible, be anticipated. If such data are obtained, the critical agenda-setting phase that shapes every other phase becomes more evidence-informed, ensuring that STI is better aligned with the broader national and international development agenda and that STI issues and opportunities can inform that agenda. If new data are required during the policy development process, for example in response to new issues or ideas raised during the consultation, an infrastructure that allows data to be obtained and analysed will enable a rapid assessment and appropriate input to be provided to the process.

The governance structure that enables this continuous capturing and analysis of data to feed into and inform STI policy, and to inform other areas of national policy through STI policy, may take many varied forms. It could be a small unit within a responsible ministry, a dedicated ministry, or a unit within the office of the president. Alternatively, it could involve a specialized agency. In South Africa, for example, the National Advisory Council on Innovation is mandated to advise the Minister of Science and Technology and, through the minister, to advise Cabinet on matters related to STI. The Council has created an information portal[6] that provides easy access to relevant data. An example of an institution established to link innovation strategies and policies to national and regional priorities can be found in the Smart Specialisation Platform and the Joint Research Centre, both established by the European Union. The latter employs scientists to carry out research to provide independent scientific advice and support to European Union policy. The South African and European Union examples are relatively financially and capital intensive. The purpose of providing these examples is not necessarily to prescribe a solution for African countries or provide an example for them to follow, but to outline some principles on how sustained information-gathering and analysis can feed into STI and national policy.

3.3 Stakeholder mapping

Policy development is both a technical and a political activity. At the end of the policy development process, the policy needs to be implemented by a range of institutions and individuals. It must be communicated to a wide constituency. The policy will affect a wide variety of individuals and institutions, in some cases positively, in others negatively. In relation to this, some priorities must be set that will affect resource availability and budgetary

[6] Additional information is available on the information portal of the National Advisory Council on Innovation at www.naci.org.za/nstiip/.

expenditure, which in turn will support some institutional interests and not others. For these reasons and many others, it is critical to involve key stakeholders so that they contribute to policy development and have buy-in once the policy has been completed. Stakeholder engagement is a recurrent theme in this section on policy design and in the entire document. It is therefore critical for a stakeholder analysis and mapping exercise to be undertaken at an early stage of the policy development process to ensure that all key stakeholders are involved.

The World Bank (2016) has developed a public-private dialogue stakeholder mapping toolkit that may be a useful starting point for this process. The objectives of the toolkit are the following:

(a) To design dialogue platforms and determine participants at the concept stage;

(b) To insert a dialogue element into an ongoing project to address specific implementation issues or midway lags;

(c) To ensure that participants are invited who match a country's unique context;

(d) To facilitate those parts of a dialogue that are concerned with deepening the understanding of political economy obstacles in order to reform processes;

(e) To help bridge the divide between different partners of the dialogue;

(f) To design a strategic reform communications plan;

(g) To catalyse reforms by building the knowledge and capacity of the right people.

A meaningful stakeholder dialogue, linked to policy development and implementation, is much more than a standard stakeholder consultation and may be established as an ongoing engagement throughout the policy cycle. Three steps are identified in the World Bank stakeholder mapping process:

(a) Identification of the purpose of stakeholder mapping;

(b) Stakeholder mapping using an interview-based mapping tool,[7] an initial facilitated process with selected individuals and groups following a step-by-step process that incorporates a general discussion on the policy and possibly incorporates the external and internal interfaces of STI policy outlined in sections 1.3.1 and 1.3.2;

(c) Stakeholder analysis to derive actions from the mapping and establish networks to drive the policy development and implementation.

Using the interview-based mapping tool involves the following six steps:

(a) Framing the right question;

(b) Identifying the stakeholders involved in taking action;

(c) Working through the nature of the formal and informal links between the various stakeholders;

(d) Determining the motivations of the stakeholders, in particular how strongly they support or oppose certain anticipated policy directions or whether they are neutral on them;

[7] Net-Map is one example of such an interview-based mapping tool.

(e) Discussing how influential the stakeholders are;

(f) Determining possible actions to ensure productive stakeholder engagement.

Stakeholder analysis may follow on from the mapping exercise and may take various forms. The World Bank suggests segmenting stakeholders using an influence-interest matrix. Other stakeholder analysis tools include the Policy Circle;[8] the stakeholder analysis guidelines by the World Health Organization (Schmeer, 2000); and other health-related stakeholder analysis frameworks (Balane and others, 2020). These will inform the levels of engagement with various stakeholders and how they are collectively managed throughout the policy cycle.

3.4 Agenda-setting

Spradlin (2012) stresses that, in any organization, for a solution to be found it is important to address the right question. Spradlin quotes a statement made by Albert Einstein: "If I were given one hour to save the planet, I would spend 59 minutes defining the problem and one minute resolving it."

In developing a policy, including on STI, it is critical to correctly identify the issues that need to be addressed. One must first ask whether the issue under discussion even needs a policy, what the policy seeks to achieve and what challenges the policy is designed to overcome. Some issues can be solved without recourse to a policy intervention.

Understanding the problem requires policy analysts, advisers and decision makers to ask the right questions to address the right problem. For instance, for which of the numerous challenges facing society could STI have a major or meaningful impact? How do any of the challenges fit in with government and public interests? Given that countries have limited resources, which areas should they focus on to achieve noticeable, measurable and desired outcomes and impacts?

Although it may sound simple and obvious to focus on identifying the right question before finding answers, many experts, policymakers and leaders are trained to find the answers to the problems of others and not to ask questions of themselves. They think that their role as leaders is to provide answers. This attitude can be summed up by the phrase "the flawless person at the top who's got it all figured out" (Ancona and others, 2007). Analysts and leaders should stop to ask questions, especially broad-based questions that can help to identify the scale of a problem.

There is also a danger of involving self-selecting individuals whose careers are built around a specific area of interest that they believe to be the single most important area for consideration, to the exclusion of all others. These individuals may seek to divert discussion to their area of expertise or to promote specific responses that they have promoted over the years, rather than objectively and comprehensively reviewing all evidence and opinion. At this early phase of agenda-setting, it is important not to restrict discussion and debate.

Table 2 sets out four steps to understanding the problem, including some associated questions that need to be asked in order to do so. These associated questions can be used to

[8] The Policy Circle provides guidelines for conducting a stakeholder analysis and a framework for assessing who the key actors are, what their interests, knowledge, positions, alliances, resources and power are and how important they are. See www.policyproject.com/policycircle/content.cfm?a0=3 a.

prioritize which steps are most appropriate and most likely to ensure there is a policy impact (Spradlin, 2012).

It should be noted that, for a topic as complex as STI, each issue may have many solutions. As a starting point for policy development, it is appropriate to try to combine challenges and issues into one, or at most a small number of, overarching issues. The process may, for example, lead to one overarching problem statement that best defines the overall policy, supported by several problem statements that form components of the overall policy. One way of organizing this for policy development could be to assign different problem statements to different task forces.

Table 2
Steps to understand the policy challenge

Step	*Questions*	*Description*
1	Establish the need for a solution: • What is the basic need being addressed? • What is the desired outcome? • Who stands to benefit, how and why?	Break down the problem and evaluate the potential benefits of a solution.
2	Justify the need: • Is the effort aligned with your institutional and national strategy? • What are the desired benefits for the country and how will they be captured? • How will you ensure that a solution is implemented?	Use qualitative and quantitative evidence to determine the scale of the benefits and start to identify who may lead the component if the impact is to be achieved.
3	Establish the context of the problem: • What approaches has the country tried before and how did it perform? • What have other countries tried and what were the outcomes? • What are the constraints on implementing a solution? • Do you have the necessary support to solicit and evaluate possible solutions? • Do you have the resources to implement promising solutions?	To avoid repeating one's own mistakes and those of others, and to learn from past efforts, it may be important to understand why the problem remains and to assess the technical competencies and resources to achieve the desired outcomes.
4	Write the problem statement: • How can the problem be articulated in simple terms, for example: "We are looking for X in order to achieve Z as measured by W." The problem statement does not need to be perfect, but it does need to be clear.	Link the policy intentions to the objectives and the objectives to the outcome targets. For example: "Increase the number of researchers in 10 years' time from 60 per million people to 600 per million people."

Source: Spradlin, 2012.

An example of a critical issue that invariably arises when STI policy is under discussion is the challenge of low expenditure on research and development. This has been the subject of various efforts, including the Lagos Plan of Action for the Economic Development of Africa (1980-2000); the Assembly of Heads of State and Government of the African Union, 2014; the 2030 Agenda; and the Science, Technology and Innovation Strategy for Africa 2024). The most straightforward recommendation is to create national research funds or to increase budgetary allocations by Governments. However, low research and development expenditure may also limit the research and development infrastructure available, (such as laboratories, testing

centres, libraries and communication facilities), the number of researchers (which means fewer scientists to attract grants and fewer research teams, etc.) and the support provided for other expenses (such as technology commercialization, conferencing, publications and outreach). Actions can be undertaken in these additional potential intervention areas to significantly enhance research and development without the expenditure falling under the research and development budget. The end response depends largely on how the question is defined.

If the right questions are asked and a detailed analysis is performed of what needs to be done to achieve the desired objectives, a range of approaches can be found. For example, Ethiopia increased its research and development expenditure from 0.3 per cent of GDP in 2010 to 0.6 per cent in 2014, largely thanks to capital investment in research and development. Kenya increased its expenditure by a similar factor, largely thanks to an increase in the number of researchers.

Evidence suggests that public[9] research and development expenditure as a share of GDP is similar in Africa to the levels observed in Latin America and the OECD countries (0.2–0.7 per cent of GDP). However, the more developed countries, which have a strong innovative output and a much higher gross expenditure on research and development, have developed a strong industrial research and development base, especially in manufacturing (e.g. in the pharmaceutical and automotive sectors), in digital, and in bioscience technologies. It is this industrial base and the associated business expenditure on research and development that is missing in most African countries.

As referred to in figures 1 and 2, the classical approach for national STI policies involves investment in research and development to build local academic research capabilities and stimulate local industry-led innovation. This aligns with the need to promote an industrial base. However, as also alluded to in figure II, many countries are now looking at broader societal issues within their STI policies and are seeking a broad societal transformation. Industrial output and finance, despite their importance, is only one of many levers for delivering the required national transformation. Consequently, another aspect of setting the STI policy agenda might include identifying overarching objectives associated with social sectors that require policy intervention and transformation.

Linking societal objectives to STI has been discussed and enunciated in relation to the delivery of the Sustainable Development Goals (United Nations inter-agency task team on science, technology and innovation for the Sustainable Development Goals, 2020; Independent Group of Scientists appointed by the Secretary-General, 2019). The STI approach suggested for the Goals identifies entry points for transformation, that is, areas and sectors that address the underlying systems that need to be addressed by the Goals. Those involved in the agenda-setting exercise for national policy may find the concept of entry points for societal transformation helpful, noting especially the six identified by the Independent Group of Scientists appointed by the Secretary-General (2019).

An established governance infrastructure with a dedicated secretariat that continuously monitors STI output and outcomes and carries out appropriate policy research, in collaboration with a broad academic and stakeholder base, can greatly assist in the agenda-setting phase of the policy cycle.

[9] The sum of research and development expenditure by higher education, government and not-for-profit sectors.

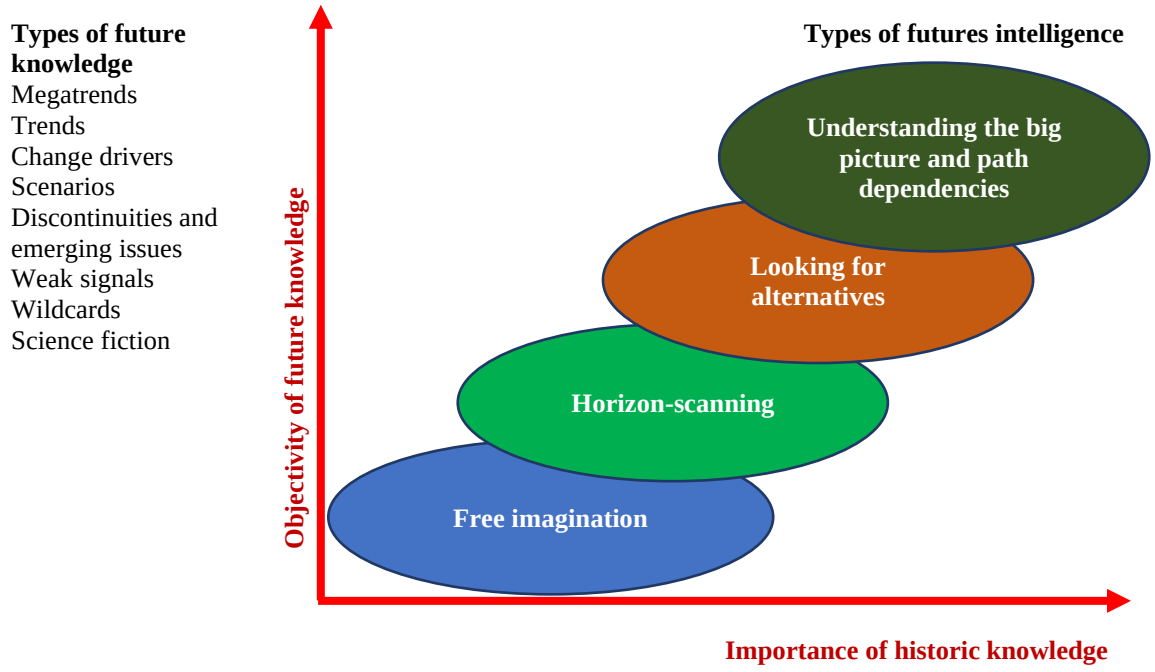
3.5 Policy analysis

Policy analysis is "the process of systematic investigation of the implementation and impact of existing policy (ex-post analysis), and of options for new policy (ex-ante analysis)" (Milovanovitch, 2019). Ideally, one needs to assess the performance, outcomes and impact of the current policy to generate information that may inform the new policy direction. The knowledge and information generated during policy analysis will help to improve agenda-setting and inform the evaluation of existing policies and the development of upcoming policy. As illustrated in figure VI, there is a strong interface between the agenda-setting process and the policy-analysis process, with the latter feeding back iteratively to inform agenda-setting.

3.5.1 Foresight analysis

The aim of most policies is to address and overcome challenges for at least the next 5 to 10 years, and in some cases even for several decades. This is particularly the case for STI. Given that the one constant in life is change, and that technological change is accelerating, it is critical to take future developments into consideration when developing STI strategies. Policymakers need to consider what the world may be like – and what they want it to be like – 5, 10, 15 or 20 years later, as well as what they want to change immediately. To do so, they need to analyse megatrends, trends, change drivers and other types of future knowledge. The likely future scenarios that they decide upon may affect the decisions taken on what to change today. The ultimate purpose of strategic foresight is to inform present-day decisions. A useful perspective on foresight analysis can be obtained by plotting the level of objectivity associated with certain types of knowledge against the importance of historical knowledge (Stucki, 2021) (see figure VIII).

Figure VIII
Understanding the big picture in foresight planning (Stucki, 2021)



Several publications report on how foresight might affect policy development (Organisation for Economic Co-operation and Development, 2019; Van Langenhove and Iglesias, 2012; United Nations Development Programme, Global Centre for Public Service Excellence, 2014a, 2014b), and in several reports, foresight analysis is used in an African STI context (Ndung'u and Signe, 2020; National Advisory Council on Innovation, 2019).[10] The Global Centre for Public Service Excellence (2014a) of the United Nations Development Programme provides a variety of useful methods and approaches to foresight analysis. It emphasizes that foresight analysis is not a substitute for traditional planning, but rather a complementary tool that broadens the planning horizon. Various futures exist based on different scenarios, and the right blend of particpants – inclusive and expert-based – is critical to produce high-quality output.

3.5.2 Inclusivity and asking the right questions

It is critical to involve a range of people in the policy analysis. The steering committee and task forces should obtain input from people who can provide or interpret information about the policy, people who are affected by the policy, and people who administer resources related to the policy. Data and evidence are vital for good policy analysis. Every effort must be made to ensure that the data are of good quality and are as complete as possible. Gaps in knowledge, data and evidence should be acknowledged. It may be appropriate or expedient to hire consultants or consultancy companies for at least some of the policy analysis, if not all of it, in which case the steering committee and task forces need to manage the process such that key experts and stakeholders are engaged and involved in the process in a manner that is open and transparent.

Policy analysis can be guided by appropriate questions. Some examples of key questions are provided in table 3 below, adapted from the policy analysis process of the Centers for Disease Control and Prevention (2021b). The questions are divided into four sets:

(a) Framing questions that help to define the policy;

(b) Criteria questions that enable a justification of the policy issue under discussion;

(c) Feasibility questions that address the likelihood that the policy can be successfully adopted and implemented;

(d) Economic and budgetary impact questions that enable a comparison of costs and benefits.

Table 3
Policy analysis: key questions

1.	**Framing questions**
(a)	What is the policy lever? Is it legislative, administrative, regulatory or of another nature?
(b)	What level of government or institution is responsible for implementation?
(c)	How does the policy operate? (Is it mandatory? Will enforcement be necessary? How is it funded? Who is responsible for administering the policy?)
(d)	What are the objectives?

[10] Other useful websites on accessing information and reports are available at www.foresightfordevelopment.org, http://foresightfordevelopment.org/bibliozone/mobile-ii, https://foresightprojects.blog.gov.uk/ and https://rossdawson.com/futurist/government-foresight/.

(e)	What is the legal landscape surrounding the policy (court rulings, constitutionality, etc.)?
(f)	What is the historical context? (For example, has the policy been debated previously?)
(g)	What are the experiences of other jurisdictions?
(h)	What is the value added of the policy?
(i)	What are the expected short-, medium- and long-term outcomes?
(j)	What might be the unintended positive and negative consequences?
2.	**Criteria: justification for the significance of the policy issue**
(a)	How does the policy address the problem or issue (for example, does it increase access)?
(b)	What are the magnitude, reach and distribution of the benefits and burdens?
(c)	Who will benefit? To what extent? When?
(d)	Who will be negatively impacted? To what extent? When?
(e)	Will the policy affect disparities and equity? If so, how?
(f)	Are there gaps in the data and evidence base?
3.	**Feasibility: likelihood that the policy can be successfully adopted and implemented**
Political	
(a)	What are the current political forces, including political history, the environment and policy debate?
(b)	Who are the stakeholders, including supporters and opponents? What are their interests and values?
(c)	What are the potential social, educational and cultural perspectives associated with the policy option?
(d)	What are the potential impacts of the policy on other sectors and high-priority issues?
Operational	
a)	What are the resource, capacity and technical needs for developing, enacting and implementing the policy?
b)	How much time is needed for the policy to be enacted, implemented and enforced?
c)	How scalable, flexible and transferable is the policy?
4.	**Economic and budgetary impact: comparison of costs and benefits**
Budget	
What are the costs and benefits associated with the policy, from a budgetary perspective, such as those related to enactment, implementation and enforcement of the policy by public and private entities?	
Economic	
(a)	How do the costs compare with the benefits (cost savings, costs averted, return on investment, etc.)?
(b)	How are costs and benefits distributed (for individuals, businesses, government, etc.)?
(c)	What is the timeline for costs and benefits?
(d)	Where are there gaps in the data and evidence base?

Source: Adapted from Centers for Disease Control and Prevention (2021b).

3.5.3 Accessing data and the value of surveys

As referred to already, policy analysis should be driven as much as possible by evidence and data. Teams should be encouraged to provide actionable evidence rather than relying on anecdotes and storytelling. For instance, statements such as "the Republic of Korea invested heavily in higher education or information technology and thus grew very quickly by over 7 per cent per year for three decades" are not useful evidence unless they are supported by information such as why the action was taken, what the need was at the time the action was taken, what worked and what failed, what the forces were that made it happen, what niches the country exploited, how coordination was achieved, where the resources came from and what

the outcomes were. It is these details that can reveal key insights to aid policy learning, which is also a key objective of policy analysis.

Similarly, statements claiming that previous policies were not fully implemented owing to a shortage of resources do not constitute evidence unless efforts are made to state, for instance, what the envisaged resource needs were when the policy was adopted, where the resources came from, who monitored and evaluated the resource requirements and resource utilization and why action was not taken during the entire lifespan of the policy to address the resource issue. More importantly, if the policy was not implemented, it is important to know whether the country achieve the envisioned outcomes, whether the areas addressed in the policy might not have been adequately advocated or might not have appealed to anyone, and whether changes in the country's political, economic, social and environmental fortunes have made the policy irrelevant or a lower political and financial priority.

Quantitative and qualitative data are both required for policy analysis, so task teams should be encouraged to collect data, including by encouraging experts and institutions to provide any existing information and data that are required. To do this, they may need to contact, meet with, and perhaps convene, whether online or physically, key stakeholders (for example, academia, industry, government entities, civil society and other innovation entities such as makerspaces, digital fabrication laboratories and innovation hubs, garages and other spaces). This may involve focus-group meetings and broad-based stakeholder consultations.

Where data are lacking, existing data may be complemented by surveys. Community innovation surveys – perhaps based on the Oslo Manual Fourth Edition (Organisation for Economic Co-operation and Development and Eurostat, 2018) – and research and development surveys drawn from the *Frascati Manual* (Organisation for Economic Co-operation and Development, 2015) should be introduced on a regular basis to inform STI policy. The surveys can provide key information on the health of the national innovation system. Such survey tools have been developed under the African Science Technology Innovation Indicators Initiative[11] and have been used to help to generate the *African Innovation Outlook* series, published every four years by the African Union Development Agency (2019).

Undertaking these surveys can be complex, but an increasing number of countries in Africa have had some engagement with the African Science Technology Innovation Indicators Initiative and 23 countries undertook surveys that contributed data to the third volume of *African Innovation Outlook* (African Union Development Agency, 2019). If a country has not undertaken any surveys prior to the development of an STI policy, it may be more appropriate to adapt these tools to generate shorter survey questionnaires to quickly generate data. For instance, ECA has tested a shorter version that focuses on knowledge generation and commercialization in publicly funded institutions (United Nations, Economic Commission for Africa, 2013). It has also created innovation policy comprehensiveness surveys that assess stakeholders' perceptions on eight different aspects.

3.5.4 Potential STI policy actions

In its 2016 edition of *Science, Technology and Innovation Outlook*, the Organization for Economic Co-operation and Development provided comparative analysis of policies and instruments being used in its member countries and in several major emerging economies

[11] For more information on the African Science Technology Innovation Indicators Initiative, see www.nepad.org/programme/african-science-technology-and-innovation-indicators-astii.

(Organisation for Economic Co-operation and Development, 2016a). The report provides a useful starting point for reviewing some generic policy tools that countries may wish to consider as part of their analysis. The report included an analysis of policy actions, which were divided into seven main groups (Organisation for Economic Co-operation and Development, 2016b, p. 168, figure 4.3). These groups and some examples of relevant policy actions are shown in table 4. An alternative categorization of regulatory levers and policy instruments can be found in the *Guidebook for the Preparation of Science, Technology and Innovation (STI) for SDGs Roadmaps* (United Nations inter-agency task team on science, technology and innovation for the Sustainable Development Goals, 2020, p. 34, table 2.2), in which four categories are identified: regulatory framework levers; instruments to absorb, disseminate and use relevant technology; instruments to adapt and disseminate new emerging technologies; and instruments to develop new technologies and system-wide innovations.

Table 4
Potential science, technology and innovation policy actions

Potential categories of science, technology and innovation policy actions	**Examples of actions**
Challenges	Responsible research and innovation Innovation for societal challenges Innovation for environmental challenges
Globalization	Internationalization of small and medium-sized enterprises Cross-border governance Internationalization of public research International mobility of skilled workers Attraction and retention of foreign direct investment
Governance	Impact evaluation exercises National strategy or plan for science, technology and innovation Science, technology and innovation policy coordination Strategic policy intelligence System evaluation Direction-setting Programme and project evaluation Policy evaluation Institution evaluation
Innovation in firms, including supply-side support versus demand-side support	Arrangements for public procurement Programmes targeting small and medium-sized enterprises Dedicated strategy for public procurement Grants and subsidies Debt funding (loans, guarantees, etc.) Equity financing and venture capital Business research and development and innovation Innovation vouchers Other demand-side instruments Research and development tax incentives Intellectual property revenue tax incentives (such as patent boxes) Personal income tax incentives Programmes targeting young firms and start-ups Tax incentives on VAT and other taxes
Universities and public research	Legislation and policy guidance on open access Interdisciplinary research Leveraging of third-party funding Competitive and performance-based funding

	Commercialization of public research results Public research infrastructures Prioritization and concentration of resources Reform of public research Legislation and policy guidance on open data New fields of research, such as mineral exploration using nuclear techniques and next-generation gene-sequencing to detect mutants (new strains), such as in coronavirus disease New funding and full cost recovery Dedicated strategy for knowledge transfer Cooperation between industry and science on research and development Open access: infrastructures Open access: public funding Open data: infrastructures Open data: public funding
Networks and transfers	Cluster policies Smart specialization Intellectual property rights Collaborative networks with small and medium-sized enterprises Intersectoral mobility of human resources
Skills	Matching of demand with supply Education for non-science and technology skills Entrepreneurial spirit and creativity Science and innovation awareness-raising Education in science, technology, engineering and mathematics Attractive research careers Reform of higher education Gender balance in science and research professions Greater participation in post-secondary education Research-oriented education Mitigation of the impact of demographic changes on human capital development Gender dimension in research content

Source: Adapted from OECD (2016b, p. 168, figure 4.3).

3.5.5 Prioritization

One of the main challenges in any policy analysis is how to identify priorities, especially for financing. The main purpose of an analysis is to enhance innovation for social and economic development. The actions highlighted in table 4 are part of a range of tools that can lead to innovation (see also figure X). The correct mix of tools will depend on the overarching strategy and associated priorities, which in turn will be linked to the country's innovation status, overarching national objectives and national culture. These overarching priorities require extensive political commitment, both for their formulation and their implementation (Hymowitz, 2016). This section will first review some of the principal issues that need to be addressed in STI policy prioritization. It will then explore some methodological approaches. Finally, it will outline some of the approaches undertaken by the Government of Singapore as an example of how prioritization can deliver policy in practice.

Several major strategic decisions centre on the level of science and technology development in the country, as outlined in section 1.2.1 (figure I), and associated developmental challenges. It is also worth noting the historical trends associated with policy prioritization, as outlined in section 1.2.1 (figure II). Gassier, Polt and Rammer (2007) point

out that, historically, Governments have added new features and approaches to existing best practices rather than switching from one approach to another. As a result, "research and technology policy today consists of a diverse set of objectives, approaches and instruments, and involve a large variety of actors. Consequently, processes of policy design have become rather complex".

These approaches include traditional or old mission-led approaches, which are focused on large-scale technologies such as energy, defence and transport; industrial approaches, which are focused on national competitiveness; systems approaches, which are focused on functional aspects of innovation; and new mission-led approaches, in which policy is geared towards societal needs and challenges.

Several strategic aspects thus need to be considered as part of any prioritization process (United Nations Conference on Trade and Development, 2017, pp. 35–37). These include:

(a) The extent to which the policy should be mediated through proactive management and coordination of specific technologies or sectors, as opposed to the creation of an enabling environment and a more laissez-faire approach;

(b) Linked to the above, the extent to which the policy should "pick winners" and identify particular technologies to promote, or specific sectors to support, or even identify specific institutions and projects to promote. Any such selection should align with national priorities;

(c) The extent to which a policy is directed towards long-term versus short-term returns on national financial investment;

(d) The extent to which national financial investment is directed towards the supply side of innovation or the demand side.

Proactive versus laissez-faire approach

The decision on how proactive and directive a policy is towards specific technical objectives is driven partly by the country's level of innovation and economic development and partly by its political and economic philosophy. Countries at an early stage of innovation development, with limited systems and infrastructure, might focus more on establishing institutional research and innovation capacity and actively supporting nascent industry with more direct, managed interventions. The United Nations Conference on Trade and Development (2017, pp. 35 and 36, chart 6) suggests that the strength of direct policy intervention may vary from strong to weak, depending on the strength of the economic system that is being operated in the country. Thus, a mature economy with strong institutions and efficient markets can afford to take a more laissez-faire approach than a less developed economy. Despite concerns among some institutions and commentators that direct interventions distort the market, the United Nations Conference on Trade and Development (2017) stresses that direct interventions are a legitimate approach for a country to take. Indeed, many of the countries that have taken proactive measures, such as the Republic of Korea and Singapore, have been the most successful at utilizing STI as a springboard for development. It is also frequently necessary for Governments to invest in technology to address the market's failure to provide enough investment where private capital investors deem it too risky. Most countries include broad priorities in their policies for areas such as information and communications technology, biotechnology, health, life sciences and new materials nanotechnology. In practice, however, there is normally a mixed system, with a range of

institutional and system support measures. Even mature, world-leading market economies at the frontier phases of technological development (figure I) may directly support key sectors, technologies and even individual firms and institutions to remain or become globally competitive. In the aerospace industry, for instance, the United States of America has consistently supported Boeing, and the European Union has similarly supported Airbus.

Selecting targeted interventions – choosing winners

Once a Government has identified the level and degree to which targeted interventions may be identified, it must face the challenge of determining which areas to prioritize. The most important consideration is to ensure that the areas prioritized are aligned with and will strengthen overall national priorities. For example, South Africa has focused on developing a pharmaceutical industry, Ethiopia on an airline hub and Morocco on an aerospace industry. The African Academy of Sciences has recently established an African Science, Technology and Innovation Priorities programme (African Academy of Sciences, 2020), with a continent-wide approach to STI prioritization. Three initial priorities identified have been gender and science, climate change and development, and food security and nutrition. Some examples of how one might select such areas and some further examples of prioritization are provided later in this section.

Long-term versus short-term investment

If a country has very weak STI infrastructure but some promising industrial development by young innovative companies, should it invest primarily in public sector education and research (the upstream elements of the innovation process illustrated in figure V), or should it look to stimulate low-technology innovation and entrepreneurship, for example through specific companies (the downstream elements)? Upstream investment builds a stronger foundation for future research-led industrial growth, but the return on investment takes longer; downstream investment channels support to existing capacity, thereby reducing support for the foundations of research and development, such as universities, but it can yield a more immediate economic return for the country and more immediate economic growth, including increased employment.

Demand-side versus supply-side support

Should a country prioritize and "push" the supply side of innovation through measures such as grants, debt financing and equity financing, or should it seek to prioritize and "pull" the demand side, such as by paying for the fruits of innovation through public procurement. These critical finance-related issues need to be carefully evaluated to ensure that investment provides value for money to the country. Pushing innovation through supply-side financing places the risk of the investment on the Government or the organization providing the resources and removes the risk from the institution undertaking the research. Pulling innovation through demand-side financing helps to ensure a successful return for the institution undertaking the research and development, but places the risk in the hands of the organization, normally a company. The options for long-term versus short-term financing and supply-side versus demand-side financing are provided in table 5 below.

Table 5
Comparative financing options for science, technology and innovation

Long-term, upstream financing targets	Short-term, downstream financing targets
Universities Academic research through innovation coordination teams Technology development Basic research New research areas	Industry Small and medium-sized enterprises Technology adoption Applied research Commercialization of results
Supply-side financing	Demand-side financing
Grants and subsidies Research infrastructure Research and development tax incentives Innovation vouchers Debt funding Equity funding	Public procurement Intellectual property revenue tax incentives Value added tax incentives

Methodological approaches to prioritization

A range of priority-setting approaches exist. Although the approaches are informed by data, they often require extensive, sometimes iterative, consultation for a consensus approach to be developed. For example, the Delphi approach (Dalkey and Helmer, 1963; Helmer-Hirschberg, 1965) and the modified Delphi approach (Gustafson and others, 1973; Graefe and Armstrong, 2011), which is often used, was implemented successfully by the Republic of Korea (Gassier, Polt and Rammer, 2007, p. 14), but practitioners need to be aware of its limitations, particularly in terms of time, resources and benefits (Ozier, 1998).[12] The African Academy of Sciences is using a more traditional academic science approach that uses coordinated reviews, expert consultations and workshops to identify the top 10 to 15 scientific priorities that will give African countries the greatest return on investment (African Academy of Sciences, 2020). A key driver of prioritization is an economic cost-benefit analysis, which can be integrated into most prioritization approaches with a greater or lesser degree of detail. This particularly applies to specified projects that may be incorporated into policy implementation plans. A study by the Sax Institute identified programme budgeting and marginal analysis as particularly relevant for situations where there is limited budget flexibility and decisions need to be made on where to spend fixed resources or where to cut spending to make resources available (Mooney, Angell and Pares, 2012). The Sax Institute also identified quality-adjusted life year tables as a useful tool for health-related priority-setting, which reflects some African experiences (de Savigny and others, 2008).

[12] A series of less rigorous consultation approaches are available, including prioritization (see www.cdc.gov/nphpsp/documents/Prioritization%20section%20from%20APEXPH%20in%20Practice.pdf and "analysing problems and selecting priority issues" at https://justassociates.org/wp-content/uploads/2020/08/14chap9_analyzing_prob.pdf).

Challenge of uncertainty and need for continuous monitoring and evaluation

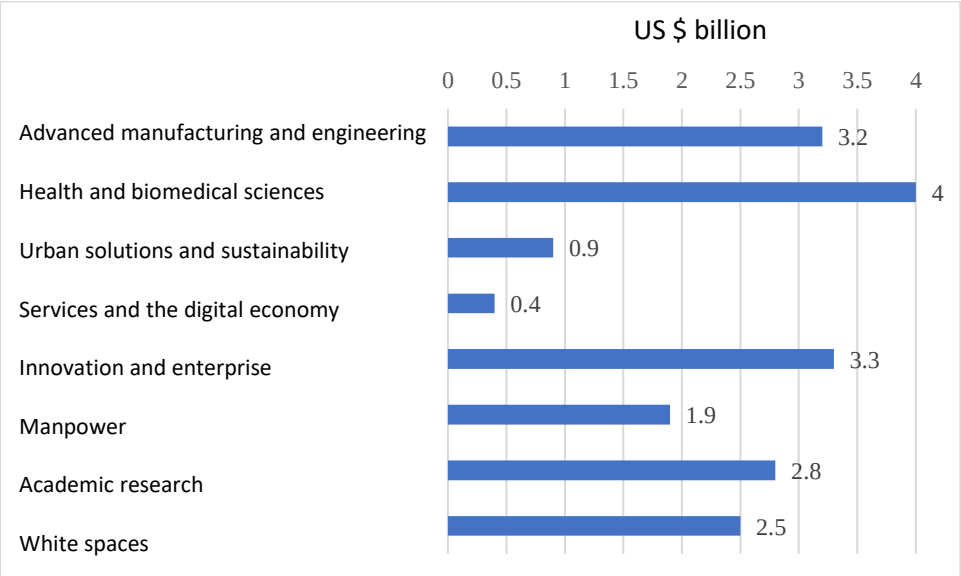
Gassier, Polt and Rammer (2007) indicate that, as innovation systems and priority-setting capacity develop, countries tend to move away from narrow, overly prescriptive, technology-oriented approaches towards broader areas of prioritization, such as information and communications technology, biotechnology and nanotechnology. Furthermore, research institutions increasingly tend to focus on "business needs rather than pre-defined scientific missions". Much of this change in strategy is to limit the risks associated with policy decisions given that, "almost by definition, in this area, policy is confronted with 'true uncertainty' i.e. the impossibility to foresee the speed and direction of future technological developments". The authors note that a variety of methodological approaches, including the application of foresight analysis, has led to mixed results.

In summary, care should therefore be taken during the policymaking process to consult a wide range of experts on the best methodological approaches and technical content for a particular national environment. While the policy is being implemented, it is also important to continuously monitor and evaluate the policy deliverables (output, outcome and impact targets) and to verify that the assumed environment, including the political, economic and technical assumptions of the policy, continues to hold true. Perhaps more than in any other area, it is necessary to keep the STI policy process under continuous review.

Prioritization by Singapore

In Singapore, the Research Innovation Enterprise 2020 Plan (National Research Foundation Singapore, 2016) emphasizes the integration of research thrusts; the creation of excellent teams and ideas through competitive funding, allowing flexibility to address emerging economic opportunities; a focus on value creation; and support for a strong research and innovation workforce. It emphasizes these thrusts by developing all three horizontal cross-cutting programmes, on academic research, manpower, and innovation and enterprise. These will support the vertical priority technology domains: advanced manufacturing and engineering, health and biomedical sciences, urban solutions and sustainability, and services and the digital economy. A significant degree of white-space funding will be included for the development of new approaches (see figure IX). This approach is accompanied by a strong emphasis on mainstreaming innovation throughout the public service, with civil servants encouraged to come forward with new ideas for public service delivery (United Nations, Economic and Social Commission for Asia and the Pacific, 2018). It has an overarching strategy to become a "smart nation" in partnership with the private sector and has an integrated approach that encourages everyone in the civil service to come forward with new ideas for improved public service delivery. An example of how the Government of Singapore provides successful support to its policies can be seen through the prioritization matrix (Singapore Economic Development Board, 2019a) that it developed as part of its efforts to catalyse the transformation of manufacturing to meet the needs of the fourth industrial revolution (Singapore Economic Development Board, 2019b). Reviews of the Singaporean approach frequently draw attention to the system's good laws and efficient administration. However, in looking at the issue of urban solutions and development, Elgin Toh and Mercy Wong (n.d.) argue that although the country's laws and administration are important factors, the key driver of the country's successful prioritization strategy for urban governance was the mindset of a "pragmatic, action-oriented approach, which identifies the problem, formulates the policy solution and sees it through with political will".

Figure IX
Singapore Research Innovation and Enterprise 2020 Plan
(billions of United States dollars)



Source: National Research Foundation Singapore (2016).

Smart specialization

The European Union established the smart specialization concept as part of its 2014-2020 Cohesion Policy. The purpose of the concept is to guide and prioritize investments in research and innovation so that each country and region can identify and develop its own competitive advantages for economic transformation. The concept promotes a partnership and bottom-up approach, bringing together local authorities, academia, business spheres and civil society to work towards the implementation of long-term growth strategies supported by European Union funds. It incorporates an entrepreneurial discovery process that produces information about the potential for new activities, thus enabling effective targeting of research and innovation policy. Critically, compliance with the principles of the process is an enabling condition for access to resources from the European Regional Development Fund. Reviews of the experiences of the smart specialization approach (Morrison and Pattinson, 2020) and its entrepreneurial discovery process (Perianez-Forte and Wilson, 2021) highlight the need for continuity in stakeholder engagement throughout the policy cycle; appropriate tools and instruments to support the process; organization and coordination with clear lines of responsibility; and adequate capacity to engage in the process. Funding calls are a key tool to quickly steer innovation policy towards supporting emerging priorities.

3.6 Policy formulation

Policy formulation is a process that involves drafting the policy document and achieving consensus on the draft policy contents, especially on how the objectives or goals of the policy may be implemented in the years ahead. Obtaining consensus is critical preparation for a policy's adoption. Policy formulation is a crucial phase involving negotiations on the content, format and drafting of the policy document. A well-drafted document is particular

important, as the words may have implications in terms of mobilizing resources, forging partnerships and building alliances.

There is a history of many African countries adopting policy documents but then not implementing them owing to a lack of planning. Policy formulation should also include the design of the implementation plan and appropriate budgetary information and assigned responsibilities. Policy formulation would then have two components: policy drafting and preparation of the implementation plan. The design of the implementation plan may help to clarify when, where, how and by whom actions and efforts are undertaken. Policy drafting and preparation of the implementation plan and the accompanying budgeting required may help with focusing on priority areas that will yield the biggest impact. If undertaken honestly and realistically, the policy formulation and associated implementation planning process can raise questions concerning some of the assumptions drawn from the policy analysis so that the agenda-setting can be refined and the overall quality of the draft policy can be improved.

It is important to underline that both components of policy formulation may be informed by the interests of influential individuals or groups, such as inventors, farmers, trade unions, professional groups and civil society groups. Some of these special interest groups may have ideas that counter, or even deny, scientific evidences. Many groups and individuals have an underlying passion (intellectual, political, ethical, etc.) for a particular area or focus of activity. There are also demands from diplomatic and development partners, which require policies to demonstrate responsiveness to certain regional and international aspirations, such as Agenda 2063 and the Sustainable Development Goals. The challenge of policy formulation is to build on the evidence-based analysis of the policies needed, but also to recognize that many of these political demands may have to be accommodated if the policy is to be supported and adopted (Craft and Howlett, 2012; Madimutsa, 2008). However, although politics is at play, policies that have a stronger evidence base should be easier to justify and accommodate.

3.6.1 Drafting the policy

This stage of the policy process consists of synthesizing the information gathered through analysis and consultation and refining the ideas to be reflected in the policy document. However, when the policy is drafted, several questions may arise that require further clarification and decisions, such as where most efforts should be devoted to achieve maximum impact, what the best route is to achieve the desired outcome and whether all possible alternatives have been evaluated. Some of the issues that may require consideration at this stage are discussed in more detail below.

National policy formulation templates may be available and should be considered, but none can provide answers of what an STI policy should focus on. A quick review of national policies demonstrates that there is no single optimal format for an STI policy (Organisation for Economic Co-operation and Development, 2016b). It is recommended that the steering committee and task teams should lead the policy formulation process.

A basic issue that needs to be clarified at this stage is which of the key problems identified through the agenda-setting and policy-analysis require or would benefit from policy actions. Not all problems identified require a new policy measure, since some could probably be addressed using existing measures or policies related to other areas. It is necessary to clearly identify which areas could be specifically targeted within the policy and could justify a policy response.

During the agenda-setting and policy analysis, many challenges and ways to address those challenges may arise. It is important for each area to be adequately reviewed and for each option or solution for every issue to be considered. It is important to conduct a comprehensive review and, where several courses of action are available, the rationale for choosing one approach over another needs to be clear. For instance, one option might be cheaper and involve more stakeholders, but it might also be slower, less effective and have a minimal impact on the desired outcome; another option might be relatively expensive and less inclusive, but also faster and scalable. It is therefore important that all possible policy options take into account issues such as contradictions, winners and losers, costs, impacts and inclusiveness. It is important at this stage to encourage all stakeholders to be involved and to keep an open mind on different policy options and combinations.

In choosing appropriate areas for prioritization and inclusion in a policy area, it is important to determine that the proposal is practical and is highly likely to be implemented. Furthermore, it should be an area whose implementation would have a major impact. The team working on the draft policy document needs to decide on the criteria to ensure that the chosen policy actions are competitive, realistic and inclusive and that the desired competencies and resources exist or can be mobilized. A balance may have to be considered between options that guarantee the country's aspiration to participate in future technological and emerging industries and options that meet current needs.

As the policy is being drafted, any gaps, inconsistencies, incoherencies and mismatches that may arise among the different aspects of the policy must be identified and resolved honestly and must be consistent with the expected outcomes and impacts. The following generic considerations should be made during the drafting and review stages:

(a) Involving key stakeholders in refining the future direction of STI;

(b) Maintaining good communications with all stakeholders;

(c) Focusing on national goals that galvanize all key stakeholders and respect their respective roles;

(d) Considering national and international trends that are likely to remain relevant for at least the next decade and flexible enough to accommodate future changes;

(e) Reinforcing existing or incoming policies where appropriate and, while noting the need to introduce change, minimizing contradictions and inconsistencies between those policies;

(f) Keeping the language simple and clear so that the policy can be understood by all stakeholders, and avoiding unclear content that could result in disputes and differences of interpretation.

3.6.2 Designing the implementation plan

The implementation planning phase plays a critical role in clarifying policy goals. During this phase, the goals are translated into actual targets and the actions that need to be undertaken to achieve the desired outcomes are determined. The implementation plan essentially breaks down the overall goals into realistic short-term actions that collectively contribute to achieving the long-term objectives. The policy implementation plan is also

important in mobilizing and allocating resources and in defining the roles and responsibilities of different stakeholders, as well as in establishing learning and accountability processes.

Implementation planning should be guided by several principles. Litman (2020), like others (Flannery and Cinnéide, 2012), suggests that it should be:

(a) Comprehensive, meaning that all significant options and impacts are considered;

(b) Efficient, meaning that the process should not waste time or money;

(c) Inclusive, meaning that people affected by the plan have opportunities to be involved;

(d) Informative, meaning that the results are understood by stakeholders (the people affected by a decision);

(e) Integrated, meaning that individual, short-term decisions should support strategic, long-term goals;

(f) Logical, meaning that each step leads to the next;

(g) Transparent, meaning that everybody involved understands how the process operates.

Implementation planning, like agenda-setting, policy analysis and policy formulation as a whole, benefits from a consultative and inclusive process. This includes working with stakeholders to share roles and responsibilities, agree on actionable targets and realistic timelines, and even agree on the consequences of failure. All options should be considered, including their positive and negative impacts on people, institutions, the environment and relationships. It is also important to recognize that implementation planning is not a linear process, but rather a learning process involving different interest groups or teams and stakeholders that can result in the cross-fertilization of ideas and the identification of synergies, with significant feedback loops.

An implementation plan might set out the following information:

(a) Desired outcomes;

(b) Key activities, actions and milestones;

(c) Resources required and their source;

(d) Responsible officers or institutions.

An implementation plan is a fairly high-level document. Although it is not a detailed execution plan, it should bring clarity on how to execute, manage, monitor and evaluate the policy. As with all stages of the policymaking process, all parties should be encouraged to be honest, realistic, creative and innovative in their thinking and suggestions. They should also, where necessary, prioritize certain actions over others. In all cases, planning should have a timeline and should be efficient and cost-effective. It is recommended that the steering committee and task team lead this process.

The desired outcomes should be drawn from the draft STI policy goals and recommendations that have already been agreed within the policy formulation process. However, they may also be based on the gaps, strengths, weaknesses, opportunities and threats

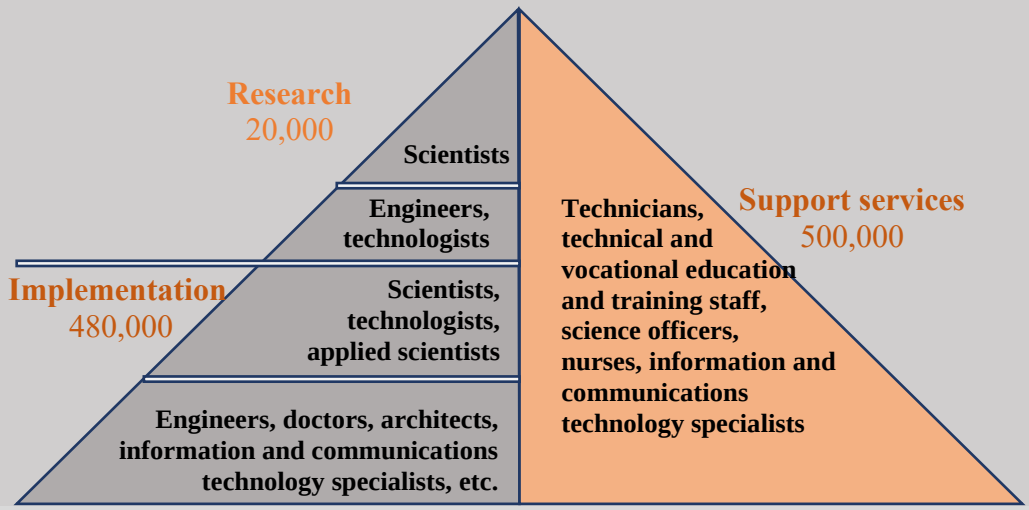
identified in the national innovation system that need to be accommodated for the policy to be fully achieved. This implementation plan should itemize or list the key desired outcomes of the policy and ideally break them down into implementable targets. For example, the goal of "building technical competencies" has more than one component and may cover a range of fields (engineering, medical, economic, etc.), skill levels (diploma, undergraduate, postgraduate, doctorate, professional, etc.) and sectors (education, health, manufacturing, digital, etc.), each requiring their own set of defined approaches to build their technical competences. While the first level of a formulated policy and the accompanying aspect of an implementation plan is broad, the second level and subsequent levels are increasingly more specific (see box 2).

Box 2
Improving human resources and skills: the case of Malaysia

The STI policy of Malaysia (2013–2020) contains several strategic thrusts, one of which is "developing, harnessing and intensifying talent" (Malaysia, 2019). This thrust would be achieved by:

(a) Increasing the ratio of researchers to at least 70 per 10,000 workers by 2020;
(b) Developing higher-order cognitive, analytical, creative and innovative skills among schoolchildren, tertiary-level students and teachers;
(c) Introducing new innovative skills in the workforce to advance the country's STI capabilities;
(d) Intensifying the brain gain and brain circulation of STI;
(e) Enhancing the talent management system to track supply and demand of skilled human capital in STI;
(f) Developing a dynamic career path for researchers in public research institutes and institutions of higher learning;
(g) Promoting and enhancing meaningful, effective and equitable female participation in STI at all levels and in all sectors;
(h) Increasing the number of workers who are skilled and competent in managing, operating and maintaining highly specialized equipment and infrastructure.

Based on this plan, it was determined that Malaysia needed a science and technology workforce of 1 million people by 2020, distributed as follows:



Source: (Academy of Sciences of Malaysia, 2015).

For example, the building of research capacity in the workforce can be broken down by sector, industry, qualification, gender, region, age, ethnicity and other variables, depending on national priorities.

The activities and actions required for the implementation of an STI policy could be undertaken by any one of several ministries or other national institutions whose remit does not directly fall under the Ministry responsible for STI. For instance, some of the common policy recommendations may include providing incentives for research and development or encouraging the Government to procure locally produced products or technologies. In this case, incentives for the private sector might be provided by a ministry or agency responsible for promoting industry or investment or by the ministry responsible for finance and tax policies. Another recommendation could be to ensure that the Government procures or sources locally developed products to encourage technology development, learning and innovation. In this case, policies on procurement may be established by the Government (e.g. parliament, cabinet or the president) but will be implemented and overseen by the national procurement agency.

The implementation plan may need to include campaigns, community consultations and evidence-backed communication strategies to explain policy changes and associated actions to ensure their effective implementation to drive change. The plan may also have need to build the capacity of the target beneficiaries, ensure close collaboration among the responsible agencies and create coalitions.

It is important to be specific when and where each activity will be held, who will ensure that it goes ahead, and what the scale of the activity will be. For instance, to train 5,000 doctorate holders in artificial intelligence, machine learning, automation and robotics, it may be useful to determine where to train them (e.g. at universities offering the course), who to train (which candidates are likely to be interested), when to train them (timelines) and what the outputs will be (graduates by time).

The resources required and the way in which they will be obtained need to be well outlined and achievable if any implementation plan is to be effective. A core part of the work of all task teams is to identify realistic resource requirements and determine how they will be financed or accessed as a core part of their work. Resource requirements, in this context, refers not only to money, but also to people (experts, competencies, skills, etc.), institutions (academia, public agencies, etc.), networks (existing or still to be created platforms, databases, etc.), partners (at home and abroad), time, facilities (laboratories, conferencing, communication, etc.), relationships (including current and future relationships and even some that need to be terminated).

The seniority of the appointed steering committee and task force teams and the seniority of the source of their mandate (such as by presidential appointment) is a critical component to ensure that resource requirements are discussed at a suitable level of government and that suitable contacts can be established to explore innovative financing and partnering avenues to obtain the required resources. The development of innovative ways to use or redirect existing resources to improve results should also be assessed. Such approaches might also involve removing or reducing regulatory hurdles and technical and non-technical barriers to access resources. The cross-cutting nature of STI policy development also requires that accessing resources be managed across Government and serves to break down silo mentalities.

3.7 Policy adoption

Policy adoption represents the legal authorization or enactment of a policy. This may occur through several defined steps, depending on the rules operating within a particular organization or country for a given policy document. For example, a cross-cutting policy document may need to be shared among and cleared by several ministries; it may then need to be approved by cabinet. It has been noted that a national policy is usually presented as a guide and not as law. The non-binding nature of a policy often leads to a lack of commitment to its implementation. Thus, for some aspects of policies, it may be worth considering introducing legal sanctions into policies to ensure policy implementation. In some cases, the policy itself may need to be presented to parliament as a bill.

The bill may have several readings where amendments can be made. If parliament passes the bill, it becomes an act of parliament, which may then have to receive assent from the president. It may then have to be published in the Government gazette to be formally adopted. As can be seen from the above description, the adoption of a policy can be a painstaking process involving several institutions, with the policy subject to potential amendments or open to further negotiation at each stage. If, at the policy adoption stage, certain key elements are not properly defined and the impacts of the development are not adequately articulated, a policy may be rejected or diluted. Furthermore, in the absence of sufficient consensus and buy-in from critical stakeholders, sufficient opposition may be mobilized to prevent the policy's adoption. The process by which a policy is developed and brought forward for adoption may be just as important, in terms of whether the policy is adopted, as the actual content of the policy.

In the case of Zambia, this stage can involve eight to ten steps and four different arms of the Government, especially for the adoption of an act of parliament. For instance, a bill may have to be drawn from the document and drafted by the responsible ministry. It is then published in the Government Gazette for the public to provide feedback. The ministry then redrafts the bill, taking into consideration the feedback received from stakeholders. The redrafted bill is sent to the Cabinet, where it is discussed by all members. Cabinet may approve the draft, make comments, or return it to the ministry for significant changes to be made. Once Cabinet has approved it, the draft bill is sent to the Government's legal adviser for clearance, and then to the National Assembly. The National Assembly sends the bill to the specialized committee, which hears from key stakeholders. Based on its findings, the committee prepares a report for the National Assembly, where the draft bill is debated and may be modified before it is passed. Once the bill has been passed, it is sent to the President to be signed into law. It is then published in the Government Gazette.

The case of Zambia illustrates why those preparing a policy must inform all key stakeholders, identify their interests and allay any major fears to build a broad coalition of supporters. Without these steps, even good policies may become derailed at any of these stages. For instance, powerful and influential stakeholders that were not involved in preparing the policy might create a space for themselves or simply oppose the document (Policy Monitoring and Research Centre, 2016).

At the end of the process, there needs to be a coherent policy that is accepted and owned by key stakeholders. For this to happen, best practices need to be applied from the outset, with multi-stakeholder engagement in the policy design and expert technical review of the options, including in-depth assessments of options that are aligned with national development priorities.

Potential areas of synergy and trade-offs need to be considered and negotiated, with the end goal of strengthening the STI environment.

3.8 Policy implementation

The practical value of a policy lies in how it is implemented; a policy has no value if it is not implemented. Policy implementation is in the action stage – the doing part, where boots are placed on the ground and intentions and plans are translated into activities. It is during this phase that all the hard work undertaken during the previous phases and planning come alive. It is the most exciting phase, in which the dreams of so many entities start to take shape. It is also a learning phase, with refinements often necessary where things do not proceed as intended. For instance, new technologies may make some earlier approaches redundant, economic changes may alter the interests and priorities of target institutions (e.g. universities) and markets (domestic sales versus exports), and unexpected international dimensions may need to be considered (e.g. new standards, partnerships and funding sources). The implementation process involves learning-by-doing, as issues emerge that need to be recognized, clarified and addressed.

3.8.1 Governance structure, coordination and accountability

An important part of the implementation plan, which needs to be in place from the outset of implementation, is the governance structure, with lines of authority, accountability and responsibility clearly delineated. This is critical, since implementation requires many arms of government and an array of stakeholders, including from the private sector, academia, civil society and other domestic and international partners. The efforts and perspectives of all these stakeholders must be accommodated and coordinated. The structure, led by an appropriate arm of government, must be robust enough to ensure that plans and responsibilities for their delivery are met, to address capacity constraints, to adapt plans to new and unexpected circumstances, and to ensure there is timely and truthful monitoring and evaluation to feed back into implementation plans and strategy. The structure of the steering committee and task team used to develop the strategy can provide a very solid foundation for the development of an appropriate governance structure for implementation, thus helping to define authority and accountability.

The phrase “when everyone is responsible, no one is responsible” is a reminder that, for complex activities to be achieved, it is important to assign responsibility for specific tasks to specific individuals. A challenge frequently faced in many policy documents is that responsibility for key elements is not rigorously apportioned to any one person or entity. The assignment of responsibility should be covered by a well-designed implementation plan. Implementation is more likely to be successful if an individual, rather than an institution, is held personally accountable for actions. Box 3 outlines an example how roles were assigned for interministerial cooperation and collaboration on policies for micro, small and medium-sized enterprises in Zambia.

Box 3
Example of the assignment of roles: inter-ministerial cooperation and collaboration on policy for micro, small and medium-sized enterprises in Zambia

The Ministry of Commerce, Trade and Industry will collaborate with other government institutions and departments, local authorities and other stakeholders involved in the development of the micro, small and medium-sized enterprise sector. In particular, the Ministry shall liaise with and maintain a close working relationship with the following institutions:

- The Ministry of Agriculture, to promote the development of agro-processing industries and related agri-business activities;
- The Ministry of Lands and Natural Resources, to facilitate the allocation of land to be developed into business incubators and industrial parks;
- The Ministry of Technology and Science, to support efforts to improve training in research and development, technology adaptation and technical skills;
- The Ministry of Green Economy and Environment and the Environmental Council of Zambia, to work on environmental safety and protection issues;
- The Ministry of Labour and Social Security and the Ministry of Youth, Sport and Arts, to promote good labour practices in the micro, small and medium-sized enterprise sector, to monitor child labour issues and to ensure decent work practices;
- The Ministry of Infrastructure, Housing and Urban Development, to ensure adequate support for activities to develop micro, small and medium-sized enterprises at the local level and to ensure effective decentralization of government services to the micro, small and medium-sized enterprise sector, such as the provision of different business licenses.

Source: *The Micro, Small and Medium Enterprise Development Policy* (Zambia, Ministry of Commerce, Trade and Industry, 2008).

The following questions need to be addressed:

(a) Who is responsible for the overall execution of the component of interest of the STI policy?

(b) Who are the key team members needed to successfully implement the component in question?

(c) Who are their key partners and what are their responsibilities in the successful execution?

(d) Who are they accountable to and what are the consequences of inaction?

While many of these questions may have been addressed during the policy formulation phase, they also need to be amplified during the implementation phase and enunciated in detail.

3.8.2 Activities – continuously assessing progress and impact

In a well-prepared implementation plan, activities are properly costed, timed and appropriately resourced, for example through funding for operations, human resources and administrative support, with clear reporting lines and responsibilities assigned. In addition to these logistical preparations, continuous attention needs to be paid to the progress and impact emanating from the activities on the ground. This may have implications on the timelines and the milestones that need to be attained; it may also have implications for the anticipated and

unanticipated impact on the systems/organizations, communities and individuals involved. For instance, an infrastructure upgrade may result in forced shutdowns, lost time and forgone opportunities, and there will almost certainly be the additional risks of the construction not being completed on time. The negative impact of such actions and indirect effect it may have on individuals, communities and the broader society need to be considered.

An example of a formalized activity that can be used to pre-empt and address these types of issues is an environmental impact assessment, which is "the systematic examination of unintended consequences of a development project or programme, with the view to reduce or mitigate negative impacts and maximize on positive ones" (Science Direct, n.d.).

To minimize the negative impacts of any activities, including the unintended consequences, it is important to ensure that there is good communication between all components and subgroups within the governance structure, including with implementation team members on the ground and the intended beneficiaries and other policy stakeholders. The names, email addresses and telephone numbers of key people should be widely available and common instant messaging and communication platforms should be fully exploited.

3.8.3 Activities – efficient and effective completion

There is a danger that an activity might be discontinued before its outcomes can be fully sustained; there is also a danger that financial and human resources might be wasted by keeping an activity open and maintaining it, even when it has essentially been completed or it is clearly failing to deliver the expected results. Finding the right balance and formally closing an activity in an appropriate way can be just as important as properly running the main part of the activity. For example, an early exit from an early phase, before the gains of that phase have been sustainably secured, may result in the failure of that phase and may inhibit the future progression and development of the overall project. Similarly, keeping successful projects running beyond their completion date in an early phase may undermine the chances of moving on to build the next big thing in a later phase. Lastly, if an activity or project is not working, it may be important to take note of this fact at an early stage and to stop the project and reassess how to proceed, rather than pouring resources into something that is doomed to fail. Recognizing failure and stopping it early is crucial in project implementation, especially when dealing with innovation, where the risk of failure is often high.

An example of how focusing on one technology can inhibit and delay the move to a second phase of technology is illustrated by the efforts made in the 1990s to develop Internet access in Zambia (Konde, 2004). In the early 1990s, the email system was working well, but many working in government and in socioeconomic development did not see the added value of connecting to the Internet. To some extent, the success of establishing email inhibited efforts to move into the new area of Internet activity. In the end, the country's first Internet service provider was developed by commercializing a university-based academic email system, rather than through a telecommunications company.

A major lesson from that experience is that any implementation requires a clear exit strategy. The Chile Foundation (2018) and the Finnish Innovation Fund provide good examples of implementing innovation with clear exist strategies.[13]

[13] For more information on the Finnish Innovation Fund (Sitra), see www.sitra.fi/en/themes/about-sitra/.

3.9 Policy evaluation

Policy evaluation can occur at several levels. Although it is placed at the end of the six-phase process, it essentially occurs in different modalities, before, during and after the intervention (United Kingdom, Her Majesty's Treasury, 2020), as follows:

(a) Before the intervention, evaluation provides evidence that feeds into the design of the policy or intervention, including the implementation and the monitoring and evaluation plan;

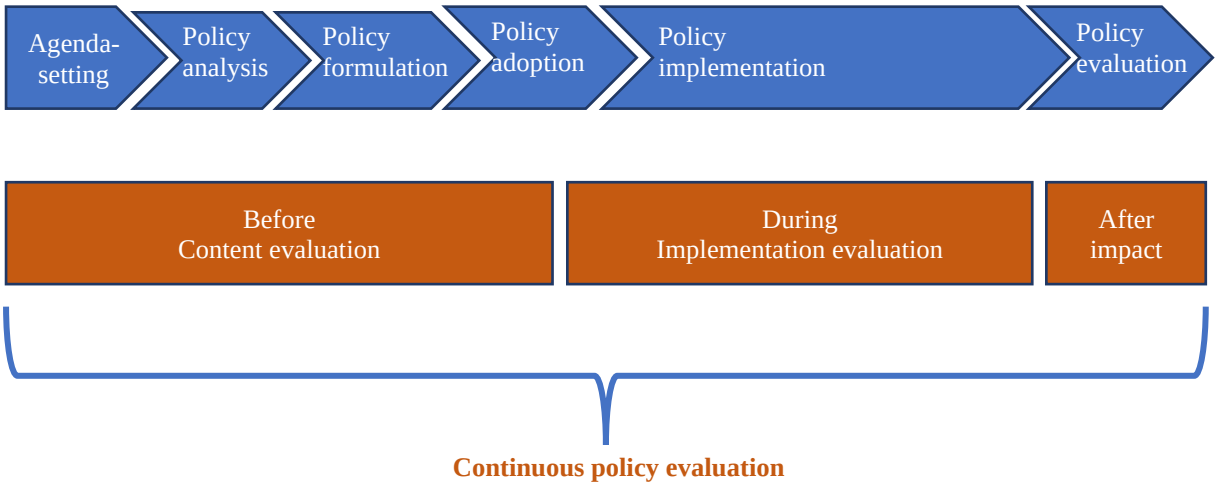
(b) During the intervention, evaluation provides evidence on the implementation of the intervention and any emerging outcomes so that it can be continually improved;

(c) After the intervention, evaluation provides evidence on the design, implementation and outcomes, with lessons for the future, and it provides an assessment of the overall impact of the intervention.

Two useful sources on policy evaluation that reinforce this point are the *Magenta Book* on policy evaluation and its supplementary documentation (United Kingdom, Her Majesty's Treasury, 2020) and two documents by the Centers for Disease Control and Prevention (2014, 2021c). These three types of evaluation are illustrated in figure X, which is based on a Centers for Disease Control and Prevention document on evaluating violence and injury prevention policies.[14] .

[14] See, www.cdc.gov/injury/pdfs/policy/Brief%201-a.pdf.

Figure X
Policy development phases and types of evaluation



Source: Adapted from *Magenta Book* (United Kingdom, Her Majesty's Treasury, 2020).

In *Magenta Book*, published by the Treasury of the United Kingdom, reference is made to two main purposes for undertaking an evaluation, namely, learning and accountability. Learning and knowledge gained from the evaluation of an intervention can help to manage risk and uncertainty. It can also feed into the intervention and improve performance, and it can help to determine what works in practice and what does not work, thus generating further evidence for future policies and interventions. Evidence obtained from the evaluation reinforces accountability and the transparency of operations. It enables an assessment of whether the stated objectives were achieved, thus allowing individual and institutional performance to be determined. Importantly, combined with appropriate audits, the evaluation can be used to determine whether the funds provided for the task were used appropriately and effectively. Evaluations can therefore be used to assess the process, impact and value for money.

The quality of the implementation plan and its accompanying monitoring and evaluation framework, which are developed during the policy formulation phase, is crucial to the success of any subsequent evaluation exercise. In principle, the implementation plan determines what will be done and how it will be measured and assessed. If the plan is not well designed or is omitted completely from the policy document, an evaluation method needs to be established after the event, which is not ideal, wastes time and ultimately fails to deliver fully on the learning and accountability expected from the evaluation.

A simple scoreboard approach can be readily adapted from a good implementation plan. A three-colour code, for instance, can be used to demonstrate how much progress was made, with green denoting a project or activity that has been completed or is on track; yellow, one that is in progress, but is slightly behind schedule; and red, one that has not yet begun or has been significantly delayed.

A good example of how effective this can be, provided that all stakeholders buy into the concept, is the approach used by African countries to self-assess their progress in achieving

the objectives of the Malabo Declaration on Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods (African Union, 2018).

Critical to the development of a scoreboard, and indeed a successful monitoring and evaluation framework, are the indicators associated with the framework. These indicators may include classical indicators associated with STI, such as those on innovation in the third edition of the *Oslo Manual* (Organisation for Economic Co-operation and Development and Eurostat, 2018) and those on research and development in the *Frascati Manual* (Organisation for Economic Co-operation and Development, 2015). They may follow certain scoreboards, such as the European Innovation Scoreboard (European Union, 2020), the South African Framework (National Advisory Council on Innovation, 2019) and selected innovation-oriented indices such as the Global Innovation Index (Dutta, 2011; Cornell University, INSEAD and World Intellectual Property Organization, 2020). They may also relate to social outcomes as described in the *Guidebook for the Preparation of Science, Technology, and Innovation (STI) for SDGs Roadmaps* (United Nations inter-agency task team on science, technology and innovation for the Sustainable Development Goals, 2020). Indicators are also essential to monitor specific aspects of any given implementation plan and support an overarching monitoring and evaluation framework. As such they may differ from context to context. Statistics New Zealand developed a set of criteria for selecting good STI indicators (Brown, 2009). Among other criteria, the organization stated that indicators should be as follows:

(a) Valid and meaningful;

(b) Sensitive and specific to the underlying phenomenon;

(c) Grounded in research;

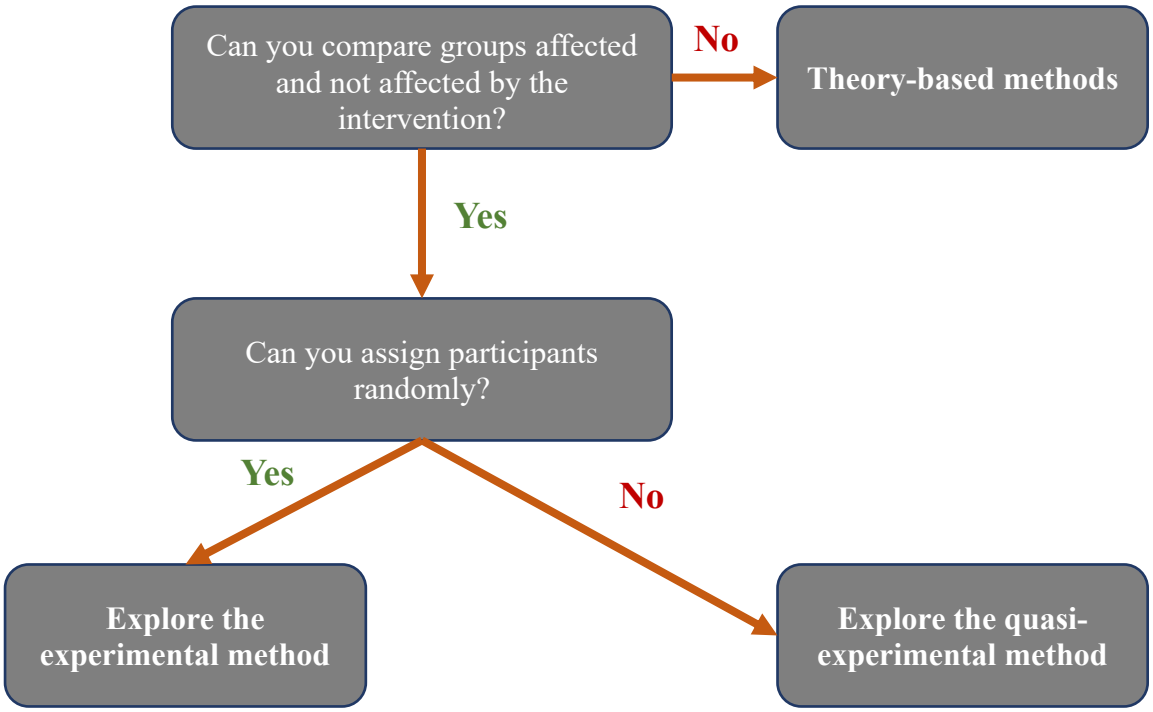
(d) Related, where appropriate, to other indicators;

(e) Consistent over time.

ECA is currently developing an African policy context.

The evaluation process may take various forms. The *Magenta Book* and the Centers for Disease Control and Prevention each split the evaluation process into similar six-phase frameworks. Both frameworks emphasize the importance of ensuring the inclusivity of all stakeholders in the process and of formally communicating the end results of the evaluation at the end of the process so that lessons are learned and accountability and transparency are assured. As with any evaluative study, some thought needs to be applied as to which methodological approaches should be used for the policy evaluation. Possible approaches range from theory-based methods to experimental, or quasi-experimental, methods and value-for-money methods. A useful decision-making tree is provided in the *Magenta Book* for deciding whether to use theory-based or experimental methodological approaches and is reproduced in figure XI.

Figure XI
Determining methodological approaches for evaluation



Source: Adapted from *Magenta Book* (Treasury of the United Kingdom, , 2020, p. 47, figure 3.1).

A formal review process, linked to the formalized governance structure, should be established to manage evaluations, which need to occur at every level of the policy team structure. Individual managers should be encouraged to hold regular meetings to assess progress with their teams. The results of these meetings may feed into a more formal review process. For example, under the structure of a steering committee and task teams, as outlined in figure VII, one might expect quarterly, semi-annual or annual reviews, or a combination thereof, to be carried out at both levels, with the task team review preceding and informing the steering committee reviews. Such regularized formal reviews encourage managers on the ground to meet regularly and assess progress with their teams to inform their reports. Such reporting should ideally be inclusive of broad stakeholder input, especially at the larger reviews, such as those conducted annually. Above all, the reviews should be honest reflections of progress, or lack of it, and policy impact, or lack of it, or even the adverse impact if the case may be. An example of how monitoring and evaluation occurred for a major multi-ministry and multi-agency project in Zambia is outlined in box 4.

Box 4
Monitoring and evaluation of the Triangle of Hope project in Zambia

The Triangle of Hope was an economic development initiative with twelve task teams appointed by the President of Zambia, Levy Mwanawasa. Each of the twelve teams had a different area of responsibility: the air cargo hub and inland ports, agriculture, banking and finance, cotton, education, government streamlining, health, information and communications technology, multi-facility economic zones, mining, small and medium-sized enterprises and tourism.

The line ministries prepared the implementation plans using the approved set of recommendations made by the task teams. Roles and responsibilities were assigned, and each responsible ministry prepared briefs and met at State House. Key activities were tracked on a colour-coded sheet, with green used for activities that had been completed or were on track, yellow for activities that were in progress and red for those that had not started or were behind schedule. In addition, the Triangle of Hope Steering Committee compiled the briefs and presented the progress to the Inter-Ministerial Technical Committee. The leader of the Steering Committee made quarterly presentations to the full Cabinet.

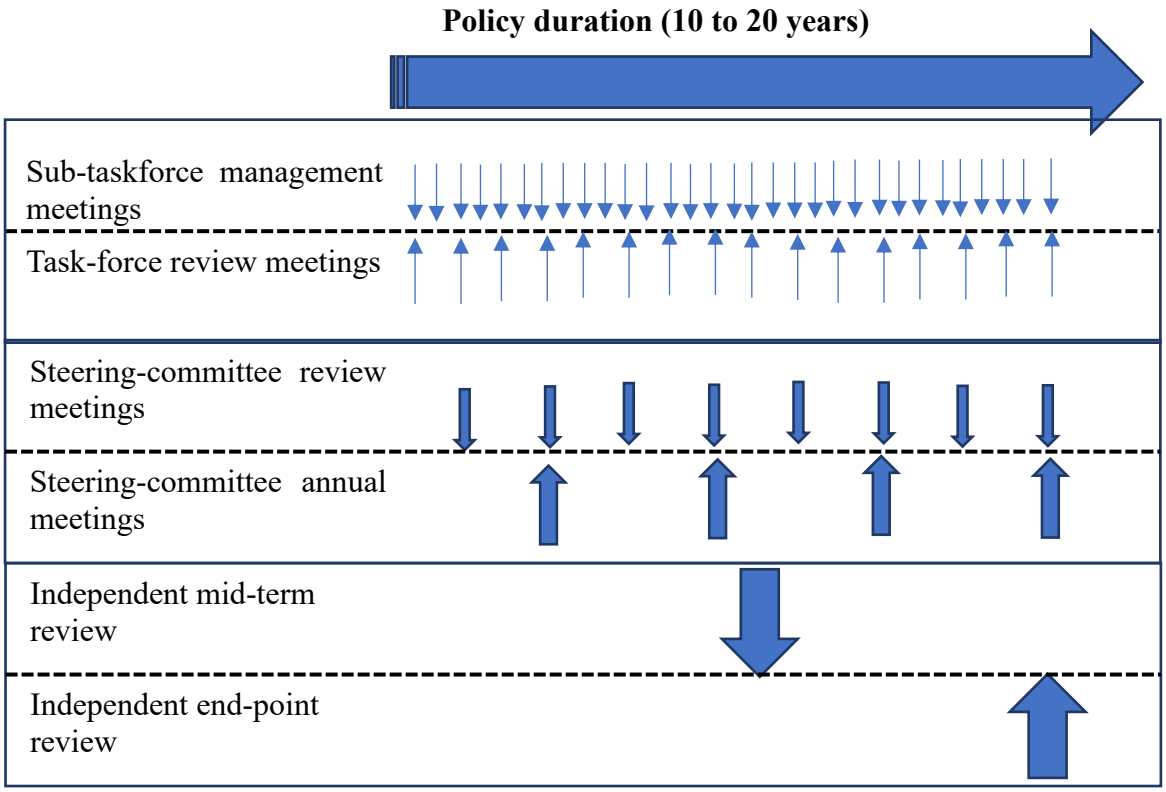
Source: Triangle of Hope: strategic action initiatives for economic development 2010 brochure (www.jica.go.jp/project/english/zambia/0901055/outline/pdf/brochure.pdf). For additional details, see Shimoda (2012).

Special attention needs to be paid to reviews of major policies, such as STI policies, which are complex in their scope and their cross-governmental and societal interactions. In the case of STI policies, key aspects may be overtaken by events, since science, technology and innovation, by their very nature, are constantly changing. For this reason, it may be appropriate to formally review the STI policy itself periodically, such as every 10, 15 or 20 years, to assess whether it remains fit for purpose. At least one interim review should also be conducted, such as every five years. Such end-of-term and midterm reviews should ideally be independent, with the reviewers reporting to the authority that appoints the steering committee, for example the office of the president and the cabinet. The frequency and nature of evaluations are outlined in figure XII. The terminal review identified at the bottom of figure XII essentially marks the end of the policy cycle described in figure VI and will inform the next round of policy agenda-setting, policy analysis and policy formulation.

4. Concluding remarks

It is hoped that this guide and its accompanying references will prove useful to those wishing to initiate and coordinate the establishment of a national STI policy and to those participating in the development of such a policy. Although it includes a six-phase cycle that provides guidance through the process and offers some options on how to proceed, it is not intended to be overly prescriptive about how the policy should be developed. Each country has certain unique characteristics, processes and STI needs that will dictate how the process is carried out and what is ultimately contained in the policy.

Figure XII
Range and periodicity of policy-related evaluation meetings



Some recurrent themes emerge throughout the cyclical policy development process that should be kept in mind as the policy is developed, whether using the six-phase cycle outlined in this document or a variation thereof.

First, all policies have a limited lifetime, especially an STI policy, which will be shaped by the ever-changing nature of its three components: science, technology and innovation. Engagement in STI policy development thus lays the groundwork for the next cyclical iteration of the policy as well, whether that cycle begins 5, 10, 15 or even 20 years later. It is therefore important for certain fundamental elements that underpin the policy development process to be correct and sustainably established. Subsequent iterations of the policy development can then be carried out more easily and can benefit from the learning and experience of the current iteration.

Second, good decisions are as good as the quality of the evidence and information that inform the decisions. In other words, “rubbish in means rubbish out”. If time is taken to gather data and link it to expert and stakeholder opinion and analysis, the correct questions can be asked and a well-informed agenda can be set. Indeed, collecting data, carrying out surveys and conducting ongoing analysis permeate the entire process, resulting in policy that is evidence-informed.

Third, linked to the importance of evidence-informed policy, one of the most critical elements to be established as an aid to policy development is an appropriate evaluation process. As illustrated in figure X, evaluation should ideally take place before, during and after policy implementation. Thinking through how the programme will be evaluated requires planning and

analysis. It incorporates scenario-planning and helps prepare those responsible for the policy to adapt to any eventuality, including a delay to the construction of infrastructure, a major new disruptive technology, a change of government philosophy, or an international disaster such as the 2008 financial crisis or the COVID-19 crisis. Planning, monitoring and evaluation enable policy managers to be flexible and adaptable to change.

Fourth, the most substantive manifestation of ongoing evaluation is the development of an implementation plan and a policy monitoring and evaluation system. The importance of this cannot be overemphasized. Many policies have failed or have led to limited and suboptimal implementation because they lack an implementation plan and lack the means of self-assessment. The significance of these two elements can be summed up by the phrase "what gets measured gets done".

Fifth, stakeholder engagement and buy-in at every stage of the policy development process is critical to developing a sound policy and ensuring its acceptance, uptake and implementation. For the development of an STI policy, it is especially critical for stakeholder engagement to be well planned, given the diverse nature of the sectors, disciplines and stakeholders involved, which span government, the private sector, academia and, increasingly, civil society.

Sixth, attention needs to be paid to the governance structure under which the entire cycle of policy development and implementation will operate. This governance may occur at two levels. The first level concerns the actual process of developing the policy and includes the idea of a steering committee and task teams appointed by a very senior government authority to drive the process. The second level can incorporate the first level through the establishment of an institutional infrastructure, such as a dedicated national agency with a secretariat, to continuously monitor and evaluate performance in STI against the background of a policy framework and to provide data to inform all aspects of the policy cycle. Throughout the policy process, it is important that those developing the policy include those who will be at the front line of implementing and benefiting from it and those who understand the reality on the ground. Similarly, those implementing the policy on the ground need continual guidance regarding whether the implementation is consistent with the original intent of the policy and coherent with broader government activities and overall national development.

Lastly, national policy, by its very nature, is a political construct. Politics is sometimes defined as "the art of the possible". An appropriate, politically attuned governance structure combined with an emphasis on evidence-informed decisions, planning, evaluation and broad stakeholder engagement can extend the realms of what it is possible for an STI policy to deliver. If developed and implemented properly, STI policies can have a profound impact on national development and well-being. To maximize this impact, STI policy development and review should be a continuous, institutionalized process that is coherent with national development policy and related sectoral policies and able to adapt, revise and reform in response to political, social, economic and technological change.

Annex I
African experiences in science, technology, and innovation policymaking: the case of the United Republic of Tanzania

1. Introduction

The United Republic of Tanzania is one of the African countries that have understood the role that science, technology and innovation (STI) plays in social and economic development. In 1985 it became one of the first to promulgate a national science and technology policy. Since then, the policy has been reviewed several times. This annex describes the STI policymaking process in the United Republic of Tanzania, focusing in particular on the stakeholders' involvement in and governance of the process, policy priority-setting, monitoring and evaluation, and financing.

It is important to note that what is described herein is only what is documented in the policy itself and in related literature, and therefore might exclude rich, undocumented procedures, especially those related to stakeholders' involvement in the entire policy process.

2. Stakeholder involvement

Stakeholders' involvement in the policymaking processes and participation in its governance is not explicit in most of the STI policy documents, but it appears to be a very important part of the process. The evidence for this is found in a project document to support the Tanzanian National Systems of Innovation (United Republic of Tanzania, Ministry of Communication, Science and Technology and Ministry of Foreign Affairs of Finland, 2015). As background information, the project document details the process of stakeholder involvement in the review of the country's latest science and technology policy, which was promulgated in 1996. According to the document, the process began with the review of the national innovation systems, as follows:

"A series of workshops were held with representatives from the government, the private sector, and academia and research institutions to get their views on the subject. Subsequently a background report was prepared by a team of Tanzanian experts. Based on the findings, an external review of the background report was carried out by a team of experts from South Africa. The two reports were presented to stakeholders including a meeting with the Permanent Secretaries and the National Planning Commission"

Based on the two reviews, a national STI policy was developed (United Republic of Tanzania, 2010). The draft policy was produced and presented to stakeholders in 2015 (United Republic of Tanzania, Ministry of Communication, Science and Technology and Ministry of Foreign Affairs of Finland, 2015). The whole process was coordinated and governed by the ministry that was responsible for STI, which at the time was the Ministry of Communication, Science and Technology. It is important to note here that science and technology in the United Republic of Tanzania has been migrated from one ministry to another. In the early 1990s, it was the remit of the National Planning Commission. The Ministry of Science, Technology and Higher Education took over this domain when it was established, and it handled the promulgation of the 1996 science and technology policy. By the time the research and development policy of 2010 was promulgated, STI was the responsibility of the Ministry of

Communication, Science and Technology. Currently, STI is the remit of the Ministry of Education, Science and Technology.

3. Priority-setting

Issues related to priority-setting in STI have been explicitly stated in Tanzanian STI policy documents. In some countries, it is commonly understood that STI is a sector in its own right, but the Tanzanian policymakers understood that it is not the case. Rather, STI is an enabler of sectors. This is clearly indicated in the science and technology policy of 1996. Under the section on priority-setting, the policy document states that science and technology should be used to solve problems in key economic, productive and social welfare sectors, such as industry, agriculture energy and social welfare. Specific priority areas include:

(a) Expanding investment in human resources;

(b) Paying special attention to applied research relating to national development goals;

(c) Increasing overall capacity for technology transfer.

While the Tanzanian policy clearly stipulates the importance of aligning national STI policy with development goals, including alignment with priority areas, there could be challenges around effectively coordinating STI policies with the other sectoral policies mentioned. This fact has been brought to the fore by the review of the national STI system that was concluded in 2014. The review indicated that there was poor coordination during the formulation and implementation of policies among various ministries, departments and agencies (United Republic of Tanzania, Ministry of Communication, Science and Technology, 2014).

Clear coordination within each component of STI could also be problematic as policy documents seem to place great emphasis on the supply-side components, that is, on science and research. Additionally, the review of the national innovation systems indicates that STI is given a narrow definition within the government hierarchy to mean research and development only. STI is also considered a sector instead of an enabler of key sectors. This is contrary to what is indicated in the policy document, implying that, at times, what is indicated in the policy document is not widely known among policy officials or is not being implemented. Policy coordination should probably be emphasized, and the United Republic of Tanzania should perhaps even make it a focus for its STI policy capacity-building.

4. Monitoring and evaluation

Monitoring and evaluation is a very important aspect in any policymaking process. Policies are living documents that need to constantly be adjusted based on the lessons learned from the implementation process. Although STI policy implementation and monitoring is not a common practice in the United Republic of Tanzania, it is widely recognized in blueprint documents. In some policy documents, such as the science and technology policy of 1996 and the research and development policy of 2010, STI policy and implementation is mentioned only in a short statement towards the end. In some policies, there is evidence that the implementation plan has been prepared, even though an implementation plan normally comes much later, in separate documents. For instance, the 1996 policy document mentions that the implementation of the 1985 policy was drawn up in 1997, but the plan was not implemented

for a number of reasons, including the lack of integration of the science and technology plan in the country's overall economic development (United Republic of Tanzania, Ministry of Communication, Science and Technology, 1996).

The 1996 science and technology policy does not include the implementation, monitoring and evaluation plan, but it does discuss the importance of science and technology indicators in the monitoring and evaluation of a policy and it lists and defines some of the necessary indicators, as follows:

(a) Size of research and development expenditure

The policy defines this as expenditure on research and development salaries, operational funds, other support for research and development activities in educational institutions, and recurring annual costs for research and development in all science and technology sectors.

(b) Ratio of research and development staff to the total labour force

According to the policy document, this is measured as the number of full-time equivalent scientists working in research and development activities per 10,000 workers.

(c) Ratio of university staff members to students enrolled

This ratio measures the quality of a country's higher education system. The policy document adds that one important aspect of this indicator is the percentage of staff time allocated to research in addition to teaching.

(d) Ratio of BSc, MSc and PhD holders in the Science and technology education system

According to the policy document, the degree of adequacy of higher education system is usually determined by the spectrum of types and levels of programmes offered beyond the high-school level. The document states that science and technology activities require the full spectrum of training levels, including senior technicians and technologists and including graduates, postgraduates and PhD holders. Since postgraduates and PhD holders are needed more in the field where research and development is considered a major science-and-technology indicator of the maturity of the education system.

(e) Publications in scientific journals

According to the policy document, the number of papers published by scientists and technology specialists in scientific journals is another indicator of a country's science and technology efforts. The higher the number of papers published, the better the country's rank in science and technology

(f) Patents

The policy document identifies the number of patents granted to the science and technology system or individuals in a country to be an indicator of the productivity of the country's science and technology system.

(g) Science and technology working facilities

Working facilities for scientists and technologists, such as workshops, machinery, equipment and other research and development instruments are an essential indicator of successful science and technology activities.

(h) Other indicators

Other indicators of the health and competitiveness of the national economy that are mentioned in the policy document include books published, expenditure on emerging and new technologies, the share of industry in research and development activities, venture capital investments in science and technology production, the degree to which informatics and computers are used in the society and the level of employment in science and technology.

5. Financing of STI

The science and technology policy developed by the United Republic of Tanzania in 1996 includes a section on the financing of STI activities. The policy focuses on the amount of resources to be committed to a given science and technology activity. Financial decisions on how much to spend are determined by the importance of a sector to which STI is applied. The policy sets out the following criteria for determining the amount of resources to be spent on STI in each sector:

(a) The sector's contribution to GDP;

(b) Its potential for the development of other sectors;

(c) Its contribution to social and economic development;

(d) Urgency;

(e) Its long-term implications;

(f) Its potential for the attainment and maintenance of national competitive advantage;

(g) The availability of resources.

Although the policy mentions the criteria for determining the amount of resources to be committed to a given STI activity, there is no indication of a policy instrument to be used. Financial policy instruments include the funding of universities and of public research and development organizations and direct financial support to the private sector through grants, loans, subsidies, tax credits and other fiscal incentives.

6. Policy reviews

Although the United Republic of Tanzania does not regularly monitor the implementation of its STI policies, it does carry out final reviews. Three policy reviews have been conducted since the first policy document was developed in 1985. Most of these reviews were prompted not by evidence gathered from the implementation of policy – in accordance with normal best practice – but by changes in the external environment, both within and outside the country, as explained below.

6.1 Review of the 1985 science and technology policy

The reasons for the review of the 1985 policy were given in the introduction to the 1996 policy document. As alluded to above, it was reviewed owing to changes in the external environment, rather than owing to lessons learned from its implementation. These changes include a different sociopolitical regime. Whereas major productive forces had previously been managed by the Government, changes to the macroeconomic environment and to other sectoral policy objectives, such as those of the Basic Industrial Strategy (1975-1995), made various policy changes necessary, including in science and technology. These changes began with structural adjustment programmes and were followed by other reforms, which culminated in the privatization exercise that began in 1991.

6.2 Review of the 1996 science and technology policy

This policy seems to have been reviewed piecemeal. The first review was of its research and development component, which led to the research and development policy of 2010. The latter indicated that the review of the research and development component was required because of the inadequate impact that research and development was having on social and economic development. The review states: "Despite the government efforts to establish a number of [research and development] institutions as well as training of researchers in the country, the benefits of research have not been fully realized" (United Republic of Tanzania, Ministry of Communication, Science and Technology, 1996, p. 2). The research and development policy of 2010 was therefore targeted at addressing the weaknesses of the 1996 policy, in particular its research and development component. Some of these gaps include the lack of adequate incentives, which reduces Tanzanian firms' interest in investing in research and development, and weakness in the coordination, funding and management of the research system. Other weaknesses include inadequate rewards for researchers, including poor marketing and little protection of their intellectual property rights.

6.3 Review of the 1996 science and technology policy and the 2010 research and development policy

The review of these two policies was initiated in 2015 as a result of the findings of the review of the national STI system. The new policy was intended to address the following system weaknesses (among others) that were revealed by the review process (United Republic of Tanzania, Ministry of Communication, Science and Technology, 2014):

(a) Coordination among ministries, departments and agencies is poor during policy formulation and implementation;

(b) Policies are formulated and approved without a direct link to a budgetary allocation by the treasury;

(c) Most policies do not have an elaborate implementation plan or a robust monitoring and evaluation framework;

(d) STI is defined narrowly within the government hierarchy to mean only research and development and is considered as a sector instead of an enabler of key sectors;

(e) The Tanzania Commission for Science and Technology has a narrow mandate and there is conflict between its supportive and regulatory roles;

(f) The role of Parliament in fostering STI is blurred, since Parliament lacks a strong technical advisory arm;

(g) No clear mechanism exists for national priority-setting and technology foresight;

(h) The research system is underfunded and does not meet the expected standard because there is no clearly defined national research agenda linked to innovation;

(i) No mechanism exists to accelerate the uptake of research results to support the country's social and economic development goals;

(j) There is a critical shortage of human resources to undertake research that could provide solutions to the country's social and economic challenges;

(k) The weak intellectual property regime at the national and institutional levels does not facilitate the commercialization and protection of research results, especially those emanating from publicly funded research;

(l) The country does not have a culture of periodic institutional review and self-assessment to identify non-performing institutions and take appropriate action to improve their efficiency;

(m) No proper linkage or collaboration exists between research institutions and industries on the one hand and the overall service and productive sectors on the other that would facilitate the use of research results to support innovation.

Despite this review of the previous policy, the new policy has not yet been published, probably because of changes in the political administration around the time of the policy review.

7. Conclusion

The experience of the United Republic of Tanzania in STI policymaking indicates that the Government understands that the role of STI in development is critical and that policy is important. Although the process includes many good elements in the design and evaluation of STI policies, there must also be some serious gaps and weaknesses, given that the policies had a minimal impact on social and economic development. These gaps and weaknesses include issues around policy coordination and a narrow understanding of the concept of STI to refer almost exclusively to research and development. The most serious weakness, however, is the lack of implementation, close monitoring and learning. This weakness is so serious that it has made other weaknesses go undetected. Without the implementation, monitoring and learning issues, other weaknesses would have been more visible and the policy would have been adjusted accordingly. These challenges are not limited to the United Republic of Tanzania, but are a general feature of most STI policies in Africa. According to Cirera and Maloney (2017), government capabilities in the design, implementation and evaluation of STI policies remain a major weakness of African science, technology and innovation systems.

Annex II
African experiences in science, technology and innovation policymaking: the case of Ghana

1. Introduction

1.1 Background

Ghana is a middle-income country with a population of 30.8 million according to the population and housing census conducted in 2021, an increase of 6.1 million since 2010. The annual intercensal growth rate was 2.1 per cent, which is lower than the growth rate of 2.5 per cent recorded in the 2010 population census (Ghana Statistical Service, 2021). The country's life expectancy rate increased from 61.03 in 2010 to 64.35 in 2020.

Table 1 provides some indicators on development in Ghana. The country was ranked 138th in the world in 2019 in the human development index. The literacy rate of adults aged 15 years and above was high, at 79.04 per cent in 2018, compared with the African average of 70 per cent and the world average of 90 per cent. However, 23.4 per cent of the population were living below the national poverty line (2008–2019) and 13.3 per cent were living below the poverty income line of $1.90 (2008–2019) (United Nations Development Programme, 2020).

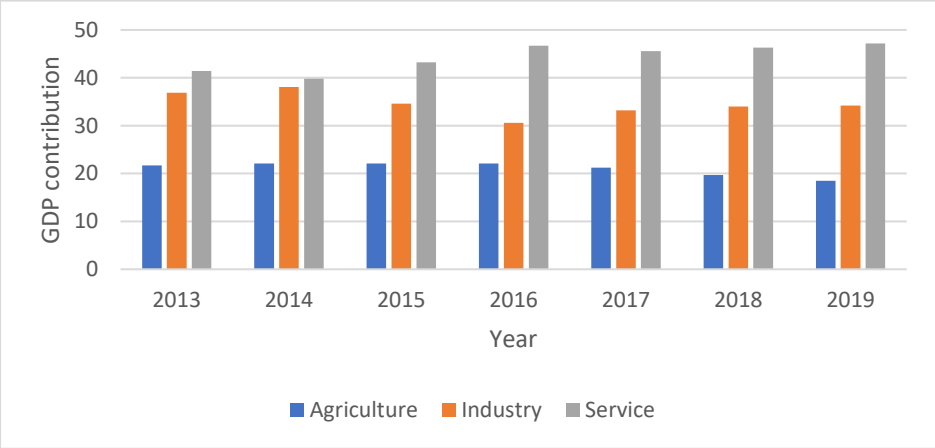
Table 1
Selected social and economic indicators in Ghana

INDICATORS	STATUS	YEAR
Global Innovation Index (rank)	112th of 132	2021
Global Competitiveness Index (rank)	111th of 141	2019
Human development index (value)	0.611	2020
Human development index (rank)	138th of 189	2019
Gross domestic product growth	0.41	2019
Population	30.8 million	2021
Population growth rate	2.1 per cent	2021
Life expectancy at birth	64.97	2020
Literacy rate (per cent of adults over 15 years of age)	79.04 per cent	2018
Doing Business (rank)	118th of 190	2019
Population living below the national poverty line	23.40 per cent	2008–2019
Population living below the income poverty line of US1.90	13.3 per cent	2008–2018

Source: Various online sources.

Until the turn of the century, agriculture was the mainstay of the Ghanaian economy, but services are now the leading contributor to the economy (see the figure). With the exception of 2014, the service sector contributed over 40 per cent to the country's GDP. This was followed by industry, with oil exports possibly having contributed significantly to the sector's improved performance.

Figure
Contributions to GDP by sector



Source: Ghana Statistical Service (n.d.).

In terms of macroeconomics, Ghana recorded GDP growth of 0.51 per cent in 2020, down from 6.51 per cent in 2019. These figures emphasize that the COVID-19 pandemic had a huge influence on the country's economic performance. Nevertheless, the country's GDP per capita for 2020 was $2,254, a 0.34 per cent increase from 2019 (Macrotrends, n.d.).

Compared with the global context, the country's general economic performance was not enviable. In the Global Competitive Index of 2019, Ghana ranked 111th out of 141 countries, down five positions since 2018. Furthermore, in the Global Innovation Index, Ghana ranked 112th out of 132 countries in 2021. Serious actions are therefore needed to increase the country's competitiveness and innovativeness, especially if Ghana wants to achieve the targets of the Sustainable Development Goals. One of the surest ways would be through pragmatic STI policies and programmes to effectively harness the potential of STI, as developed countries have done.

1.2 STI policy in the development context

Throughout the world, the role of STI in driving sustainable development and vastly reducing poverty has long been highlighted. Tapping into the benefits of STI can be achieved by creating robust STI systems and appropriate policy frameworks (Quaye and others, 2019). At the same time, it is recognized that STI policies should be developed based on strong pillars within the national, regional and global political, economic (and social) contexts of national development. In addition, there have been calls to move away from traditional STI policies, with their strong emphasis on an innovation system centred on industrial growth, by incorporating transformative social change aligned with the Sustainable Development Goals (United Nations, Economic Commission for Africa, 2021).

Africa has sought to harness STI for continent-wide development through many declarations and, more recently, through initiatives such as the African Innovation Outlook of the African Union Development Agency, Agenda 2063 and the Science, Technology and Innovation Strategy for Africa 2024. These concrete, comprehensive programmes provide impetus for African countries to urgently integrate STI into their development agendas so that

they can effectively exploit STI and thus reduce their development gap with the developed world, or even leapfrog the developed world.

Specifically, the Science, Technology and Innovation Strategy for Africa 2024 serves as a strategic document to drive the development of STI and its adoption into the African development agenda. The Strategy is a response to the demand for STI from critical sectors, including agriculture, health, infrastructure development, mining, security, water, energy and the environment. However, although STI can be harnessed through pragmatic policy environments, the few coherent STI policies that exist in Africa do not directly respond to the intricacies of STI, most often because the country's policymaking process is fraught with challenges, including a lack of clear-cut implementation strategies.

There is no single optimal approach to developing a national STI policy. The process depends on many factors, including the nature and culture of the country concerned. It is against this background that ECA is developing a policymaking guide that outlines issues that should be considered when STI policies are developed. This report is a case study on the STI policymaking process in Ghana to put into context the objectives of the ECA policy guide.

Section 1 is the introduction to the report. Section 2 is a review of the STI policymaking process of Ghana. Section 3 is a discussion of the elements involved in policymaking. Section 4 is the conclusion of the case study.

2. Public policymaking in Ghana

This section of the case study is a review of the public policy process in Ghana, including STI policymaking. The purpose is to share the country's experience in STI policymaking in the light of the ECA policymaking guidelines.

At present, there is a national guideline for public policymaking that was produced in 2020. Previously, however, a different approach was used for the national STI policymaking process. This document contains a discussion of both the former and the current approach.

2.1 STI policy process before the guidelines

Amankwah-Amoah (2016, p. 136) identifies three eras in the history of STI policies in Ghana: the era of the first President, Kwame Nkrumah (1957–1966); the era immediately after Kwame Nkrumah (1966 to the 1990s); and the "new dawn", which began in 2000. The focus of the analysis that follows is on the most recent era, during which Ghana has attempted to formulate three policies on either science and technology or science, technology and innovation. Table 2 shows a list of STI policies in Ghana. The first national policy on science and technology was launched in 2000 by the Ministry of Environment, Science and Technology. This policy did not have an implementation plan owing to a change in Government in 2001. It was almost abandoned altogether following the merger of the Ministry of Environment, Science and Technology with the Ministry of Education, Sports and Science in 2006.

Ghana formulated a science and technology policy in 2000 after realizing that there was no explicit, legally implemented science and technology policy to guide the national development agenda. The situation was considered the biggest obstacle to capitalizing on the technology factor for development. A group of scientists and policymakers was therefore

formed to prepare a single document outlining science and technology programmes and projects. The 2000 science and technology policy was formulated with a vision to:

"support national socio-economic development goals with a view to lifting Ghana to a middle-income status by the year 2020 through the perpetuation of a science and technology culture at all the levels of society, which is driven by the promotion of innovation and the mastery of known and proven technologies and their application in industry and other sectors of the economy." (Ghana, Ministry of Environment, Science, and Technology, 2000, p. 4).

The 2000 science and technology policy lacked an implementation plan with funding to achieve the objectives set after almost being abandoned due to a change of Government and, as already mentioned, the dissolution of the Ministry of Environment, Science and Technology in 2006.

In 2007, at the request of the Government of Ghana, the United Nations Conference on Trade and Development and the World Bank, in collaboration with the Science and Technology Policy Research Institute of the Council for Scientific and Industrial Research, began a review of the science, technology and innovation policy of Ghana. The objective was to critically look at the country's STI capacities and assess how they were being translated into innovations that will help to meet the country's social and economic development objectives, including supporting economic growth, poverty reduction and structural transformation of the economy. It sets out specific recommendations for practical actions, including policy reforms to build STI capacity and create a more dynamic economy to move Ghana towards middle-income levels more quickly (United Nations Conference on Trade and Development, 2011b). Even before the final report was published, the review revealed that the country needed a new STI policy. The review supported the STI policy process by evaluating the 2000 science and technology policy and by setting the agenda for the 2010 STI policy.

In 2009, a process was established for the formulation of a new science and technology policy. This time the policy included innovation and placed special emphasis on it. First, the Ministry of Environment Science and Technology appointed consultant to draft the new STI policy. The consultants presented the draft to the Ministry, which then organized consultative forums to elicit inputs for the revised draft. Several consultative forums were then organized at the regional level, bringing together a wide array of stakeholders, including academics, private sector representatives, policymakers, development planners and civil society organizations. The regional consultative forums culminated in a national consultative forum organized to elicit more input. The 2010 STI policy was then published and an implementation plan was developed.

New developments in STI and the desire of the Government of Ghana to accelerate the country's development led to a review of the 2010 STI policy by a consultant appointed by the Ministry of Environment, Science, Technology and Innovation in 2017. The review, coupled with several consultations, led to the drafting of the 2017 STI policy. Table 2 provides a summary of STI policy development in Ghana.

Table 2
STI policies in Ghana (1980s–2027)

Period	*STI policy document*	*Lead institution*
1980s–1990s	"Science and Technology Plan Options" report, developed in 1990 by the Council for Scientific and Industrial Research but not adopted	Ministry of Industry, Science and Technology (MIST)
2000–2010	"National Science and Technology Policy"	Ministry of Environment/Ministry of Environment, Science and Technology
2010–2017	"National Science, Technology and Innovation Policy"	Ministry of Environment, Science, Technology and Innovation
2017–2027	"National Science, Technology and Innovation Policy" (revised)	Ministry of Environment, Science, Technology and Innovation

Source: Essegbey, Asante and Oti-Boateng (2019).

2.2 National Development Planning Commission guidelines

As noted above, until 2020, different approaches were used for public policymaking in Ghana, which resulted in several challenges. For instance, it was found that some public policies formulated in Ghana had:

- Varied policy formats and structures
- Different processes and procedures
- Limited stakeholder engagement in some policy formulation processes
- Weak implementation arrangements
- Weak policy ownership
- Inadequate funding arrangements as well as policy conflicts
- Inconsistencies, duplications and contradictions

In 2020, the National Development Planning Commission of Ghana therefore produced the *National Public Policy Formulation Guidelines*, which were intended to rationalize public policymaking and policy approval in the country (National Development Planning Commission, 2020). Figure 1 in those guidelines illustrates the stages of the public policymaking process in Ghana.

As shown in figure 1, public policies can be initiated by the President of Ghana either directly through the Office of the President or through a ministry, department or agency. Regardless of where the public policy is initiated, other entities are involved in the drafting and approval stages and in providing feedback (e.g. the Ministry of Justice, the Attorney General and Parliament) and advice (e.g. the National Development Planning Commission and the Office of the Head of Civil Service).

The *National Public Policy Formulation Guidelines* describe a nine-step policymaking process. Step 1 is the constitution of the policy formulation team at the ministry, department or agency, which has eight members, including the minister, chief director and other heads of departments. All members of the team are from within the ministry, department or agency.

In step 2, issues for which a policy needs to be formulated are identified and analysed. The issues may emanate from the Government's agenda and priorities, including subregional, regional and global conventions, treaties and protocols; public concern and awareness of an issue; constitutional obligations or recommendations; laws; social, political, cultural, environmental or economic changes; physical or technological changes; crises and emergencies; the national long-term development agenda; and the state of the nation address.

Step 3 of the *National Public Policy Formulation Guidelines* requires the formulation of policy options to address any issues identified in step 2. The policy options being formulated should take into account their economic, sociocultural, gender, environmental and other impacts and make recommendations for the optimal policy options. The guidelines require the following to be undertaken and considered:

- Research on good practices
- Estimates of the resource requirements for implementation (e.g. financial, human and technology)
- Quantitative and qualitative analysis of the options
- Risk analysis of the options
- Performance appraisal methods for the proposed option
- An impact assessment of each option
- A strategic environmental assessment of each option (National Development Planning Commission, 2020, p. 28)

The policy options to adopt should be backed by strong technical and evidence-based justification.

Step 4 is the stage where stakeholder consultations are organized around the policy options identified to build consensus on the recommended policy options. As part of the step, stakeholder mapping analyses are carried out. Ultimately, the consultation is expected to include three key elements: data collection, analysis and validation; a discussion of policy options; and the validation of the recommended policy options.

In step 5 of the policymaking process, the vision, goals, objectives and strategies of the recommended policy options are developed. The vision should convey optimism and hope for the future and should provide a mental picture of what the policy is expected to achieve in the short, medium or long term. In addition, the goal must be clear and credible and must reflect the vision of citizens and policymakers. The policy objectives must be specific, measurable, attainable, realistic and time-bound; the strategies must provide the road map for how the policy will be implemented, with the steps to be taken to achieve that presented in detail (National Development Planning Commission, 2020, p. 21).

Step 6 involves identifying and articulating a strategy for mobilizing internal and external resources for developing and implementing the policy. This step must also include identifying funding for capacity-building where it is needed.

In step 7, the arrangements for implementing the policy are determined. A set of organized activities to be undertaken by public institutions to address a policy issue is established. The guidelines stipulate that, as part of the policy implementation process, an action plan should be developed that clearly specifies the indicators and targets to be achieved with measurable programmes, projects and activities within a stipulated timeframe (National Development Planning Commission, 2020, p. 32). While policy objectives and strategies are being implemented, it is important for them to be monitored at the sector and district levels through their medium-term plans and presented as progress reports.

Step 8 of the policymaking process deals with the arrangements for policy monitoring and evaluation – a key component of policymaking – which is necessary to determine whether policies are relevant, efficient and effective so that they can be adjusted when necessary.

Step 9 completes the policymaking cycle. In this step, the policy formulation team must develop a communication strategy that articulates ways in which information will be communicated to stakeholders throughout the policy formulation and implementation process. Since communication takes place throughout all the steps of the process, the strategy must address these as well.

Table 3 is a summary of the discussion thus far. The experience of STI policymaking in Ghana has been different from the National Development Planning Commission public policy guidelines developed in 2020 and different from the ECA guidelines. Some of the proposals in the ECA policy guide, however, had already been adopted in earlier STI policies. The ECA guide referred to using champions to drive the process in each country. Ghana had followed this practice, using champions, experts and consultants to set the policy agenda, conduct policy analysis and design policy options. In addition, the role of consultations with stakeholders for these activities has been amply demonstrated in the country's STI policymaking process. Once a policy has been formulated and validated through stakeholder engagement, the policy must be adopted. The example of the policy developed in 2000, which was not subsequently implemented because it was not adopted, reinforces this point. Policy adoption is therefore very important, since it is one of the means by which legitimacy is given to a policy.

Table 3
STI policymaking in Ghana and the ECA steps proposed

	ECA policy steps	*Steps in 2010 STI policy*	*Steps in 2017 STI policy*	*National Development Planning Commission policy guidelines*
Preliminary				Formation of the policy team at the ministry, department or agency
1	Agenda-setting	Champion in the lead organization (ministry) and experts	Champion in the lead organization (ministry) and experts	Identification and analysis of issues
2	Policy analysis	Experts Stakeholder consultation workshops	Experts Stakeholder consultation workshops	Policy options Stakeholder consultations
3	Policy formulation	Experts and technical committee	Experts and technical committee	Policy formulation Identification and development of strategies
4	Policy adoption	Presentation of the policy to Cabinet for adoption, by the minister responsible for science, technology and innovation (Ministry of Environment, Science, Technology and Innovation)	Presentation of the policy to Cabinet for adoption, by the minister responsible for science, technology and innovation (Ministry of Environment, Science, Technology and Innovation)	
5	Policy implementation	Ministry of Environment, Science, Technology and Innovation and departments and agencies under its responsibility	Ministry of Environment, Science, Technology and Innovation and departments and agencies under its responsibility	Policy implementation
6	Policy evaluation	Never evaluated. However, the Ministry of Environment, Science Technology and Innovation has the Policy, Planning, Monitoring and Evaluation directorate, which should initiate the move for independent evaluation	Never evaluated. However, Ministry of Environment, Science Technology and Innovation has the Policy, Planning, Monitoring and Evaluation directorate, which should initiate the move for independent evaluation	Monitoring and evaluation

3. Key elements of policymaking

It is important to note that different countries will have different needs and methods in STI, which means they will have different ways of formulating and implementing STI policy. It is also important to note, however, that there are certain key elements required in policymaking to ensure that policies stand the test of time. This section briefly presents the key elements of policymaking: the institutionalization of STI policymaking, prioritization, the development of implementation strategies, monitoring and evaluation, and resource mobilization.

3.1 Institutionalizing policymaking

An institutionalized culture of policymaking is the linchpin for effective policy implementation and delivery. The institutional framework for policymaking in Ghana includes universities, independent research institutions, think tanks and the private sector. Specialized policymaking institutes and agencies have also been created in most government ministries and departments.

STI policymaking is a mainstay activity for STI management. In some countries, the policymaking process has been mainstreamed into the institutions that govern STI activities. However, to ensure better management of STI, it is important to institutionalize STI policymaking. The need to have organizations or agencies dedicated to developing and regularly revising STI policy is key. Malaysia is the best example, where STI policymaking has been institutionalized, strengthened and mainstreamed into all sectors and is present at all levels of the country's development agenda.

The sequence of policy development in Malaysia also demonstrates the country's commitment to the institutionalization of STI policymaking. It has formulated and implemented the National Science and Technology Policy (1986–1989), Industrial Technology Development: A National Action Plan (1990–2001), and the Second National Science and Technology Policy and Plan of Action (2002–2010). STI development in Malaysia has been driven by the various initiatives and programmes that were implemented under these policies, including the advancement of national capabilities and capacities through the research and development system, the development of a partnership between the public research and development system and the private sector, and the development of new, knowledge-based industries.

In Ghana, the Ministry of Environment, Science, Technology and Innovation is responsible for managing and implementing government policies on STI. The policymaking process in Ghana has not been fully institutionalized like it has in Malaysia, the Republic of Korea, Singapore and other countries. No clear time frame or mechanisms exist to set in motion policy revisions to address emerging technological, economic, political and social issues. However, the Presidential Advisory Council on Science, Technology and Innovation was established to advise the President of the Republic on all issues pertaining to STI and to support the Government's policy development and decision-making. As an institutionalized high-level advisory body on STI, the Presidential Advisory Council will, among other roles, advise on the coordination and harmonization of STI policies and programmes so that STI activities are comprehensive and complementary across all sectors and ministries. The Council was established by the President of Ghana in 2018 in response to a recommendation in the ECA

policy guidelines stating that STI in African countries should be driven by high-level bodies. The Council was created through an executive instrument to "advise the President on advances made in science, technology and innovation and the best ways to include those advances in the socio-economic development of the Republic" (Ghana, 2018, p. 3012). The body is in its formative stage and it is not certain whether the Government will maintain its members in its new term of office.

STI also needs to be institutionalized within the organs of government, as is the case in the United Kingdom of Great Britain and Northern Ireland, where the Parliamentary Office for Science and Technology serves as a research and advisory body to the two Houses of Parliament. The Office provides insights into emerging STI developments, which serve as critical tools for informed parliamentary debate on STI.

3.2 Prioritization

In all public policymaking, prioritization is necessary, especially during policy formulation, because of the limited resources available to address unlimited needs and demands. Prioritization should establish the means available to achieve the most important goals. This may involve identifying a range of broad approaches that the policy is seeking to address and then identifying and designing the specific sets of policy tools for each approach.

The implementation plan for the 2010 STI policy in Ghana (Ghana, Ministry of Environment, Science, Technology and Innovation, 2017) had 17 programme areas, each with a set of projects to be executed. STI activities were therefore indirectly prioritized to help to achieve national development.

Although priorities might have been set by the Ministry of Environment, Science, Technology and Innovation and then shaped through participatory policy formulation, an implementation plan has arguably not yet been developed for the policy. However, a road map has been prepared to use STI to achieve the Sustainable Development Goals. The road map for Ghana in the *Science, Technology and Innovation (STI) for SDGs Roadmaps* seeks to prioritize areas in which the country's STI activities will be harnessed through seven prioritized Sustainable Development Goals: Goals 1, 2, 3, 4, 6, 8 and 9. The road map for Ghana also outlines specific activities in which STI will be used to help to achieve those Goals. For instance, for Goal 1, the road map identified the following activities:

- Promoting technology and innovation for livelihoods
- Strengthening technology promotion centres such as the Rural Technology Facility to provide agricultural technologies for rural industries
- Promoting information and communications technology-based business, such as the availability of mobile money transfers in 50 selected communities in five regions (Essegbey and others, 2021, p. 49)

The need for prioritization to support STI policy development cannot be underestimated. The prioritization of STI by Malaysia is very instructive. The National Policy on Science, Technology and Innovation (2013–2020) prioritized six strategic thrusts, namely:

- Advancing scientific and social research, development and commercialization

- Developing, harnessing and intensifying talent
- Energizing industries
- Transforming STI governance
- Promoting STI
- Enhancing strategic international alliances

These prioritized areas are driving social and economic development in Malaysia.

3.3 Developing an implementation strategy or plan

Once formulated, policies should be executed, hence the need to develop an implementation plan or strategy to identify the steps required to successfully implement the policy. The key elements to be considered in the implementation plan include a clear definition of obligations and roles, communication strategies to publicize the policy, a budget and timelines.

In Ghana, an implementation plan was developed to execute the 2010 STI policy. It was the first time an implementation plan had been developed to support an STI policy. As already mentioned, the implementation plan involved 17 programmes and 84 projects, which were prioritized in the earlier phase of the policy development. The list of programmes included the following:

- Mainstreaming STI into the national development agenda
- Promoting a culture of STI in Ghana
- Developing human capital for the development of STI
- Establishing an effective national innovation system
- Developing national capacity for space science and technology
- Advancing research in emerging and promising STI fields (Ghana, Ministry of Environment, Science and Technology, 2011)

The implementation plan provided an indicative cost for the project, set timelines, stated the responsible institution and the monitoring and evaluation agency and provided an output indicator. The Plan was never implemented for several reasons, including a lack of political commitment. Preparing the implementation plan was therefore a futile exercise and contributed nothing to national development.

3.4 Continuous monitoring and evaluation

Policy formulation is often seen as the end-game, but it should not be so, since policymakers should learn from the policy process and apply the lessons learned to policy revisions and future policies they design. Monitoring and evaluation therefore constitute a key element of the policymaking process. A continuous and systematic management process is therefore needed to collect and analyse information on policy design and implementation and on impact assessments of programmes and projects under the policy. It is equally important to conduct studies to determine and improve the conceptualization and design of STI policies,

plans, programmes and projects to ensure that they are relevant, effective and efficient. For Ghana, prior to the 2010 STI policy, a review of science, technology and innovation policy by the United Nations Conference on Trade and Development was conducted to provide an objective and critical look at the STI capacities of Ghana and assess how they were being translated into innovations that helped to meet the country's social and economic development objectives (United Nations Conference on Trade and Development, 2011b). The review therefore served as a form of evaluation of the STI landscape in Ghana.

Prior to the formulation of the 2017 STI policy, there was no evaluation in the sense of how the 2010 implementation plan was envisaged. The implementation plan for the 2010 STI policy outlined five projects under the monitoring and evaluation programme:

- Establishing national STI
- Conducting a national STI baseline survey
- Building capacity for STI monitoring and evaluation
- Conducting annual reviews of the national STI development programme
- Evaluating the national STI development programme (MEST, 2011)

Although two studies (Adjaloo, 2016; Universität Bremen, n.d.) provided input to inform the revision of the present policy revision, no formal evaluation was carried out to evaluate the 2010 STI policy, as outlined in its implementation plan. The public policy guide produced by the National Development Planning Commission provided a mechanism for monitoring and evaluation, which should be enforced. The experience of Ghana has shown that not carrying out a policy evaluation can be detrimental to the policy cycle.

3.5 Resource mobilization

Resources are needed not only for policy implementation, but also for policy formulation, monitoring and evaluation. The availability of resources should therefore be a major consideration during policymaking on STI. In Ghana, for instance, it was recognized that the Government should increase expenditure on STI to 1 per cent of GDP, as stipulated by the Africa Union Commission and in other declarations. To mobilize resources for STI, the recent STI policy (Ghana, Ministry of Environment, Science, Technology and Innovation, 2017, pp. 66 and 67) makes provisions to do the following:

- Establish the STI Fund
- Encourage the private sector to support the funding of research and development activities
- Institute an attractive tax incentive mechanism for contributors to the instituted funds or provide direct support to research and development activities
- Encourage the formation of a venture capital fund with the authority to commercialize new technology
- Encourage the public procurement of products and services from science and technology institutions

These measures are designed to raise funds for STI activities in the country. The call for the establishment of a venture capital fund is a step in the right direction. Singapore has established Innosight Ventures to support incubator development in the country.

Prior to this, attempts were made to establish a science and technology fund to raise money from public and private institutions to support STI development in Ghana. For example, under the presidency of Jerry Rawlings, a science and technology fund was established at the Council for Scientific and Industrial Research, with a full-fledged office. The next President, John Kufuor, pledged 5 million cedis to the fund. Despite these measures, there is little information about the operations of the fund under the two presidencies.

The implementation plan for the 2010 STI policy included a programme for financing STI. One of the key objectives was to foster public-private partnerships in STI investment. Although this was a good objective, the private sector should have been encouraged to lead STI investment, as occurs in the Republic of Korea and other developed countries. In the Republic of Korea, private research and development spending accounted for nearly 80 per cent of the country's total research and development spending in 2019, a higher proportion than in leading innovative countries such as Germany, Sweden and Switzerland (Dayton, 2020). The situation, according to Dayton, was anchored by research and development tax incentives and systemic reform backed by strong investment (Dayton, 2020). This is evidenced by the leading roles of South Korean companies in the manufacture and export of high-technology products.

In Ghana, although the private sector was engaged in the processes leading to the most STI policies, the sector's involvement and commitment was anecdotal. Earlier attempts to establish STI funds suffered from a lack of support from the private sector, and private investment in research and development and STI activities is minimal, with little visible impact.

4. Conclusion

Until the development of the public policy guide by the National Development Planning Commission, different approaches were used in the development of the various STI policies of Ghana. These approaches were different from those set out in the STI policy guide of ECA. As illustrated in table 3, there are differences between the guidelines provided by the National Development Planning Commission and those provided by ECA, mainly in terms of the number of steps per process rather than the main elements.

STI policymaking has been institutionalized, with the Ministry of Environment, Science Technology and Innovation leading the way. The high-level Presidential Advisory Council on Science, Technology and Innovation was established in 2018 to advise the President on matters pertaining to STI. This body is in line with the structure proposed by ECA for policymaking. Nevertheless, the Council is a young institution and has not yet made an impact on the STI environment. The Government needs to give it adequate support to enable the National Development Planning Commission to function as expected. Although it is an advisory council, it can emulate the role played by the Parliamentary Office for Science and Technology in the United Kingdom by conducting or commissioning independent research on emerging issues in STI and it can advise the Government appropriately.

It is argued in this case study report that there was no prioritization in the drafting of the 2017 STI policy of Ghana. This gap should be corrected in the next revision, with the

guidelines of the National Development Planning Commission followed. Since resources are finite, prioritization is essential to ensure that resources are allocated to critical sectors and areas of the national economy. Ghana can learn from the best practices of countries that have prioritized their needs in their STI policymaking process.

One advantage that Ghana has is its participation in the development of the *Guidebook for the Preparation of Science, Technology and Innovation (STI) for SDGs Roadmaps*. This participation has given the country the opportunity to prioritize its developmental areas based on the SDGs. Prioritized areas are highly likely to receive greater attention thanks to the availability of global funding and thanks to monitoring and evaluation mechanisms.

As espoused in the ECA and National Development Planning Commission policy guide, monitoring and evaluation should form an integral part of every policy process, but, in the case of STI, it should not be the remit of the Ministry of Environment, Science Technology and Innovation alone. The cross-sectoral nature of STI makes it difficult for a single ministry to effectively assess its implementation. Monitoring and evaluation are part of the activities of the Presidential Advisory Council on Science, Technology and Innovation and can be done by commissioning independent research to generate evidence-based outcomes to advise the Presidency.

Resource mobilization and allocation are critical issues in developing countries owing to the myriad of challenges that these countries must face. Developed and developing countries alike have established dedicated funds to support STI development. For Ghana, the effective functioning of research funds in Malaysia and Singapore should provide lessons for it to emulate. The idea of establishing an STI fund has been raised a few times in the country's history, but it has never materialized. However, Parliament is currently processing a bill to establish a national research fund.

In conclusion, Ghana has made major strides in developing STI policies over the years. These policies have used different processes, but they are now harmonized by the public policy guide developed by the National Development Planning Commission. Though there are differences between the policy guidelines of the Commission and ECA, both documents set out certain required steps. Furthermore, some of the issues raised in the ECA policy document can be used while the guidelines of the Commission are being followed.

The real challenge identified in this case study is the implementation of key policymaking elements, namely the institutionalization of the policymaking process, prioritization, an implementation plan and implementation strategies, continuous monitoring and evaluation, and resource mobilization. This case study has shown a range of experiences in the use of these elements in policymaking in Ghana. The country has established a high-level body to advise the presidency on STI issues, which is a step in the right direction. Although the Presidential Advisory Council on Science, Technology and Innovation is an advisory body, it can learn from the experiences of the Parliamentary Office for Science and Technology in the United Kingdom.

Lastly, Ghana should benefit from learning from the experiences of countries such as Malaysia, the Republic of Korea and Singapore in developing pragmatic policies and programmes to effectively harness STI for national development.

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