AFRICA BEYOND 2030

LEVERAGING KNOWLEDGE AND INNOVATION TO SECURE SUSTAINABLE DEVELOPMENT GOALS

The African Academy of Sciences

Driving Scientific and Technological Development in Africa

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Edited by

Evelyn Namubiru-Mwaura, PhD, AAS
Elizabeth Marincola, AAS

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LIST OF ABBREVIATIONS

AAS	African Academy of Sciences
AAU	Association of African Universities
ACBF	African Capacity Building Foundation
AMT	Advanced Manufacturing Technologies
AESA	Alliance for Accelerating Excellence in Science in Africa
GAVI	Global AIDS Vaccine Initiatives
AOSTI	African Observatory of Science Technology and Innovation
ASTIF	African Science, Technology and Innovation Fund
AURGP	AU Research Grants Programme
BECA	Biosciences Eastern and Central Africa
CARI	Coalition for African Research and Innovation
CGIAR	Consultative Group on International Agricultural Research
CIRCLE	Climate Impact Research Capacity and Leadership Enhancement
COMESA	Common Market for Eastern and Southern Africa
CSIP	Consortium for Science and Innovation Policy
DELTAS AFRICA	Developing Excellence in Leadership, Training and Science
DFID	Department for International Development
DST	Department of Science and Technology
EAC	East African Community
ECOWAS	Economic Community for West African States
ECREEE	ECOWAS Centre for Renewable Energy and Energy Efficiency
EDCTP	European and Developing Countries Clinical Trials Partnership
GAVI	Global AIDS Vaccine Initiative
GCA	Grand Challenges Africa
GEF	Global Environment Facility
GERD	Gross Expenditure on Research and Development
GFAR	Global Forum for Agricultural Research
GII	Global Innovation Index
H3Africa	Human Heredity and Health in Africa
ICSU	International Council for Science
ICTs	Information and Communication Technologies
ILRI	International Livestock Research Institute
MDGs	Millenium Development Goals
MVSL	Maghreb Virtual Science Library

NABNet	North Africa Biosciences Network
NASAC	Network of Africa Science Academies
NCDs	Noncommunicable Diseases
NEPAD AGENCY	New Partnership for Africa's Development
NSSD	National Strategies on Sustainable Development
PAEPARD	Platform for African-European Partnership on Agricultural Research for Development
R&D	Research and Development
RECs	Regional Economic Communities
SADC	Southern Africa Development Community
SANBIO	Southern Africa Biosciences Network
SDGs	Sustainable Development Goals
SMEs	Small and Medium Scale Enterprises
STEI	Science Technology Engineering and Innovation
STISA	Science, Technology and Innovation Strategy for Africa
STI	Science, Technology and Innovation
STPI	Sectoral Technology Policy Instruments
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNCSD	United Nations Commission on Sustainable Development
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organization
WCED	World Commission on Environment and Development

FOREWORD

Science, Technology and Innovation (STI) will drive the future of Africa

Fifty years ago, Africa emerged from its colonial past by training two generations of its people to run their governments as civil servants, thus taking control of their countries, and creating a robust African middle class. Today, Africa and the world are facing a "Fourth Industrial Revolution", characterized by a job market that demands scientific and technical training, as well as a cultural shift to accept risk-taking.

Over the coming decades, jobs will move by the millions from white collar office positions to those in computer, healthcare, scientific research, architectural and engineering fields. According to the World Economic Forum, an astounding 65% of children born today will eventually be in jobs that don't even exist yet.

This great transition is both a challenge and an opportunity. Africa is the world's fastest-growing continent, and boasts the youngest population. And she will need all the energy and vigor of its youth to overcome her burdens: Africa is home to 15% of the world's population, yet produces just 3% of global GDP and at the same time suffers 25% of the global burden of disease, including a startling increase in non-communicable disease. Today, Africa accounts for just 2% of world research output, 1.3% of world research spending and a holds a tiny 0.2% of patents worldwide.

But our strengths are also legion. Over about a hundred years, life expectancy at birth skyrocketed from under 30 years to over 70. The internet offers unparalleled access to the world's scholarship and to technology that helps level the knowledge playing field. And Africa already has a robust entrepreneurial class thriving everywhere from urban incubators to remote villages, creatively adapting mobile-based solutions to uniquely African challenges.

This momentum is a critical driver of the economy, both because it facilitates access to basic needs such as energy, education, weather data, financial services and transportation, and because it represents a shift to the knowledge-based economy that will carry Africa into a prosperous future.

This report, ***Africa Beyond 2030: Leveraging Science and Innovation to Secure Sustainable Development Goals,*** provides insight into how STI is essential to closing the gap between Africa and the Global North, by achieving the UN's Sustainable Development Goals. It is not an exaggeration to say that our success in reaching every one of the 17 SDGs is highly correlated with our investment in STI.

Moreover, the right policy and governance conditions must exist to incentivize and nurture our investments in science, technology and innovation. Thus, the thought leadership of organizations such as the African Academy of Sciences is a key contributor to shifting the moment on our Con-

tinent from a resource-based, extraction-focused economy, to one driven by entrepreneurship and innovation. Creative initiatives, such as the Coalition for African Research and Innovation (CARI) must be supported in order to build and develop partnerships among more R&D generators with high standards, more skills, more funds, more support and more ambition.

There are many moving parts in Africa, as there are everywhere in the world. Human health and wellbeing are not just dependent on the delivery of preventive and clinical medical services, but are also driven by nutrition, agriculture, the environment and the economy. These interdependent factors must be considered holistically if we are to successfully reach the SDGs.

This timely study provides comprehensive and specific recommendations to improve Africa's science, technology and innovation policies to build the capacity of governments to monitor and evaluate its investments in STI, required for sustainable growth.

Africa must mobilize its own resources – most pointedly its youthful human resources – to drive its scientific and development agenda. The need to invest in STI at every level of government to achieve the SDGs and build a thriving future for Africa is no longer a question. The question is how we ensure that our investments are as effective as they can be.

Her Excellency Ameenah Gurib-Fakim, PhD, President of Mauritius
Member, African Union Presidential Science Committee
Chair, Coalition for African Research and Innovation (CARI)

PREFACE

The future of Africa is driven by investment in science, technology & innovation

Every government in the world has recognized that its economic welfare is dependent on its development of science, technology and innovation (STI). The nations of Africa have accordingly increased their research productivity from 0.44% to 2.6% of total global research, driven mostly by the health and agricultural sciences, two sectors of particular relevance to Africa.

The Continent's high disease burden and food insecurity - an estimated 153 million people age 15 or older suffered from severe food insecurity in sub—Saharan Africa as recently as 2015 make research in the health and agricultural sciences necessary to achieve the SDGs. Yet, as this report shows, investment in STIs is still far from proportional to its importance, undermining Africa's prospects for harnessing STIs for sustainable development.

Overcoming Challenges

That UN's SDGs, alongside Agenda 2063, Africa's blueprint for socio-economic development, provide a roadmap to stimulate the political will to promote sustainable growth and thus contribute to overcoming the challenges that impede a robust economy and human well-being.

This study recommends a way forward to countries to promote STIs for sustainable development. A critical element of the recommendations is the need to reform STI policies so that relevant legislative oversight is created to monitor and evaluate impact and build institutional capacity to ensure successful implementation.

SDGs, the successor framework to the Millennium Development Goals, seek to address urgently the ability of African nations to fund the programmes that Africa needs to leverage domestic funding to adequately harness STI for SDGs. This is because national investment is essential to promote ownership in Africa itself and thus create infrastructure that improves the lives of its people indefinitely. This study demonstrates that, we Africans are the change we have been waiting for.

> 'We Africans are the change we have been waiting for.'

In parallel, private sector investment in R&D must increasingly displace foreign aid. In order to achieve this transition, African nations must create policy that encourages African and non-African investment to promote research uptake of transformative science that results in real benefits to its people.

The Role of Academies

The African Academy of Sciences and national academies across the Continent play an important role as "the voice of science", as reflected in the theme of the 10th AAS General Assembly held in Botswana in 2016.

Academies provide an essential convening role, facilitating policy recommendations based on the wisdom of the most prominent scientists in Africa, as well as through the research programmes that academies create, implement and oversee.

Africa Beyond 2030: Leveraging Science and Innovation to Secure Sustainable Development Goals extends the "voice of science" to build the value of academies as thought leaders. Such thought leadership offers essential service to governments and development partners as a generator of dispassionate, science-driven data and evidence-based research that stakeholders can rely upon in policy development and the determination of investment priorities.

We acknowledge with gratitude the study oversight of Dr. Evelyn Namubiru-Mwaura, Strategy and Policy Manager and Think Tank and Advisory Section Lead at the AAS, as well as the AAS Fellows and others who contributed their time and wisdom.

This report was based on extensive surveys and interviews with scientists, policy-makers and development partners between 2016 and 2017. It offers specific policy recommendations and concrete actions that African countries must—individually and collectively—implement to successfully leverage science, technology and innovation to achieve the SDGs.

Nelson Torto, PhD
Executive Director
The African Academy of Sciences (AAS)

Tom Kariuki, PhD
Director
The Alliance for Accelerating Excellence in Science in Africa (AESA)

ACKNOWLEDGMENT

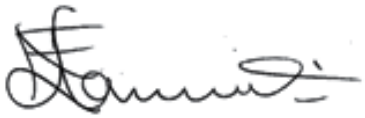
The report is an outcome of the engagement of key expertise and diverse experiences amongst STI stakeholders spread across the continent and in various parts of the world.

We would like to acknowledge Prof. John Mugabe, an expert in the study of science, technology and innovation and an AAS Fellow, who drafted the report.

We thank various contributors that gave extensive advice and comments throughout the concept and writing stages. Special appreciation goes to Prof. Berhanu Abegaz (University of Johannesburg), Prof. Aggrey Ambali (NEPAD), Prof. Catherine Odora Hoppers (University of South Africa), the late Prof. Calestous Juma (Harvard University), Ms. Elizabeth Marincola (AAS), Prof. Kevin Marsh (Oxford University/AAS), Dr. Tom Kariuki (AAS), Dr. Simon Kay (Wellcome Trust) for their support at various stages of production, especially for validation and external reviews. Their input helped shape the content and quality of the report.

We are also grateful to our fellows, scientists, policymakers, development partners and members of the Independent Advisory Board who participated in our survey and interviews and took time to review the report and provide input.

Special thanks go to AAS staff that reviewed the report and worked hard to meet the tight and sometimes unpredictable deadlines: Ms. Susan Gichoga, Dr. Evelyn Gitau, Dr. Benjamin Gyampoh, Ms. Janet Kariuki, Dr. Michael Kilpatrick, Dr. Jennifer Maroa, Ms. Nduta Mbarathi, Dr. Alphonsus Neba, Ms. Deborah-Fay Ndlovu, Mr. Charles Njagi, Ms. Hannah Ngugi, and Ms. Olivia Osula.



Evelyn Namubiru-Mwaura, PhD
Lead and Coordinator
Strategy and Policy Manager, African Academy of Sciences
February 2018

EXECUTIVE SUMMARY

Sustainable Development Goals (SDGs) were adopted by the United Nations (UN) in September, 2015. These 17 SDGs, consisting of 169 targets, replaced the Millennium Development Goals (MDGs) for 2000-2015. SDGs are ambitious and universal, encompassing social, economic and environmental aspects of development in an integrated way. Achieving them will require considerable institutional and policy investment at all levels of governance—local, national, regional and international.

This study considers how African countries can leverage science, technology and innovation (STI) to achieve the SDGs and the related aspirations of the African Union (AU) as articulated in its Agenda 2063. The study examines strategies to implement national, regional, continental and international policies and programmes for STI in Africa. Africa's challenge is how to translate STI policies into practical actions, and to effectively implement programmatic initiatives such as those of the AU and Regional Economic Communities (RECs).

Based on a survey, face-to-face and telephone interviews, and a review of various reports and academic papers, this study identifies factors that influence the effective application of STI to achieve SDGs. An open-ended questionnaire and a survey instrument were used to gather information and opinions from various stakeholders on:

(a) How well policies and programmes of African countries are aligned to the SDGs;
(b) Institutional programmes that focus on specific SDGs;
(c) National expenditure on Research and Development (R&D) and factors that influence a government's expenditure on STI;
(d) Effectiveness of national, regional and continental policies for STI;
(e) International cooperation in STI among African countries and institutions and;
(f) Specific actions that national governments, the AU and institutions, such as the African Academy of Sciences (AAS) can take to promote the development and application of STI to attain SDGs in Africa.

Conventional analysis presumes a predictable relationship between STI (input) and sustainable development (outcome). But the relationship between STI and sustainable development is non-linear and complex. For this reason, this study examines the adoption and use of STI through the framework of its governance, which is the actual driver of SDGs.

Governments must ensure that the benefits of STI are broadly and appropriately distributed through wise investment, policy and regulation.

Key issues and findings of this study:

1. **African countries must improve the quality and relevance of their national STI policy frameworks to sharpen focus on social and environmental dimensions of sustainable development. In 2016, fewer than half of African countries had adopted STI policies, including Algeria, Angola, Botswana, Burundi, Ethiopia, Egypt, The Gambia, Ghana, Kenya, Lesotho, Malawi, Mozambique, Namibia, Nigeria, Rwanda, Tanzania, Tunisia, Senegal, South Africa, Swaziland, Uganda, Zambia and Zimbabwe. But most of them do not consider sustainable development imperatives holistically. Instead, they tend to focus on funding scientific research with less emphasis on technology development, procurement and innovation. This may stimulate the production of knowledge for short-term economic growth, but fails to spur social inclusion and environmental sustainability that are necessary to long-term sustainable development.**

2. **Efforts to implement effective STI policy are limited by low policy literacy, weak human capacity, insufficient monitoring and accountability, and inadequate budgets for STI policy. Enhancing these capacities is essential in order to achieve SDGs.**

3. **Progress regarding investment in R&D in the last decade has been mixed across the continent. Algeria, Botswana, Kenya, Rwanda, Namibia, and Tunisia, have increased their national annual Gross Expenditure on Research and Development (GERD). But GERD had declined in South Africa, while The Gambia, Malawi and Mozambique, are heavily reliant on foreign sources for their GERD. Even the greatest investments have not reached the target of 1% of GDP as gross expenditure adopted by the AU in 2007.**

4. **Adoption and diffusion of Information and Communication Technologies (ICTs), particularly mobile telephony, has been a bright spot in Africa. ICT penetration has driven economic growth in multiple sectors in Africa, including agriculture and education. Platforms such as M-Pesa, which was initially developed and launched in Kenya and is now common across East Africa, and virtual education across most of the continent, are improving access to social and economic assets.**

5. **In contrast, the diffusion and adoption of biotechnology and nanotechnology has been slow. Genetic Modification (GM) in commercial crops has been adopted only in Burkina Faso, South Africa and Sudan. In Kenya and Nigeria, the adoption of GM technologies is constrained by policy uncertainty and inconsistency across various levels of government and institutions. This undermines the potential for GM applications to contribute to achieving SDGs.**

6. **Weak coordination and collaboration between the scientific research and the science policy communities has resulted in misalignment of research design and prioritization with SDGs. This is evident in a lack of ownership of and even familiarity with the SDGs among African scientists. Most scientific research programmes launched in the past decade must be realigned with SDGs and their targets, and conversely, targets must be realigned to areas of greatest scientific progress and promise across sectors.**

7. **Regional and international research and innovation (R&I) collaboration is under-resourced and under-funded in Africa. In most countries, governments and research institutions do not dedicate funding nor implement policy to promote regional and international R&I partnerships. Cooperation in R&I is in many cases *ad hoc* or short-term, based on the interests of individual scientists, with inadequate institutional and government support.**

Key recommendations:

1. **Ensure executive accountability for implementation of STI policy frameworks in order to meet national targets on GERD. This will require greater political and legislative oversight and civil society participation in STI policy development. National parliaments, the Pan African Parliament, and civil society organizations must engage directly in STI policy formulation and monitoring and evaluation. The AAS, in partnership with international institutions such as the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the International Council for Science (ICSU), must build the capacity of parliamentary and civil society organizations for STI policy monitoring and evaluation.**

2. **Institutions such as the AAS and the United Nations Economic Commission on Africa (UNECA) must develop a comprehensive scientists' guide to SDGs, focusing on STI-sustainable development and best practices to enable scientific research to drive these goals.**

3. **The Coalition for African Research and Innovation (CARI) is a sustainability platform for AAS. It will ensure that there is sustainable funding of current and future science, technology and innovation programs at AAS. Efforts of AAS, NEPAD Agency, AU, the Bill and Melinda Gates Foundation, the Wellcome Trust and the National Institutes of Health must be supported to enable CARI to effectively establish a pan-African mechanism to fund and coordinate research and innovation initiatives. CARI should be endorsed by the AU Summit and endowed by African governments and development partners.**

4. **To build and mobilize STI policy capacity, the AAS must collaborate with institutions such as the African Centre for Technology Studies (ACTS), the African Technology Policy Studies Network (ATPS) and African universities that offer graduate courses on innovation and technology management to develop executive courses on STIP policy. These organizations are positioned to develop and teach multidisciplinary expertise for executive training in STIP policy.**

5. **The AAS, national science academies and business associations must design and organize pan-African and national science-business-society dialogue. Such platforms will contribute to the capacity of private companies to bring to bear their expertise, funding and infrastructure to promote research and innovation in Africa.**

INTRODUCTION

Africa entered this millennium with optimism and a renewed sense of purpose. After many decades of poor economic performance, low levels of human development, economic instability, governance deficits and political conflict, the continent is making great efforts to achieve sustainable development.

The transformation of the Organization of the African Unity (OAU) into the African Union (AU) and the creation of the New Partnership for Africa's Development (NEPAD Agency) in 2001 are a reflection of Africa's commitment to sustainable development through investment in science, technology and innovation. Africa's Regional Economic Communities (RECs) have been revitalized and there is a greater focus on regional economic integration of the continent through STI and industrialization.

African countries have invested in institutional reforms and the development of long-term development strategies for sustainable economic growth.

The AU has adopted an ambitious long-term sustainable development vision: ***Agenda 2063—The Africa We Want***. The report argues for transition from short-term poverty reduction strategies to long-term visions with emphasis on industrialization and the development of knowledge-based economies by 2030.

Africa includes some of the fastest-growing economies in the world. According to the ***African Economic Outlook 2016,*** Africa was the world's second fastest growing economy, after East Asia, in 2015.[1] Investments in and within Africa have increased over the past decade. The continent is more resilient to global economic instability and geopolitical changes than it was two decades ago. Many African countries have made progress towards attaining the Millennium Development Goals (MDGs).[2] But notwithstanding these encouraging signs, progress has been slow and uneven within the continent. Africa still faces significant sustainable development challenges, particularly the persistence of hunger and malnutrition, a high burden of disease, water and energy insecurity, social inequality, climate change and loss of biological diversity.

1.AfDB, OECD and UNDP (2016), African Economic Outlook 2016. African Development Bank, Organization for Economic Cooperation and Development, and United Nations Development Programme.

2.UNECA, AU, AfDB and UNDP (2015), Assessing Progress in Africa Toward the Millennium Development Goals. United Nations Economic Commission for Africa, African Union, African Development Bank and United Nations Development Programme, Addis Ababa.

There is recognition that for the continent to address these challenges and to attain the Sustainable Development Goals (SDGs) and Agenda 2063 of the AU, African countries, coalitions of countries and global partners need to invest more in the development, procurement and application of scientific knowledge and technological innovation. Individual countries and the continent as a whole cannot sustain current levels of economic performance and achieve SDGs without developing and implementing bold policies and programmes for science, technology and innovation (STI). The AU, RECs and regional institutions such as the African Development Bank (AfDB), as well as international organizations such as the World Bank and United Nations agencies, have developed strategies and programmes to advance STI for Africa's sustainable development. At the national level, many countries have adopted or are developing modern policies, strategies and implementation programmes for STI. The scientific community, through institutions such as the African Academy of Sciences (AAS) and several national academies, have launched various programmes for promoting STI for development.

This study is about how current efforts and new initiatives can be leveraged to stimulate progress toward SDGs through STI. It focuses on specific mechanisms to promote the implementation of national, regional, continental and international policies and strategies. It offers empirical evidence and suggests recommendations to accelerate the implementation of policies and programmes for STI, with explicit focus on achieving SDGs. The report also proposes strategic options for enhancing policy implementation and effectiveness. It is based on an extensive review of the academic literature and policy reports, focus group discussions, interviews with scientists and policy-makers across the continent, open discussions at multiple forums and an electronic survey.

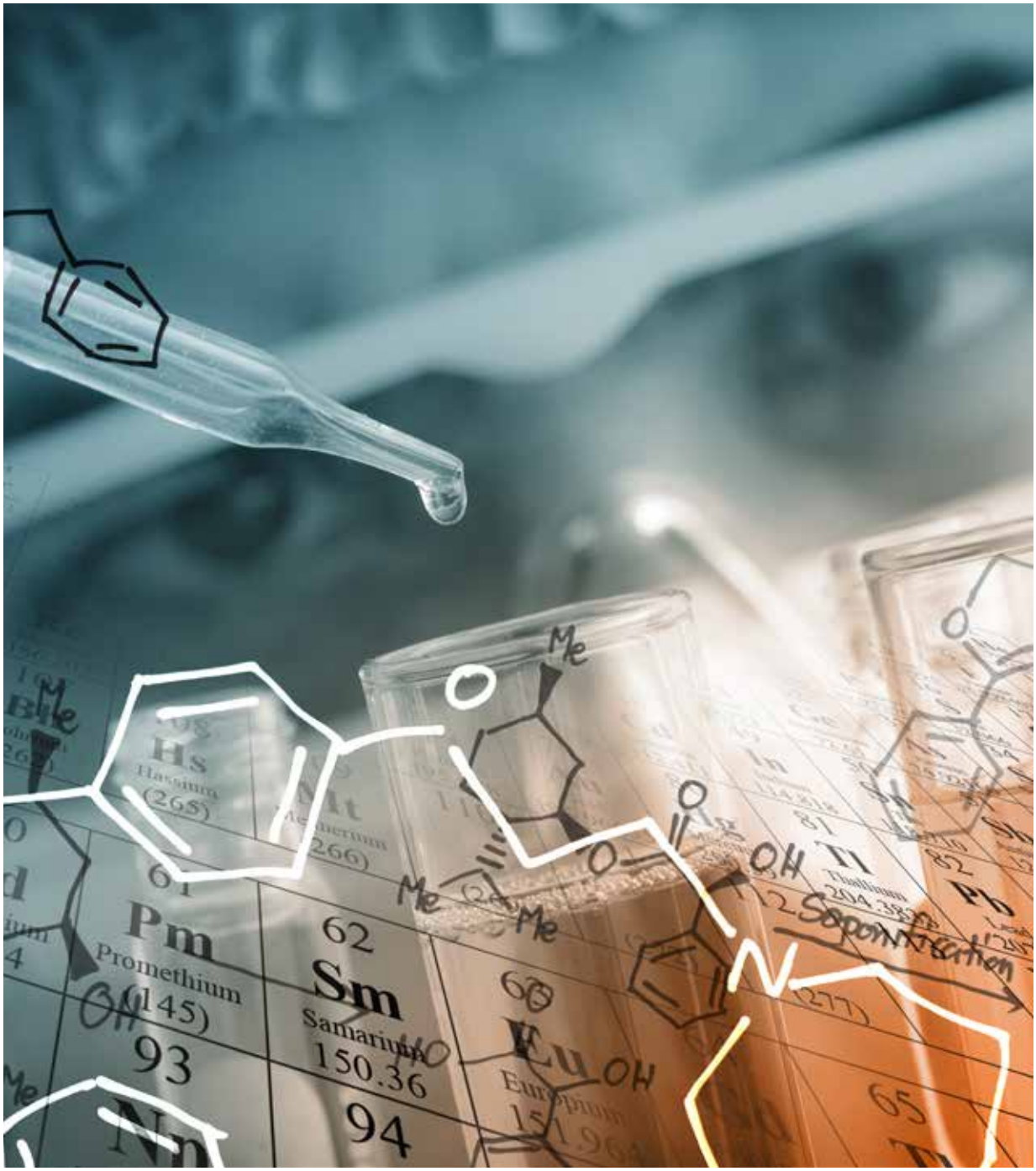
The first section considers development trends, analyses economic growth, measures progress against Millennium Development Goals (MDGs), and considers the continent's long-term development agenda as articulated in AU's Agenda 2063. The central issue is that Africa's positive economic growth in the past two decades has been based on unsustainable export of natural resources, including oil, minerals, timber products, and traditional agriculture products. This commodity export-based growth has attracted increased Foreign Direct Investment (FDI) for natural resource-rich countries. But evidence warns that this kind of growth is not sustainable. This is why, despite good economic performance, African countries have not made substantive progress against MDGs.

The next section addresses methodology. It describes how empirical information was gathered and analysis conducted. Section 3 provides background and recommends a conceptual approach to studying an STI-sustainable development (SD) nexus. It defines the distinction between STI and sustainable development, and suggests adoption of governance of STI as the appropriate conceptual approach to promoting STI for SDGs in Africa. It also covers global scientific and technological trends and how they impact the attainment of SDGs, and applies recent forecasts to map out specific scientific advances and technological innovation that address big global challenges. These include poverty, hunger and malnutrition, disease, climate change, loss of biological diversity, water and energy insecurities, social exclusion (especially gender) and other injustices, youth unemployment, and geo-political conflict. It also examines how Africa's sustainable development challenges can be addressed by the effective application of STI.

Section 4 is an overview of the state of science, technology and innovation in Africa. Drawing from sources such as the Africa Innovation Outlook 2014, Africa Capacity Report 2017, the World Bank, the African Development Bank (AfDB), the Global Competitiveness Report 2016-2017, and the Global Innovation Index (GII 2016). It analyses trends in national Gross Expenditure on Research and Development (GERD) and innovation capacity of specific scientific fields. It also discusses how STI is integrated into national development plans and vision statements and the nature and effectiveness of national policies and programmes to promote STI. Regional, continental and international initiatives for promoting STI for development in Africa are reviewed.

Section 5 is about the importance of international cooperation in enabling African countries to leverage STI to secure SDGs. It focuses on integration of STI into development plans, improvement of STI policies, building scientific and technological capacities through increased investment and strengthened institutions for Research and Innovation (R&I), and enhancement of regional and international cooperation. Emphasis is placed on the effective engagement and coordination among the AU, AAS and national academies to support the efforts of countries to apply STI to achieve SDGs.

The last section makes recommendations on policy implementation and effectiveness. It provides suggestions to enable African countries to individually and collectively leverage STI to achieve SDGs. Emphasis is placed on building broad-based citizen coalitions, political leadership and effective accountability frameworks for STI policy action.



1. AFRICA'S DEVELOPMENT IN PERSPECTIVE

After many decades of poor economic performance and low levels of human development[3], Africa started this century focused on long-term development. At the beginning of the century, most African countries started creating political and policy conditions for sustainable development, inspired by the economic ascendency of some Asian and Latin American countries, and the adoption of the Millennium Development Goals (MDGs).

International development assistance and cooperation was reenergized, particularly with the entry of China and India as sources of foreign aid and foreign direct investment (FDI) for Africa. Combined with a big and growing Asian market for natural raw materials and commodities and favourable domestic macro-economic conditions, many African economies have experienced new growth in the past two decades. Thus the narrative 'Africa Rising'.

The first decade of the millennium also witnessed major institutional developments in Africa. The AU was established through a Constitutive Act in 2001. It represented the next-generation transformation of the Organization of African Unity (OAU) that had been created in the 1960s to achieve political liberation of the African continent. Its remit is to further economic and political integration and sustainable development on the continent. Its programmes focus on economic development, peace and security, agriculture, education, science and technology, industrialization and trade, gender and youth, environment and natural resources, and regional integration and international cooperation.

In addition to the establishment of the AU, African leaders also created the New Partnership for Africa's Development (NEPAD) in 2001. NEPAD is a technical agency of the AU dedicated to the advancement of sustainable development. It has been instrumental in contributing to the design and implementation of programmes and strategies for health, agriculture, STI, environment and climate change, and infrastructure. NEPAD plays a key role in mobilizing international support for African sustainable development initiatives.

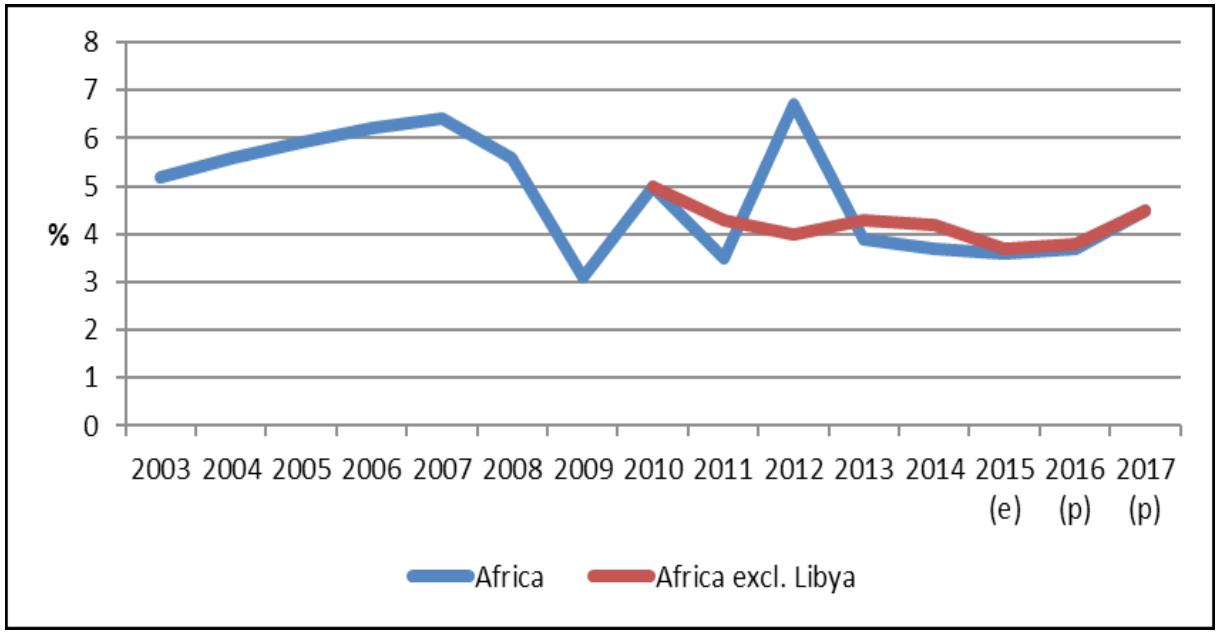
Geopolitical and institutional changes have been in no small measure accountable for the recent impressive economic performance of the continent. As shown below, sustaining and increasing current levels of growth, and, more importantly, translating economic growth into human development through the attainment of SDGs, will require qualitative economic change. This can only be achieved through wise investment in the development and application of STI.

3. Human development is the process of building or enlarging people's social and economic opportunities and freedoms. See UNDP (2016), Human Development for Everyone. United Nations Development Programme (UNDP), Human Development Report 2016, http://hdr.undp.org/sites/default/files/2016_human_development_report.pdf

1.1 Growth and Development Trends

Economic growth in Africa over the past decade has been impressive compared to other continents. Growth has averaged between 3% and 5% of Gross Domestic Product (GDP) per year over the past ten years. In 2006, the continent experienced 5.7% growth in GDP; in 2015 it experienced GDP growth of 3.6%.[4] Though there has been a slowdown in aggregate growth, the continent has some of the world's fastest-growing economies. Figure 1 provides an overview of economic growth trends over the past decade.

FIGURE 1: Overview of economic growth 2003-2017, AfDB (2016), African Economic Outlook 2016



Source: AfDB (2016), African Economic Outlook 2016. African Development Bank

4. AfD (2016), African Economic Outlook 2016. African Development Bank

The relatively high rates of economic growth experienced by African countries are attributable to exports of oil and non-oil commodities, mainly to China. FDI plays a corresponding role. But according to the AfDB, since 2015 there has been a slump in commodity exports due to the economic slowdown in China and other Asian countries; "China's weaker growth and its transition from investment and exports [of] industrial goods towards consumption and services is an important factor in the recent drop in commodity prices, which suggest that the 'commodity super cycle' of the past decade has come to an end."[5]

Commodity-based economic growth has not translated into enhanced development. Poverty, new disease outbreaks such as Ebola in Western Africa, the persistence of HIV and AIDS, ecological catastrophes such as the 2015-2016 drought in Southern Africa, widespread famine and malnutrition, high incidence of malaria and tuberculosis (TB), and low manufacturing and industrial productivity continue to hold back growth and development in Africa.

Though the rate of HIV and AIDS infection and incidences of disease outbreaks such as cholera have been declining in the past decade, non-communicable diseases (NCDs), such as cancer, hypertension and diabetes, are on the rise in Africa. According to the World Health Organization (WHO) and several recent studies, NCDs pose a growing burden on the continent. For example, Sub-Saharan Africa is home to at least 22 million people affected by diabetes, with a prevalence of 5.1%.[6] Combined with infectious diseases, NCDs are a double burden with huge social and economic costs that undermine the prospects of sustainable development.

Food insecurity and malnutrition are other sustainable development challenges faced by Africa. It is estimated that in 2014/2015, about 153 million people age 15 or older suffered from severe food insecurity in sub-Saharan Africa.[7] According to The UN Food and Agriculture Organization (FAO), this is the highest rate of food insecurity in the world.[8] Industrial productivity and manufacturing have not significantly stimulated increased growth, created new jobs, particularly for the growing youth population, nor enabled diversification of economic activity on the continent. According to a recent study by the United Nations Economic Commission for Africa (UNECA), new economic growth has not had a significant effect on decent job creation. Over the period 1980-2013, the contribution of manufacturing to GDP on the continent as a whole declined by about 11%.[9]

Hindrances to progress of MDGs

- ***The absence of explicit national strategies for implementation of MDGs; most countries took too long to develop their vision and implementation plans. For example, South Africa adopted its* National Development Plan (NDP) 2030 *at least ten years after adoption of MDGs. In other African countries, five-year development plans were not aligned with MDGs.***
- ***STI considerations were not adequately articulated in strategies for implementing MDGs.[10] One interviewee asserted: "like many previous African plans, strategies and many programmes for MDGs did not say much if anything about research, science and technology. For SDGs scientists need to push for integration of science and technology into plans." Public awareness of and support for MDGs was relatively low.***
- ***Implementation of MDGs was not adequately supported by domestic resources. Funding for much of the planning and work has been foreign-sourced. This is particularly true in the areas of health (MDG 6: Combat HIV/AIDS, malaria and other diseases) and environment (MDG7: Ensure environmental sustainability), which are magnets for global funding. The scientific community and private sector have not been adequately engaged in planning for and implementation of MDGs.***

5. AfD (2016), African Economic Outlook 2016, p.25. African Development Bank
6. Nyirenda, M., (2016), 'Non-communicable diseases in sub-Saharan Africa: understanding the drivers of theepidemic to inform intervention strategies', Int Health (2016) 8 (3): 157-158.

In Africa, progress toward achieving most of the MDGs has been slow compared to other regions. Box 1 is a summary of a 2015 analysis by UNECA, AU, AfDB and UNDP.

Box 1: Africa's progress in achieving MDGs (2000-2015)

1. Poverty is falling, albeit slowly with a risk of reversals.
2. Africa's growth has been relatively strong, but not rapid or inclusive enough to create adequate employment opportunities.
3. Disasters and persistent conflict are obstructing the path to food security.
4. Improving primary education completion rates remains a challenge.
5. Challenges abound in maternal health despite progress.
6. Uneven gains in the share of women in wage employment in non-agricultural sector.
7. Notwithstanding the progress being made, Africa accounts for more than half of all cases and death rates of HIV/AIDS, malaria and tuberculosis.
8. Access to safe drinking water and sanitation is improving slowly, but progress remains skewed towards urban areas.

Source: UNECA, AU, AfDB and UNDP (2015), MDG Report 2015: Assessing Progress in Africa toward the Millennium Development Goals.

7. *FAO. 2017. Regional Overview of Food Security and Nutrition in Africa 2016. The challenges of building resilience to shocks and stresses. Accra.*
8. *FAO. 2017. Regional Overview of Food Security and Nutrition in Africa 2016. The challenges of building resilience to shocks and stresses. Accra.*
9. *UNECA (2016), Transformative Industrial Policy for Africa. United Nations Economic Commission for Africa, Addis Ababa.*
10. *UNECA, AU, AfDB and UNDP (2015), MDG Report 2015: Assessing Progress in Africa toward the Millennium Development Goals.*

1.2 Overview of National Development Visions

Most African countries have developed long-term development vision statements and National Strategies for Sustainable Development (NSSDs). By 2016, at least 35 African countries had national development vision documents. Vision statements vary from country to country, informed by local political and economic conditions, and based on history and policy culture. But most strategies were developed in the early 1990s, with vision statements adopted typically at the end of the same decade, or even later. For example, Namibia adopted its Vision 2030 in 2004, Liberia's Vision 2030 was adopted in 2012, Nigeria's Vision 2020 was adopted in 2010, Senegal's Vision 2035 was adopted in 2016, and Kenya's Vision 2030 in 2007.

National Strategies on Sustainable Development (NSSD) fail to identify and put emphasis on STI. The main foci of the NSSDs are environmental sustainability and economic development, largely informed by Agenda 21, adopted at the United Nations Conference on Environment and Development (UNCED) in 1992. The NSSDs of a few African countries make passing reference to STI as critical to achieving sustainable development. Algeria, Egypt, Kenya, Mauritius, South Africa Uganda, and Zambia identified ICTs, energy and climate adaptation technologies as important for sustainable development, but no country emphasizes the critical contribution of scientific research and technological innovation to agriculture, health or other sectors.[11]

Some African countries have national long-term visions that promote STI for development. A review of national vision statements of several African countries shows that STI is incorporated with varying degrees of depth. Some of the countries which have STI in their long-term development plans and visions are Ethiopia, Ghana, Kenya, Namibia, Nigeria, Rwanda, South Africa and Uganda.

Among these plans, Kenya's stands out. Its Vision 2030 is conceptually rich for STI. For example, Section 3.6 is dedicated to the contribution of STI to achieving a national aspiration of prosperity, industrialization and economic competitiveness. It states, "Vision 2030 will be based on the creation of international competitiveness through more efficient productivity at the firm and household level, with government support. However, all the strategies and flagship projects will exploit knowledge in science, technology and innovation (STI) in order to function more efficiently, improve social welfare, and also promote democratic governance."[12]

Other countries make the connection, but less broadly. Namibia's Vision 2030 links STI to education and training as follows: "As required by this Vision, the country will operate a totally integrated, unified, flexible and high quality education and training system that prepares Namibian learners to take advantage of a rapidly changing global environment, including developments in science and technology", and "There will be equal access to excellent educational and vocational training institutions and quality sports services/facilities by all, with basic education placing emphasis on Science and Mathematics."[13]

11. http://www.unosd.org/content/documents/ECA,%20NSDS%20Africa%20Study%202011.pdf
12. Government of the Republic of Kenya (2007), Kenya Vision 2030, p.8. Republic of Kenya, Nairobi.
13. Government of the Republic of Kenya (2008), Namibia Vision 2030. Republic of Namibia, Windhoek.

Rwanda integrates STI into various sections of its Vision 2020.[14] Science and technology are treated as enablers of prosperity in a sustainably developed and cohesive country. Its Vision 2020 emphasizes the development of science and technology education at secondary and university levels to facilitate the creation of technology enterprises and exploit development opportunities associated with ICT.

Uganda's Vision 2040, adopted in 2007, emphasizes policies to enable the country to leapfrog in science, technology and engineering.[15] It articulates a range of government policies to build a strong science, technology, engineering and innovation (STEI) system to transform the country's natural resources and become economically as well as technologically competitive. Section 4.2.4 of the vision document outlines specific policy measures for STEI, with emphasis on an innovation-driven and technology-based economy.

The challenge for African countries is to translate provisions of their vision statements into fundable and implementable programmes. Discussions and interviews with various stakeholders in Kenya and Uganda show that STI objectives lack sufficient political attention and resources for implementation. We found many reasons for this, notably that national vision statements and their STI objectives are not well socialized with and known to the general public, and more important, to the scientific community across Africa. At least 75% of interviewees were aware of the existence of the vision statements, but could not identify nor elaborate on specific STI objectives. In general, levels of knowledge of the national long-term vision are low in most countries, making it difficult to implement or translate them into action.

1.3 Africa's Agenda 2063

In 2013, the AU adopted ***Agenda 2063, The Africa We Want*** a long-term development vision for a continent that is prosperous, peaceful, industrialized, integrated into the global economy and trading systems, socially and economically inclusive and developing sustainably.

In designing Agenda 2063, African countries drew lessons from previous efforts to turn national economies around and secure sustainable development. They were inspired by at least 50 years of development experience within and among their countries and other countries of the world. Having experimented with many development policies and programmes, such as Structural Adjustment Programmes (SAPs) and Poverty Reduction Strategies in the 1980s and 1990s, respectively, and after 15 years of effort to achieve MDGs, African countries have accumulated diverse and rich policy experience that informs Agenda 2063.

Agenda 2063 recognizes explicitly that structural transformation of African economies and sustainable development require long-term investment in STI.

One of the lessons is that policies and programmes associated with previous initiatives, such as SAPs and PRSPs, may have been too focused on short-term solutions to surmount complex development challenges. There is a significant body of evaluation that has concluded that such initiatives have not enabled the continent to create a sustainable development path.

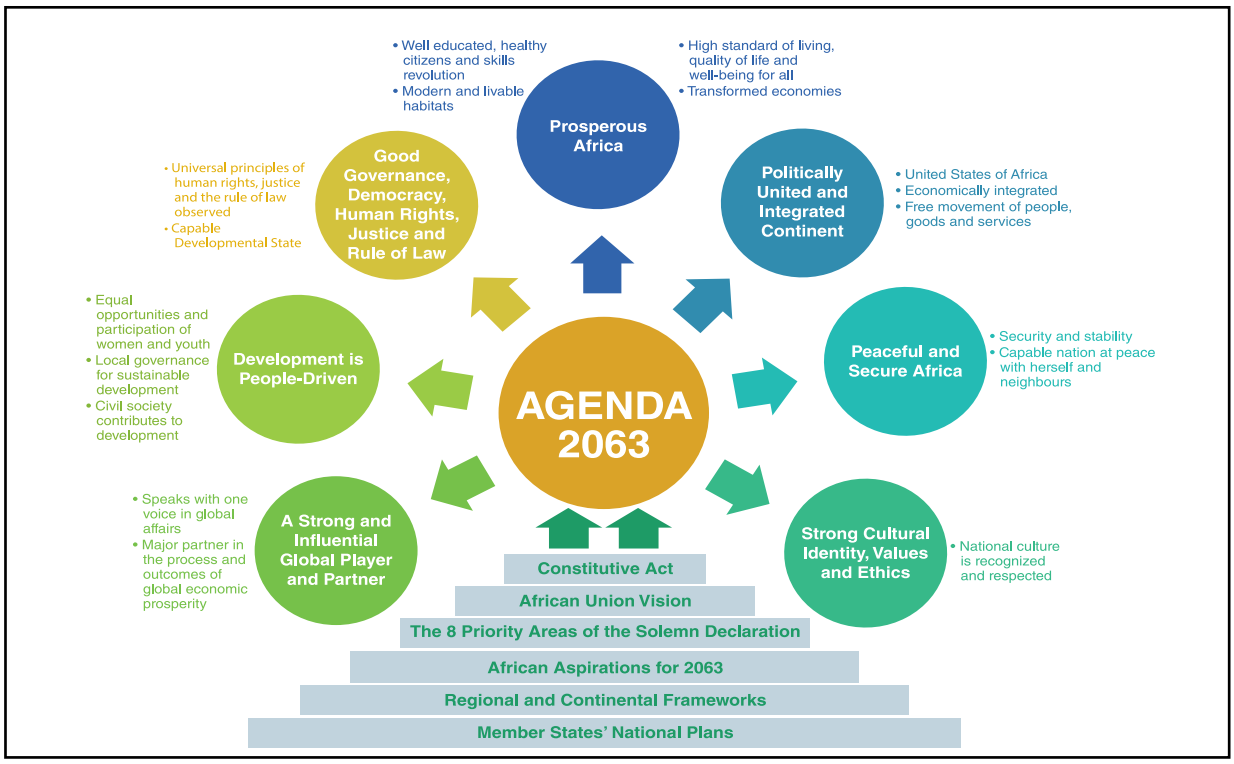
According to Heidhues and Obare (2011), the implementation of SAPs was poor as a result of lack of ownership and political will.[16] Stewart and Wang (2003) concluded that PRSPs did not

14. Government of the Republic of Rwanda (2000), Rwanda Vision 2020. Ministry of Finance and Economic Planning, Kigali.
15. Government of the Republic of Uganda (2007), Uganda Vision 2040. Ministry of Finance and Planning, Kampala.
16. Heidhues, F., and Obare, G., (2011), 'Lessons from Structural Adjustment Programmes and their Effects in Africa'. Quarterly Journal of International Agriculture 50 (2011), No. 1:55-64. DLG-Verlag Frankfurt, Germany.

empower poor countries, particularly in Africa, to engage effectively with development planning and practice.[17] Agenda 2063 promises to be different. It envisions inter-generational, long-term, explicit sustainable development imperatives. It deals with issues of qualitative transformation of African societies and countries. Its foundation is a clear implementation plan, with aspirations that are realistic and attainable. Moreover, "Agenda 2063 seeks to integrate STI in education and training." It advocates measures to "actively promote science, technology, research and innovation, to build knowledge, human capital, capabilities and skills to drive innovations and for the African century", and to "build and expand an African knowledge society through transformation and investments in universities, science, technology, research and innovation; and through the harmonization of education standards and mutual recognition of academic and professional qualifications."[18] Paragraphs 11-16 of Agenda 2063 are policy goals pertaining to the development and application of STI.

The realization of the STI policy objectives of Agenda 2063 will depend largely on programmes that are designed and implemented by the AUC, RECs, continental and regional organizations (such as the AfDB and NEPAD), AAS, international organizations such as UN bodies and development partners, national governments of AU member states, scientific and engineering associations, and private sector organizations. STI objectives of Agenda 2063 are articulated in the AU/NEPAD Science, Technology and Innovation Strategy for Africa (STISA) 2024 that was adopted by African leaders in 2014. STISA's mission is to accelerate Africa's transition to an innovation-led and knowledge-based economy. Its objectives address the continent's infrastructure, entrepreneurial and technological capabilities, and the implementation of STI policies and programmes that promote sustainable development.[19]

Figure 2: Agenda 2063



17. Stewart, F., and Wang, M., (2003), 'Do PRSPsPs empower poor countries and disempower the World Bank, or it is the other way round?.OEH Working Paper Series—QEWPS108.
18. AU (2013), Agenda 2063—the Africa We Want. African Union Commission (AUC), Addis Ababa, Ethiopia.
19. AU and NEPAD Agency (2014), Science, Technology and Innovation Strategy for Africa 2024. NEPAD Coordinating and Implementing Agency, Midrand, South Africa.

1.4 The Global Agenda 2030 and Sustainable Development Goals

Sustainable development has been the preoccupation of the international community for nearly 50 years. Indeed, since the 1970s, the international community has debated the most effective means to achieve sustainable development, i.e. that meets the needs of current generations without compromising the opportunities of future generations.[20]

Key international activities that have shaped the discourse on sustainable development include the 1972 Stockholm United Nations Conference on the Human Environment, the 1987 World Commission on Environment and Development (WCED), the 1992 Rio United Nations Conference on Environment and Development (UNCED), the 2000 UN Conference on Millennium Development Goals (MDGs), and the 2015 UN Conference on Sustainable Development Goals (SDGs).

SDGs were adopted in September 2015 at the UN General Assembly in New York, articulating 17 goals and 169 targets (see below). They are the core of the new UN 2030 Agenda for Sustainable Development, a framework that builds on but is broader than the MDGs.

The SDGs framework integrates social, economic and environmental aspects of development, and is universal.[21] The overall goal of the SDGs is to provide global policy guidance to countries to increase the prospects of their success in achieving sustainable development by 2030.

FIGURE 3: Sustainable Development Goals

20. WCED (1987), Our Common Future. The World Commission on Environment and Development (WCED), Oxford University Press.
21. UN (2015), Transforming Our World: The 2030 Agenda for Sustainable Development. United Nations, New York.

Attainment of SDGs depends to a large measure on investments in the development and application of STI, as explicitly recognized in the 2030 Agenda for Sustainable Development and articulated in SDG 9. Paragraph 17.6 - 17.8 of the Agenda covers industry, innovation, and infrastructure.

Various policy reports on the role of STI in implementing Agenda 2030 and achieving SDGs have been issued.[22] They explore policy issues pertaining to the development and application of STI, with emphasis on measures to build the capacity of countries to harness and apply STI for the SDGs. A report by Schmalzbauer and Visbeck (2016) emphasizes the procurement and use of science in policy-making on and for SDGs. It claims that "in the coming years, science will need to play an important role in the provision of the data, information and knowledge that is required to facilitate the successful implementation of the 2030 Agenda for Sustainable Development and the associated SDGs. The 2030 Agenda explicitly recognises that sustainability challenges are fundamentally interrelated. Focusing exclusively on single goals will therefore not be effective. All actions need to be assessed for policy coherence across the goals."[23] This means that science and society need to be aware of the broad SDG spectrum to find the best pathway to progress towards all the goals. There is a clear alignment between AU's Agenda 2063 and the SDGs as illustrated in Table 1. The successful implementation of both agendas requires STI. African countries need policies, programmes and processes that focus on SDGs, alongside the aspirations articulated in AU Agenda 2063.

Experience from the implementation of MDGs shows that the development of explicit strategies to harness and apply STI is necessary for sustainable development.[24] A recent report of the European Union (EU) emphasizes that countries and regional blocs must renew and realign their STI policies and programmes to the SDGs.[25]

22. See for example UNESCAP (2016), Science, Technology and Innovation for Sustainable Development in Asia and the Pacific: Policy Approaches for Least Developed Countries. United Nations Economic and Social Commission for Asia and the Pacific, Bangkok, Thailand; and Schmalzbauer B., and Visbeck, M., eds., (2016), The contribution of science in implementing the Sustainable Development Goals. German Committee Future Earth, Stuttgart/Kiel.

23. Schmalzbauer B. and Visbeck, M. (eds.) (2016), The contribution of science in implementing the Sustainable Development Goals. German Committee on Future Earth, Stuttgart/Kiel.

24. UN Millennium Project 2005. Innovation: Applying Knowledge in Development. Task Force on Science, Technology and Innovation.

25. EU(2015), The Role of Science, Technology and Innovation Policies to Foster the Implementation of the Sustainable Development Goals (SDGs). European Commission (EC), Brussels.

TABLE 1: Convergence and alignment between AU Agenda 2063 and SDGS

	Goals	Priority Area		SDGSs
1	A high standard of living, quality of life and well-being for all citizens.	▪ Incomes, jobs and decent work ▪ Poverty, inequality and hunger ▪ Social security and protection, including persons with disabilities ▪ Modern, affordable and liveable habitats and quality basic services	1 2 8 11	End poverty in all its forms everywhere in the world End hunger, achieve food security and improved nutrition and promote sustainable agriculture. Promote sustained, inclusive and sustainable Economic growth, full and productive employment and decent work for all. Make cities and human settlements inclusive, safe, resilient and sustainable.
2	Well educated citizens and skills revolution underpinned by science technology & innovation	▪ Education and science, technology and innovation (STI) driven skills revolution	4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
3	Healthy and well -nourished citizens.	▪ Health and nutrition	3	Ensure healthy lives and promote well-being for all at all ages.
4	Transformed economies	▪ Sustainable and universal economic growth ▪ STI driven manufacturing industrialization and value addition ▪ Economic diversification &resilience	8 9	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.
5	Modern agriculture for increased productivity and production.	▪ Agricultural productivity and production	2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture.
6	Blue/ocean economy for accelerated economic growth.	▪ Marine resources and energy ▪ Port operations & marine transport	14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
7 8 9 10	Environmentally sustainable and climate resilient economies and communities A United Africa (Federal or Confederate). Continental financial and monetary institutions established and functional. World class infrastructure criss-crosses Africa.	▪ Bio-diversity, conservation and Sustainable natural resource management. ▪ Water security ▪ Climate resilience and natural disasters preparedness ▪ Frameworks and institutions for a United Africa ▪ Financial and monetary institutions ▪ Communications and infrastructure connectivity.	6 7 13 15 9	Ensure availability and sustainable management of water and sanitation for all. Ensure access to affordable, reliable, sustainable and modern energy for all. Take urgent action to combat climate change and its impacts. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

	Goals	Priority Area		SDGSs
11	Democratic values, practices, universal principles of human rights, justice & the rule of law entrenched.	▪ Democracy and good governance ▪ Human rights, justice and the rule of law	16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
12	Capable institutions and transformative leadership in place.	▪ Institutions and leadership ▪ Participatory development and local governance. ▪ Maintenance and preservation of peace and security ▪ Institutional structure for AU instruments on peace and security ▪ Defence, security and peace ▪ Fully operational and functional APSA all pillars ▪ Values and ideals of Pan Africanism ▪ Cultural values and African Renaissance ▪ Cultural heritage, creative arts and businesses ▪ Women and girls empowerment ▪ Violence and discrimination against women and girls ▪ Youth empowerment and children's rights ▪ Africa's place in global affairs ▪ Partnerships	16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
13	Peace, security and stability is preserved.		5	Achieve gender equality and empower all women and girls.
14	A stable and peaceful Africa.		4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
15	A fully functional and operational APSA		5	Achieve gender equality and empower all women and girls.
16	African cultural renaissance is pre-eminent.		17	Strengthen the means of implementation and revitalize the global partnership for sustainable development
17	Full gender equality in all spheres of life			
18	Engaged and empowered youth and children.			
19	Africa as a major partner in global affairs and peaceful coexistence.			
20	Africa takes full responsibility for financing her development Goals.	▪ African capital markets ▪ Fiscal systems and public sector revenue ▪ Development assistance	10 17	Reduce inequality within and among countries. Strengthen the means of implementation and revitalize the global partnership for sustainable development

Source: AU Agenda 2063 and UN 2030 Agenda

2. METHODOLOGY

2.1 Objectives of the Study

This study is about the role of STI in sustainable development. It concerns specific policy measures and practical actions that African countries must—individually and collectively—take in order to leverage STI to achieve the SDGs. It examines policy and programmatic initiatives for tapping global scientific and technological opportunities to address sustainable development challenges of the African continent. It was undertaken to identify:

(a) How well current STI initiatives are aligned with SDGs and AU's sustainable development agenda;
(b) Policy barriers to scientific research and technological innovation for SDGs; and
(c) Means to enable African countries to improve approaches to harnessing and deploying STI for sustainable development.

2.2 Methodology

The study was conducted between September 2016 and August 2017 through a series of interrelated activities involving scientists, policy-makers and development partners. First, review of the large body of academic and policy literature on STI and development was conducted, with emphasis on the conceptual nexus between STI and sustainable development, national and regional STI policy frameworks, how STI issues are treated in African national and continental vision statements and development plans, and national and AU as well as UN reports on progress made in achieving MDGs. Based on the literature review, key conceptual issues were identified and a framework for analysis developed.

A semi-structured (open- and closed-ended questions) questionnaire covering a range of issues on the nature of STI programmes and projects and their relevance to SDGs was designed. It covers institutional mandates and priorities, understanding of national development policies and SDGs, policy and institutional barriers to STI advancement in Africa, and factors that influence the participation of African countries and scientists in regional and international STI partnerships.

Based on the questionnaire, an on-line survey was conducted in October and November 2016. The survey instrument was sent to 600 persons, including AAS fellows, AAS affiliates, policy makers, research and education institutions, and development agencies. One hundred and sixty nine (169) responses were received, a rate of almost 30%. The results provide a basis for qualitative analysis of how respondents' institutions and programmes are aligned to SDGs, STI priorities, barriers to scientific research and innovation, relevance and effectiveness of national STI policies, awareness and/or knowledge of STI, and opinions on how best to enhance scientific research and technological innovation to achieve SDGs.

In addition to the on-line survey, face-to-face, telephone and Skype interviews were conducted with 79 persons from the scientific community and academia, government and policy-making circles, non-government organizations, and two people from the private sector, all continent-wide. Questions and foci of the interviews varied depending on the professional background and institutional affiliation of the interviewees.

The study also benefited from discussions at workshops on STI in Africa held throughout 2016 at different institutions and countries on the continent. It draws on proceedings of workshops held in Seychelles (March, organized by the National Science and Technology Institute), Namibia (April and July, organized by UNESCO), Nairobi (August, organized by the African Centre for Technology Studies and the University of Nairobi), and South Africa (November and December, organized by the Department of Science and Technology and various partners, and group discussions with AAS managers and directors).

3. STI AND SUSTAINABLE DEVELOPMENT

3.1 Conceptual Issues

The relationship between STI and sustainable development has attracted academic and public policy discourse. There is a large body of reports that shows that STIs are critical for sustainable development.[26] It demonstrates that to achieve sustainable development, countries—both developed and developing—must invest in the production and wise use of scientific knowledge and technological innovations. The United Nations Commission on Sustainable Development (UNCSD), through what is known as the Brundtland Commission, emphasized that STI, and technology in particular, offer both benefits and risks to sustainable development. Some technologies can be exploited to grow economies through extraction of natural resources, but at the same time degrading the ecology, thus undermining prospects of future generations from enjoying a healthy environment. Thus, economic growth on its own does not constitute or lead to sustainability.

There are numerous benefits of technology and STI in general. Many of the world's health, food, water and energy insecurities or challenges have been addressed through the development and application of STI. The development of human health vaccines, new varieties of seeds and/or crops, solar technologies, and many other technologies created by R&D has improved livelihoods of many millions of people around the world. STI have also improved communications and social interactions. However, the benefits of STI are not equitably distributed within and between countries and regions around the world. Indeed, there are still millions of people who have no access to basic health treatments, clean water and sanitation, secure energy and means of communication. In some cases, the development, diffusion and deployment of communication technologies have increased social exclusion, widening the digital divide.

Whether and the extent to which STI promote sustainable development depend on how they are governed. Indeed, purposeful governance of STI is necessary to make them work for sustainable development. It is not the mere development and deployment of STI that matter, but the existence of capable institutions (both the normative and agency types) that ensure that relevant R&D is conducted to develop 'appropriate' technologies that are accessible to and wisely used by households and communities around the world, particularly in African countries. Putting emphasis on governance of STI enables us to avoid the conventional approach of linking R&D to innovation and then to development in a linear way. The linear approach presupposes that the production of scientific knowledge leads in some automatic way to the development of new technologies (products, practices and processes) which then get commercialized or diffused into society or an economy.

One of the most comprehensive attempts at applying the concept of governance to STI is the study by Boekholt, et. al (2002) for the Dutch Ministry of Economic Affairs.[27] The authors define the governance of STIs as being about the roles that "various actors in the innovation system play, how rules of the game work, how decisions are taken and how changes in the overall innovation system come into being."[28] Their study deals with issues such as how research organizations and research funding agencies are held accountable for their activities, ways of

26. See the UN Millennium Project 2005. Innovation: Applying Knowledge in Development. Task Force on Science, Technology and Innovation for a detailed review of the STI-sustainable development nexus.

27. Boekholt, P., et. al. (2002), Governance of Research and Innovation: An International Comparative Study. Technopolis-Group.

28. Boekholt, P., et. al. (2002), op. cit. p. i.

increasing transparency in the design and implementation of STI policy, how stakeholders are involved in STI policy processes, and improving coordination mechanisms for STI policy.

Governance of STI focuses on systemic linkages and articulation of all actors—from public and private sectors—including potential users of scientific knowledge and technological innovation. It deals with issues such as accountability for and relevance of R&D investments, access to STI, social inclusion and environmental sustainability. In addition, adopting governance of an STI conceptual approach enables us to focus on the role of various state (e.g. ministries of STI and parliamentary bodies) and non-state actors (e.g. NGOs and private sector) in promoting STI for sustainable development.

In general, the STI-sustainable development nexus is complex and requires robust policy instruments beyond the traditional science policy that largely focuses on allocation of funds to R&D activities or technology policy that simply deals with the choice of one technology from a few competing choices. There are many issues of ethics, fundamental rights and associated obligations, equity, and sovereignty that have come to the public fore.

3.2 Overview of Scientific and Technological Advances

The world is experiencing rapid advances in STI. The global pool of scientific knowledge and technological innovation is expanding dramatically. Countries—developed and developing—are exposed to a wide range of technologies with applications in agriculture, health, energy, environment, business, transport, communications and many other spheres of human endeavour. There is a rich body of literature of global scientific and technological advances and their applications in different economic sectors and social development domains. [29] Some of the reports focus on the relevance and penetration of the technologies into African economies.[30]

Almost ten years ago, the World Bank report ***Global Economic Prospects 2008*** argued that the level of technological achievement in many developing countries had converged with those of high-income industrialized countries.[31] It attributed this to the implementation of policies that promoted technology adoption and adaptation in developing countries. This is mainly the case for ICTs for which adoption is widespread. Governments of these more successful countries are implementing policies and regulatory measures that enable access, adoption and adaptation of ICTs.

ICTs are platform or generic technologies with wide applications in various sectors and impacts on socio-economic systems.[32] They are pervasive and can be disruptive. The development, diffusion, and adaptation of ICTs depend on a range of factors, particularly the existence of strong physical infrastructure, such as energy or electricity. ICTs are rapidly advancing in such areas as computing, mobile communications, Internet and social media applications. Their applications are transformative. For example, mobile money (M-Pesa) is transforming local economies in countries such as Kenya by widening access to financial capital.

Biotechnology is another cluster of technologies that is driven by major scientific development. Biotechnology is a technological system of many converging techniques and scientific

29. For foresight and impact analysis of global scientific and technological advances see RAND (2006), The Global Technology Revolution 2020, In-Depth Analyses. http://www.rand.org/content/dam/rand/pubs/technical_reports/2006/RAND_TR303.pdf
30. See for example World Bank (2008), Global Economic Prospects: Technology Diffusion in the Developing World. The World Bank, Washington DC; UNECA (2013), African Science, Technology and Innovation Review 2013, United Nations Economic Commission for Africa, Addis Ababa; and UNIDO (2013), Emerging Trends in Global Manufacturing Industries, United Nations Industrial Development Organization, Vienna, Austria.
31. World Bank (2008), Global Economic Prospects: Technology Diffusion in the Developing World. The World Bank, Washington DC.
32. UN Millennium Project (2005), Innovation: Applying Knowledge in Development. UN Taskforce on Science, Technology and Innovation.

applications. Key developments have included gene sequencing, editing and typing, driven largely by advances in molecular biology and bioinformatics (the convergence of biotechnology and ICTs). Applications to medicine and health care, food and agriculture, environmental management, industrial production and manufacturing, and other economic activities are also increasing.

One of the major developments in biotechnology that has attracted public interest worldwide is genetic modification (GM), also known as genetic engineering. It is the transformation of a genome (human, animal or plant) that results in changes in the makeup of their cells. It can involve the transfer of genes within and across species to produce desirable traits. For example, genetic modification techniques in agriculture have produced novel traits to improve drought resistance and adaptation to water stress, pest resistance, high yielding crop varieties, and other ecological and agro-economically useful products. In 2015, global total acreage of GM crops was approximately 180 million hectares.[33] The adoption of GM crop technology is largely influenced by public perceptions about the perceived risks and benefits of it.

Nanotechnology

Nanotechnology is another technology with the potential to transform economies and address societal challenges. It involves scientific techniques that manipulate small particles and/or very thin films to develop or exploit unique properties of materials. [34] Like ICTs and biotechnology, nanotechnology enjoys wide application across sectors. It offers an enormous range of applications to agriculture, water and environmental management, health and medicine, and other areas. For example, "[w]ith the help of nano medicine early detection and prevention, improved diagnosis, proper treatment and follow-up of diseases is possible. Gene sequencing has become more efficient with the invention of nano devices like gold nano particles [… which], when tagged with short segments of DNA can be used for detection of genetic sequence in a sample." [35]

Advanced Manufacturing Technologies (AMTs) are driven by advances in information and communications technologies and the convergence of these technologies with others, such as biotechnology and nanotechnology. Indeed, the convergence of these technologies is the foundation of advanced manufacturing.[36] Such advances include additive and precision manufacturing; nano-materials and surfaces; next generation electronics; robotics/artificial intelligence, smart automation and adaptability; sustainable manufacturing; pharmaceutical and bio-manufacturing, and supply chain design and management.

In addition to advances in technology described above, there are many scientific breakthroughs in other sectors focusing on specific problems and/or issues. These developments are driving economies and transforming society. They offer the potential to address many contemporary societal challenges, such as climate change, disease, food insecurity, loss of biological diversity, water and energy insecurities, urbanization and human settlement, youth unemployment, and migration conflicts. Science is not only directly stimulating technological change, it is improving our knowledge and understanding of societal challenges, leading to policy interventions that improve the human condition.

Science is a source of international diplomacy and solidarity. The dominant contemporary example of a challenge that has served to coalesce global solutions is climate change. Science is the main basis for policy options and international cooperation to address the problems of carbon emissions and global warming. The discovery of the impact of methane and other greenhouse gases, and the design of mathematical models of climate change that identify variations in temperature and related measures such as sea level rise, have coalesced international solidarity against human activities that undermine the health of our planet. The Paris Agreement on climate change adopted in 2015 is a manifestation of the international solidarity driven by scientific evidence. Science has effectively used technology to generate informed human intervention.

33. https://www.ft.com/content/6e11eeea-00d7-11e6-99cb-83242733f755
34. Nikalje, A.P. (2015), Nanotechnology and its Applications in Medicine. Journal of Medical Chemistry, 2015, 5:2. https://www.omicsonline.org/open-access/nanotechnology-and-its-applications-in-medicine-2161-0444-1000247.pdf
35. Nikalje, A.P. (2015), Nanotechnology and its Applications in Medicine. Journal of Medical Chemistry, 2015, 5:2, p.83. https://www.omicsonline.org/open-access/nanotechnology-and-its-applications-in-medicine-2161-0444-1000247.pdf
36. Swezey, D., and McConaghy, R., (2011), Manufacturing Growth: Advanced Manufacturing and the Future of the American Economy. The Schwartz Initiative on the American Economic Policy.

3.3 Science, Technology and Innovation to Secure Sustainable Development: Illustrative Cases

The ongoing fight against infectious diseases such as HIV/AIDS, malaria and tuberculosis, and non-communicable diseases, such as cancer, diabetes and heart disease, is also driven by science. Science has enabled the international community to understand the nature and causes of these killer diseases.

The global drive to develop vaccines and other preventions and treatments is spearheaded by global coalitions and institutions, such as the Global AIDS Vaccine Initiative (GAVI), that are manifestations of science-driven international cooperation. Science is driving the global search for health technologies. It is informing many public health measures by enhancing insights into the causes of diseases and transmission of vectors.

The converging and pervasive nature of STI makes it possible to target and achieve SDGs. The attainment of SDG1 (No Poverty) is, to a large extent, dependent on achieving the other 16 Goals. Poverty is a manifestation of hunger, disease, social exclusion and inequalities, lack of access to water, sanitation and environmentally safe energy, vulnerability to climate change and its consequences, such as drought and floods, lack of access to healthcare, and exclusion from decision-making. Banishing poverty requires investment in STI to confront and address these manifestations. ICTs are enablers of human development. They make it possible for individuals and communities to access economic and social amenities; they also facilitate access to information and can promote participation in decision-making.[37]

The economic history of our world is rich with cases of poverty successfully reduced through the application of knowledge and technology. The Industrial Revolution and ascendency of affluence in Europe and other Western societies are largely attributable to investments in the production and use of new knowledge and techniques.[38]

Current differences in economic affluence and well-being between these countries and contemporary developing and less developed countries are largely correlated to gaps in science and innovation. As the Nobel economist Joseph Stiglitz remarked (2006): "What separates developed from less developed countries is not just a gap in resources but a gap in knowledge, which is why investments in education and technology—largely from government—are so important."[39]

Innovation technological and institutional - will also be key in spurring increased food production and security and ultimately ending hunger. Technological innovation will come from a range of sources, formal and informal, public and private, particularly from small-scale farmers in developing countries. They will have to be accompanied by institutional innovation involving reconfiguration of research institutions, cooperative alliances, universities, extension services and funding agencies.

37. United Nations (1997), An Assault on Poverty: Basic Human Needs, Science and Technology. IDRC and UNCTAD; UN Millennium Project 2005. Innovation: Applying Knowledge in Development. Task Force on Science, Technology and Innovation;
38. Landes, D., (1998), The Wealth and Poverty of Nations: Why some are so rich and some so power. W.W. Norton & Company, New York; and Stiglitz, J., (2006), Making Globalization Work: The Next Steps to Global Justice, Allen Lane Publishers, UK.
39. Stiglitz, J., (2006), Making Globalization Work: The Next Steps to Global Justice p.28. Allen Lane Publishers, UK.

SDG2 is attainable through investment in agricultural R&D, application of a combination of a wide range of technologies including ICTs, biotechnology and nanotechnology. No single technology, no single innovation and no single body of scientific knowledge is a magic bullet for ending hunger in all its manifestations. Indeed, ending hunger by 2030 will require concerted multidisciplinary scientific research, multifaceted technological innovations and a range of non-technical social and political innovations.

Recent studies show that biotechnology in general and new genetic technologies including genetic modification will play a major role in increasing food production in developing countries and across the world. [40] Developing and applying these technologies will require investments in scientific research, including basic research in genomics.

Innovation-technological and institutional will also be key in spurring increased food production and security and ultimately ending hunger. Technological innovation will come from a range of sources, formal and informal, public and private, particularly from small-scale farmers in developing countries. They will have to be accompanied by institutional innovation involving reconfiguration of research institutions, cooperative alliances, universities, extension services and funding agencies.[41]

Attaining SDG3 on "Good health and well-being" involves eradicating communicable and non-communicable diseases and achieving nutritional security. It involves and is indeed largely dependent on developing and enlarging access to medical innovations, and strengthening healthcare systems. A 2015 report by PATH identifies 30 high impact innovations the attainment of SDG3 targets in particular. Technological innovations to reduce maternal and child mortality, combat infectious diseases such as TB and malaria, control non-communicable diseases such as diabetes, and address other health challenges exist.

They include technologies such as uterotonics to prevent postpartum haemorrhage, oral rehydration solution (ORS) to treat diarrhea, and new nucleic acid amplification tests for rapid diagnosis of TB. However, these and other health innovations are not easily accessible in many low-income countries where they are needed most. These countries have weak innovation systems to procure, adapt and diffuse existing technologies.

40. See for example Bennett, D., and Jennings, R., eds., (2013), Successful Agricultural Innovation in Emerging Economies: New Genetic Technologies for Global Food Production. Cambridge University Press, UK and New York.
41. See Juma, C., (2011), The New Harvest: Agricultural Innovation in Africa. Oxford University Press, for how combined institutional and technological innovations are needed to feed Africa.

SDG6 - Clean Water and Sanitation - is related to the SDG3. Access to clean water and sanitation is a fundamental aspect of good health and well-being. Scientific research and technological innovation are crucial in developing, managing and ensuring access to clean water and sanitation. Water quality sensor technologies, remote sensing and assessment technologies, bioremediation, and other technologies offer enormous potential for achieving SDG6. Promoting wider access to and building local capacities to use the technologies, and increasing investment in R&D to develop new ones are issues that national and international policies must focus on.

Science is critical in fast tracking the implementation of the UN Agenda 2030 and attainment of the SDGs. A recent study by the International Council for Science (ICSU) demonstrates how the SDGs are interrelated and how science helps to reduce their complexity as well as to develop integrated policy tools for achieving them. Science helps to reduce uncertainty and enhance effectiveness for policies for SDGs.

The next section of this report focuses on how sustainable development considerations and SDGs are integrated into or expressed in different African national, regional and continental initiatives for STI. Key issues and questions addressed are:

- Trends in and priorities of scientific research and innovation;
- How STI policy frameworks and related programmes address issues of social and environmental sustainability; and
- Challenges and opportunities of enhancing STI policy and programme effectiveness to secure SDGs in Africa.

4. STI POLICY AND PROGRAMME EFFECTIVENESS IN AFRICA

4.1 Scientific Research and Innovation Trends

African countries have made great efforts to grow their research productivity in the past decade or so. Recent assessments by institutions such as the AU, UNESCO, the African Capacity Building Foundation (ACBF) and the World Bank all show that Africa's scientific productivity has improved and though its contribution to global scientific publication has increased marginally.

A recent report by the World Bank and Elsevier concluded that Sub-Saharan Africa's research output increased from 0.44% to 0.72% of total global research between 2003 and 2013.[44]

The ***African Innovation Outlook (AIO) report*** of 2014 by the AU and NEPAD concludes that there was increased scientific research output by 29 African countries between 2010 and 2013. [45]

Similar conclusions were also made in ***African Science, Technology and Innovation Review 2013*** of the United Nations Economic Commission for Africa (UNECA) and UNESCO Science Report 2015.[46] Health and agricultural sciences produced the greatest increases in research productivity over the past decade. Health sciences (with health research emphasis on HIV and AIDS, malaria and tuberculosis) and agricultural sciences (with emphasis on crop/plant breeding for disease and drought resistance) accounted for about 45% and 30% respectively of total research publication outputs from Africa in the past decade.[47]

The survey and interviews conducted for this report suggest that at least 50% of research priorities and projects are in health sciences and at least 30% in agricultural sciences. Engineering and the geological, environmental and other sciences receive limited funding and have correspondingly lower output. This may undermine Africa's prospects of attaining SDGs related to environmental sustainability. Relatively high scientific productivity in health sciences is attributable to big investments by international health programmes that support or conduct research in African countries. For example, the Global AIDS Vaccine Initiative (GAVI) and the U.S. Centers for Disease Control (CDC) are supporting research in West, Eastern and Southern Africa. They have supported the establishment of good R&D facilities in institutions in Kenya, Senegal, Uganda and Zambia, among other African countries. A recent study by CAASTNet-Plus estimates that the European Union (EU) contributed at least Euro 15 billion to EU-Africa collaborative health research programmes from 2005 - 2015.

44. World Bank and Elsevier (2014), A Decade of Development in Sub-Saharan African Science, Technology, Engineering and Mathematics Research. https://www.elsevier.com/research-intelligence/research-initiatives/world-bank-2014

45. NEPAD Agency (2014), African Innovation Outlook 2014. NEPAD Planning and Coordinating Agency, Pretoria, South Africa.

46. UNECA (2014), African Science, Technology and Innovation Review 2013. United Nations Economic Commission for Africa, Addis Ababa; and UNESCO (2016), Science Report 2015. United Nations Educational, Scientific and Cultural Organization, Paris.

47. World Bank and Elsevier (2014), A Decade of Development in Sub-Saharan African Science, Technology, Engineering and Mathematics Research. https://www.elsevier.com/research-intelligence/research-initiatives/world-bank-2014; and NEPAD Agency (2014), African Innovation Outlook 2014. NEPAD Planning and Coordinating Agency, Pretoria, South Africa.

Gross Expenditure on Research and Development (GERD) as a percentage of GDP is increasing in African countries, but is still below the national and AU targets of 1%. Over the past decade, African countries have increased their national or domestic investments in R&D, and foreign funding has also grown, raising the GERD of many countries. According to the AIO 2014, only Kenya, South Africa, Senegal, Tanzania and Uganda had GERD above 0.5%. Egypt had GERD of 0.43% in 2013 compared to about 0.25% in 2005. Namibia's GERD was estimated at 0.35% in 2016 compared to 0.04% in 2005.

The GERD of most African countries is mostly or exclusively externally financed. According to the Global Innovation Index (GII) 2015, in 2010 100% of Mozambique's, 73% of Uganda's, 60% of Kenya's, and approximately 50% of Tanzania's, Burundi's, and Senegal's GERDs was financed by external sources, mainly foreign development partners, as part of their development assistance initiatives. [50] Various studies have shown that a large share of funding for R&D in Africa, particularly Sub-Saharan Africa, is from international funding agencies from Europe (particularly UK, Germany, Nordic countries, Netherlands, and EU), USA and Japan.[51]

Innovation and entrepreneurial capabilities of African countries have improved, though a lot more needs to be done to strengthen national innovation systems. Over the past two decades, there has been a remarkable improvement in the abilities of African countries to innovate and engage in entrepreneurial economic activities. The Global Innovation Index (GII) 2015 shows that some African countries' global ranking on innovation capabilities has improved. For example, the GII 2015 report shows that Mauritius, Kenya, Namibia, Uganda, and Rwanda improved their 2014 global ranking on innovativeness. This is mainly due to improved institutional factors, particularly better legislative and regulatory measures for enterprise development and performance. Chapter 11 of GII 2015 examines Uganda's innovation policies for development (summarized in Box 2).

48. CAAST-Net Plus (2016), Africa-EU Research Collaboration on Health: A Critical Analysis of the Scope, Outputs and Potential Outcomes. https://caast-net-plus.org/object/document/1522/attach/0_CN__HealthReport_v6_WEB.pdf
49. NEPAD Agency (2014), African Innovation Outlook 2014. NEPAD Planning and Coordinating Agency, Pretoria, South Africa.
50. Cornell University, INSEAD, and WIPO (2015): The Global Innovation Index 2015: Effective Innovation Policies for Development, Fontainebleau, Ithaca, and Geneva.
51. See for example CAAST-Net Plus (2016), Africa-EU Research Collaboration on Health: A Critical Analysis of the Scope, Outputs and Potential Outcomes. www.caast-net-plus.org

Box 2: Effectiveness of Uganda's Innovation Policies for Development

In 2014, Uganda was classified as an 'innovation achiever' for the second time by the GII. This means that Uganda's GII score relative to its GDP is significantly higher than that of other economies in its low-income bracket. Uganda was ranked 106th in 2011, 117th in 2012, 89th in 2013, and 91st in 2014, consistently outperforming a number of low-income countries. Although its GII performance might appear to be an outlier, long-term observers of the country's stable economic policies and performance will not find its GII scorsurprising. For the period 1986–2010, the government's emphasis was on economic recovery; now it is on transforming Uganda into a middle-income society. The government is currently focusing on deepening private-sector investment by improving its business environment and competitiveness through innovation. Uganda's GII strength in areas such as strong foreign direct investment net inflows is a direct result of the relative stability of the economy. Reform processes currently underway are aimed at addressing structural and institutional weaknesses that directly relate to Uganda's weak areas in the GII indicators, such as the ease of starting and the cost of doing business. However, as discussed the existing legal and policy framework is responsible for Uganda's positive innovation attributes.

Source: Cornell University, INSEAD, and WIPO (2015): The Global Innovation Index 2015: Effective Innovation Policies for Development, Fontainebleau, Ithaca, and Geneva.

Table 2 below shows African countries' ranking out of a total of 128 countries that were surveyed for the GII report.

Table 2: The Global Innovation Index 2015 for some African Countries

Country	Rank in GII Report 2016 (out of 128 countries)
Mauritius	53
South Africa	54
Morocco	72
Tunisia	77
Kenya	80
Rwanda	83
Mozambique	84
Botswana	90
Namibia	93
Malawi	98
Uganda	99
Ghana	102
Tanzania	105
Senegal	106
Egypt	107
Ethiopia	110
Madagascar	111
Mali	112
Algeria	113
Nigeria	114
Cameroon	118
Benin	121
Burkina Faso	122
Burundi	123
Niger	124
Zambia	125
Togo	126

Source: Cornell University, INSEAD, and WIPO (2015): *The Global Innovation Index 2015: Effective Innovation Policies for Development*, Fontainebleau, Ithaca, and Geneva

Africa's share of the total number of patents filed globally has also increased in the past decade, albeit marginally compared to some other regions of the world. In 2000, Africa accounted for less than 0.2% of global patent applications; by 2006, this had grown to 0.6%.[52] Between 2005 and 2015, Africa's world share of patent applications increased by about 3.1%.[53] Most of the continent's patent applications are in agriculture and pharmaceuticals. South Africa accounts for at least 50% of Africa's share of global patent applications, and Kenya, Namibia, and South Africa have each increased their patent applications since the 1990s. For example, in 1990, Namibia had no patent registered with WIPO. In 2016, the country had 8 patents registered.

The growth in Africa's innovation capabilities can also be gauged from the rate of enterprise formation on the continent. Many African countries have grown their entrepreneurial capabilities and created more new enterprise, particularly Small and Medium Scale Enterprises (SMEs), in the past two decades. Data on continent-wide enterprise formation is scanty. However, review of individual countries' enterprise and/or private sector growth shows that in most countries, the number of new enterprises created has increased substantially in the past two decades.[54]

4.2 National STI Policy Frameworks

During the past decade, many African countries have also formulated and adopted explicit STI policies. In 2000, fewer than 15 countries had policies for promoting science and technology. Now many more countries have STI policy frameworks, including Algeria, Angola, Botswana, Burundi, Cameroon, Egypt, Ethiopia, The Gambia, Ghana, Kenya, Malawi, Mali, Mozambique, Namibia, Nigeria, Rwanda, Seychelles, Sudan, Swaziland, South Africa, Tunisia, Tanzania, Uganda, Zambia, and Zimbabwe.

> ***"Most STI policy frameworks for African countries are built on economic growth and competitiveness rationales."***

There are key features of African national STI policy frameworks relevant to the advancement of SDGs. The first is the economic justification for the objectives. That is, STI policies are driven by imperatives to grow economies. For example, the Kingdom of Swaziland's STI policy framework is based on the "…desire to make Swaziland a first world country or catch up with the first world countries; make Swaziland to be more competitive in the world market and trade; and improve value addition to the many products Swaziland produces."[55] The country's policy framework makes no explicit reference to attaining sustainable development by addressing national challenges of high levels of poverty and social inequalities that are outlined in the National Policy objectives of many STI frameworks that are framed around increasing GERD as a percentage of GDP.

Most frameworks set general GERD targets, such as 1% of GERD for Angola, The Gambia, Namibia, Swaziland and Tanzania, and 2% of GDP for Kenya. These targets are often not based on clear R&D investment plans, and do not necessarily cover technology and innovation activities. Quantitative indicators used by countries to measure STI policy effectiveness are GERD-driven, often focused on inputs into the research system, with few if any goals for development outcomes of R&D and innovation.

52. WIPO (2016), World Intellectual Property Protection Indicators 2016. World Intellectual Property Protection Organization (WIPO), Geneva.

53. WIPO (2016), World Intellectual Property Protection Indicators 2016. World Intellectual Property Protection Organization (WIPO), Geneva.

54. UNECA (2016), Industrializing through Trade: Economic Report on Africa 2015. United Nations Economic Commission for Africa, Addis Ababa. http://www.un.org/en/africa/osaa/pdf/pubs/2015era-uneca.pdf

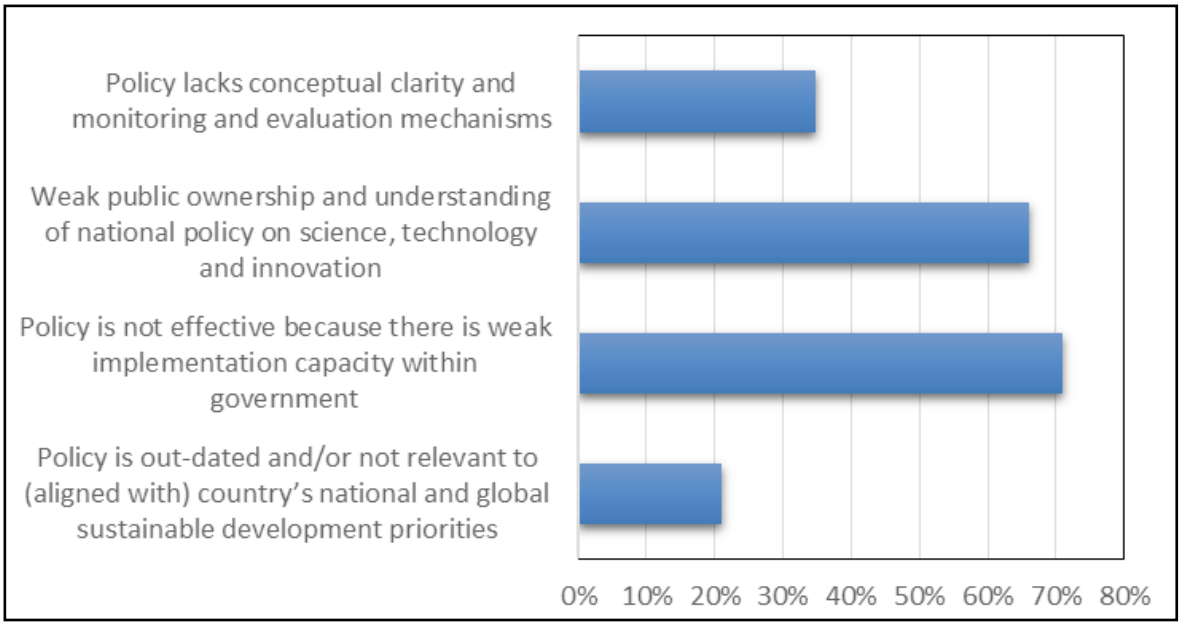
55. Government of the Kingdom of Swaziland (2011), National Science, Technology and Innovation Policy 2011-2016, p. 37. Ministry of Information, Communication and Technology, Swaziland.

Social and environmental goals are not adequately integrated into national STI policy frameworks of African countries.

While many of the frameworks make reference to the importance of STI being harnessed and applied for socio-economic transformation, few contain explicit policies for achieving social and environmental goals. STI policy frameworks make reference to the importance of promoting women's participation in scientific research but do not really address issues such as women's access to health technologies and maternal healthcare. According to one interviewee for this study, "policies for science and technology just focus on the promotion of research and technology but fail to cover important aspects of ensuring that the research and technologies that are developed are relevant and address needs of marginalized and socially excluded groups such as women and people with disabilities." Innovation is often an add-on to R&D policies in STI policy frameworks and not an integral part of policy to promote scientific research, technology development and innovation. A review of frameworks shows that in many instances, while the word "innovation" is in the title, they lack policies for promoting innovation. For many countries, broad areas of technology e.g. biotechnology and ICTs and/or economic sectors are identified in the policy documents, but they lack specific policy interventions to harness and apply innovation to address specific development challenges and/or priorities.

Most STI policy frameworks have no monitoring and evaluation mechanisms, nor budgets for implementation. With the exception of Namibia's National Research, Science and Technology Policy of 1999, none of the national frameworks, including those that were adopted during the last five years, have clear mechanisms for monitoring and evaluating their implementation.[56] Moreover, the adoption of the policy frameworks has not been enabled by a dedicated budget. The lack of monitoring and evaluation and budgets for STI policy implementation are major impediments to leveraging STI to achieve SDGs in Africa.

Figure 4: Factors influencing implementation and effectiveness of STI policy frameworks in Africa



56. UNECA, AU and AfDB (2016), Innovation, Competitiveness and Regional Integration, chapter 5. United Nations Economic Commission for Africa, African Union and African Development Bank, Addis Ababa.

Other factors that influence the implementation of STI policy frameworks are weak capacities of government departments and ministries and weak or low public understanding and ownership. About 70% of respondents in the survey (see Figure 4) for this study identified weak capacities while 65% identified weak public ownership of policy frameworks as major factors hindering STI policy implementation and effectiveness. Poor understanding or knowledge of specific STI policy measures—what we refer to as low policy literacy—is another contributor to weak implementation and low policy effectiveness. A study by AOSTI (2013) established that STI policy literacy was low in many departments or ministries responsible for STI in many African countries.[57]

"'Science for policy' is as an essential facet of STI policy".

'Science for policy' is about measures or actions to ensure that science is procured for and used in policy-making processes. However, STI policy frameworks of many African countries do not contain provisions on "science for policy". As stated earlier, the frameworks largely focus on policies for promoting scientific research. Integrating into STI policy frameworks specific measures to promote the procurement and use of science in public policy will help to align them to SDGs and Agenda 2063. According to three of the interviewees for this study, many African countries do not have expertise in STI policy and experience in organizing science advisory mechanisms. The 2013 AOSTI study also identified lack of adequate expertise in STI policy analysis as limiting the abilities of African countries to design and implement measures and programmes for "science for policy".

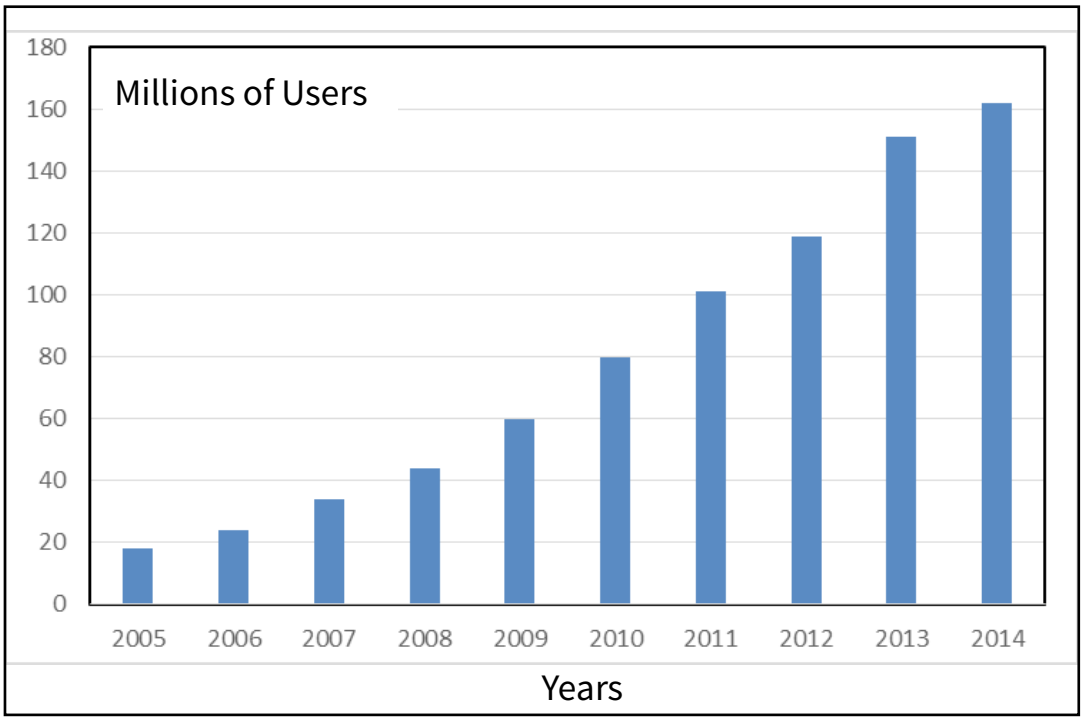
4.3 Sectoral Technology Policy Instruments

African countries have also adopted technology policy instruments covering fields such as ICTs, biotechnology, indigenous and traditional knowledge, intellectual property protection, climate change and energy. As stated earlier, they also have implicit policies for FDI and trade. At least 45 African countries have ICT policy frameworks that deal with liberalization of media and broadcasting, promoting accessibility and diffusion of ICTs, ICT infrastructure development, particularly broadband, e-commerce, e-government and mobile or cellular telephone penetration.

Policies for ICTs have been adopted and are being implemented with effectiveness by many African countries.

57. AOSTI (2013), 'Science, Technology and Innovation Policy-Making in Africa: An Assessment of Capacity Needs and Priorities'. AOSTI Working Papers No. 2, 2013. AU African Observatory of Science, Technology and Innovation.

Figure 5: Penetration of mobile phones in Sub-Saharan Africa



Guerriero, M., (2015), The Impact of Internet Connectivity on Economic Development in Sub-Saharan Africa, Economic and Private Sector, University of Birmingham.

There has been remarkable diffusion and adoption of ICTs in African economies over the past two decades. The penetration of mobile phones and related ICT infrastructure has been pronounced: in 2005 there were about 18 million people with access to mobile phones on the continent. By 2015, at least 160 million people had access to mobile phones (see Figure 5).

The rapid diffusion and adoption of mobile phones and ICTs in general is associated with the deliberate ICT policies. Socio-economic benefits of the policies are now widespread in many African countries. In agriculture, for example, farmers are utilizing mobile phones to access information on weather and markets. And in Kenya, the Farmers Helpful Network (FHN) provides farmers with information on crop rotation, artificial insemination, and crop insurance. This enables farmers to make informed decisions and to improve their agricultural production and profitability.

Since the 1990s, there has been a continuous debate on potential socio-economic impacts of biotechnology on African economies. Most African countries have not adopted national policies and strategies for promoting the development and application of biotechnology. Egypt, Kenya and South Africa are the only countries with explicit policy instruments. Only Burkina Faso, South Africa and Sudan have allowed commercial production of GM crops. South Africa has Bt maize and Bt cotton while Burkina Faso and Sudan are producing Bt cotton. In other countries, efforts to adopt biotechnology policies have been resisted by anti-biotechnology lobbies. There is heavy reliance on foreign funding and weak local constituencies for biotechnology in most countries.

Many countries have adopted biosafety regulations, mainly in response to the United Nations (UN) Cartagena Protocol on Biosafety, to regulate the development and application of modern biotechnology. They include Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Malawi, Mali, Mozambique, Namibia, Nigeria, Senegal, South Africa, Sudan, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe.

> Policy uncertainty and discontinuity as well as weak institutional leadership undermine Africa's prospects of effectively developing biotechnology.

Africa's entry into biotechnology, such as the adoption of genetic modification for agriculture, is slow compared to Asia and Latin America. In 2014, Africa accounted for less than 2% of the global total land acreage under GM crop cultivation, while Latin America accounted for about 45% and Asia about 10%. [58] The absence or inconsistency of biotechnology policies, inefficient and rigid regulatory mechanisms, and small domestic investment in R&D are some of the factors responsible for weak adoption and commercialization of GM crops in Africa.[59]

The development and implementation of climate change and energy technology policies have also preoccupied African countries, as they have nations globally, in the past decades. Many African countries have policies to promote the development, procurement and use of technologies that increase energy security, which often favor energy infrastructure and installation of solar energy.

African countries are creating policies for climate change technology development, procurement and transfer. With support from institutions such as the Global Environment Facility (GEF), more than 30 African countries have conducted climate change technology needs assessments (TNAs) to identify needs and priorities for developing, procuring and applying technologies for climate change adaptation and mitigation.[60] The TNAs have identified various barriers, including weak national innovation systems, poor implementation of existing technology policies, and limited budgets for R&D on climate change.

Another area of interest to some African countries is advanced manufacturing. Ethiopia, Kenya, Namibia and South Africa have prioritized advanced manufacturing technologies in their national STI policy frameworks. However, with the exception of South Africa, no African country has developed specific technology policies and strategies in this realm. Even the implementation of South Africa's Advanced Manufacturing Technology Strategy (AMTS), adopted in 2011, has been constrained by poor institutional support and lack of adequate financing.

4.4 Policies on Indigenous Knowledge and Traditional Technologies

The role of indigenous knowledge and traditional mechanisms for sustainable development in Africa is broadly recognized by governments, civil society and other stakeholders. Indigenous knowledge is embedded in farming and fishing practices, health care and treatment systems, and the environmental conservation practices of rural communities in Africa. There are numerous empirical studies demonstrating the existence and utility of native understanding and related technologies in African communities. They make a compelling case for promoting, protecting and preserving indigenous knowledge.

Many African countries have adopted policy measures and launched programmes to promote and protect the use of indigenous knowledge and related traditional technologies. In most countries, these are integrated into environmental policies and legislation, and STI policy frameworks. Ethiopia, Kenya and Uganda have integrated policies for the protection of indigenous knowledge in their legislation on intellectual property protection and access to genetic resources.

Some countries have adopted explicit policies for promoting and protecting indigenous knowledge. For example, South Africa adopted the Indigenous Knowledge Systems Policy (2004) that established a National Office on Indigenous Knowledge Systems within the Department of Science and Technology (DST). It requires the Government of South Africa to fund research and create centres of excellence on indigenous knowledge studies.

58. James, C., (2014), Global Status of Commercialized Biotech/GM Crops: 2014. The International Service for the Acquisition of Agri-biotech Applications (ISAAA).
59. Bailey, R., Willoughby, R., and Grzywacz, D., (2016), On Trial: Agricultural Biotechnology in Africa. The Royal Institute for International Affairs, London.
60. Mugabe, J., (2012) "African Perspectives on the UNFCCC Technology Mechanism"; in (2012); Realizing the potential of the UNFCCC Technology Mechanism: Perspectives on the Way Forward; ICTSD Programme on Innovation, Technology and Intellectual Property; Issue Paper No. 35; International Centre for Trade and Sustainable Development, Geneva, Switzerland, www.ictsd.org

4.5 Regional Initiatives on Science, Technology and Innovation

Africa's RECs have adopted STI policy frameworks and some have established agencies with programmes dedicated to STI. Some REC treaties have provisions on STI. For example, the treaties that established the Common Market for Eastern and Southern Africa (COMESA), the East African Community (EAC), the Economic Community for West African States (ECOWAS) and the Southern African Development Community (SADC) contain provisions on regional cooperation on STI (see Table 3). These form the basis of these countries' respective policy frameworks.

SADC and EAC adopted protocols in 2009, while ECOWAS adopted a regional STI policy framework in 2013. Different RECs put different emphases on different aspects of STI. For example, SADC has focused mainly on enhancing technological innovation for industrialization and mining, and the EAC emphasizes agricultural R&D and pharmaceutical manufacturing. COMESA's focus is on innovation in biotechnology and climate change technologies.

Table 3: Regional initiatives on science, technology and innovation

Regional Economic Communities	Treaty Provisions on STI
COMESA	Article 100(d) of COMESA calls on member countries to cooperate to promote "industrial research and development, the transfer, adaptation and development of technology, training, management and consultancy services through the establishment of joint industrial support institutions and other infrastructural facilities."
EAC	Article 80(e) of EAC Treaty: "promote industrial research and development and the transfer, acquisition, adaptation and development of modern technology, training, management and consultancy services through the establishment of joint industrial institutions and other infrastructural facilities." In Article 103 of EAC Treaty, member states commit themselves to "promote cooperation in the development of science and technology within the Community through: (a) the joint establishment and support of scientific and technological research and of institutions in the various disciplines of science and technology; and (b) the creation of a conducive environment for the promotion of science and technology within the Community.
ECOWAS	Article 3 of ECOWAS Treaty outlines "harmonization and co-ordination of national policies and the promotion of integration programmes, projects and activities, particularly in food, agriculture and natural resources, ...science, technology..."
SADC	Article 21(d) of SADC Treaty makes explicit reference to member States cooperating in science and technology as one of the major areas necessary for fostering regional development and integration. SADC's Protocol on Education and Training, aims at promoting the development of a common science and technology policy, establishing joint research facilities and regional centres of excellence, and facilitating the movement of scientists in SADC countries

RECs have launched their STI protocols and policy frameworks through various funding programmes. Under the auspices of NEPAD, each REC hosts programmes dedicated to agriculture, health and biodiversity conservation R&D. For example, the SADC launched the Southern Africa Biosciences Network (SANBIO)[62] in 2005 as a platform for shared R&D facilities to enable institutions and scientists in the region to collaborate on specific R&D priority issues. The platform offers world-class facilities to the region's scientists to engage in translational research on biocontrol, biosafety, bioprospecting to develop remedies for infectious diseases, fish farming in communities and schools, and the development of diagnostic tools.

The Biosciences Eastern and Central Africa (BECA) is also a NEPAD-AU initiative in ECA and Central Africa; its central hub is the International Livestock Research Institute (ILRI) in Nairobi. BECA convenes scientists from the two regions to work on common challenges in food and nutritional security. Through institutions including national agricultural research institutes and universities in the two regions, BECA is advancing scientific research in genomics, bioinformatics, bio-fortification and biosafety.

One of the barriers to agricultural production in eastern and central Africa is viral attack and pest infection of crops, particularly legumes. The production of beans is vital to nutritional security in these regions, but it is low and decreasing due to aphid-transmitted viruses. BECA, in collaboration with the University of Cambridge, UK, is developing biochemical means of controlling aphids in eastern and central Africa.

The project is studying the impact of virus-infected aphids in different ecological zones in Uganda. Using molecular analyses and mathematical tools, scientists are identifying and deploying plants that attract aphids. Genes and RNA that are involved in bean-virus-aphid interactions are identified. This enables the development of applications to control viruses affecting beans.

STI initiatives in the ECOWAS region include the establishment in 2010 of the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) in Cape Verde, with the support of the ECOWAS Commission, the Austrian and Spanish Governments and the United Nations Industrial Development Organization (UNIDO). Priority is on supporting ECOWAS member states to develop coherent national energy policy frameworks, and facilitating the procurement and/or transfer of climate change mitigation technologies.

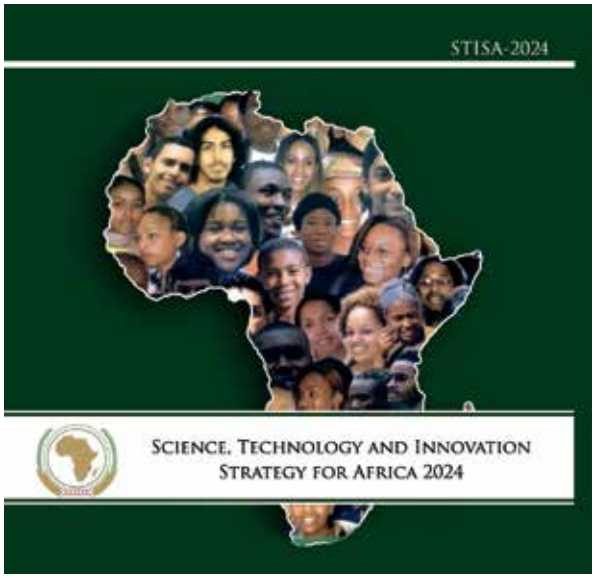
A related ECOWAS initiative is the World Bank-funded Centres of Excellence in scientific research and technology development.[63] The project supports selected universities to design strategies for scientific leadership and training, to build excellence in Science, Technology, Engineering and Mathematics (STEM) education, and to invest in research in phyto-medicine, infectious diseases pathologies and reproductive health.

The North African countries under the auspices of the African Maghreb Union have launched North Africa Biosciences Network (NABNet), the Maghreb Virtual Science Library (MVSL) Programme, and the ICT Maghreb Technology Platform. The Maghreb Virtual Science Library (MVSL) Programme is the most developed, supporting national research portals to address information needs of scientists.

4.6 Continental STI Policy Frameworks and Programmes

There have been numerous Pan-African STI initiatives designed in the past decade or so. These initiatives are differentiated into those dedicated to policy frameworks, to funding scientific research and training, and to capacity building for training and infrastructure.

STISA-2024 is the main Pan-African STI policy framework adopted by the AU to promote scientific research, technology development and innovation for sustainable development. Its core programmatic goals consist of infrastructure development, innovation and entrepreneurship, technical competencies, and an enabling environment. STISA's overall goal is to encourage sustainable development in Africa through the eradication of hunger, creating food and nutritional security, disease control and prevention, the promotion of physical and intellectual mobility, environmental and space management, and creating a peaceful, cohesive society through integration, good governance and wealth creation.



A significant barrier to implementation of STISA 2024 is limited public knowledge and ownership of the strategy. Even when African scientists, policy-makers and private sector practitioners are aware of the existence of STISA-2014, they generally are not familiar with its goals nor its relevance to their work. Most respondents (52%) to our survey -- scientists associated with the AAS -- were not aware of STISA-2024. Another barrier to implementation of STISA-2024 is the limited funding allocated to the development and implementation of programmes by AUC, NEPAD Agency, RECs, national governments and associated implementing agencies. So far, no AU funding mechanism has been created for implementation of STISA-2024. The strategy calls for the creation of an African Science, Technology and Innovation Fund (ASTIF), but it has not been established. RECs and national governments of most countries have dedicated some financial resources to STISA-2024, but budgets are modest because of lack of integration of the strategy's provisions into national STI policy frameworks.

The implementation of STISA-2024 is also hampered by a lack of demonstrated commitment by African governments and political champions. No organized collective efforts have been effected by African leaders to implement STISA-2024, although recent identification of a ten-member presidential committee on STI is a step in the right direction. One senior policymaker said, "African politicians including educated ministers and presidents have a tendency to adopt strategies and plans at AU summits without reading them and without carefully thinking about implementation. Adoption of documents such as the STISA was a mere formality, ritual with no political mileage for ministers and presidents." More than 60% of survey respondents attributed lack of government commitment to poor or slow implementation of STISA-2024.

Initiatives of AAS

Continental initiatives for mobilizing and administering financial resources for scientific research and innovation include the **Alliance for Accelerating Excellence in Science in Africa (AESA)** under the auspices of AAS and NEPAD Agency, with financial support from global funders including the Wellcome Trust, the Bill and Melinda Gates Foundation and the Department for International Development of the UK government (DFID.)

AESA was endorsed by the African Union as an agenda setting and funding platform especially for research on health and other developmental challenges. It develops and funds current and future leaders in scientific research and research environments through programmes such as Climate Impact Research Capacity and Leadership Enhancement (CIRCLE), Grand Challenges Africa (GCA), Human Heredity and Health in Africa (H3Africa) and Developing Excellence in Leadership, Training and Science (DELTAS) Africa.

CIRCLE is a multi-disciplinary programme that builds the research skills of early career researchers in a broad range of disciplines that impact climate change. It provides 100 scholarships per year to postgraduate and postdoctoral researchers in mitigation of and adaptation to climate change, emphasizing impacts on water, agriculture, health and energy.

GCA promotes science and technological innovation to achieve SDGs. Designed and implemented as a partnership among AAS, NEPAD and the Bill and Melinda Gates Foundation, it provides seed funding to potential African innovators and grants to scientists who are tackling aspects of Africa's sustainable development and health challenges.

Grand Challenges Africa directly supports African scientists in the development and diffusion of technologies for maternal, newborn and child health (MNCH) in Africa, as well as food and nutritional security and climate change adaptation.

H3Africa contributes explicitly to the attainment of SDGs. Launched by the National Institutes of Health (NIH), the Wellcome Trust and African Society of Human Genetics (AfSHG) in 2012 and administered by AAS, H3Africa focuses on research on genomics and environmental determinants of common diseases in order to improve the health of African populations.

The Initiative will promote access to health genomic technologies, build Africa's capacity in genomics research and innovation, and on the whole, contribute to the attainment of SDG3.

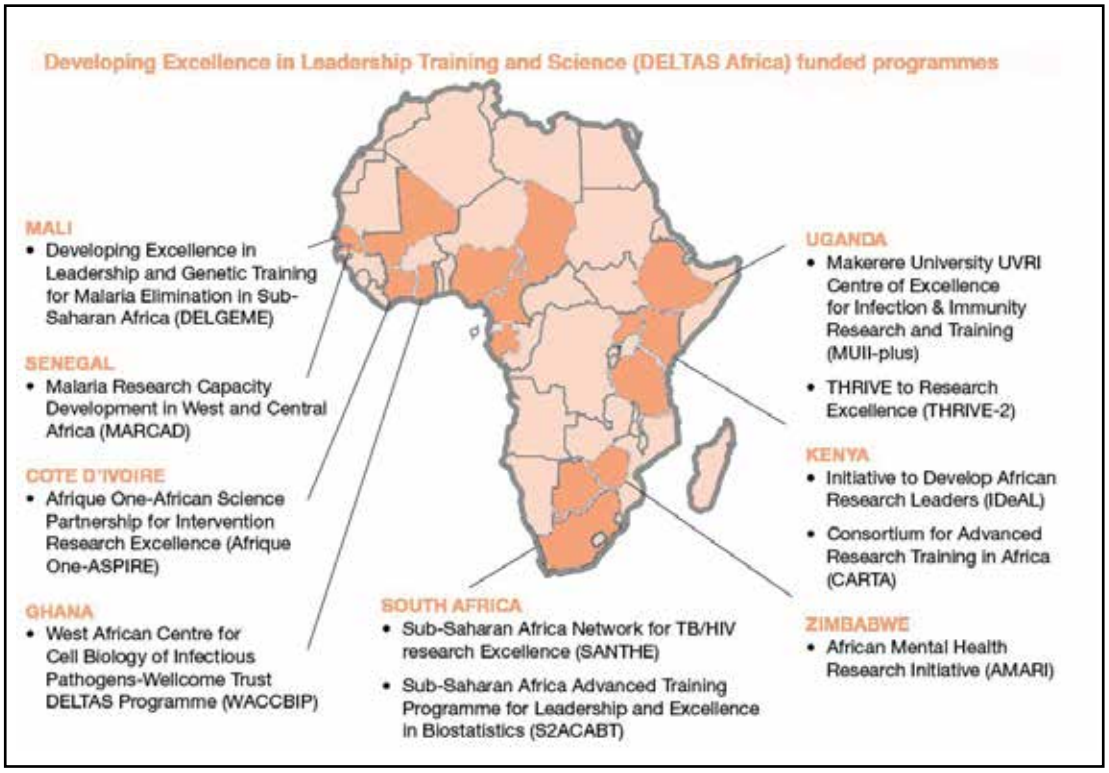
DELTAS Africa is an AAS programme funded by the Wellcome Trust and the UK DFID at US$100 million. It supports the development of world-class researchers and scientific leaders in Africa.

Launched in 2015, this programme funds research teams and consortia, as well as institutions in Africa to build infrastructure and skills for scientific excellence in the health sciences. DELTAS Africa promotes collaboration between African and Northern institutions, especially in the UK.

Eleven health research and training initiatives in Sub-Saharan Africa are funded at an average of $7M million over 5 years (see Figure 6).

62. http://www.nepadsanbio.org/
63. http://www.aau.org/content/africa-centres-excellence-project-ace

FIGURE 6: DELTAS AFRICA-FUNDED RESEARCH PROGRAMMES



The programmes launched under AESA explicitly focus on promoting scientific research and innovation that target SDGs 1-13. Research and capacity-building projects funded by the AAS are all aligned with SDGs. According to several of the interviewees for and reviewers of this study, AESA needs to be scaled up and domesticated by African countries by their own investments. It is a strategic initiative for harnessing STI to achieve many of the SDGs.

The AU Research Grants Programme (AURGP) is administered by the AU Commission and funded by the European Union (EU), and provides grants to African scientists to conduct research in food and nutrition security, water and sanitation, renewable energy and climate change. In 2016 and 2017, the EU allocated 17.5 million euros to support the implementation of food and nutritional security projects that are aligned with STISA-2024.

Continental STI initiatives for capacity building in higher education and training include the African Institute for Mathematical Sciences (AIMS) and the Pan African University. AIMS was launched in 2003 as a partnership among Stellenbosch University, University of Cape Town, University of Western Cape, Cambridge University (UK), Paris Sud XI and Oxford University (UK). It builds skills in mathematical sciences and promotes mathematical sciences in agriculture, health, banking, manufacturing, environmental conservation, mining and engineering. AIMS is a pan-African network located in Cameroon, Ghana, Rwanda, Senegal, and South Africa which has produced over 1,000 graduates from 42 African countries.

The Pan-African University (PAU) was launched in 2011 as a post-graduate training and research initiative operating through selected universities in the five regions of Africa. It encompasses basic sciences, technology and innovation; life and earth sciences; water and energy sciences; space sciences; and governance, humanities and social sciences. The Institute for Basic Science, Technology and Innovation is at Jomo Kenyatta University of Agriculture and Technology in Kenya; the Institute for Governance, Human and Social Sciences is at the University of Yaounde in Cameroon; the Institute for Life and Earth Sciences is at Ibadan University in Nigeria; and the

Institute for Water and Energy Sciences is at the University of Tlemcen in Algeria. The Institute for Space Science is planned for a university in South Africa.

Other continental research and professional networks, including the AAS and Network of Africa Science Academies (NASAC), promote STI for development. They include initiatives to advance research and training in health, energy, engineering, climate change, agriculture and food. But most research networks are fragmented and dependent on external funding.[64] Over-reliance on external funding undermines the sustainability and effectiveness of many African STI initiatives. There is widespread recognition that it is critical to mobilize domestic African funding for STI on the continent. One observer remarked: "our institutions survive on foreign money to do many things including pay for basics such as electricity and water for research. They cannot focus on local problems and are forced to service foreign development partners' interests."

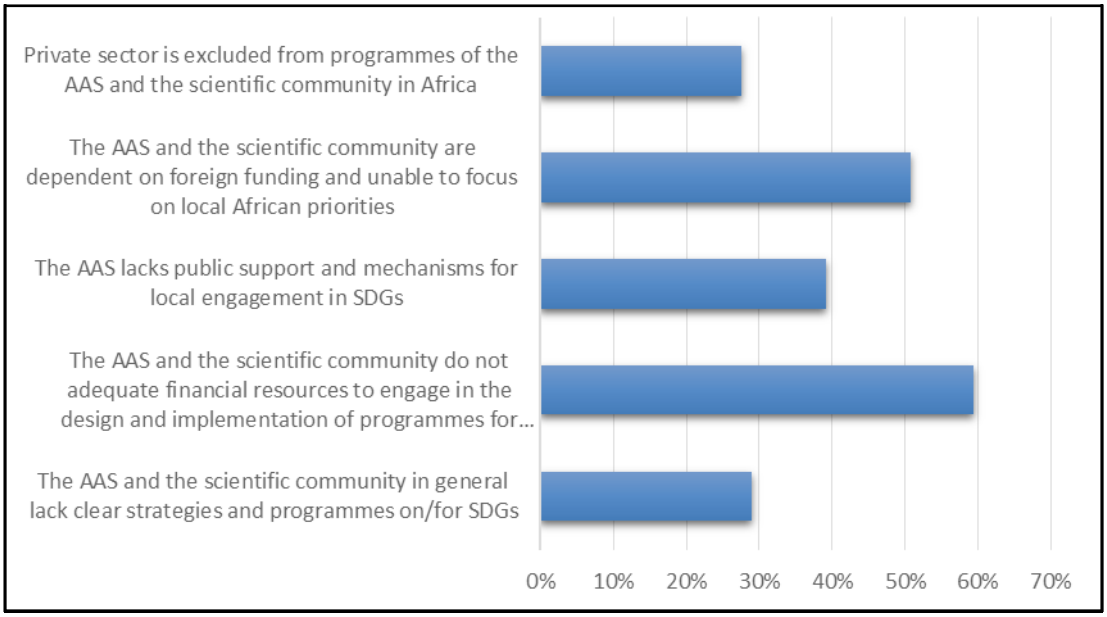
About 50% of survey respondents (see Figure 7) identified dependency on foreign funding and inadequate domestic funding as major barriers to effective engagement of the AAS, national academies and the African scientific community in the promotion of STI to attain the SDGs.

There are various efforts to establish national and continental funding mechanisms for STI. To ensure effective implementation of STISA, African countries agreed to establish an African Science, Technology and Innovation Fund (ASTIF).

Under AAS, the establishment of the ***Coalition for African Research and Innovation (CARI)*** was announced at the World Economic Forum in January 2017. CARI will be a Pan-African mechanism to consolidate and reduce fragmentation of funding. It will spur greater African investment in and ownership of research and innovation initiatives for the SDGs. Modalities of resource mobilization and governance of CARI are being explored by AAS, NEPAD Agency and other institutions.

According to several interviewees for this study, the success of a Pan-African funding mechanism for STI depends on political commitment and leadership from African countries to contribute financial resources, the extent to which CARI and/or ASTIF will help countries create and/or strengthen their own national funding instruments or agencies, and whether governance of the fund will allow poorer African countries to have a voice in setting priorities for research and innovation.

Figure 7: Barriers to AAS, national academies and scientific community engagement in promotion of the SDGs



64. EU (2014), Mapping of Best Practice Regional and Multi-country Cooperative Initiatives Between Africa and Europe. European Union, Brussels.

5. INTERNATIONAL COOPERATION IN STI FOR SDGs IN AFRICA

International cooperation and partnerships can help African countries to build endogenous scientific and technological capabilities needed to secure the SDGs. Through international cooperation on STI countries build human expertise,[65] access global scientific and technical knowledge,[66] and engage in STI policy learning. This is being recognized by many African governments and research institutions as manifested in the growing number of multilateral and bilateral STI cooperation and partnership agreements involving African countries.

SDG17 calls for partnerships to implement the Goals, through enhanced "global partnership for sustainable development complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technologies and financial resources to support the achievement of sustainable development goals in all countries, particularly developing countries."

Global STI partnerships for achieving SDGs already exist in different institutional and programmatic forms. Many of them focus on health, food and agriculture, climate change and energy. For example, SDG3, on good health and well-being, is being served through collaborative or partnership initiatives such as the Global AIDS Vaccine Initiative (GAVI) and the European and Developing Countries Clinical Trials Partnership (EDCTP), which are critical for building scientific research and innovation capabilities in Africa.

Similar STI partnerships serve SDG2 on Zero Hunger include the Consultative Group on International Agricultural Research (CGIAR), the Global Forum for Agricultural Research (GFAR), and the Platform for African-European Partnership on Agricultural Research for Development (PAEPARD). CGIAR is a partnership of 15 international research centres, mainly in developing countries. It is funded by the World Bank, the EU, the AfDB, national governments and private foundations. It focuses on research on selected crops (rice, maize, sorghum and millet) and livestock, fisheries, forestry, water and soils.

Recent studies such as EU (2014) [67] and CAAS-TNet-Plus (2016) [68] show that governments, research institutes and individual scientists from Africa are increasingly participating in international programmes and forums on STI. Governments are involved in various UN forums on STI such as the UN Commission on Science and Technology at which issues of STI policy for sustainable development are addressed.

65. Lee, S., and Bozeman, B., (2005), 'The Impact of Research Collaboration on Scientific Productivity', p. 677 in Social Studies of Science, Vol. 35, No. 5, 673-702. www.jstor.org/stable/25046667

66. Wagner, C., (2008), The New Invisible College: Science for Development p. 107. Brookings Institution Press, Washington, D.C.

67. EU (2014), Mapping of Best Practice Regional and Multi-country Cooperative STI Initiatives Between Africa and Europe. European Union (EU), Brussels.

68. CAAST-Net Plus (2016), Africa-EU Research Collaboration on Health: A Critical Analysis of the Scope, Outputs and Potential Outcomes. https://caast-net-plus.org/object/document/1522/attach/0_CN__HealthReport_v6_WEB.pdf

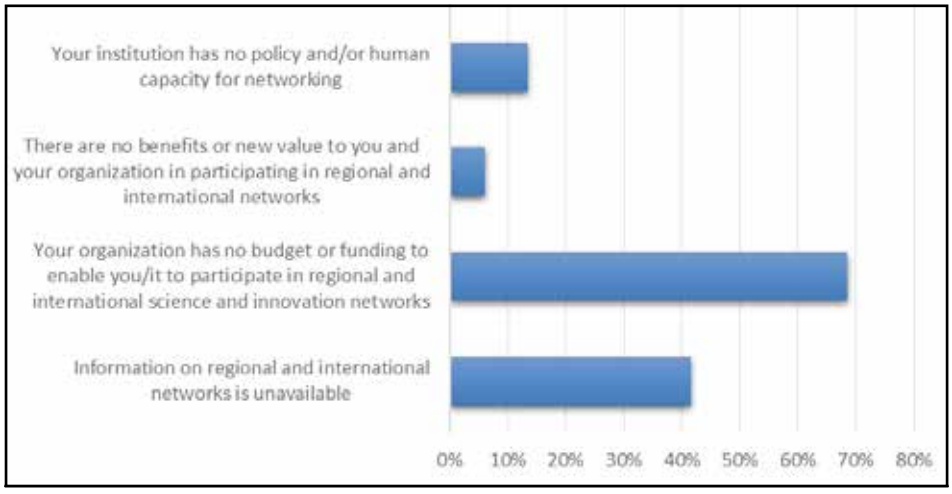
African scientists and research institutes participate in numerous STI programmes and networks on various SDG-related issues such as food security, infectious diseases, water, energy and climate change. Africa's participation in international STI cooperation and partnership programmes is influenced by a wide range of factors including:

1. **Dependence on funding from outside or foreign sources**
   African countries do not make adequate financial contributions to international STI programmes and partnerships. Most of the collaborative STI initiatives involving African countries, scientists and research institutes are financed by international development partners such as the EU.[69] About 65% of respondents to the survey for this study noted that their institutions lack budgets to participate in international research networks.

2. **Weak policies and institutional arrangements for STI cooperation and partnerships**
   Majority of African countries do not have explicit policies and programmes to promote international STI cooperation and/or have not integrated international cooperation objectives into their STI policy frameworks. Only Ghana, South Africa, Nigeria and Seychelles have integrated international STI cooperation objectives in their STI policy frameworks, and only South Africa that has an institutional arrangement with dedicated resources for international STI cooperation and partnerships.

3. **Weak institutional capacities to forge and manage STI cooperation and partnerships**
   Many research institutes and researchers in Africa do not possess requisite capacities to effectively engage in the design, implementation and governance of international STI programmes and partnerships. Few research institutes have institutional budgets and programmes for building and managing partnerships as well as personnel with skills in partnership development (See Figure 8 below). About 68% of respondents in the survey for this study identified lack of institutional budgets and at least 50% of interviewees made reference to lack of personnel as barriers to African scientists' participation in international STI partnerships.

Figure 8: Factors influencing African institutions participation in international partnerships



69. EU (2014), Mapping of Best Practice Regional and Multi-country Cooperative STI Initiatives Between Africa and Europe. European Union (EU), Brussels.

There are few programmes and networks that are dedicated to building African capacity for international STI cooperation and partnerships. Those that do exist include CAASTNet-Plus—a network for strengthening Africa-EU cooperation in STI.[70] CAASTNet-Plus has been in operation since 2008 funded by the EU to support Sub-Saharan African countries and the AU in general to improve the quality of STI partnerships with the EU and EU institutions focusing on global challenges of food security, health and climate change. Between 2011 and 2015, CAASTNet Plus organized a series of workshops to help African and EU researchers to engage in joint priority setting exercises and identify common research goals.

70. www.caastnet-plus.org

6. EMERGING ISSUES AND RECOMMENDATIONS

6.1 Building Understanding of SDGs and the Role of STI

Many African countries have institutions and programmes for promoting STI to achieve sustainable development. Our survey indicates that 80% of researchers and many of their institutions either have existing programmes or plans in development. However, there is limited understanding of specific SDGs and their targets. Most scientists have not studied nor analysed SDG targets. At least 55% of survey respondents indicate that they did not know and understand the Goals and their targets. To address this, it is recommended that a programme for building awareness and understanding of SDGs and the related Agenda 2063 be launched in Africa. Such a programme would help to "socialize" SDGs and Agenda 2063 among African scientists, students in primary and higher education, and the general public, all of whom are essential to building political and financial support.

Low levels of awareness of SDGs in the scientific community undermines Africa's prospects of harnessing and applying STI to attain the Goals.

Recommendation 1: ***The AU, in partnership with the AAS, the African Association of Universities (AAU), NASAC, ICSU, national science academies, UNESCO and NGOs directly involved in promoting SDGs should design a comprehensive scientists' guide to sustainable development, focusing on the STI-sustainable development nexus, integration of SDGs and Agenda 2063 objectives into scientific research and innovation programmes, and indicators for measuring STI contributions to SDGs and Agenda 2063.***

6.2 Aligning STI Policy Frameworks to Sustainable Development Considerations

Many STI policy frameworks adopted by African countries are built on traditional rationales of economic growth and competitiveness and are guided by linear models of knowledge production. This approach is not aligned with the sustainable development aspirations of the national vision statements Agenda 2063 and Agenda 2030. Issues and goals of social inclusion, such as gender and youth empowerment, and environmental sustainability, are not adequately accounted for in the scope of most African STI policy frameworks. Thus, STI policy frameworks must be strengthened to enhance scope and focus on innovation policy measures and integration into sustainable development goals.

Recommendation 2: ***Institutions such as UNESCO, AAS, AOSTII and NEPAD, in collaboration with leading universities offering public policy training courses should develop STI policy guidelines with clear articulation of effective STI policy approaches for sustainable development. Such guidelines would draw on best practices in STI policy formulation and implementation, and provide clear indicators of measuring STI policy outcomes.***

6.3 Strengthen Executive Accountability and Parliamentary Oversight for STI Policy Implementation

To achieve SDGs through the application of STI in development, African countries must mobilize and invest domestic resources in scientific research and innovation, as described in target 17.1. "Strengthen domestic resource mobilization, including international support to developing countries to improve domestic capacity for tax and other revenue collection." As observed above, although African countries have set targets on GERD and some have established agencies for funding R&D, they are not meeting the targets and continue to rely on development partners for funding STI.

Recommendation 3: ***There is pressing need to establish mechanisms for executive accountability and parliamentary oversight on STI policy implementation with emphasis on ensuring that African countries meet national GERD targets and increase domestic investment in STI. Strengthening and/or promoting the establishment of parliamentary portfolio committees on STI will help to stimulate greater executive accountability on GERD targets and enhance STI policy implementation. The AAS, in collaboration with institutions such as UNESCO, ICSU and NEPAD Agency, should design and implement a programme for strengthening legislative capacity for STI policy monitoring and evaluation, including supporting national parliaments to establish portfolio committees on STI where they do not exist and enhancing them where they already exist. Such a programme should include training workshops for parliamentary committees on STI budgeting and monitoring GERD.***

6.4 Leverage Domestic Funding and Create an African Fund for STI

With strengthened executive accountability and parliamentary oversight, it is possible to secure increased domestic funding for national and continental STI initiatives. Mobilization of domestic resources and international support can be realized through coordinated national and continental funding mechanisms. As stated earlier, few countries have dedicated national agencies or mechanisms for funding STI in general and R&D in particular. At the continental level no coherent funding instruments and coordinating mechanisms exist.

Recommendation 4: ***The Coalition for African Research and Innovation (CARI) is a sustainability platform for AAS. It will ensure that there is sustainable funding of current and future science, technology and innovation programs at AAS. Efforts of AAS, NEPAD Agency, AU, the Bill and Melinda Gates Foundation, the Wellcome Trust and the National Institutes of Health must be supported to enable CARI to effectively establish a pan-African mechanism to fund and coordinate research and innovation initiatives. CARI should be endorsed by the AU Summit and endowed by African governments and development partners.***

6.5 Building STI Policy Research and Science for Policy Capacity

STI policy formulation, implementation, monitoring and evaluation and the procurement and use of science for policy-making are increasingly knowledge and information intensive. Countries require specialized expertise in STI policy and institutional arrangements for science advisory services. As noted earlier, African countries do not have capacity for STI policy within their governments. They lack expertise in STI policy research and analysis as well as science advisory mechanisms.

Recommendation 5: ***To build and mobilize STI policy capacity, various stakeholders including the AAS, the African Centre for Technology Studies (ACTS), the African Technology Policy Studies Network (ATPS), and African universities that offer graduate courses on innovation and technology management should collaborate to develop executive courses on STIP policy. Under the leadership of AAS and the Association of African Universities (AAU), a Consortium for Science and Innovation Policy (CSIP) should be established to mobilize and organize multidisciplinary expertise for executive training. CSIP would partner with leading universities or institutes such as the Kennedy School of Government at Harvard University and the Science Policy Research Unit (SPRU) at University of Sussex to design and offer training in STIP policy.***

6.6 Private Sector and Businesses are at the Periphery of STI Initiatives in Africa

The private sector, including manufacturing companies, commercial banks, small-medium scale enterprises (SMEs) and multinational companies, is not adequately engaged in STI policy and programmes in Africa. This limits the potential to build innovation and create entrepreneurial systems on the continent. The private sector tends to be hesitant to participate in STI initiatives due, in part, to unfavourable policy conditions. Most African countries do not enforce intellectual property protection, and many lack financial incentives for private sector investment in research and innovation. Moreover, private entities were not involved early enough in the design of STI policy, programmes and partnerships to properly account for their priorities

Recommendation 6: ***Establish platforms for science-business-society dialogue, to bring the capacity of private companies—expertise, funding and infrastructure—to help bridge the gap between research and innovation in Africa. AAS, NASAC, national science academies and business associations should design and organize pan-African and national science-business-society dialogues similar to the one held in South Africa in December 2016, organized by NASAC, the Academy of Sciences South Africa (ASSAf) and the German Academy of Sciences.***

6.7 Strengthen International Cooperation Including South-South Partnerships in STI

International cooperation in general and different kinds of bilateral, regional and bí-regional partnerships are critical in enabling African countries to leverage the global pool of technological and scientific knowledge to meet SDGs. Africa has increased its participation in international STI cooperation and its countries have established various forms of R&D partnerships with the EU, USA, China, Japan and India. However, more strategic policy measures and institutional arrangements are needed to strengthen cooperation in STI.

Recommendation 7: ***African countries should individually and collectively, through the AU and RECs, seek to integrate STI considerations into their foreign policy and diplomatic activities with the international community in general and in the UN system in particular. More specifically, they need to allocate funding and establish science and innovation attache or offices at their embassies in China, India and other countries of the global South in order to strengthen South-South STI cooperation, and similar resources should also be dedicated to strengthening engagement in the UN Technology Mechanism and regional bodies such as the EU.***

7 CONCLUSION

This study focuses on measures that will enable African countries to leverage STI to achieve SDGs and related goals of Agenda 2063. Based on a survey, interviews and a comprehensive report review, the study shows that African countries are making considerable effort to promote the development and application of STI through a wide range of national, regional and continental policy approaches. Many African countries have adopted national policy frameworks and created agencies to promote STI.

The continent's scientific productivity and innovative capabilities have improved. However, GERD is still below the AU target of 1% of GDP, there is high reliance on foreign financing, STI policy frameworks and related programmes are not adequately aligned with SDGs, and STI policy implementation and effectiveness are relatively weak.

In order to harness and apply STI for sustainable development, African countries must strengthen policy implementation. Governments and institutions such as the AUC, NEPAD and AAS must promote the alignment of STI policy frameworks to SDGs and Agenda 2063.

Building awareness of the SDGs and their targets, enlarging public and political constituencies for STI, developing accountability mechanisms to hold governments responsible for increasing domestic financial investment in STI, strengthening the participation of parliaments and civil society in STI policy processes, establishing national funding mechanisms and a continental framework such as the proposed CARI, and enhancing international cooperation in STI will grow the prospects for Africa to attain SDGs.

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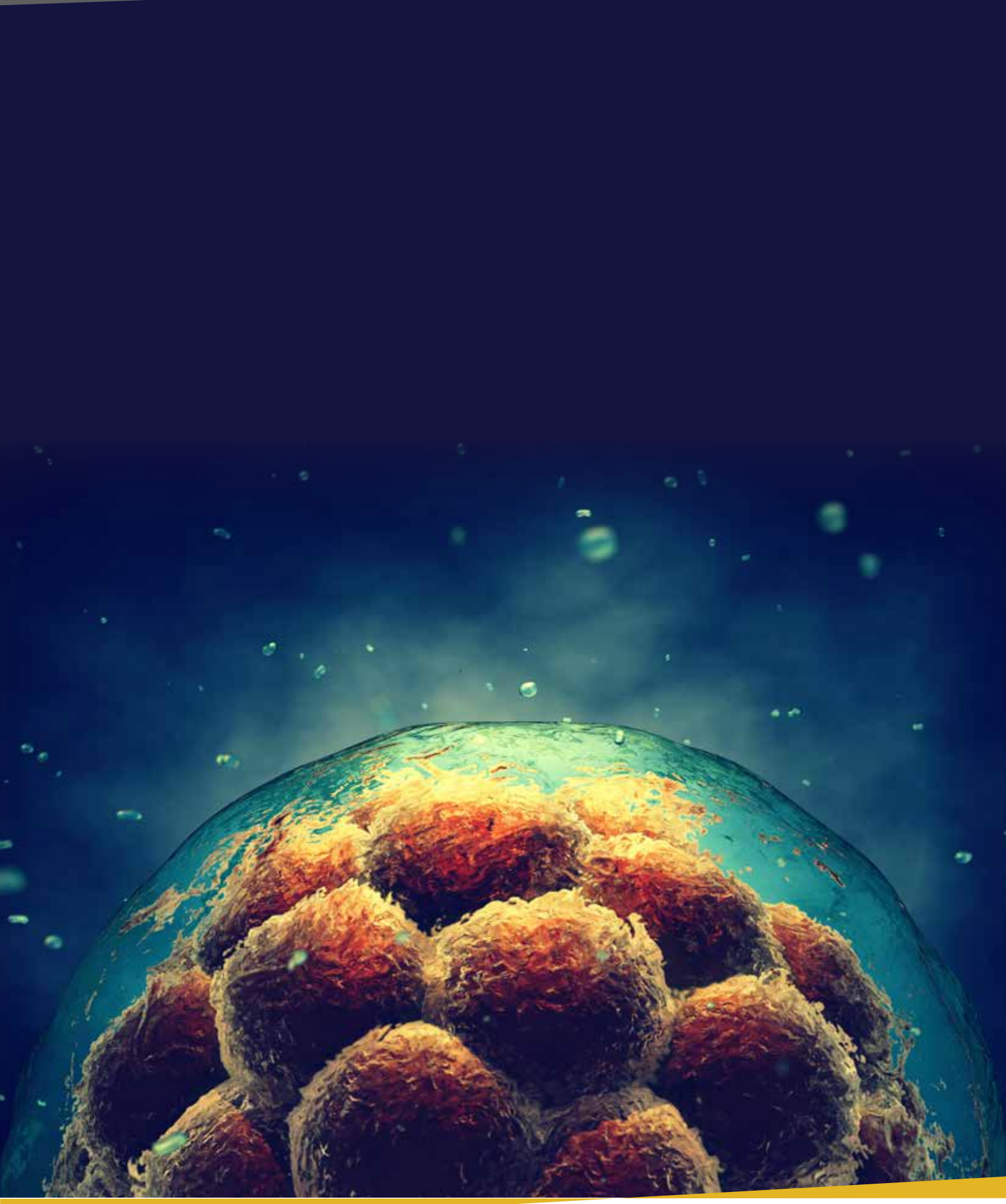

Contact Us:

African Academy of Sciences
Tel: +254 20 896 0674/5
f: facebook.com/aasciences
t:@AASciences
Email: think-tank@aasciences.ac.ke
www.aasciences.ac.ke