NATURE’S SOLUTIONS: Policy Innovations and Opportunities for Africa’s Bioeconomy
ACKNOWLEDGEMENTS

This report was produced by Meera Shah (Research Associate, Imperial College London), Mahamadou Tankari (Senior Scientist, AKADEMIYA2063), Sarah Lewis (Research Assistant, Imperial College London) and Katrin Glatzel (Director Policy Innovation, AKADEMIYA2063) the program head of the Malabo Montpellier Panel. It was produced under the guidance of Ousmane Badiane (Executive Chairperson, AKADEMIYA2063), and Joachim von Braun (Distinguished Professor, University of Bonn), the Co-chairs of the Malabo Montpellier Panel. We would like to acknowledge and thank Mariam Diallo (Associate Scientist, AKADEMIYA2063), Emmanuel Nshakira Rukondo (German Development Institute; Apata Insights, Kampala Uganda), Gazali Issahaku (Senior Lecturer, University of Bonn), and Ewere Evelyn Anyokwu (Junior Researcher, University of Bonn) for their support on the country case studies. The input and advice of the members of the Panel are especially acknowledged, in particular Debisi Araba and Dorothy Okello. The guidance and input from Julius Ecuru (BioInnovate Africa), Artur Runge-Metzger, Detlef Virchow (OneDollarGlasses), Progress Kashandula (N-BiG Namibia), Daniel Sarpong (College of Basic and Applied Sciences, University of Ghana), Saa Dittoh (University for Development Studies, Ghana), Eshchar Mizrachi (University of Pretoria), Musa Kwehangana (Uganda National Council for Science and Technology) and Paul Kwame Nkegbe (University for Development Studies Ghana), Awal Abdul-Rahaman (University for Development Studies Ghana), and Maneshree Jugmohan-Naidu (South Africa Department of Science and Innovation) has been particularly valuable in shaping this report. The report was designed by Tidiane Oumar Ba (AKADEMIYA2063).
CONTENTS

FOREWORD ....................................................................................................................................................... VIII
INTRODUCTION ................................................................................................................................................... 1

1. DEFINITIONS OF A BIOECONOMY ............................................................................................................... 2

2. ACTION AGENDA AND KEY LESSONS & OPPORTUNITIES FROM FOUR AFRICAN COUNTRIES ...... 5

3. CONTINENTAL AND REGIONAL POLICY FRAMEWORKS ........................................................................ 7
   3.1. African Union Agenda 2063 .................................................................................................................... 7
   3.2. Africa Bioenergy Policy Framework and Guidelines ............................................................................. 7
   3.3. African Biosciences Initiative (ABI) ........................................................................................................ 10
   3.4. Biological intellectual property in Africa .............................................................................................. 10

4. OPPORTUNITIES CREATED BY THE BIOECONOMY ................................................................................. 11
   4.1. Income and employment generation ................................................................................................... 11
       Agro-processing and industrial development ....................................................................................... 11
       New value chains and markets ................................................................................................................ 12
       Agricultural production system changes with bioeconomy benefits ................................................. 13
   4.2. Food security and nutrition .................................................................................................................... 13
       An increase in food availability ................................................................................................................ 13
       Improving nutritional content .................................................................................................................. 14
   4.3. Natural resource management .............................................................................................................. 14
       Sustainable management of natural resources ..................................................................................... 14
       Climate change resilience and mitigation .............................................................................................. 15
   4.4. Trade-offs and unintended spillover effects ........................................................................................ 16
   4.5. Conclusion ............................................................................................................................................... 16

5. THE ENABLING ENVIRONMENT FOR A THRIVING BIOECONOMY ........................................................ 17
   5.1. Governance .............................................................................................................................................. 17
       Multisectoral and multistakeholder coordination ................................................................................. 18
   5.2. Demand of bioproducts ......................................................................................................................... 18
   5.3. Intellectual property ................................................................................................................................ 18
       Harmonizing intellectual property rights across Africa ......................................................................... 19
   5.4. Science, research, and innovation ......................................................................................................... 21
       Bioeconomy education ............................................................................................................................. 21
       Research ecosystem/lab-to-market/entrepreneurship ......................................................................... 22
   5.5. Infrastructure ............................................................................................................................................ 24
   5.6. Finance ..................................................................................................................................................... 26
   5.7. Partnerships and collaborations ............................................................................................................ 27
       Connecting higher education, research institutes, and private sector stakeholders ........................ 27
       Leveraging regional strengths and similarities .................................................................................... 27
       South-South cooperation and learning ................................................................................................. 28
6. METHODOLOGY FOR CASE STUDY SELECTION ...................................................................................... 29
   6.1. Innovation and manufacturing .............................................................................................................. 29
   6.2. Biomass use and GII ................................................................................................................................ 29
7. COUNTRY ANALYSES .................................................................................................................................... 31
   Ghana Case Study .......................................................................................................................................... 32
   Namibia Case Study ...................................................................................................................................... 42
   South Africa Case Study ................................................................................................................................. 52
   Uganda Case Study ........................................................................................................................................ 64
8. CONCLUSION ................................................................................................................................................. 74
ENDNOTES .......................................................................................................................................................... 77
FOREWORD

Current global events provide an urgent reason to maintain our focus on the strategic orientation of food systems and agricultural transformation, and on innovation. Supply chain disruptions, war, the critical global economic situation, and rapidly rising inflation have prompted a global effort to develop and mainstream innovative solutions. With this report, on the opportunities of a bioeconomy, the Malabo Montpellier Panel draws attention to fields of innovations that are rapidly evolving worldwide, and where Africa is well-positioned to create its own unique approach, despite starting from a comparatively low base. Innovations in developing a sustainable bioeconomy in Africa offer real opportunities to address multiple challenges simultaneously. Bioeconomy refers to the application of science, technology, and innovation to the sustainable production and use of biological resources to create innovative products, processes, and services for all economic sectors. Indeed, the evolution of bioeconomy is defined by megatrends and the need to respond to them: climate change, a growing world population, socioeconomic pressures, and the rapid development of new sciences. This has resulted in a growing recognition of the importance of sustainable biological processes and products among emerging and advanced economies. Industries related to construction, food and agriculture, bioenergy, and biopharmaceuticals are significantly connected or based on bioprocesses. The use of biomass in these industries can reduce their impact on the environment and global climate, create new and well-paid jobs, and spark further innovation. At the same time, the Fourth Industrial Revolution (4IR), characterized by the fusion of the digital, biological, and physical worlds, as well as the growing utilization of new technologies such as artificial intelligence, cloud computing, robotics, 3D printing, the Internet of Things, and advanced wireless technologies, among others is rapidly reshaping the world as we know it.

The COVID-19 pandemic has accelerated the arrival of the 4IR and has cemented its role in our global future. The uptake and use of digital technologies have rapidly become second nature to many, and the development of vaccines at unprecedented rates was underpinned by recent advances in molecular biology and in information and communications technology (ICT). In fact, Africa already demonstrates strong traits of bioeconomies, some of which are not sustainable, such as the large share of fuel wood and charcoal in primary energy. Although most African countries are still in the early stages of developing sustainable bioeconomies, trends at the global level—in particular in Europe, Southeast Asia, Latin America, and India—indicate a move toward a bioeconomy approach. As African countries are rapidly updating and transforming their science capacities, skills development, innovation, entrepreneurship, and infrastructure leapfrogging into bioeconomy becomes a real opportunity. Policy, governance, and institutional frameworks will have to advance in tandem, and the continent already has several building blocks in place for that. It has made a strong start and in many ways progressed on digitalization and agricultural reform through the Comprehensive Africa Agriculture Development Programme (CAADP) and the Malabo Declaration. African bioeconomy agendas shall be addressing practical and concrete issues and opportunities, such as broader food security, carbon farming as part of the climate agenda, clean cooking fuels, bioplastic, sustainable construction, and biopharmaceuticals. The next stage of developing a thriving bioeconomy will need to harness these opportunities. It will be necessary to strengthen education, innovation, and entrepreneurship in order to engage across a spectrum of sectors.

In Africa, the bioeconomy strategy of the East African Community (EAC) is currently being finalized, while in some countries—as this report will show—the first generation of bioeconomy strategies is under development. There is hence a clear opportunity for Africa to show leadership and to leapfrog to a developing bioeconomy. This report draws on the experience of four African countries - Ghana, Namibia, South Africa, and Uganda - that are already exploring various bioeconomy approaches, and whose policy and institutional innovations are noteworthy for other countries on the continent.

The Malabo Montpellier Panel convenes 18 leading experts in agriculture, engineering, ecology, nutrition, and food security. Its aim is to facilitate policy choices by African governments in order to accelerate progress toward food security and improved nutrition. The Panel identifies areas of progress and positive change across the continent and assesses the things that successful countries have done differently. It identifies the institutional and policy innovations and program interventions that can best be replicated and scaled by other countries. The related Malabo Montpellier Forum provides a platform to promote policy innovation; it uses the evidence produced by the Panel to facilitate dialogue among high-level decisionmakers on African agriculture, nutrition, and food security.

Ousmane Badiane
Co-Chair, Malabo Montpellier Panel

Joachim von Braun
Co-Chair, Malabo Montpellier Panel
THE MALABO MONTPELLIER PANEL

The core mission of the Malabo Montpellier Panel, a group of leading African and international experts from the fields of agriculture, ecology, food security, nutrition, public policy and global development, is to support evidence-based dialogue among policy makers at the highest level. The Panel’s reports seek to inform and guide policy choices to accelerate progress toward the ambitious goals of the African Union Commission’s Agenda 2063, the Malabo Declaration and the global development agenda. The Panel works with African governments and civil society organizations to provide support and evidence-based research that facilitate the identification and implementation of policies that enhance agriculture, food security and nutrition.

Ousmane Badiane
Senegal | co-chair
Executive Chairperson, AKADEMIYA2063

Joachim von Braun
Germany | co-chair
Distinguished Professor, Center for Development Research (ZEF), University of Bonn

Debisi Araba - NIGERIA
Visting Researcher, Imperial College London

Lee Ann Jackson - UNITED STATES
Head of the Agro-Food Trade and Markets Division, Organisation for Economic Co-operation and Development (OECD)

Tom Arnold - IRELAND
Ireland’s Special Envoy on Food Systems Chair, Irish 2030 Agri-Food Strategy Committee

Muhammadou M.O. Kah - THE GAMBIA
Permanent Representative of The Gambia, United Nations Offices in Geneva

Elisabeth Claverie de Saint-Martin - FRANCE
CEO, Agricultural Research Centre for International Cooperation (CIRAD)

Agnes M. Kalibata - RWANDA
President, Alliance for a Green Revolution in Africa (AGRA); UN Special Envoy to the 2021 Food Systems Summit

Gordon Conway - UK
Professor for International Development, Imperial College London

Nachilala Nkombo - ZAMBIA
Country Director for the World Wildlife Fund (WWF)

Gebisa Ejeta - ETHIOPIA
Distinguished Professor of Plant Breeding & Genetics and International Agriculture, Purdue University

Dorothy Okello - UGANDA
Dean, School of Engineering at Makerere University, Uganda

Karim El Aynaoui - MOROCCO
President, Policy Center for the New South

Wanjiru Kamau-Rutenberg - KENYA
Executive in Residence, RISE, Schmidt Futures

Ashok Gulati - INDIA
Infosys Chair Professor for Agriculture at Indian Council for Research on International Economic Relations (ICRIER)

Ishmael Sunga - ZIMBABWE
CEO, Southern African Confederation of Agricultural Unions (SACAU)

Sheryl Hendriks - SOUTH AFRICA
Head, Department of Agricultural Economics, Extension and Rural Development, University of Pretoria

Rhoda Peace Tumusiime - UGANDA
Former Commissioner for Rural Economy and Agriculture, African Union Commission (AUC)
INTRODUCTION

The world economy, including many African economies, is confronted with challenges to address short-term issues due to rising inflation, debt distress, supply chain disruptions due to COVID-19 and conflicts, while maintaining due focus on innovations and on the strategic orientation of food systems and agricultural transformation. A strategic opportunity for many countries is the development of a sustainable bioeconomy. Africa is abundant in natural resources but value addition remains weak. Combined with its young, dynamic, and educated population, the rapid expansion of scientific knowledge, and the growth of digitalization, the continent has the opportunity to revitalize the progress toward achieving its continental and global development commitments and also to leapfrog into the development of a sustainable bioeconomy.

Current global trends and developments further strengthen the case for the development of a bio-based economy. These trends, however, have different meaning and relevance in different regions and countries around the world. A growing focus on global grand challenges—such as the urgent need to transition away from the use of fossil fuels and fossil-fuel-based products, and meeting the UN Sustainable Development Goals (SDGs)—are driving the global demand for new, innovative, and sustainable (renewable) products and technologies. While this is a crucial motivation for countries in Europe, Latin America, and Asia, developing a sustainable bioeconomy in Africa can draw on rich biological resources and growing science and knowledge capacities that may offer opportunities to leapfrog to a bioeconomy.

The use of renewable biological resources, primarily from the agricultural sector, provides a platform from which to accelerate a global transition toward greater sustainability. The growing demand for biomass offers opportunities to mitigate and adapt to climate change and natural resource constraints. Moreover, recent efforts in phasing out single-use plastic bags in Rwanda and Kenya, which was spearheaded by the United Nations Environment Programme (UNEP), have provided additional incentives for developing a bioeconomy.

A transition to a bio-based economy can accelerate the kind of growth in productivity that is crucial to improving food security and nutrition, and which contributes to rural development and overall economic growth. A bioeconomy also has positive benefits that go beyond just the food system; it draws together inputs, expertise, and skills from a broad range of sectors and industries such as energy, education, research, science, and technology; environment and forestry; land; and industry.

This report by the Malabo Montpellier Panel shows that countries in Africa can leverage their knowledge and biological resources to develop sustainable bioeconomies to provide products, processes, and services that optimize social, economic, and environmental benefits and achieve societal prosperity. Some African countries have initiated the development of a bioeconomy to a varying extent to harness the potential benefits. Four of those: Ghana, Namibia, South Africa, and Uganda, are featured in this report to present a consolidated evaluation of their endeavors.

The first part of the report provides an overview of the definitions of a bioeconomy. This is followed by a discussion of the continental, regional, and global bioeconomy strategies that are already in place, and of the frameworks that are relevant, as African countries and Regional Economic Communities (RECs) embark on developing their bioeconomy strategies. Chapter 4 highlights some key opportunities and trade-offs that are presented in the development of a bioeconomy and finally, the ingredients of an enabling environment needed for thriving bioeconomies.

The second part of the report presents the policy context for bioeconomy development in Africa. It analyzes the policy and institutional innovations that some African countries have implemented to advance the development of sustainable bioeconomies. Much can be learned from these government actions; they serve as a tool for other African governments to decide how to develop their own bioeconomy strategies and/or support bioeconomy initiatives on the continent.
1. DEFINITIONS OF A BIOECONOMY

The 2018 Global Bioeconomy Summit adopted the description of a bioeconomy as, “the production, utilization and conservation of biological resources, including related knowledge, science, technology and innovation, to provide information, products, processes and services across all economic sectors aiming toward a sustainable economy.”

A bioeconomy thus extends the use of biomass beyond food, feed, and fiber to include a range of pharmaceutical, industrial, and other value-added products such as green chemicals, industrial materials, and energy.

Recent definitions of a bioeconomy also emphasize the use of science, technology, and knowledge in the transformation of biological resources into new, sustainable, and competitive products. This “knowledge-based bioeconomy” applies scientific research and knowledge to bioresources in order to produce a broad range of value-added products that can be deployed in pharmaceuticals, chemicals, materials, energy, and construction. As such a bioeconomy aims to expand the production of value-added products from renewable biological resources, in turn leading to an intensification of the interlinkages between production, processing, and markets.

A cascading approach extracts “value” from bioresources in descending order. Where bioresources are derived from agricultural produce, for example, food production is prioritized, and residue and waste form the inputs of new downstream products. The highest “value” is thus extracted first and conversion into energy or compost forms.

A bioeconomy thus combines natural resources, scientific knowledge, and technologies with markets and business opportunities. The adoption of a biobased economy through clear policy guidance and institutional support can, in turn, tackle societal challenges such as natural resource scarcity, waste generation, fossil fuel dependence, climate change, loss of biodiversity, and food and energy insecurity, while at the same time achieving sustainable growth.
the final step. A circular approach, similarly, uses waste from one process as input for another value chain, the aim being to eliminate waste altogether. As resources are utilized and reutilized, a complex “value web” develops which links multiple value chains across a variety of sectors and industries. This dynamic interaction within a value web further intensifies efficiency and innovation. A circular bioeconomy provides the basis for a sustainable production-consumption system and contributes to halting resource depletion. Among the key elements of the circular bioeconomy are the sustainable sourcing of biomass and the designing of products and processes such that they are ensured an integrated, regenerative, and restorative use in the economy. Consequently, bioeconomy transcends vertical and linear approaches to expressing the potential in Africa’s agriculture sector in its interdisciplinary and intersectoral nature.

Bioeconomy is not just the use and processing of biomass (see the boxes on biopharmaceutical, biochemicals, biomimicry below). While Africa’s agricultural and forest sectors will play a core part in the transition to a bio-based economy by supplying renewable biomass for new and value-added products, of equal importance are bioscience and biological knowledge. The growing demand for biomass to supply a rising demand for food and a bioeconomy can stimulate production and productivity, thereby empowering the sectors to meet their potential. For smallholder farmers who are the primary food producers in Africa, the transition to a bio-based economy offers a way to connect to expanded markets, value chains, and agro-processing opportunities. Equally, for communities that rely on forests for energy, food, and other products, a forest-based bioeconomy could support and enhance these important functions while providing the foundations for progressively moving away from traditional forest uses and developing value-added products using non-timber forest products. This, in turn, can facilitate biodiversity protection. A bioeconomy also presents opportunities for climate mitigation through carbon sequestration in plant and forest matter and soils (referred to as carbon farming), and for adaptation, particularly in Africa’s agricultural sector. It elevates agricultural value addition beyond the traditional concept of value chains.
Box 1: Biopharmaceuticals

Biopharmaceuticals are medicinal products that are extracted from biological resources and processed using biotechnological processes. This includes the use of biological organisms such as sugars, proteins, acids, tissues, and stem cells, used to synthesize and generate pharmaceutical therapeutics. Innovations in biopharmaceuticals can have profound benefits for health and economies. The foundation of the biopharmaceutical industry includes research on, and development of, innovative medicinal products that will improve the ability of the health sector to meet societal needs. Biopharmaceuticals are capturing a growing share of the global pharmaceutical market. Valued at over US$265 billion in 2020, the global biopharmaceutical market is expected to grow to US$856 billion by 2030. However, as the patent protection for biopharmaceuticals expires, the market is being challenged by “biosimilars” which are causing a renewed restructuring of the market and of corporate models. Biopharmaceuticals and biosimilars are an important avenue for developing and emerging economies to capitalize on their natural endowments and research environments in order to participate in drug development and dissemination.

Box 2: Biochemicals

Biochemicals are chemical compounds made up of bio-based organisms including weeds, rather than of fossil fuel inputs. The sale of bio-based chemicals is increasing across the globe and is seen as an emerging market in Africa south of the Sahara (SSA). In 2020, the global market was valued at over US$81 billion and it is expected to grow to nearly US$161 billion by 2028. Biochemicals that are widely produced include ethanol, polymers, and enzymes. Predominantly utilized in the pharmaceutical and agricultural sectors, biochemicals can catalyze complex reactions. For example, some species of weeds produce biochemicals that deter insects and thus can be exploited as insecticides, while others contain active biochemicals that can be extracted for their medicinal properties and applications.

Box 3: Biomimicry

Biomimicry emulates natural processes, systems, and adaptations to spark innovations that may solve complex challenges. Thus, biomimicry is not the physical consumption of biological resources; rather, it is the adaptation and adoption of the knowledge contained within their evolution and ecosystems. Biomimicry solutions can be adopted across a variety of sectors and industries from construction to health, and materials development to aeronautics. Indeed, this practice encourages the conservation of biological resources to further benefit from the expansion of knowledge on nature’s systems. In South Africa, a local community near the Berg River was suffering from health risks caused by the overflowing polluted water. To identify sustainable solutions, the Genius of Place project looked to biomimicry for solutions that would solve the challenge; in the end, the community diverted the water supply using tree pits lined with carbon and rubble and developed an upstream filtering system that mimics natural energy and water flows in rivers, relying on gravity to improve the quality of water.

Box 4: Biorefineries

Biorefineries convert biomass into by-products such as biochemicals, biofuels, and biopharmaceuticals. They help in the design and production of greener, more ecofriendly, and more sustainable materials. Biorefineries require biomaterials and strong technological capabilities to convert biomass into finished products. “Green biorefineries” process renewable biomass feedstock, including food and agricultural waste. In South Africa, for example, a biorefinery was established in 2018 which processes waste from forestry and other bio-based industries to produce high value biochemicals and sludge that can be used as biogas, cellulose, and polymers.
2. ACTION AGENDA AND KEY LESSONS & OPPORTUNITIES FROM FOUR AFRICAN COUNTRIES

The bioeconomy combines innovations in the economy with ecology and knowledge to ensure a more sustainable use of biological resources. An environment conducive to innovation will allow for the development of creative and original policy and technological solutions by a wide range of stakeholders. This report draws on the experience of four African countries: Ghana, Namibia, Uganda, and South Africa. It focuses on their policy and institutional innovations, which have moved the needle toward systems-level change and transformation and have allowed them to leapfrog into the development of a sustainable bioeconomy. While emphasizing the importance of Africa’s diversity in ecologies, bioresources and science capacities, the Malabo Montpellier Panel hence makes the following five policy recommendations:

1. Identify gateway sectors through which to initiate the development of transition to a bioeconomy. The development of a bioeconomy can be initiated via selected ‘gateway’ sectors. These sectors would ideally match those that form the focus of long-term national development plans, align with broader food security and resilience ambitions, provide clear innovation opportunities such as clean cooking fuels, the reduction of plastic pollution, bio-based materials for sustainable construction, and biopharmaceuticals, or which represent a comparative advantage or complementary approach. Working with a shortlist of sectors or challenges allows policymakers to model context-specific approaches prior to mainstreaming a bioeconomy strategy across other sectors.

2. Strengthen links to R&D and markets for new bioproducts and biosolutions. Energizing the national innovation system necessitates investments in education, research, and development. STEM subjects (science, technology, engineering, and mathematics), sustainability education, and indigenous knowledge are critical components of a curriculum that is designed to empower students and young people to participate meaningfully in the development of a bioeconomy. Closer collaboration between higher education, national research institutions, and the private sector can be facilitated via incubators, competitions, and challenges. Enhancing the financial sustainability of national research institutes with hybrid funding models that accommodate private sector services and international development partners can enhance bioeconomy research outcomes and impacts and can further strengthen collaboration across sectors and among stakeholders.

3. Develop demand for bioproducts and biosolutions. Public awareness campaigns, public procurement, and industrialization and trade strategies can facilitate a bioeconomy market and can drive demand for bioproducts and biosolutions. At the same time, the introduction of recycling and biofuel mandates or of bans on single-use plastic products can provide low-hanging fruits with which to kick-start innovation in the bioeconomy.

4. Regulate for sustainability incentives and to manage trade-offs. The use of geographical indications, standards, and certification schemes ensures the realization of maximum benefits and gains from developing a bioeconomy. Policymakers across Africa can customize a vast range of existing (voluntary) global-level guidelines and frameworks; while carefully crafted intellectual property (IP) regimes can protect Africa’s domestic research outputs and indigenous knowledge while creating an attractive and innovation-driven environment for private sector investments in the bioeconomy.

5. Set up independent national advisory boards to inform and guide the development of bioeconomies. Given the complexity and multisectoral nature of the bioeconomy, the central task of the bioeconomy advisory board or council—whose expertise would cover all aspects of the bioeconomy—would be to keep abreast of emerging developments in science, research and innovation and identify those that are relevant to national development.
Ghana

Ghana is endowed with rich plant and animal biodiversity, and the availability of large stocks of biomass makes it highly suitable for setting up bio-industries and a thriving bioeconomy. Ghana’s bioeconomy-related activities are currently focused on agriculture, forestry, energy, and waste management. Promoted by the Council for Scientific and Industrial Research and COCOBOD, the country has transformed the cocoa sector with biosciences and technology and established a wide range of industries for cashew, shea, and their by-products. Science, technology, and innovation play a central role in Ghana's socio-economic development and in the development of its bioeconomy. This, in turn, provides a strong foundation for scaling up its emerging bioeconomy to other sectors. The last two decades have seen renewed interest in enhancing the role of tertiary institutions in advancing their science and technology outputs. These higher education institutions are well-positioned to contribute to the Ghanaian bioeconomy. Ghana has also successfully integrated herbal medicines into standard healthcare delivery, supported by public and private sector actors, as well as research and financial institutions.

Namibia

Namibia has demonstrated a strong political commitment to bioeconomy development. The country has launched a number of bioeconomy-related initiatives, and many actors, including government ministries and agencies, civil society, and universities, are playing critical roles in the bioeconomy’s development. Recent institutional, policy and programmatic interventions demonstrate a multifaceted approach to bioeconomy development. In terms of policy, the country has collaborated with the FAO to develop its first bioeconomy strategy, and a number of bioeconomy-supporting policies are already in place. Namibia also promotes technology and innovation for economic growth as a key enabler for the development of the bioeconomy. In addition, the country recognizes the importance of game meat in the development of the food value chain and the economic utilization of biomass from controlled bush thinning of pastureland. Finally, Namibia supports sustainable management and use of biodiversity with the development of the National Biodiversity Strategy and Action Plan, which was recognized internationally as one of the best first-generation plans.

South Africa

Recognizing the potential of capitalizing on its natural wealth, over the last two decades South Africa’s policymakers have developed a portfolio of policies, strategies, and supporting institutions to develop a thriving bioeconomy. The Department of Science and Innovation, the National Advisory Council on Innovation (NACI), the Technology Innovation Agency (TIA), and the National Intellectual Property Management Office (NIPMO) form the basis of an impactful system of innovation. Moreover, by investing in education, improving collaboration between universities and industry, strengthening its IP environment, and supporting small businesses, South Africa has developed a leading biopharmaceutical and biotechnology sector, and evolved to an attractive destination for investments in the bioeconomy. Policy adjustments in parallel have ensured that the process is rooted in a clear vision and focused on key sectors (agriculture, health, and industrial sectors). These interventions have placed South Africa at the forefront of continental and global efforts to establish successful bioeconomies; it is currently the only one in Africa that has an approved, dedicated and comprehensive bioeconomy strategy.

Uganda

In the last two decades, Uganda has fashioned a robust and forward-looking trajectory to capitalize on the potential of a bioeconomy. Its geography, soil, diverse agroecological zones, and rich biodiversity give Uganda a comparative advantage in the production of biomass, which is a key input into a thriving bioeconomy. The country has drafted a comprehensive bioeconomy strategy and approved a green growth strategy which provides a platform to intensify the development of a bioeconomy. Uganda has become a hub of excellence on agricultural R&D; its National Agricultural Research Organization and universities have become a beacon for advancing food and agricultural biotechnology, in turn earning a position on the coveted African Higher Education Centers of Excellence Project by the World Bank. While the incubators at Makerere University (Food Technology and Business Incubation Centre) and the Uganda Industrial Research Institute provide a valuable launchpad for bio-enterprises, PHARMBIOTRAC at Mbarara University is rapidly building a critical mass of skilled human resources to promote the domestication and commercialization of traditional medicines and biopharmaceuticals.
3. CONTINENTAL AND REGIONAL POLICY FRAMEWORKS

There are several continental frameworks in Africa that can contribute to the development of sustainable bioeconomies. For example, several objectives and targets under the Malabo Declaration commitments and the African Union Agenda 2063 are supportive of the development of a bioeconomy as they include frameworks for biomass production and improving value addition across bio-based value webs as well as for raising the quality of science, research, and innovation. In addition, strategies on energy, mining, industrialization, and climate change can all accelerate the transition to a bio-based economy. At the same time, bioeconomy can also enable governments to meet their global commitments, particularly within the SDGs.

3.1. African Union Agenda 2063

Several goals under the African Union (AU) Agenda 2063’s Aspiration 1 (a prosperous Africa based on inclusive growth and sustainable development) provide an impetus for the development of a bioeconomy. The second goal within Aspiration 1 promotes education and skills development, particularly in science, technology, and innovation. To meet this aspiration, the AU adopted the Science, Technology and Innovation Strategy for Africa 2024 (STISA–2024). This 10-year strategy aims to transform Africa into a knowledge-based and innovation-led society through the promotion of human capital development, innovation, value addition, industrialization, and entrepreneurship. STISA–2024 identifies food security, nutrition, and the eradication of hunger as the top 3 of its 10 priority areas in terms of where there would be most benefit from the increased application of science, technology, and innovation. The elements of agricultural value chains that would benefit most from a transition to a bio-based economy are highlighted by STISA–2024 as being research and innovation in cultivation methods, seeds, soil and climate change; value addition and food transformation; and infrastructure and techniques for its distribution. To this end, STISA–2024 calls upon member states to: upgrade their science, technology, and innovation infrastructure; expand the availability of quality postgraduate education including through technical and vocational education and training (TVET); strengthen the innovation and entrepreneurship environment; and introduce appropriate policies and national science, technology, and innovation programs. STISA–2024 emphasizes the need for African governments to allocate at least 1 percent of GDP to R&D. It is thus an important enabler of Africa’s advancement in the development of a bio-based economies.

Aspiration 1 includes a goal to modernize agriculture on the continent. The key action plans for agriculture in Africa are the Comprehensive Africa Agriculture Development Programme (CAADP) and the subsequent Malabo Declaration, both of which set out targets to stimulate agricultural growth across the continent. To achieve this, these frameworks define elaborate targets for finance, productivity, research, and sustainability within Africa’s agricultural sector, all of which, directly and indirectly, can advance a bio-based transition. For instance, the Malabo Declaration commits African governments to double agricultural productivity from 2014 levels by 2025. This ensures that more biomass—a primary input to the bioeconomy—is available to drive the bioeconomy’s growth. Agro-processing—also a key factor in a thriving bioeconomy—is further promoted by the target to halve postharvest losses for 5 commodities (national priority) to 11 commodities (AU priority) by 2025. Underpinned by an increase in access to finance and by investment in research, the CAADP/Malabo Declaration commitments re-inforce the basis for a growing bioeconomy. The inclusion of targets on sustainability—specifically on land management and water use—will also help ensure that the transition to a bio-based economy will have a reduced impact on the environment.

The sustainable use of biological resources is also promoted under a separate goal within Aspiration 1 of Agenda 2063; this is under the title, “environmentally sustainable and climate-resilient economies and communities”. This goal urges member states to manage their natural resources sustainably, conserve biodiversity, foster sustainable consumption and production patterns, improve water security, strengthen climate resilience and natural disaster preparedness and prevention, and expand the provision of renewable energy. To achieve this objective, African governments and the African Union Commission (AUC) are implementing the Green Recovery Action Plan which has five priority areas, including to “embolden nature-based solutions and focus on biodiversity through work on sustainable land management, forestry, oceans and ecotourism”.

3.2. Africa Bioenergy Policy Framework and Guidelines

In the energy sector, there is a clear political commitment to achieving a bioeconomy as reflected in the Africa Bioenergy Policy Framework and Guidelines, a joint effort by the AUC and the United Nations Economic Commission for Africa (UNECA).
Published in 2013, it aims to enhance energy security and access, as well as rural development in Africa. Principles and guidelines are also provided for RECs and African countries in order to guide their policies and regulations for the promotion of a sustainable bioenergy sector.

The policy framework is a response to the increase in, and fluctuating costs of fossil fuels at the global level, to deficits in the supply of fossil fuels, and to environmental degradation. In addition, the bulk of energy consumption in African households is the traditional use of biomass mainly in the form of charcoal, firewood, crop residues and manure. Not only is this inefficient, it also results in severe health impacts, particularly on women and girls, and contributes to deforestation. On the other hand, advanced bioenergy solutions such as briquettes, biochar, and biogas offer opportunities to replace petroleum-based products, reduce pollution, and contribute to rural development. The Bioenergy Policy Framework emphasizes the role of regional coordination of the production, trade, and use of bioenergy. Coordination efforts include the harmonization of policies that facilitate the development of a viable modern bioenergy sector led by RECs.¹⁸

Elements of a sustainable bioeconomy in Africa can already be delivered through existing strategies. Some parallel initiatives are also underway to develop strategies at national and regional levels. The Bioresources Innovations Network for Eastern African Development (BioInnovate Africa), for example, has been working with national governments since 2019 to develop an East Africa regional bioeconomy strategy which is currently under review.¹⁹ This strategy aims, with the help of science and technology, to tap into the potential of the modern bioeconomy to produce materials, food, feed, and fuel from biological resources, with the goal of reducing poverty and ensuring a transition toward sustainability.
## Box 5: Emerging bioeconomy policy initiatives in Africa

### Bioeconomy policies at national and regional levels

African countries are increasingly recognizing the importance of bioeconomy strategies to the development and transformation of their economies. As a result, bioeconomy policies are emerging at national and regional levels on the continent. South Africa launched its bioeconomy strategy in 2013 to foster the transition toward a knowledge-based bioeconomy by guiding bioscience research, innovation investments, and decision-making within a high-level framework. A robust momentum of bioeconomy policy development is also evident in Ghana, Kenya, Mali, Mozambique, Nigeria, Senegal, and Uganda, all of which have designed policies that promote activities in bioenergy/biofuel production. In fact, Senegal has issued two bioenergy strategies, one in 2008 and another in 2012, called Lettres de Politique de Développement du Secteur de L’Energie. Bioprospecting policies have also been at the center of the strategies of some African countries, such as Kenya and Mauritius, with the aim of tapping into their unique biodiversity and commercializing knowledge about traditional bioresources. Other policy efforts to develop the bioeconomy at the national level include the adoption of national biotechnology strategies by Eastern African countries including Ethiopia, Kenya, Uganda, and Tanzania. Mauritius developed a comprehensive Ocean Economy strategy in 2013, while in 2015 Namibia implemented the National Programme on Research, Science, Technology and Innovation (NPRSTI), which integrates key issues for bioeconomy development. 20

Like regional bioeconomy policies in Europe, Latin America, and the Caribbean, some countries in Africa that have similarities in their resource endowment and economic conditions have also produced macro-regional policy approaches. In 2020, seven eastern African countries (Burundi, Ethiopia, Kenya, Rwanda, Tanzania, South Sudan, and Uganda), with the support of the Bioresources Innovations Network for Eastern African Development (BioInnovate Africa), developed a regional innovation-driven bioeconomy strategy that enables the pooling of resources to address shared regional priorities. The strategy was formulated via the BioEconomy Strategy for Eastern Africa project, in close consultation with all relevant ministries from the seven countries, and implemented by the East African Science and Technology Commission (EASTECO), the African Technology Policy Studies Network (ATPS), the Scinnovent Centre, Bio-Innovations Ltd, and the Africa Centre of the Stockholm Environment Institute (SEI Africa). It aims to inspire and catalyze the development of national bioeconomy strategies and of subsequent policy developments and interventions that can create new jobs and sustainable bio-based and inclusive economic growth in the region. 21

### Africa’s participation in dialogues for bioeconomy policy development

Momentum is building within the scientific community for the promotion of bioeconomy policy through exchange platforms such as the Eastern Africa Bioeconomy Conference. In 2021, the two-day conference was co-hosted by BioInnovate Africa/International Centre of Insect Physiology and Ecology (icipe), the Biosciences eastern and central Africa-International Livestock Research Institute (BecA-ILRI) hub, EASTECO, and SEI Africa. The theme of the conference was “Building a Sustainable and Resilient African Bioeconomy”. It aimed to contribute to the global urgency to reduce carbon emissions and to build resilience against emerging and re-emerging diseases such as COVID-19; it also aimed to unlock new possibilities for biologically based research and innovation. The conference discussed opportunities for developing a regional bioeconomy which would maximize the benefits of a sustainable bioeconomy. It highlighted the role of regional economic communities (RECs) in anchoring regional bioeconomy policies and strategies. 22

At the global level, African representatives have participated in the Global Bioeconomy Summit (GBS). The GBS aims to provide thought leadership in shaping global bioeconomy policies and to be a platform that connects stakeholders across bioeconomy science, industry, policy, and sustainable development. It hopes to contribute to a future where bioeconomies benefit society and the environment through sustainable solutions. 23 In 2020, the GBS digitally brought together around 3,000 representatives from politics, science, civil society, and business, from more than 50 countries, among whom the latest developments and challenges in the global bioeconomy were discussed. EASTECO and BioInnovate Africa, presenting the East Africa Bioeconomy Strategy, were official partners together, alongside the European Union, Japan, the ASEAN region, and Latin America & the Caribbean. 24
3.3. African Biosciences Initiative (ABI)

In an effort to harness science and technology for the socioeconomic transformation of the continent and for its greater role in the world economy, African leaders adopted a Science and Technology Consolidated Plan of Action (CPA) in 2005. One of the flagship programs of the CPA is the African Biosciences Initiative (ABI), which focuses on R&D in the areas of biotechnology, biodiversity, indigenous knowledge systems, and technology development. ABI focuses on harnessing biological applications in the agricultural, environmental, health, and mining sectors. Its strategic objectives are to: develop new bioscience networks to protect the environment and conserve biodiversity; build and strengthen the human capacity for biosciences; promote access to affordable and world-class research facilities; and harness indigenous technology and knowledge for the sustainable use of natural resources and wealth generation. ABI feeds into the agricultural, environmental and health strategies of the New Partnership for Africa’s Development (NEPAD) and is being implemented through four regional bioscience networks: the Southern Africa Network for Biosciences (SANBio); the Biosciences eastern and central Africa Network (BecANet); the West Africa Biosciences Network (WABNet), and the North Africa Biosciences Network (NABNet). These networks comprise institutions and laboratories that have agreed to share their infrastructure and human resources for R&D at regional levels.

3.4. Biological intellectual property in Africa

Various frameworks currently guide the protection of biological intellectual property in Africa. The most recent continental instrument addressing biological IP is the Continental Strategy for Geographical Indications 2018–2023, which was designed by the AUC’s Department of Rural Economy and Agriculture (DREA), later renamed the Department of Agriculture, Rural Development, Blue Economy and Sustainable Environment (ARBE). The Continental Strategy was drawn up in collaboration with AU member states, RECs, and technical and development partners such as the World Intellectual Property Organization (WIPO) and the Food and Agriculture Organization (FAO). It seeks to align IP goals with the AU Agenda 2063, CAADP, Malabo Declaration, and the SDGs.

Alongside the Continental Strategy is the Organisation of African Unity’s (OAU’s) Model Law for the Protection of the Rights of Local Communities, Farmers and Breeders, and for the Regulation of Access to Biological Resources (African Model Legislation), which was adopted by the African Union in 2000. It allows for a contextual adaptation of the World Trade Organization’s (WTO) Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), the Convention on Biological Diversity (CBD), and the FAO’s International Treaty on Plant Genetic Resources for Food and Agriculture, all of which provide guidance on managing traditional knowledge and genetic information. The African Model Legislation balances private ownership rights with the conservation, sustainable use, and fair and equitable benefit-sharing from the use of biological diversity and genetic resources, and the national and regional laws of African countries. However, it also explicitly excludes patents for life forms and biological processes, thereby potentially limiting their impact on a bio-based transition.

The implementation and enforcement of IP rights in Africa is overseen by two leading “regional” institutions, the Organisation Africaine de la Propriété Intellectuelle (OAPI) comprising francophone countries, and the African Regional Intellectual Property Organization (ARIPO) comprising anglophone countries. These institutions also work alongside IP frameworks designed by RECs, such as the Economic Community of West African States (ECOWAS), EAC, the South African Development Community (SADC), and the Common Market for Eastern and Southern Africa (COMESA). In addition, several countries have domestic IP protocols and institutions. In 2007, the AU Assembly adopted a decision to create a new single Pan-African Intellectual Property Organisation (PAIPO) to promote a development-oriented intellectual property system. Although PAIPO is still in the process of being established at the time of writing, this process was boosted when the African Union adopted STISA-2024. PAIPO will work with OAPI and ARIPO to extend their influence and scope and to further support policy implications. PAIPO is also mandated to disseminate patent information, provide technical and financial support to invention and innovation, and promote protection and exploitation of research results.

Section 6.1.4. of this report discusses how a strong IP regime that provides copyrights, patents, trademarks, and similar rights to the developers of knowledge into products can propel a bio-based transition.
4. OPPORTUNITIES CREATED BY THE BIOECONOMY

The development of a bio-based economy presents a number of opportunities for rural development in Africa. If adopted on the basis of inclusivity, sustainability, and accountability, a bioeconomy can drastically reduce poverty by increasing job opportunities and ensuring resilient and stable incomes. This is particularly important for Africa’s rural areas where a vibrant bioeconomy can increase agricultural productivity and support the expansion of agro-industries, both of which are vital for sustainable economic growth, employment generation and enhancing economic competitiveness. Meanwhile, greater uptake of biotechnology can also effectively increase food availability, raise its nutrient content, while promoting new food (and non-food) value chains and improve food safety. There are also opportunities for protecting, conserving and restoring biodiversity and their habitats, as well as climate change mitigation.

4.1. Income and employment generation

Employment opportunities are crucial in Africa. The continent’s youth population is expected to double to over 830 million by 2050 and most young people do not have stable employment opportunities. With 10 to 12 million youth entering the workforce every year and only 3.1 million new jobs being created, the transition to a bioeconomy can play an important role in addressing Africa’s employment gap. Currently, a large share of the jobs in Africa’s agricultural sector are in production. As much as 90 percent of employment in the food economy (production, manufacturing and processing, marketing and hospitality) in Namibia, Tanzania, Uganda, and Zambia is concentrated in the agricultural production segment. However, as a transition to a bio-based economy stimulates greater agro-processing, Africa’s young jobseekers will have more opportunities to access well-paid and stable jobs. A bioeconomy can foster employment opportunities by promoting the agro-processing sector; this can lead to an increase in agro-industrial and other value-added products with potential applications in many sectors, such as pharmaceuticals, green chemicals, industrial materials, and energy.

**Agro-processing and industrial development**

At the heart of a bioeconomy is an effective agro-processing sector which is adding value to biomass. The application of cutting-edge biotechnology to waste is a key element of developing a sustainable bioeconomy. A knowledge-based bioeconomy can revitalize rural commu-
the technology for cultivation and processing of the plants to rural community-owned businesses. A community-based candle-manufacturing factory has also been established and mosquito-repelling candles are now on sale in various shops in South Africa. Extraction of liquorice from the roots of the naturalized plant *Glycyrrhiza glabra* is another example of investment and support being provided to African SMEs to help them fulfill their role in deploying modern bioeconomy technologies to African markets. CSIR has assisted rural communities in establishing agro-processing businesses in the small community of Dysseldorp, in the Cape, extracting liquorice from the roots of the naturalized plant, *Glycyrrhiza glabra*. The liquorice blocks are now exported to markets around the world.

Biomass businesses offer opportunities for rural populations and other stakeholders to increase their incomes based on the sustainable management of forest resources. In Zambia, forest-related activities represent more than one million jobs in the formal and informal sectors and supplement or sustain the livelihoods of up to 80 percent of rural Zambian households. Tree and forest-based biomass products, can be less vulnerable to climatic shocks than are some horticultural crops such as fruits and vegetables. This makes a forest-based bioeconomy an important source of incomes for the most vulnerable groups who seeking to diversify their incomes to cope with the impacts of socioeconomic or climatic shocks. A case in point is Sudan where, in 2013, the production of gum arabica provided between five and six million jobs, contributed about 21 percent to the household income of gum farmers, and made up 17 percent of total Sudanese exports. The forest-based bioeconomy can also function as a safety net during lean seasons, conflicts or other times of hardship such as unemployment, or illness when farmers can collect and sell wood fuel and non-wood forest products (NWFPs) to gain additional income.

**New value chains and markets**

Bioeconomy can transform the African food processing sector by effectively allowing the value addition to biomass to produce valuable food products in an environmentally friendly manner. The application of research and knowledge, both scientific and indigenous, can enhance conventional linear value chains into complex interconnected value webs that reuse waste from processes to create new products. This transformation of Africa's food processing sector will create new value chains and markets in the food system.

Edible insects, for instance, are an important source of protein and can be processed into more palatable forms. By grinding them into paste or powder, they can be added to otherwise low-protein foods to increase their nutritional value. Black soldier fly larvae are also being used as a supplement for animal feed. More advanced technologies that isolate and extract insect protein are also becoming more readily available. They can be used to
fortify food products in a more acceptable form for to discerning consumers. However, further research is required to understand the properties of extracted proteins and boost their use for food supplementation. Edible insects such as termites (Isoptera: Termitidae) and lake flies (Diptera, Chironomidae, and Ephemeroptera) are abundant in the Lake Victoria region in East Africa and provide an important source of nutritious food for both humans and livestock. However, they are both seasonal and highly perishable. Processing lake flies will extend their availability and foster conservation. A study in the Lake Victoria region found there to be a robust potential for commercialization of termite-based and lake fly-based crackers, muffins, meat loafs, and sausages.

A bioeconomy also offers the opportunity to promote local processing of indigenous fruits. The monkey orange (Strychnos spp.), for instance, is widely available in southern Africa, and is rich in vitamin C, zinc, and iron. A study recommends the upgrading of processing and preservation techniques at the household level in order to improve the availability of this food outside of its production season, thereby harnessing the health benefits from its consumption for longer. A company in Gaborone manufactures snack foods and drinks made from indigenous fruits such as marula, wild cucumber, Kalahari melon, and the Kalahari desert truffle. The fruits are collected by local villagers and processed into 11 products in a variety of packaging sizes. The company is currently marketing and distributing its products to airlines, supermarkets, and safari lodges in Botswana, and is now seeking expansion into regional markets.

**Agricultural production system changes with bioeconomy benefits**

The use of biomass products and biofertilizers can enhance soil nutrients with lower environmental impacts. For instance, the composting of green forest leaves can provide organic fertilizer that can enhance the productivity of agricultural crops. Bioeconomic practices such as agroforestry can also increase soil fertility. Trees such as Faidherbia albida shed their leaves during the early rainy season and produce leaves when the dry season begins and can thus improve agricultural land fertility. This reversed leaf phenology also ensures that the trees do not compete with crops for light, nutrients, and water. It also results in an increase of carbon stocks both above ground and in the soil and in improvement of soil water retention and nutrient status including nitrogen. Evidence shows that planting Faidherbia albida among crops results in a yield increase of between 6 and over 100 percent, depending on crop type. In Malawi, more than 180,000 farmers who planted fertilizer trees obtained increased maize yields, a greater period of food security per year, and improved dietary diversity.

**4.2. Food security and nutrition**

A sustainable bioeconomy can effectively improve food security and nutrition. The increase in demand for biomass can significantly increase food availability, while innovations such as biofortification can help improve the nutritional content of food.

**An increase in food availability**

Biomass products such as forest foods are an important source of food and income. In Burkina Faso, forest restoration produced fodder for livestock, small wildlife, and crops including cereals and legumes. Restoration based on agroforestry approaches also provided more than 26 percent of fruits, nuts, leafy vegetables, and spices produced to households, all of which are micronutrient-dense foods, crucial for improving nutrition outcomes. Notably, leaves from trees such as Vitellaria paradoxa (shea tree), Parkia biglobosa (African locust bean tree), and Adansonia digitata (baobab) supplement local diets. The sale of these biomass products and of other non-timber forest products contributes 16 to 27 percent of women’s income, which is mainly used to supplement diets with purchased foods. A 2013 study found that children in Malawi who lived in communities that experienced deforestation had less diverse diets than children in communities where there had been no deforestation.

**Improving nutritional content**

The use of advanced biotechnology tools such as DNA marker-assisted breeding, tissue culture, and genetic engineering has led to the development of tailor-made crops that have specific characteristics, including improved nutritional value. Among these, biofortification uses conventional plant breeding methods to enrich the micronutrient content of the staple crops that form the largest share of diets in rural populations. Three crucial micronutrients—vitamin A, zinc, and iron—are bred into key staple food crops and when consumed regularly, these new crops provide sufficient amounts of the nutrient for a healthy diet. Biofortified crops are bred not only to have higher micronutrient content, but also to have high yield, pest resistance, climate adaptability, and consumption traits such as taste and cooking time, in order to match—if not outperform--non-biofortified varieties. Over 130
varieties of biofortified crops have been released in over 30 countries globally; these include vitamin A-enriched banana/plantain, cassava, maize, and sweet potato; iron-rich beans and pearl millet; zinc-rich rice and wheat; and iron- and zinc-rich cowpea, lentils, and sorghum. Several more varieties are under testing in over 50 countries.54, 55, 56

Orange flesh sweet potatoes (OFSP) is an example of a biofortified crop. OFSPs are rich in beta-carotene, which can be converted easily into Vitamin A by human bodies. An effectiveness study was implemented in Mozambique and Uganda between 2006 and 2009 to evaluate the impact of the delivery of OFSP vines on the OFSP adoption of beneficiary households, as well as on their vitamin A intake and on vitamin A status outcomes. The study found that 61 to 68 percent of beneficiary households were cultivating OFSP in Uganda and Mozambique, respectively. Evidence from Uganda also showed that the introduction of OFSP resulted in significantly increased vitamin A intakes among children and women and measurably improved vitamin A status among some children.57 In Mozambique, delivery of vitamin A-rich OFSP resulted in a doubling of vitamin A intakes, with OFSPs providing almost all of children’s total vitamin A intake.58 Consumption of vitamin A-rich OFSPs was also found to reduce the prevalence and duration of diarrhea among children, revealing that child health could be improved through biofortification.59

Other products such as milk, meat, and eggs can also be modified to provide additional nutritional benefits. For instance, if salmon oil is added to the feed for laying hens, their eggs contain higher levels of omega-3 fatty acids, which are important for brain functioning, immune and nervous systems, and healthy hearts. This is already being practiced in egg production in South Africa.60 Although milk and meat already contain protein, calcium, iron, zinc, and vitamin B12, it is also possible to enrich these products with selenium, iodine, calcium, iron, and beneficial lipids by using specialty diets or long-acting supplements and by modifying ruminal microflora and selecting traits or phenotypes.61

4.3. Natural resource management

A transition to a bioeconomy helps to ensure a sustainable utilization of land, water, air, minerals, forests, fisheries, and wild flora and fauna. This is ensured by more efficient bioeconomic production and processing practices and reducing input demand and providing new sources of nutrients for people from biomass products.

Sustainable management of natural resources

A central tenet of bioeconomy is the efficient use of natural resources and the circularity of products through the recycling and reuse of waste. The opportunities to develop new value-added products from waste, especially agricultural waste, offer some
of the most noteworthy prospects for developing a bioeconomy. The application of cutting-edge biotechnology to reuse and transform waste from agro-processing and other value-adding sectors such as livestock, coffee, cotton, wood, sisal fiber, and fruit offer clear entry points for Africa’s bioeconomy development. Nigeria is the highest producer of cassava in the world; it generates millions of tons of solid and liquid wastes from its production and use. Evidence shows that there is a high potential for Nigeria’s dynamic private sector to produce biofuels and bioelectricity via microbial fuel cell (MFC) technology, and value-added biochemicals from effective management of cassava waste. Similarly, the development of packaging for cushioning soft fruits and vegetables such as tomatoes and papayas from banana pseudostem provides an interesting example of the circular use of biomass in producing innovative products. Globally, agricultural waste from banana harvests, including pseudostem, leaves, and peel have been estimated to amount to 114 million metric tons (Mmt) of biomass per year. The use of banana pseudostem for biodegradable packaging offers an environmentally friendly solution to plastic waste and displaces the need for plastics made from fossil fuels. The banana biowaste innovation also performs equally well as conventional plastics in protecting fruits and vegetables during transport. Moreover, biomaterial innovations present new employment opportunities for rural regions that relying on agriculture for their income.

**Climate change resilience and mitigation**

The growing demand for biomass also offers opportunities to mitigate and adapt to climate change and support the decoupling of the agricultural sector from environmental degradation, in some cases doing so simultaneously. In order to prevent global temperatures from rising more than 1.5°C by 2100 requires simultaneous efforts in mitigation and sequestration. Currently, several global mitigation scenarios rely on large emissions reductions across agriculture, forestry and other land use sector and concurrent deployment of reforestation/afforestation and biomass use in a multitude of applications. Among these, the transition to a low-carbon, fossil-free global economy is expected to depend extensively on bioenergy. Low-efficiency traditional biomass already forms a large source of energy for cooking, lighting, and heating across Africa. However, this presents serious negative impacts on health and living conditions, particularly for women and girls, and causes deforestation. High-efficiency modern bioenergy can play an important role in providing improved ‘green’ energy to nearly 73 percent of the continent’s residents who remain disconnected from the grid, in turn, improving local air conditions and the pressure on Africa’s forests. In 2015, a study explored the potential of biogas production in Ethiopia; it used by-products from coffee processing, including husks, pulp, and mucilage. The findings showed that the anaerobic digestion of these products could generate as much as 238,000 megawatt hours (MWh) of electricity and 273,000 MWh of thermal energy. The coffee processing facilities could then use the energy generated from that biogas production, which could lead to energy cost savings for the industry. Secondly, a programmatic partnership facilitated by BioInnovate Africa brings together scientists, researchers, innovators and entrepreneurs in Kenya, Tanzania, and Uganda to develop new fuels for rural households from food waste. The project looks to commercialize a fuel that offers a more environmentally friendly alternative for households that rely on charcoal, paraffin, and firewood to meet their energy needs. A bio-alkanol gel was developed using fruit waste to burn without smoke or soot and can be used as a cooking fuel using existing infrastructure. This new bioeconomic product is expected to reduce deforestation for fuelwood. Academic and business institutions from the three countries collaborated in the identification and development of the new technological product and have established a bio-alkanol gel production facility for commercial expansion.

**Climate action is propelling a relocation of energy production to regions with abundant low emissions energy and feedstocks for bioenergy. This is likely to provide significant benefits for recipient countries, in the form of employment and income generation.** If combined with restorative agriculture and forestry, bioenergy and other bioeconomy programs can in fact sequester emissions and help to protect and conserve biodiversity too. Greater adoption of locally adapted agroecological techniques such as agroforestry, can help to restore biodiversity in agricultural landscapes, while increasing soil fertility by enhancing the accumulation of organic matter from decaying plant matter, in turn reducing the dependency on chemical fertilizers and pesticides which can harm biodiversity. Similarly, the adoption of conservation agriculture (combining no tillage, permanent soil mulch cover, and diversification of plant species) can further boost climate and biodiversity outcomes. By some estimates, carbon sequestration in African agricultural soils through
conservation agriculture amounts to approximately 524 Tg of CO2 per year.71

Climate-smart agriculture and forestry approaches can offer co-benefits in food security, livelihoods, biodiversity and health aspects. Tree plantations can be a source of pulp, timber, and fuelwood, thereby relieving pressure on primary and protected natural forests such as the Acacia senegal plantations producing gum arabic in eastern Africa, the rubber and teak plantations in West Africa, and the eucalyptus plantations of South Africa.72 Timber products in construction and industry can also mitigate emissions from steel and cement production. Moreover, combining agroforestry with livestock farming fosters the adoption of circular agriculture in which external inputs are minimized and the environmental impact is thus reduced. Many smallholder farmers raise livestock and then use crop residue biomass as animal fodder, which reduces the available soil cover; if trees are grown on farms, however, there is more available biomass to meet livestock needs and thus maintain constant soil cover and productivity.73

Hence, the expansion of Africa’s bioeconomy can provide several possibilities to engage in global efforts to address climate change and natural resource constraints.

4.4. Trade-offs and unintended spillover effects

Achieving the sustainability benefits of a bioeconomy requires careful consideration of the trade-offs and spillover effects that manifest in producing and consuming more biomass. These effects can include the overuse of, and competition for, water resources and land, which can result in unintended spillover effects such as loss of natural vegetation and biodiversity, reduced food security, labor competition, and other adverse socioenvironmental outcomes.

One of the key drivers of bioeconomy development is the transition to low carbon societies, but the production of bioenergy feedstocks and other biomass inputs on forest-cleared land or through cropland expansion, particularly in large monoculture formats, can in fact be counterproductive. On the other hand, the production of biomass in marginal or rehabilitated degraded lands can result in various rural and socioenvironmental benefits including soil carbon sequestration and climate change mitigation, reduced need for deforestation, biodiversity protection, and employment generation.

According to one estimate, global energy production from degraded land is approximately 57 exajoules (EJ); by comparison, primary energy consumption in Africa in 2020 was 18.6 EJ. Bioenergy can thus be a key driver of investments in marginal and degraded lands and the use of this land can reduce the competition between food and other non-food bioproduction. It is essential, however, to pay attention to other land uses such as pastoralism and cultural uses and to ensure that communities are sufficiently consulted and are included in decision-making processes regarding proposed land use changes. In addition, co-locating biomass and feedstock production with food production through silvo-agroforestry, can also offer an approach that resolves trade-offs and avoids or mitigates potential conflicts. Countries and regions can also adopt guidelines, standards, and certification schemes for sustainable feedstock and biomass products that capture both social and environmental outcomes and achieve near- and long-term goals to eradicate hunger. There is currently a dearth of standards and guidelines in Africa, although there are several exist at the global level and across Europe.

4.5. Conclusion

It is clear that the development of a bioeconomy in Africa can offer opportunities to address a number of challenges concurrently. But the development of a bioeconomy also presents several trade-offs. If they are not carefully articulated and implemented, there are risks of unintended and indirect effects. Fundamentally, the success of a bioeconomy will rely on identifying trade-offs in advance and collaborating across stakeholder groups to develop inclusive solutions. The next chapter therefore presents key ingredients for creating an enabling environment that minimizes the potential negative outcomes of a bioeconomy and maximizes its benefits and gains. In doing so, it identifies potential stakeholders and pathways for enhanced collaboration.

Co-locating biomass and feedstock production with food production through silvo-agroforestry, can also offer an approach that resolves trade-offs and avoids or mitigates potential conflicts.
5. THE ENABLING ENVIRONMENT FOR A THRIVING BIOECONOMY

A bioeconomy offers opportunities for addressing several key challenges simultaneously. It can be a central strategy for sustainable economic growth that includes agricultural growth, job creation, food security, and environmental protection. These potential benefits have already motivated the launching of a bioeconomies in some African countries (see case studies). It is now up to policymakers elsewhere on the continent to create a suitable enabling environment that can harness the power of abundant natural resources, a growing population that is increasingly well-educated, a steadily improving R&D infrastructure, as well as rapid digitalization. Incentives and a coherent policy environment are required to mobilize the continent’s thriving and entrepreneurial private sector, finance, and research environments to advance the development of a sustainable bioeconomy.

A wide range of mechanisms and tools can be deployed to promote the development and growth of bio-based transitions. Ensuring that the benefits are equitable, inclusive, and environmentally and financially sustainable requires a strong and supportive enabling environment. While a robust governance framework addresses potential risks and trade-offs, investments in supporting structures and institutions, infrastructure, education, and research capacity cement implementation and foster private sector participation in a sustainable bioeconomy. The advancement of Africa’s emerging bioeconomies can be accelerated by policies and regulations, clear and transparent land governance systems, information campaigns, monitoring frameworks.

5.1. Governance

Executing a bio-based transition is a long-term commitment that requires clarity of vision, policy coherence, and continuity beyond changes in governments and election cycles. It is essential to plan and effectively prioritize investments, be it in human capacity, science infrastructure, innovation systems, or the pioneering of financial tools and mechanisms. Governments across the world are adopting different paths to facilitating the development of a bioeconomy. Countries like Brazil and Tanzania are focus on raising productivity in their agricultural sectors while countries like South Africa, Kenya, and several developed nations are focused on transitioning away from fossil fuels, raising agricultural productivity, fostering new and more efficient biomass use, and building new industries and sectors. 74 Policy tools can be tailored to reflect the scale, scope, and stage of transition. They can focus either on specific industries and sectors such as fossil fuels and energy, pharmaceuticals, chemicals, or the ocean-based sector; or aim for a comprehensive economy-wide transformation. The first of these approaches has been adopted in Ghana, Mozambique, Nigeria, and Senegal who initiated their bioeconomy development via biofuels and bioenergy, while Mauritius has developed a strategy for its “blue” (oceans) economy. 75 On the other hand, South Africa first implemented a biotechnology strategy in 2001, and has since scaled up its bioeconomy vision. Although the biotechnology strategy was successful in establishing several biotechnology incubation centers and commercializing the innovations, it highlighted a gap in the wider innovation value chain. As a result, in 2013 the Department of Science and Technology launched a bioeconomy strategy to foster backward linkages with three key sectors: agriculture, health, and industry.

An alternative avenue to initiate the development of a bioeconomy can be through long-term climate change strategies. As part of their commitments to the global climate frameworks, all African governments are developing plans to mitigate and adapt to climate change. In many cases, these have also been cross-referenced to other economic sectors such as agriculture and forestry. For example, Kenya’s National Climate Change Action Plan for 2018-2022 promotes the expansion of agroforestry to reduce emissions from its agriculture, forestry, and other land use sectors by 3.7 million tons of CO₂ equivalent. 76 Not only can this make a significant dent in one of the largest sources of the country’s emissions, it can also strengthen the adaptive capacity and resilience of farmers. As policymakers prepare domestic climate plans and their Nationally Determined Contributions to the UN Framework Convention on Climate Change, they can aspire to harmonize them with bioeconomy strategies.

Designing a comprehensive bioeconomy policy offers an opportunity to build on and integrate a broad range of existing strategies. 77 This also presents the challenge of compiling a coherent policy framework that strengthens the bioscience innovation system, supports market development,
protects the environment, and ensures that indigenous and other communities are not disadvantaged. Globally, only 15 countries have a dedicated bioeconomy strategy. Experience from countries that have taken the initial steps to formulating bioeconomy policies shows that this is unlikely to be a linear process. Rather, devising and implementing bioeconomy policies will require regular reviews and iterations. This presents an opportunity to widen the scope, attract new players, and explore innovative and context-specific pathways to the establishment of a sustainable bioeconomy.

**Multisectoral and multistakeholder coordination**

Bioeconomies are multisectoral by nature, drawing together inputs, expertise, and skills from a broad range of sectors such as agriculture and food, energy, education, research, science and technology, environment, forestry, land management, and industry. Therefore, bioeconomy strategies add another policy layer to existing interconnected policies. This can intensify competition among existing actors and create new winners and losers or, alternatively, it can foster greater collaboration across agendas. Foreign policy and diplomacy also play an important role where the development of a bioeconomy facilitates cross-border connections between industries and stakeholders. The development of a bioeconomy therefore requires close coordination among existing domestic institutions, international actors, development partners, private sector actors, and farmers. While national agricultural ministries coordinate the policy environment to deliver greater biomass without jeopardizing food security, implementing institutions including private sector and extension agents are crucial in supporting the adoption of productive technologies and inputs by rural farmers. At the same time, farmers are themselves crucial in facilitating knowledge exchange and innovation; a “bottom-up” engagement process ensures that farmers accept the transition to a bio-based economy and play an active role in its development and growth.

5.2. Demand for bioproducts

Policy instruments such as subsidies and tax breaks, infrastructure investments (including in the development of science and technology parks), and clear legislative signals (particularly on land governance) can attract private sector involvement to accelerate the development of a bio-based economy. Policy instruments can also be deployed to generate demand for bioproducts, for example, by discouraging the production and use of unsustainable and environmentally harmful practices and products such as conventional pesticides, while rewarding improved practices, products, and technologies such as biopesticides, “push-pull”, and other integrated pest management methods. At the same time, product standards, certification, and labeling can reinforce information campaigns, cultivate confidence in outputs and outcomes, and ease the barriers to entry for producers of innovative and novel bioproducts.

Supporting regulatory bodies to develop and implement such incentive structures in partnership with research institutions and businesses (especially SMEs) engaged in the bioeconomy can ensure that they are fit for purpose. Greater compliance can also be fostered by providing incentives such as capacity enhancing financial advantages, such as low-interest loans, capital spending subsidies, and aligning public procurement to build demand. Harmonizing certification across borders is another powerful tool for unlocking demand for bioproducts and biotechnology, and the bioeconomy can be further popularized across the private sector by securing supply chains for inputs and supporting market creation through trade linkages.

5.3. Intellectual property

A bioeconomy is recognized as a knowledge-based economy. The capacity to harness knowledge and monetize/commercialize it through innovative and sustainable bio-based solutions provides small and large companies with a competitive advantage. Similarly, for countries that are heavily reliant on their agricultural, mineral, and low value-added manufacturing sectors, the conversion of bio-knowledge into value addition processes and products provides an important avenue for market development, job creation, and contribution to economic growth. “In particular, Africa’s rich agricultural resources, traditional knowledge and cultural repositories afford it comparative advantages with [geographical indications], plant variety protection, traditional knowledge and traditional cultural expressions”. As such, IP becomes the currency in a knowledge-based bioeconomy. A strong IP regime that provides copyrights, patents, trademarks, and similar rights to the developers of this knowledge into products can propel a bio-based transition.

Robust IP systems can be used to induce investments into R&D and innovation and can foster collaboration in a bio-based transition. As
developed countries and multinational companies increasingly look beyond traditional markets, new approaches are being developed to reduce risk and share benefits in a more equitable and flexible manner. The use of open source and open science initiatives, patent pooling and patent clearinghouses, and flexible licensing practices can allow for a broader range of purposes and perspectives. Where domestic research institutes can leverage these for greater access and equity in research, countries can circumvent the early stages research and tap into potential benefits sooner.  

Extending these benefits to local communities remains a challenge, although several business models are now being tried, especially in southern Africa. It is important to ensure the equitable and authorized sharing of knowledge and resources through effective IP systems in order to protect vulnerable communities—which are often abundant with genetic resources and untapped knowledge—from acts of biopiracy/unsanctioned bioprospecting, and appropriation. One successful examples of benefit-sharing is that between the South African San Council, the National Khoisan Council, and a local pharmaceutical company called Cape Kingdom Nutraceuticals. The agreement addresses the use of *Agathosma crenulata* (*buchu*), a South African plant that is used for medicine, food, and in the fragrance industry, giving the San and Khoi communities 3 percent of the profits from products that use it. A robust IP regime ensures that the farmers and indigenous communities who produce, harvest, and conserve biological materials receive a fair share of the benefits resulting from the use of this knowledge.

It is essential to recognize that property rights within agricultural biotechnology are far more complex than in pharmaceuticals. Agricultural biotechnology has the characteristic of being similar across regions and borders while at the same time vastly diverse. Agricultural biotechnology therefore offers more opportunities for specialization and large-scale impact than do pharmaceutical products. It is therefore necessary to foster greater coordination among agricultural biotechnology innovators and patent officers and to ensure that the latter have the skills and resources to oversee management of the licenses. Where breaches occur, and in the event of anti-trust litigation, it is critical that there is access to institutions that can enforce and protect domestic interests (see Box 7 below). Within this context, arbitration is an important tool and skill. This in turn requires close communications between those who negotiate international agreements and those who implement and manage IP regimes domestically.

As the continent moves toward greater unification through the African Continental Free Trade Agreement (AfCFTA), there is also room for negotiators to prioritize, strengthen, and streamline IP protocols on “geographical indicators, plant variety protection, traditional knowledge and traditional cultural expressions, which embody Africa’s innovative and creative strengths”.

*Harmonizing intellectual property rights across Africa*

Total patent applications in Africa are only a minuscule share of global patent applications. Of those patent applications that are made in African countries, an even smaller share comes from domestic innovators and companies. Research and innovation in Africa are largely led by the public sector and rely on access to public-domain technologies. Thus, any changes to IP regimes that restrict or alter their access to these technologies can severely hamper key inputs. IP regimes must therefore be carefully constructed and updated, bearing in mind local science and innovation systems.
Box 6: Biopiracy and Biodiplomacy

Biopiracy is the illicit appropriation or commercial exploitation of biological resources such as plants, seeds, genes, and the associated traditional knowledge. Africa’s vast biodiversity wealth combined with its weak legal systems and complex traditional associations expose the continent to potential biopiracy. In some cases, foreign companies have patented and limited the use of all parts of a particular plant, including its genetic material (see Box 7). For communities that identify and depend on those resources, the creation of appropriate benefit-sharing schemes can compensate for the commercialization of their knowledge and the use of their local biodiversity.

Biodiplomacy is the use of international relations to support efforts to maintain biological and cultural diversity through holistic global utilization of natural resources. Biodiplomacy adopts a relatively forward-thinking stance on the use of biodiversity. The concept is founded in the necessity for cooperation to expand the opportunities for bioeconomy development across the world, and to enhance technological uptake for the use of renewable resources.

Geographical indications (GIs) are one way of recognizing the origin of a product. A GI is a labeling system that denotes products that have a specific geographical origin and possess qualities or a reputation that are specific to that location. In 2014, South Africa was successfully able to register geographical indication status for rooibos tea in an economic partnership agreement with the European Union, thereby protecting the plant and its name from potential IP theft.

While developments in harmonizing Africa’s IP frameworks can support a bio-based transition, policymakers must recognize that strengthening the IP regime can also undermine R&D, R&D investments, and jobs, especially where the existing base of science, technology, and education is not well-established. For economies with large sectors that rely on producing imitations and derivatives from existing technologies and products that are registered elsewhere, the enforcement of IP regulations and standards can weaken technology transfer, disrupt the replica market, and reduce the ability of entrepreneurship to thrive and the potential for the sectors to generate new jobs.

In such cases and when countries do not have the capacity to develop their own IP instruments, it is possible to acquire rights or access to them through alternative means. Lessons can be drawn from other developing countries that have benefited from transnational trade in biological IP. One such case is India, which has developed a flourishing biopharmaceutical industry that thrives on producing and scaling up generic versions of medical solutions and drugs that have been developed elsewhere. The country has achieved this by using various IP instruments, to adopt and adapt technologies developed elsewhere thereby accelerating its bio-based transition.

Similarly, countries can benefit from robust IP systems by simply strengthening their certifying and testing facilities to support IP regimes in other countries. High capital costs are required to establish state of the art testing and certification facilities, but they provide employment opportunities for skilled technicians and require a minimum throughput of bioproducts to be viable. Where such testing facilities serve regions, they facilitate greater cooperation and they benefit from shared costs.

To ensure that such a pathway contributes toward economic growth and sustainable development, it is critical to have effective negotiating strategies and skills that can create and manage special and transdisciplinary partnership structures and can accommodate flexible licensing agreements. For instance, South Africa’s leadership in housing such a large share of patents filed in Africa has been boosted by the establishment in 2013 of the National Intellectual Property Management Office (NIPMO). Working through a national network of technology transfer offices, NIPMO’s mandate includes the purchase of intellectual property for producing biosimilars.
Box 7: Who owns teff?

In 2003, the Ethiopian Agricultural Research Organization (EARO) signed a memorandum of understanding (MoU) with Larenstein University in The Netherlands and with a Dutch company named Soil & Crop Improvement (S&C) to conduct research on, and develop international markets for, teff-based products. Teff is a fine gluten-free grain that is native to the Horn of Africa. S&C applied for, and was granted, the patent for the exclusive use of teff flour; this included the use of all ripe grain, the fine flour made from it, dough or batter made from the flour, and a broad range of nontraditional products. The extent of the patent even locked Ethiopia out of developing uses of teff itself—an outcome that was neither expected nor accepted by Ethiopia. In 2005, following legal challenges and a restructuring of Ethiopia’s agricultural research institutions to clarify responsibilities, a new ‘Teff Agreement’ was reached which clarified the conditions for access to teff genetic resources. The agreement was prepared by a panel of Ethiopian and Dutch experts and diplomats. The panel was led on the Ethiopian side by Dr Tewolde Berhan Gebre Egziabher, who drew upon his vast experience from international negotiations, including at the heart of the Convention on Biological Diversity. The company was required to acknowledge the origin of teff in Ethiopia and was prohibited from claiming rights over traditional Ethiopian knowledge in relation to the grain and from profiting commercially from its use. It was also required to share benefits with Ethiopia through shares of the royalties, license fees, and profits, as well as through research cooperation and the sharing of research results. Only four years after the Teff Agreement was signed, however, the company was declared bankrupt and had transferred only EUR4,000 (about US$5,700) to Ethiopian farmers, an amount which remains in dispute. Prior to declaring bankruptcy and without informing Ethiopian authorities, S&C had also transferred the agreement to new companies for a paltry EUR60,000 (US$85,000). Eventually, Ethiopia filed a case against the director of the company at the International Court of Arbitration in Paris. This did not result in the release of rights back to Ethiopia; however, another Dutch company challenged the validity of the patent and won the argument at the Dutch patent office, which was reinforced by a court at The Hague in 2018.

Ethiopia’s experience has highlighted the challenges of protecting agricultural produce, particularly when domestic institutional frameworks are not sufficiently robust. As governments across Africa seek to grow their bioeconomies, they must invest in the development of appropriate systems, institutions, and policies that will protect local biodiversity as its use is increasingly commercialized. Institutions must also be resourced by skilled and knowledgeable experts and must be funded well enough to assess and manage risks.

5.4. Science, research, and innovation

A bioeconomy relies on physical plant or biomass materials as inputs as well as the information and knowledge that is contained within them, either in the form of genes or otherwise. This makes a bioeconomy both a “biomass economy” and a “knowledge economy”. The conversion of this bio-knowledge into innovative bioproducts and biotechnologies relies on a strong foundation in science and research as well as a flair for entrepreneurship and business. In other words, a sustainable bioeconomy is founded upon an effective and dynamic national innovation system, which is in turn composed of a knowledge-generation subsystem. The latter is made up of an education system, public and private research institutions, and a thriving private sector that is able to scale the production and dissemination of innovations into mainstream products.

Bioeconomy education

The multisectoral nature of a bioeconomy implies the need for an interdisciplinary approach to a “bioeconomy curriculum” that brings together life sciences, social sciences, and business skills. Stellenbosch University in South Africa hosts Africa’s leading biotechnology research department. Their Bachelor of Science (BSc) in Molecular Biology and Biotechnology not only provides students with the opportunity to apply scientific methods and master biotechnological skills, it also allows students to conduct practical research projects and collect data and communicate findings applicable to the field of bioeconomy.
Whether gained through higher education, vocational training, entrepreneurship programs, or other capacity enhancing programs, new education and skills programs will ensure that Africa’s emerging workforce has the required expertise to respond to the needs of a bioeconomy. Education and training programs must stress systems thinking and strategic planning, as well as provide a strong foundation in the evolving global discourses on sustainability, circularity, law and IP management, and ethics. At the same time, experts in sustainable bioeconomy will benefit from stronger critical thinking and problem-solving skills and from acquiring the knowledge and capacity to develop technical solutions and to disseminate them through innovative, profitable, and well-managed businesses. For example, an honors-level course in biotechnology at the University of Pretoria teaches students how to identify innovative biotechnology ideas and how to establish a fictional company around a particular idea. At the University of Witwatersrand in Johannesburg, a postgraduate course on biotechnology includes business aspects that train students on commercializing their innovations.

In order to execute such a renewal of broader education curricula, educators and trainers will also need to update their skills in delivering transformative learning experiences. Exchange programs for teachers can be an impactful way to immerse them in teaching methods and outcomes that support the development of a bioeconomy. These interventions in turn, require clear and deliberate policy signals combined with appropriate financing and reward mechanisms for educators.

Research ecosystem/lab-to-market/entrepreneurship

Research and innovation in Africa are largely led by the public sector. Public sector research institutions are often the torchbearers for producing outputs that address social, environmental, and societal issues. Working in partnership with national research institutions, international development partners and CGIAR (formerly the Consultative Group on International Agricultural Research) also promotes and disseminates innovative technologies to enhance the role of Africa’s agricultural sector in bioeconomy. Africa’s agricultural sector is a key beneficiary of national agricultural research institutions that are responsible for creating new technologies ranging from seed varieties to machinery. However, most African countries currently have less than 100 researchers per million inhabitants, which is about 8 percent of the global average. Public sector R&D is a critical element of developing a bioeconomy, so it is essential to strengthen it and ensure that research outputs and outcomes are made available openly. Doing so will continue to inject momentum into the development of solutions that result in public and private goods.

Alongside public research institutions, universities play an important role in developing and commercializing biotechnology and bioproducts. South Africa’s emerging health biotech sector relies substantially on the research capabilities of universities and research institutes for identification of novel technologies and products for commercial development. For example, the National Health Laboratory Service and the
University of Witwatersrand are working to produce novel solutions to limit the spread of HIV in human bodies. The project has resulted in the creation of a company called Elevation Biotech, which has subsequently received grants from the South African government and from the International AIDS Vaccine Initiative to develop and test new vaccine antigens. Several other commercial spin-offs which are developing and manufacturing drugs for tuberculosis, malaria, and HIV/AIDS, as well as “hardware” such as coronary artery stents have emerged in a similar fashion across South Africa.105

Private sector companies—often small- and medium-sized research-oriented and biotechnology companies—are also important actors in driving innovation in bioscience.106 Where the private sector has not matured, a suitable alternative can be to offer support to scientists and students in research institutions and universities for developing and growing their own enterprises. For universities to inspire demand-led, bio-based entrepreneurship and innovation, they can introduce challenges, competitions, and awards, universities, in partnership with public research institutions or the private sector. To do so effectively, universities and public research institutions must bolster their innovation and technology transfer offices so they can provide support for scientists and students in defining and presenting the business case of their innovations and managing IP requirements.107

By linking public sector research with universities and private sector and industrial partners to scale the production of bio-innovations, countries can create a dynamic ecosystem for a thriving bioeconomy.108 For example, In Kenya, the International Centre of Insect Physiology and Ecology (icipe), the Jomo Kenyatta University of Agriculture and Technology, and a private sector company called Real IPM have jointly developed biopesticides that are ready for commercialization.109 Such an ecosystem would also facilitate a pipeline of innovations and incubation-stage research outputs.

African countries have already begun experimenting with such partnerships through innovation hubs or science and technology parks (incubators). Largely publicly funded, these hubs and incubators often begin with a broad remit and then specialize as their clientele matures. Incubators for bioeconomy-related activities have become increasingly specialized because of their need for specific support infrastructure and services. Such specialized bio-incubators are now present in a number of countries across the continent including South Africa (see Box 8), Uganda, and Kenya. They offer flexible office and laboratory spaces, as well as support services such as high-speed internet, legal and managerial support, and networking opportunities. The survival rate of start-ups and their rate of development into spin-offs and successful global businesses can be improved by continuous support and assistance on IP management, regulatory services, employment and human resource matters, and by the longer-term availability of a broad range of capacity building, networking, and outreach programs. Managing bio-incubators therefore requires a vast range of skills, and in some cases poor management has led to incubator failures. This, in turn, has impacted the companies and entrepreneurs that are hosted there. Recruiting, training and supporting incubator managers is therefore crucial to ensure that they can propel companies and entrepreneurs forward and toward self-sufficiency.110
Taking direction from South Africa’s 2001 National Biotechnology Strategy and from an early draft of the 2008 Ten-Year Innovation Plan (TYIP) by its Department of Science and Technology, Gauteng province in South Africa produced its own 2007 Gauteng Biotechnology Strategy via the Gauteng Department of Agriculture and Rural Development (GDARD). The strategy aims to “develop resources for agricultural and environmental biotechnology, increase public awareness and understanding of agricultural and environmental biotechnology, expand R&D, ensure effective regulations, address commercialization and industry requirements, and develop and maintain networks.”

To implement this strategy, GDARD established a science and technology park called, “The Innovation Hub”. It aimed to attract high tech firms, institutions, and investors engaged in three sectors: smart industries (information and communications technology, or ICT, and advanced manufacturing); bioeconomy (health and agro-processing); and green economy (energy, water, and waste). The Innovation Hub attracts firms at different stages (incubator, start-up, revenue, and mature), universities and research institutions, and other nontechnical but supporting businesses. Constructed in a phased approach and with a modular design, the hub offered access to infrastructure and services such as laboratory spaces, tenant offices, and high-speed internet access.

Initial funding for incubation came via an agency within South Africa’s Department of Trade and Industry (DTI) called the Small Enterprise Development Agency (SEDA), and GDARD, with the intention of attracting a university or research institutes to establish campuses at the hub. The Innovation Hub also hosted service providers who offered support on legal and financial aspects, IP, product development and approval, funding, marketing, and business development. In addition, The Innovation Hub offered skills development and training programs for R&D, building innovation capacity and entrepreneurship skills. It also hosted networking events to facilitate sharing, learning, empowerment and equipping, connection, marketing of activities and informing stakeholders. Entrepreneurs were selected for incubation through competitions.

Along with several other government departments, GDARD provided funding for the establishment of an AgriPark as part of its Agrihubs program. The aim was to foster the development of an agricultural biotechnology cluster that would attract businesses focused on food security, enhancement of the nutritive quality of indigenous and other foods, and agro-processing. It comprised a 5,000 m² high tech greenhouse and a 200 m² pack house and was designed to extend agro-processing apprenticeships to local jobseekers and expand market outputs via local and global partnerships.

In 2018, more than 80 entrepreneurs had received support from BioPark, of which 70 percent came from the health sector, including biopharmaceuticals, nutraceuticals, cosmeceuticals, medical devices, and diagnostics. A further 23 percent came from the industrial sector and 7 percent came from agricultural biotech. The biopharmaceutical, health, and agriculture-related businesses that have been successfully incubated through The Innovation Hub include: Livestock Wealth, a company that offers opportunities to invest in livestock; and In2Food, a food refrigeration enterprise employing 600 people directly and 5,000 people across the agricultural value chain.

5.5. Infrastructure

A thriving sustainable bioeconomy relies on access to energy, water, transport infrastructure, data, and information in order to improve biomass production, support research and innovation, and provide access to markets for bioproducts. Water, particularly for irrigation, is essential for improving agricultural productivity on existing land and extending growing seasons throughout the year, thereby providing a steady and sustainable supply of biomass for the bioeconomy. Although some African countries have made progress in expanding irrigation uptake, less than 10 percent of cultivated land is currently irrigated in Africa. In order to raise agricultural productivity, the Malabo Montpellier Panel’s report titled “Water-wise: Smart irrigation strategies for Africa” recommends: elevating irrigation to a top policy and long-term investment priority, deploying public-private partnerships, and easing access to finance to encourage smallholder farmers to invest in irrigation.

Expanding irrigation relies on access to energy, both for the production of biomass, as well as downstream activities that transform biomass into value-added bioproducts and biotechnology. Africa’s agricultural sector will be able to participate
in a thriving bioeconomy if it has access to reliable, affordable, sustainable, and modern sources of energy for preparing land, planting, harvesting, processing, distributing, and cooking food.

While agriculture is a primary consumer of energy in Africa, it is also an important source of it. Africa is the world’s largest consumer of traditional solid biomass such as fuelwood, charcoal, and farm residues (including animal dung). However, this continued reliance on biomass is taking a toll on the continent’s forests and soils. More sustainable and efficient use of bioenergy can also unlock the potential of the agricultural sector by attracting new and additional investments to raise agricultural productivity. Within Africa’s energy mix, biomass-based energy needs to be transformed toward clean and environmentally friendly systems. Across Africa, whether providing energy for agriculture or using agricultural biomass for energy, there is an urgent need to invest in energy infrastructure, especially off-grid and mini-grid solutions. The Malabo Montpellier Panel’s report entitled Energized: Policy Innovations to Power the Transformation of Africa’s Agriculture and Food System recommends that African governments design integrated approaches for energy strategies that benefit rural areas, and deploy and scale up innovative finance mechanisms policies to ensure energy security and sustainability at all times. Governments, the private sector, and farmers organizations need to ensure that biomass is produced more sustainably, and more emphasis needs to be placed on ensuring that indoor cooking is redesigned to be more environmentally friendly and not harmful to health.

While greater use of water and energy would boost biomass production and processing, access to digital technologies, computing capacity, and high-speed internet will further elevate Africa’s bioeconomy. Rapidly advancing computing capacity and technologies such as nanotechnology, information technology, green chemistry, and engineering are transforming the fields of synthetic biology, genomics, microbiome studies, and the broader life sciences. This convergence has initiated the biggest potential transformation in the design of tailored solutions and products to address several grand challenges, including food security, nutrition, and climate change.115,116,117

As the Malabo Montpellier Panel’s report Byte by Byte: Policy Innovation for Transforming Africa’s Food System with Digital Technologies concludes, Africa’s digital transformation is already underway. The continent can now leverage the potential benefits of digitalization and new technologies for a transition to a bio-based economy. Sound digital infrastructure that provides high-speed connectivity and affordable internet is a prerequisite for a thriving bioeconomy. Both the public and private sectors have a role to play in delivering last mile connectivity infrastructure, establishing digital innovation hubs, and providing skills development, training, and education programs.118

Investment in infrastructure for bioeconomy, however, does not always need to be large scale, nor does need to be deployed at scale immediately. Small modular approaches to constructing biorefineries119 and incubators allow for flexibility in the speed and timing of scaling up, for example, once funding is secured. Policymakers may also choose to optimize the use of existing infrastructure, including knowledge centers such as universities and national research centers, to intensify a bio-based transition. This has been the preferred approach for South Africa’s bio-incubator projects, which have mostly been located close to education and research hubs. Utilizing existing infrastructure can also be a useful approach to reindustrializing or revitalizing decommissioned plants and areas that are at risk of abandonment. For example, under current plans, the Kenya Petroleum Refineries Limited facility, which was shut down in 2013, will be converted to processing used cooking oil to produce biofuels.120

Small modular approaches to constructing biorefineries and incubators allow for flexibility in the speed and timing of scaling up, for example, once funding is secured.

A bioeconomy also provides an opportunity for policymakers to reimagine, redesign, and recalibrate how economic activities are (re-) distributed across their countries to support job creation, poverty alleviation, and economic growth across urban, peri-urban, and rural areas. One way to do this would be through the provision and location of infrastructure in selected regions and spaces to drive bioeconomy development. For example, where existing infrastructure is unable to support new bio-based industries, policymakers may look at providing infrastructure for biorefineries and manufacturing in locations that are at some distance from industrial hubs.
and nearer to biomass production. This has been the preferred approach in Ethiopia, where the government has promoted large-scale integrated agro-industrial parks for agro-processing mostly in rural areas. The parks offer shared infrastructure such as roads, power, water, communications, laboratory facilities, and by-product utilization. They also extend additional fiscal incentives for private sector investors to process and transform local crop and livestock production into exportable goods. Although few operate at optimum scale, they provide the ideal environment for developing a dynamic sustainable bioeconomy in Ethiopia.

5.6. Finance

The framework conditions for bioeconomies are changing globally as explicit and implicit carbon pricing is emerging, not only in Europe and China, but beyond. This will also create opportunities for Africa to enter climate finance and climate sequestration markets. Access to finance is fundamental to a bio-based transition. Funding is core across all stages of a bioeconomy, including research, innovation, technology development and transfer, business growth, and the implementation and monitoring of sustainability impacts. At a national scale, funding priorities are likely to be linked to overhauling the education system, providing infrastructure, investing in public research institutions, and enhancing legal frameworks for technology transfer and IP. For bio-enterprises, finance needs stretch across lifetimes, including for establishing pilot projects, scaling up demonstration projects, and moving to flagship/first-of-a-kind and industrial-scale plants.

Africa's public research institutions are largely funded by governments (national budgets) and donors. Stakeholders in Nigeria's maize bioeconomy such as national research agencies, agrodealers, and seed companies are funded from both state and federal sources, as well as by donor agencies. This in turn facilitates greater collaboration among them. African countries are urged to allocate 1 percent of their GDP to R&D as part of the 2010 “Khartoum Decision” that was concluded at the AU's Executive Council Ninth Ordinary Session, few countries have achieved this target. The latest data, recorded in 2015, shows that average expenditure on R&D as a share of GDP in Africa stands at about 0.4 percent, compared to a global average of 2.2 percent. Only Egypt, Kenya, Mali, Morocco, South Africa, and Tunisia are close to the 1 percent target. Algeria, Cabo Verde, and Lesotho, meanwhile, spent less than 0.1 percent of GDP on R&D. In some cases, funding from donors is larger than national allocations, while private sector contributions are less than 50 percent. Meeting the AU target will enable sustained investments in research and innovations in agriculture, energy, education, health, and biosciences—all of which will significantly accelerate the development of a bioeconomy.

The COVID-19 pandemic and the ensuing vaccine inequity has strongly demonstrated that there is an urgent need for Africa to invest in its own science, technology, and capacity for innovation. Persistent climate impacts are also driving a continental and global shift toward a green economy. By positioning the establishment of a bioeconomy within these wider global transitions, African governments can mobilize funds beyond their own national resources, and access sources through the European Green Deal, the Global Environment Fund, and the Green Climate Fund, to play an active role in developing homegrown solutions for addressing global challenges. The UN Framework Convention on Climate Change's 26th Conference of Parties, held in 2021 drew attention to the importance of nature-based solutions in addressing climate change. As developed countries increasingly seek for investment opportunities to counter their emissions, African countries can benefit from developing strategies and plans to tap into these funds.

Given the potential diversity of bio-enterprises, it is essential that bioeconomy entrepreneurs have access to a range of affordable and reliable financial sources. Public sector funding can be extended through budgetary line items to national research institutions that are earmarked for bioeconomy activities. It can also be directed through innovation agencies or through incubators that provide infrastructure and supporting services, or in the form of competitive awards. Importantly, a larger and fixed base of public sector investment in R&D can provide some de-risking that can crowd-in private sector and commercial finance. This, in turn, can unlock a vast range of creative funding models (such as first loss financing or second loss financing) to bring innovations to market and to advance from pilot projects to demonstration phase. For example, the Uganda Green Enterprise Finance Accelerator (UGEFA) improves access to green finance for the country's SMEs. UGEFA works with Uganda's local commercial banks to facilitate access to loans. It uses EU funding to enhance capacity among the SMEs to bring solutions to scale and improve impact evaluation, thereby strengthening business viability.
Furthermore, providing concessional financing (finance at below market rates), underpinned with strong due diligence processes can strengthen business acuity and ensure that public sector support for bioeconomy offers remains sustainable over the long term. This type of model can accelerate the transition from demonstration phase to flagship/first-of-a-kind bio-enterprises. One successful public-private model has led to the formation of the Biovac Institute in South Africa, which is the only vaccine manufacturer in SSA. It was founded in 2003 as a joint effort, after the failure of a purely public-sector-led attempt to supply vaccinations to South Africa.128

The development and commercialization of some bio-based products such as biotechnology and biopharmaceuticals often requires a very long timeframe and large upfront costs, for example for laboratory equipment and trials which in turn carry a high risk.129 The outputs and outcomes can bring significant public and private benefits, therefore offering an attractive opportunity for private finance providers such as angel investors, venture funds, and patient capital providers. Start-ups are ideal for this type of financing and scaling them to industrial-scale plants and taking products to market can indeed prove to be lucrative. Combinations of different financial instruments such as grants, equity, and loans can also provide effective risk management in uncertain environments.

5.7. Partnerships and collaborations

Connecting higher education, research institutes, and private sector stakeholders

The development of bio value webs fosters the emergence of new partnerships and collaborations among farmers, researchers, and industry. Convening platforms across institutions and stakeholders involved in the bioeconomy facilitates the dissemination of knowledge and innovative technologies, provides access to new markets, and allows producers and industry to achieve economies of scale.130 BioInnovate Africa, for example, provides a platform for scientists and innovators across Africa to collaborate on advancing the research, development, and dissemination of new bioeconomy technologies and knowledge. It also assists in accessing grants and provides support services to partners in order to accelerate the transformation of knowledge into innovative solutions. Similarly, BiomassNet is a pan-African networking platform connecting scientists and experts across public and private sectors working on food and non-food biomass concerns in Africa. Established in 2017 by the Forum for Agricultural Research in Africa (FARA) and the Center for Development Research (ZEF) at the University of Bonn, the BiomassNet project aims to promote innovations in biomass value webs, thereby contributing to food security and the emerging bio-economies in Ghana, Nigeria and Ethiopia. In particular, the online platform focuses on biomass sources such as roots and tubers, cereals and legumes, bamboo, trees and grasses, fruits and nuts, vegetables and mushrooms, and livestock, and eight major thematic areas including Production and Storage, Equipment and Technology, Markets and Trade, Institutions and Policies, Environment and Conservation, Bioenergy, Health and Nutrition, and Education and Capacity Development.131

Leveraging regional strengths and similarities

Bioeconomy has strong regional and local characteristics. Internationally, bioeconomy has diversified rapidly into sub-national patterns. This is caused by location specific forces, especially these three: bioresources, science capacities, and concentrated demand. Policies facilitating regional cooperation are important in the development and scaling of Africa’s bioeconomies.132 Similarities in climatic conditions, flora and fauna, and socioeconomic conditions motivate nations to identify solutions that are contextually appropriate. Moreover, with the increasing globalization of natural resource and governance structures that are built to manage extraction and use of global biomass, strategic partnerships can enable differing comparative advantages from the various actors to work with global resources and global governance structures to yield the most efficient outcomes.133

Successful regional integration of the bioeconomy starts with understanding regional strengths and with the development of regional systems for cooperation such as bio hubs or institutional agreements. BioInnovate Africa’s eastern African innovation consortia works to harness the use of local resources to address public health concerns, particularly on malaria.134 With partners from Burundi, Tanzania, Kenya, and Uganda, the partnership has kickstarted the development of a natural mosquito repellent.135 This BioInnovate Africa regional initiative has helped identify joint challenges and cost-effective solutions that can be scaled regionally.
In 2020, EASTECO hosted the first Eastern Africa Bioeconomy Conference, bringing together actors from seven countries in the region. It aimed to draft a regional bioeconomy strategy that pulls together shared experiences from bioeconomy development on the continent. The conference aimed to develop an enabling environment through shared knowledge, partnerships, investment, and a common regional strategy that is driven by innovation. The current efforts to formulate a regional strategy have encouraged Ethiopia, Uganda, and Tanzania to mobilize funding for research into bioeconomy activities and embark upon planning their own bioeconomy strategies.

**South–South cooperation and learning**

South–South learning and cooperation offers opportunities for the sharing of experiences and successes among countries that have similar experiences. Much like regional cooperation, South–South cooperation allows for developing countries with similar geographical, climatic, and socioeconomic environments to develop contextually aligned solutions by leveraging lessons learned from each other. In particular, knowledge-sharing on the development and implementation of suitable and cost-effective innovative technologies can help countries accelerate the transition to a bio-based economy. For example, the Brazilian Agricultural Research Corporation (Embrapa) has been working with the University of Sciences, Techniques and Technology of Bamako in Mali to develop and deploy mycorrhizal fungi to improve soil quality in Mali. The fungi, which was developed in Brazil, improves phosphorus breakdown in soil, hence its uptake by plants. The project seeks to improve the use of innovative biotechnology processes, thereby benefiting local crop production, improving food security, and increasing incomes in rural communities. This cooperation and knowledge transfer decreased the costs for local smallholders and resulted in the construction of fungi production facilities and a manual for efficient AMF production.

The health biotech sector also offers a number of opportunities for South–South cooperation and learning, particularly across the BRICS countries (Brazil, Russia, India, China, and South Africa). All of these countries have an emerging and rapidly specializing health biotech sector, whether in diagnostics and medical devices (Brazil and South Africa), vaccine development (India), recombinant products (China), or cancer solutions (Brazil). Successful companies from these countries are leveraging local biological products, access to skilled and educated staff, and a carefully designed enabling environment to become major players at the global level. Vision Biotech, for example, is among the largest manufacturers in the world of rapid test kits for malaria, while India’s Serum Institute is now a household name, having produced and supplied the largest share of COVID-19 vaccines to the Global South.

The transition to a sustainable bioeconomy can have significant socioeconomic and environmental benefits. While the terminology and definition of bioeconomy may still be in flux, several African countries and governments already recognize the benefits that can be harnessed from it. They are already making efforts to strengthen the policy and institutional environment to support this transition.
6. METHODOLOGY FOR CASE STUDY SELECTION

The bioeconomy definition adopted at the Global Bioeconomy Summit in 2018 introduced two key changes beyond the traditional production-oriented approach in agriculture, forestry, and fisheries: the added prominence of knowledge (scientific and traditional), technology, and innovation; and an emphasis on the development of bio-based processes, products, and services. When combined with the production and use of biomass, the potential and success of a bioeconomy can be evaluated on three major elements: production and use of bioresources, access to a dynamic innovation system, and the capacity to process or manufacture (or reuse and recycle) new bioproducts.

To identify countries that are leading on the development of bioeconomy and those that have the greatest potential to leverage existing strengths across the three aspects presented above, this methodology draws upon data from the UN IRP Global Material Flows Database, the Global Innovation Index, and World Bank national accounts and OECD National Accounts; they correspond to biomass use, innovation and manufacturing respectively. It then adopts a two-part approach: one part establishes a strong positive relationship between innovation and manufacturing, while the second compares the frontrunners in innovation with current biomass capacity, estimated as the extracted domestic biomass per capita, including crops, crop residues, wood, grazed biomass, and fodder crops.

6.1. Innovation and manufacturing

The GII is produced by Cornell University, INSEAD business school, and the World Intellectual Property Organization (WIPO). It ranks the innovation ecosystem performance of countries around the globe each year. The index averages two sub-indices: an innovation input sub-index and an innovation output sub-index. The innovation input sub-index is made up of five pillars that enable and facilitate innovative activities, including institutions, human capital and research, infrastructure, market sophistication, and business sophistication. The innovation output sub-index is made up of three pillars that measure the results from innovative activities, including knowledge and technology outputs, and creative outputs. The pillars, collectively, are comprised of nearly 80 indicators which provide a comprehensive overview of national performance on skill and knowledge development and on technologies for manufacturing capacities. Countries are scored out of 100. To reduce possible measurement errors, average values of the data for the period 2017-2019 are used. Globally, the best-performing country during this time period has been Switzerland, which scored on average of 67.8 over the three years. In Africa, Mauritius was the best performer in 2017 and 2018, scoring 34.82 and 31.31, respectively. South Africa was the best performer in 2019, scoring 34.04. The median score for 28 African countries over the 2017 to 2019 period is calculated at 24.5; this is set as the threshold for high and low performers.

This indicator is well-correlated to countries’ manufacturing capacities\(^1\), meaning that countries with a high GII score also display a high level of manufacturing capacity. The GII therefore reflects both a country’s level of innovation capacity and the degree to which it is a thriving environment within which the production of bioproducts and bio-based product industries may be scaled up. Therefore, this methodology combines GII and biomass extraction indicators to identify the best performing countries in Africa.

6.2. Biomass use and GII

The second part of this methodology maps biomass use against the GII performance of African countries, with the aim to produce clusters of high and low performers in each combined category. The biomass use data is sourced from the IRP Global Material Flows Database. The Global Material Flows Database\(^2\) provides data to help governments, policy researchers and interested stakeholders understand and trace the linkages between economic growth and raw material usage.\(^3\) The database is based on authoritative, publicly accessible international data sources wherever possible, combined with the most recent methodologies for establishing material flow accounts. It covers the period 1970-2019, for more than 200 countries and reports extraction and direct trade of raw materials, indirect trade flows (including material footprints), as well as intensities derived from these material measures. For biomass, the indicator uses data for four categories: crops, grazed biomass and fodder crops, wood and wild catch and harvest. Data is primarily sourced through FAO.\(^4\)

\(^1\) Authors’ calculations using data for manufacturing value added per capita level (2017-2019) from the World Bank national accounts and OECD National Accounts reflecting countries’ capacities in processing biological resources.
Countries’ biomass capacities and GII scores were organized in descending order and split into two groups, separated by a threshold that was set at the median of each category (average score over the 2017 to 2019 period). The median for the average domestic extracted biomass per capita for the 28 countries over the 2017 to 2019 period was calculated to be 2.55 metric tons (mt) per capita. Countries that reported a biomass per capita equal to or above 2.55 mt per capita were placed in the high biomass per capita cluster and countries below that threshold were put in the lower cluster. Countries scoring 24.5 or higher on the GII were grouped in a high innovation cluster, with the rest put in a low innovation cluster.

Country data for the two indicators were organized into four clusters. This categorization resulted in six countries falling under the combined category of high biomass per capita and high GII: Mauritius, South Africa, Namibia, Uganda, Ghana, Tanzania. For the purposes of this report and to ensure regional representation, Ghana, Namibia, Uganda, and South Africa were selected for in-depth analysis with respect to policy and institutional innovations and programmatic interventions on the grounds that they are contributing toward the development of sustainable bioeconomies.

Table 1. Biomass and Global Innovation Index (GII) clusters

<table>
<thead>
<tr>
<th>Low GII</th>
<th>High GII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cameroon</td>
<td>Mauritius</td>
</tr>
<tr>
<td>Zambia</td>
<td>South Africa</td>
</tr>
<tr>
<td>Benin</td>
<td>Namibia</td>
</tr>
<tr>
<td>Guinea</td>
<td>Uganda</td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>Ghana</td>
</tr>
<tr>
<td>Mali</td>
<td>Tanzania</td>
</tr>
<tr>
<td>Malawi</td>
<td></td>
</tr>
<tr>
<td>Niger</td>
<td></td>
</tr>
<tr>
<td>Ethiopia</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Low biomass</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria</td>
<td>Tunisia</td>
</tr>
<tr>
<td>Nigeria</td>
<td>Botswana</td>
</tr>
<tr>
<td>Togo</td>
<td>Morocco</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>Egypt</td>
</tr>
<tr>
<td>Mozambique</td>
<td>Senegal</td>
</tr>
<tr>
<td></td>
<td>Côte d’Ivoire</td>
</tr>
<tr>
<td></td>
<td>Kenya</td>
</tr>
<tr>
<td></td>
<td>Rwanda</td>
</tr>
</tbody>
</table>
1. INTRODUCTION

Ghana is endowed with diverse plant, animal, and insect species across its regions and agroecological zones. This rich diversity of biological resources is an important precursor to the country's development of an effective and sustainable bioeconomy. Over the years, Ghana has demonstrated the important role that science, technology, and innovation can play as critical drivers for socio-economic development and for the development of a bioeconomy. Currently, Ghana's bioeconomy-related activities are centered on agriculture, forestry, renewable energy resource management, and waste management. It has established a wide range of industries for cocoa, cashew, and shea and for the by-products of these crops. This, in turn, provides a strong foundation for scaling up its emerging bioeconomy to other sectors, including energy and waste. This case study identifies the current state of the country's bioeconomy—what it has done right in terms of institutional and policy innovations and what programmatic interventions it has initiated to accelerate bioeconomy development. It highlights the positive impacts of some of these policies and programs and the opportunities they present for local and international collaboration in the development of a sustainable bioeconomy. If brought to scale, the initial interventions to develop a bioeconomy have the potential to transform a broad range of sectors.

2. INSTITUTIONAL INNOVATIONS

2.1 Scientific research for bioeconomy: The Ministry of Environment, Science, Technology and Innovation and the Council for Scientific and Industrial Research

Biomass-rich African countries, including Ghana, are increasingly acknowledging the economic potential and sustainability of the transition to a bio-based economy. Over the last two decades, the Government of Ghana (GoG) has introduced several interventions to help transition Ghana into the global bioeconomy. The current institutional framework in Ghana facilitates the optimal and sustainable exploitation of these emerging and potential opportunities for the successful development of a bioeconomy. Although there is no single institution responsible for overseeing the bioeconomy, the Ministry of Environment, Science, Technology, and Innovation (MESTI) plays a prominent role. It is tasked with advancing Ghana's socioeconomic development using environmentally friendly, scientific, and technological practices and techniques. To achieve this goal, MESTI's key task is to craft a sound enabling environment to support the growth of national science and innovation frameworks. This Ministry oversees six semi-independent national agencies, of which three—the Council for Scientific and Industrial Research (CSIR), the Environmental Protection Agency (EPA), and the National Biosafety Authority (NBA)—are directly linked to promoting Ghana's bioeconomy. In addition, the Biotechnology and Nuclear Agricultural Institute overseen by Ghana Atomic Energy Commission at MESTI, also conducts R&D to explore the application of isotope, ionizing radiation and other nuclear techniques and related biotechnologies for increased agricultural and economic development. Working alongside MESTI and its agencies are the Cocoa Research Institute of Ghana and COCOBOD, specializing in both, upstream and downstream development of cocoa value chains Working alongside MESTI and its agencies are the Cocoa Research Institute of Ghana and COCOBOD, specializing in both, upstream and downstream development of cocoa value chains. CRIG, in particular, has a long history of research on tree crops of economic importance to Ghana, including cocoa, coffee, kola, and cashew. These research institutions drive the formal public sector innovation in agriculture in Ghana.

2.2 Collaboration at the helm: Council for Scientific and Industrial Research

CSIR is Ghana's principal national research institution. Established prior to the country's independence and known then as the National Research Council, CSIR has undergone a number of fundamental structural changes since 1958. Its current configuration is the outcome of the adoption of the CSIR Act 521 in 1996. CSIR is overseen by a Statutory Governing Council that is composed of representatives from:

- the Ministries of Food and Agriculture (MoFA); Health; Trade and Industry; Education; and Environment, Science, Technology and Innovation;
- universities;
- commercial associations representing mining, industry, commerce, and engineering;
- the Ghana Academy of Arts and Sciences; and
- the National Development Planning Commission.

The inclusion of representatives of the MoFA on the board of CSIR ensures that agricultural research carried out at the institutes is aligned with national agricultural policies. Equally importantly, the CSIR Act requires that 40 percent of CSIR membership is drawn from the private sector, a structure that is designed to foster collaboration across stakeholders. Not only is CSIR mandated to conduct and coordinate research into scientific and
The research institutes comprising the CSIR include: Animal Research Institute (ARI), Crops Research Institute (CRI), Soil Research Institute (SRI), Oil Palm Research Institute (OPRI), Food Research Institute (FRI), Forestry Research Institute of Ghana (FORIG), Plant Genetic Resources Research Institute (PGRRI), Savanna Agricultural Research Institute (SARI), Water Research Institute (WRI) and Science and Technology Policy Research Institute (STEPRI).

CSIR is Ghana’s main agency for agricultural R&D. It receives about 50 percent—the largest share—of public agricultural R&D expenditure, and public funds underpin as much as 80 percent of CSIR’s total annual budget. This is both a boon and a curse, however, as funding fluctuates in line with annual public spending. Long-term research planning is therefore a challenge and the capacity to make capital investments in, for example, laboratory equipment is impacted. A large share of CSIR’s annual budget is in fact expended on direct costs such as salaries, and it is expected that any shortfalls in disbursed funds should be covered by international partners. Despite this, CSIR has been almost solely responsible for the identification and generation of agricultural technology in the country, even if its commercialization is limited. MoFA is the primary disseminator of agricultural research outputs generated by CSIR.

### 2.3 Advancing food bioeconomy: Food Research Institute

Within CSIR, the Food Research Institute (FRI) also supports bioeconomy development. Its mandate is to support the food industry by addressing research questions related to food processing and preservation, food safety, storage, marketing, distribution and utilization, and national food and nutritional security; it also advises the government on food policy. To be successful in achieving its aims, FRI works closely with entrepreneurs, food processors, the local food industry, the Food and Drugs Authority, and the Ghana Standards Board. An internal evaluation of FRI revealed that the institute benefits from high quality, and technically proficient staff, who have a multi-disciplinary approach to work; well-equipped laboratories and good access to machinery and other equipment; high quality work on nutrient analysis and food technology; and proven track record on commercial uptake of results. However, there are growing overlaps between FRI and other institutions that are challenging its continued success. Despite this, FRI has successfully introduced a variety of new products and technologies. For example, FRI engaged with farmers, processors, consumers, and policymakers to enhance the production, processing, marketing, and consumption of Ghana’s edible and medicinal mushrooms. It also provides stakeholders in the food industry with support in primary food processing and equipment. The FRI has developed several technologies on food value addition, enhanced food processing technologies, and Hazard Analysis and Critical Control Points (HACCP) systems for various food processing lines. These include technologies for processing fufu flours (yam, cocoyam, plantain), improved kokonte and gari, Banku Mix Powder, fermented maize meal powder, high quality cassava flour, cassava starch, rice- and maize-based cereal (baby weaning food / breakfast meal), and fruit juice. The new technologies have led to a reduction in postharvest losses, particularly in fruits and vegetables. Many small and medium-sized agro-based enterprises have also emerged from technology transfers from these institutions.

### 2.4 Deploying nuclear techniques for agricultural development: Biotechnology and Agricultural Research Institute

The Biotechnology and Nuclear Agricultural Institute (BNARI) was established in 1993 to support the scientific and rural communities to develop improved crop and livestock varieties, to improve food quality
and its nutritive value, to raise the level of nutrition by improving food quality, to identify solutions for animal production and health, and to minimize harmful residue in food and other agricultural products. BNARI undertakes scientific and industrial research in collaboration with government agencies, research institutions, universities and the private sector to deploy processes such as irradiation to preserve food, radioisotopic methods and radioimmunoassays to address animal nutrition and reproduction, radiation-induced sterile insect technique to manage pests and diseases, and in-vitro tissue culture and germplasm conservation for plant regeneration. While the R&D programs are approved by the management board, they are financed by funds from the public sector, international organizations and developmental partners. To date, BNARI established Ghana’s largest functional tissue culture laboratory, where it analyzes and grows explants from selected crops in vivo and in vitro. The institute has been able to develop improved varieties of many food crops, including an improved cassava and a cacao plant resistant to “swollen shoot” disease. BNARI has collaborated with Bioplantlet Company Limited (a subsidiary of the Sea-freight Pineapple Exporters of Ghana) to mass-produce planting materials of a pineapple variety to boost its production for the export market. BNARI also houses one of the few gamma radiation facilities on the continent which enables the country to meet export standards and reduce quarantine periods in importing countries. It has also developed standards for irradiated food. Previously, BNARI collaborated with the Animal Research Institute at CSIR (CSIR-ARI) to deploy sterile insect technology for the eradication of tsetse flies.

2.5 Transforming the cocoa sector with biosciences and technology

Cocoa Research Institute of Ghana

The cocoa subsector remains a significant contributor to Ghana’s GDP. In 2020, it contributed US$385 million to GDP and employed about 800,000 farm households, spread over six regions of the country. Ghana’s cocoa is considered to be the gold standard in the international market in terms of quality and Ghana is now the second-largest producer of cocoa beans in the world. The Cocoa Research Institute of Ghana (CRIG) was formed out of the West African Cocoa Research Institute (WACRI) after independence. CRIG’s initial mandate was to investigate the pests and diseases that were having a considerable effect on cocoa production. In 1993, a New Products Unit was created at CRIG, mandated to diversify cocoa products and to help farmers generate extra income by processing their produce and by-products. Since then, several new and innovative products have been designed, some of which have been adopted by entrepreneurs for commercial production. For example, Kasapreko Co. Ltd. is a leading manufacturer of alcoholic and non-alcoholic beverages in Ghana. One of its more successful products is cocoa brandy, which it bottles for the local and export market.

CRIG’s mandate was subsequently expanded to include research on other indigenous and introduced tree crops that produced fats similar to cocoa butter, particularly cashews and shea nuts. Since 2002, cashews have become a mandate crop of CRIG. The institute now conducts research into the development of by-products of cocoa and the other mandate crops with the aim of diversifying utilization and generating additional income for farmers. CRIG’s research activities have led to successes which include: isolation and characterization of the cacao swollen shoot virus and the development of diagnostic methods; identification of fast-growing, exotic, and indigenous shade trees for cocoa; a better understanding of cocoa fermentation and flavor chemistry; the production of by-products from cocoa wastes, including pectin, alcohol and alcoholic beverages, animal feed, soap, and cosmetics. CRIG has won several awards for research achievements both at the local level and at international fairs. In conjunction with the Animal Research Institute (ARI) and KNUST, it has produced a number of products from cocoa pod husk (CPH), including animal feed, potash for soaps, and fertilizers; it has also successfully developed useful products from the apple and nut of cashew fruits, including wine, vinegar, industrial alcohol, and brandy.

COCOBOD

The success of Ghana’s cocoa sector can largely be attributed to the programs put in place and managed by the state-run marketing board, COCOBOD, which was established in 1947 as the Cocoa Marketing Board. It was mandated to support the production, research, extension, marketing, and quality control of Ghana’s cocoa, coffee, and shea nut outputs. Although CRIG leads science and technology inputs for the cocoa industry, COCOBOD works through CRIG to develop and introduce a new curriculum for extension and offers training to these extension agents. COCOBOD, through specialized divisions, also oversees both pre- and postharvest elements of the value chain. It is responsible for the regulation of the domestic purchasing of cocoa, coffee, and shea nut in such a way that the most favorable outcomes are secured in the purchase, grading and packaging, certification, and sale and export of the three crops.

** CRIG won the award for Research & Development Organisation of the Year at the 2019 Ghana Cocoa Awards and a CRIG researchers won Woman of Excellence (Research) in 2020.
COCOBOD and the broader cocoa sector in Ghana have undergone three significant structural changes since the colonial period. Its current fourth phase seeks to balance the economics with social and environmental outcomes. COCOBOD currently has five subsidiaries/divisions: Cocoa Research Institute, Seed Production Division, Cocoa Health and Extension Division, Quality Control Division, and the Cocoa Marketing Company. The Quality Control Division—since renamed the Quality Control Company—remains responsible for ensuring that the overall quality of the beans is kept to a high standard. It conducts quality checks of cocoa beans at different collections points, including in villages, at district-level depots, and at ports immediately before export. The Quality Control Company is solely responsible for the inspection and certification of storage sheds across the country; no grading or sealing or storage of any cocoa is allowed anywhere without prior certification by the QCC. QCC is also responsible for fumigation and disinfection. The Cocoa Marketing Company (CMC) remains the only exporter of Ghanaian cocoa, while COCOBOD operates as the sole buyer in the domestic market. QCC samples and certifies (“purity certificate”) cocoa prior to shipment for export.

After the sector reforms of the early 1990s, the structure and functioning of the internal market saw the farm-gate procurement of cocoa delegated to a growing number of private licensed buying companies (LBCs), with COCOBOD being responsible for issuing their licenses. LBCs entered the domestic segment of the cocoa supply chain as competitors, but they were required to pay producers amounts that were equal to, or greater than, the announced prices. This institutional change re-energized the cocoa industry then and has resulted in greater innovation in the sector.

In the 2000s, a renewed effort to further boost growth in the cocoa sector took place. COCOBOD implemented a Hi-Tech program and a Cocoa Diseases and Pest Control (CODAPEC) program to reverse declines in yield and raise production to a target level of 1 million metric tons (Mmt) of beans. The policies implemented since 2001 have generated a remarkable turnaround in land productivity. Over the years, COCOBOD has implemented or supported the implementation of various cocoa-related programs to enhance either yields or quality. These include mass spraying, cocoa sector development strategies, and cocoa high tech (fertilizer subsidy) programs, all of which have resulted in a growth in production.

Growth in yields has accounted for 80 percent of the growth in cocoa production between 2001 and 2010, with annual growth in land productivity at 5.5 percent per year over the period.

More recently, efforts have been made to enhance the processing of cocoa beans and the conversion of cocoa by-products into useful products through value addition. The objective in the cocoa sector is to achieve up to 50 percent processing (value addition) of the annual cocoa production. To that end, in 2019 the Ghana Cocoa Board signed a memorandum of understanding (MoU) with the China-Africa Development Fund and China’s Genertec International
Corporation for the establishment of a US$100 million cocoa processing factory at Sefwi Wiawso, the main cocoa producing area in Ghana. It is expected that, upon completion, the factory will have a capacity to process 450,000 metric tons (mt) annually; this will boost Ghana’s exports, improve value addition and increase domestic cocoa consumption. As of the 2018/2019 cocoa season, Ghana’s cocoa grindings were estimated at 300,000 mt, which represented about 37 percent of the country’s cocoa bean production. The cocoa pod husks will be processed into animal feed, potash for soft soap manufacturing, compost and organic fertilizer; cocoa “sweatings” (pulp juice) will be processed into soft drinks, wine, vinegar, alcohol and pectin. Discarded cocoa beans can be processed into cocoa butter soap and into cosmetics that use a cocoa butter base. If the needed investments and institutional support can be guaranteed, these developments in the cocoa sector will propel Ghana’s development toward a successful bioeconomy. As part of the European Green Deal, the cocoa sector will constitute a flagship partnership for its European partners; its aim is to ensure a decent income for farmers and deforestation-free and child-labor-free cocoa production. As part of sustainable cocoa production, Ghana’s European partners, together with the private sector and NGOs, aim to work together to address the various challenges facing the country’s cocoa sector.

2.6 Technology transfer and commercialization

The success of bioeconomy development hinges on the availability of, and access to, appropriate technology within the agricultural and food subsectors. The Ghana Regional Appropriate Technology Industrial Service (or GRATIS) Foundation is a government agency that was incorporated in 1999 under the Ministry of Trade and Industry (MoTI). Overseen by a Board of Directors appointed by the Ministry, GRATIS provides support to industries, including those that are bio-based; it helps these industries to design, develop, manufacture, and market appropriate technology-based products and services for small, medium, and micro enterprises (SMMEs), with the aim of facilitating socioeconomic and industrial development in Ghana and other African countries. The main aim is to reduce postharvest losses and ensure value addition through agro-processing, while preserving the environment and improving sanitation. In particular, GRATIS manufactures agro-processing equipment for palm oil extraction and processing shea butter, fruits, cassava, cereals, and grains. Examples of such equipment include grinding mills, poultry feed mixers, maize thresher, multicrop threshers (for cereals and legumes), cassava graters, fufu processors, chipping machines (for cassava), palm fruit strippers, palm fruit steamers, palm oil expellers, and palm nut crackers. These pieces of equipment are sold to individuals, SMMEs, companies, farmers, and/or farmer groups involved in Ghana’s agricultural value chain.

In 2018, MESTI launched the Ghana Innovation and Research Commercialization Centre (GIRC-Centre) to facilitate the commercialization of research findings by strengthening partnerships between the Government, public research institutions, academia, and the private sector. Although the Centre was not operational at the time of writing, it is expected to foster interministerial and international research collaboration; solicit, evaluate and support projects that are aligned to the national development agenda; and institute solid monitoring and evaluation and economic impact assessments; thereby harmonizing innovations and research activities in Ghana.

2.7 Sustainability education and innovation at higher education institutions

Since the early 2000s, the GoG has shown renewed interest in increasing the role of tertiary institutions in developing science and technology to enhance economic development. Several biotechnology programs have been launched at Ghanaian universities, including the University of Ghana Biotechnology Research Centre, the Department of Biochemistry and Biotechnology at the Kwame Nkrumah University of Science and Technology (KNUST), the Molecular Biology and Biotechnology Department at the University of Cape Coast (UCC), and the Department of Biotechnology at the University for Development Studies (UDS). These departments run undergraduate and postgraduate programs in biochemistry, molecular biology, and biotechnology. Although most of the programs still focus on biosciences, recent developments have shown that when given the necessary support and funding, they can play significant roles in training individuals to fulfill the labor requirements of a successful bioeconomy.

These higher education institutions are well positioned to contribute to the Ghanaian bioeconomy. They play an important role in offering solutions to pertinent national sustainability challenges through related R&D, science and technology curricula, teaching, and general engagement with society. Universities are also scaling up demand-driven research that accelerates the growth of Ghana’s bioeconomy. In 2010, for example, the Department of Nutrition and Food Science at University of Ghana collaborated with the Cocoa Processing Company Ltd to produce a low-calorie sugar-free chocolate made from a
In 2010, the University of Ghana established an Office of Research, Innovation and Development (ORID) to promote, facilitate, and coordinate cutting-edge research. In addition to grant and research support, ORID also assists with IP and technology transfer through its Technology Development and Transfer Centre (TDTC). In 2012, University of Ghana also launched the Institute of Applied Science and Technology (IAST) to build strategic partnerships between academia and industry. IAST facilitates partnerships through networking opportunities such as exhibitions, symposia, workshops, and seminars to enhance engagement and showcase technologies. These two additions to the University of Ghana serve as a conduit between industry and academia to demonstrate research concepts, commercialize outcomes, and secure the necessary IP.

Growing proficiency in bioeconomy-related subjects also provide a platform for international bioeconomy programs to partner locally. For example, from 2014-2017, the University of Ghana’s Institute of Agricultural Research and Tropical Agricultural Marketing and Consultancy Services (TRAGRIMACS) partnered with the United Nations Industrial Development Organization (UNIDO) to promote neem-based biopesticides in Ghana. While the university oversaw bioefficacy and phytotoxicity studies and field trials, TRAGRIMACS was responsible for raising awareness of the project and establishing a production and distribution center. In addition to providing training for stakeholders, the project also transferred the low-cost technology to the University of Ghana to produce neem kernel aqueous extract.\(^\text{174}\) A study in 2020 conducted by the Savanna Agricultural Research Institute (CSIR-SARI) and other institutions have revealed that the neem-based biopesticides are as effective as synthetic/chemical pesticides in fighting the Fall Armyworm (FAW) in Ghana.\(^\text{176}\)

Another successful partnership with international institutions is that with the Open Bioeconomy Lab,\(^\text{††}\) which, through the Hive Biolab, serves as a platform for providing training to university students, graduates, and Ghanaian academics in emerging and cutting-edge advances in biotechnology such as synthetic biology, genetic engineering, and DNA technology.\(^\text{177}\)

2.8 Harnessing indigenous and herbal medicines for bioeconomy

In Ghana, efforts to promote traditional/herbal medicine practice started with the creation of the Ghana Psychic and Traditional Healers Association in the 1960s. These efforts were validated in 2000 when the Traditional Medicine Practice Act 2000, Act 375 was passed. The Act regulates herbal medicines and the practice of traditional medicine. In 2011, herbal clinics were piloted in selected government hospitals nationwide, and in September 2012 the practice of clinical herbal medicine was integrated into Ghana’s main healthcare delivery system by the Ministry of Health.\(^\text{178}\) This integration was pushed for by the Ghana Association of Medical Herbalists (GAMH) with support from the Business Sector Advocacy Challenge Fund (BUSAC). The process that eventually led to the integration of herbal medicines into standard healthcare delivery involved the participation of public and private sector organizations and of research and financial institutions, and the drawing up of legislation that backed the activities of all stakeholders, thus demonstrating a process that will be vital for the full development of Ghana’s bioeconomy. Indigenous and herbal medicine in Ghana received a further boost when the Food and Drugs Authority (FDA) approved the first herbal medicine (Cryptolepis sanguinolenta) for clinical trials on COVID-19 treatment.\(^\text{179}\)

2.9 Ensuring public safety in bioeconomy

Ghana’s Food and Drugs Authority is another institution that could play a vital role in its potential bioeconomy transition. In order to protect public safety, the Food Division of the FDA ensures food product registration, premises registration, and post-approval market surveillance of food and feed. It is responsible for foodborne disease surveillance and investigation, and serves as the contact point for Ghana’s International Food Safety Authorities Network (INFOSAN).\(^\text{180}\) It also organizes training on biosafety, conducts consumer complaints investigations, and is responsible for the approval of drugs (including herbal medicines) for use. Ghana’s FDA is classified as a World Health Organization (WHO) “maturity level 3” regulatory agency, making it only the second African healthcare institution with this classification.

3. POLICY INNOVATIONS

Over the last one to two decades, the GoG has made tremendous efforts and robust commitments toward enhancing the bioeconomy via a number of policy innovations; the overarching goals have been to alleviate poverty and stimulate accelerated national economic development.\(^\text{181}\) While agricultural

\(^{††}\) The Open Bioeconomy Lab is an interdisciplinary research group based in the Department of Chemical Engineering and Biotechnology at the University of Cambridge; it works closely with researchers in Cameroon and Ghana. In 2011, nodes of the lab were established at Mboalab and Hive Biolab in Kumasi.

healthy sugar substitute called maltitol.\(^\text{173}\) This in turn endorsed the need for support systems to strengthen links with industry.

In 2010, the University of Ghana established an Office of Research, Innovation and Development (ORID) to promote, facilitate, and coordinate cutting edge-research. In addition to grant and research support, ORID also assists with IP and technology transfer through its Technology Development and Transfer Centre (TDTC). In 2012, University of Ghana also launched the Institute of Applied Science and Technology (IAST) to build strategic partnerships between academia and industry. IAST facilitates partnerships through networking opportunities such as exhibitions, symposia, workshops, and seminars to enhance engagement and showcase technologies. These two additions to the University of Ghana serve as a conduit between industry and academia to demonstrate research concepts, commercialize outcomes, and secure the necessary IP.\(^\text{174}\)

Growing proficiency in bioeconomy-related subjects also provide a platform for international bioeconomy programs to partner locally. For example, from 2014-2017, the University of Ghana’s Institute of Agricultural Research and Tropical Agricultural Marketing and Consultancy Services (TRAGRIMACS) partnered with the United Nations Industrial Development Organization (UNIDO) to promote neem-based biopesticides in Ghana. While the university oversaw bioefficacy and phytotoxicity studies and field trials, TRAGRIMACS was responsible for raising awareness of the project and establishing a production and distribution center. In addition to providing training for stakeholders, the project also transferred the low-cost technology to the University of Ghana to produce neem kernel aqueous extract and standardized technology for seed collection.\(^\text{175}\) A study in 2020 conducted by the Savanna Agricultural Research Institute (CSIR-SARI) and other institutions have revealed that the neem-based biopesticides are as effective as synthetic/chemical pesticides in fighting the Fall Armyworm (FAW) in Ghana.\(^\text{176}\)

Another successful partnership with international institutions is that with the Open Bioeconomy Lab,\(^\text{††}\) which, through the Hive Biolab, serves as a platform for providing training to university students, graduates, and Ghanaian academics in emerging and cutting-edge advances in biotechnology such as synthetic biology, genetic engineering, and DNA technology.\(^\text{177}\)

2.8 Harnessing indigenous and herbal medicines for bioeconomy

In Ghana, efforts to promote traditional/herbal medicine practice started with the creation of the Ghana Psychic and Traditional Healers Association in the 1960s. These efforts were validated in 2000 when the Traditional Medicine Practice Act 2000, Act 375 was passed. The Act regulates herbal medicines and the practice of traditional medicine. In 2011, herbal clinics were piloted in selected government hospitals nationwide, and in September 2012 the practice of clinical herbal medicine was integrated into Ghana’s main healthcare delivery system by the Ministry of Health.\(^\text{178}\) This integration was pushed for by the Ghana Association of Medical Herbalists (GAMH) with support from the Business Sector Advocacy Challenge Fund (BUSAC). The process that eventually led to the integration of herbal medicines into standard healthcare delivery involved the participation of public and private sector organizations and of research and financial institutions, and the drawing up of legislation that backed the activities of all stakeholders, thus demonstrating a process that will be vital for the full development of Ghana’s bioeconomy. Indigenous and herbal medicine in Ghana received a further boost when the Food and Drugs Authority (FDA) approved the first herbal medicine (Cryptolepis sanguinolenta) for clinical trials on COVID-19 treatment.\(^\text{179}\)

2.9 Ensuring public safety in bioeconomy

Ghana’s Food and Drugs Authority is another institution that could play a vital role in its potential bioeconomy transition. In order to protect public safety, the Food Division of the FDA ensures food product registration, premises registration, and post-approval market surveillance of food and feed. It is responsible for foodborne disease surveillance and investigation, and serves as the contact point for Ghana’s International Food Safety Authorities Network (INFOSAN).\(^\text{180}\) It also organizes training on biosafety, conducts consumer complaints investigations, and is responsible for the approval of drugs (including herbal medicines) for use. Ghana’s FDA is classified as a World Health Organization (WHO) “maturity level 3” regulatory agency, making it only the second African healthcare institution with this classification.

3. POLICY INNOVATIONS

Over the last one to two decades, the GoG has made tremendous efforts and robust commitments toward enhancing the bioeconomy via a number of policy innovations; the overarching goals have been to alleviate poverty and stimulate accelerated national economic development.\(^\text{181}\) While agricultural

healthy sugar substitute called maltitol.\(^\text{173}\) This in turn endorsed the need for support systems to strengthen links with industry.
and forestry policies boost the production and processing of renewable biomass, environmental and waste management policies provide a baseline for ensuring that Ghana’s bioeconomy development is sustainable.

3.1 Agricultural and forestry policies to facilitate biomass supply

Developing a sustainable bioeconomy requires adequate production and availability of biomass. This implies that an increase in the productivity of traditional cropping systems is a significant precondition for the successful development of a bioeconomy.\textsuperscript{182} Ghana has a vibrant and effective institutional framework with which to drive the formulation, implementation, and development of policies that can contribute to the development of a bioeconomy.

The Ghana Shared Growth and Development Agenda (GSGDA) I (2010–2013) and II (2014–2017) were medium-term policy frameworks that sought to ensure accelerated agricultural modernization and enhance natural resource management, energy development, sustainable employment creation, and income generation, with the primary aim of reducing poverty. The implementation of the agricultural component of GSGDA I and II hinged on strategies to facilitate value chain efficiency; these included improved agricultural productivity, enhanced integration of farmers into domestic and international markets, sustainable natural resource and biodiversity management, and building farmers’ resilience against climate change.\textsuperscript{183,184} While the implementation of the 2002 Food and Agricultural Sector Development Policy I (FASDEP I) emphasized strategies to modernize the agricultural sector, FASDEP II (introduced in 2007) emphasizes the sustainable utilization of all resources and the commercialization of activities in the sector, with market-driven growth.\textsuperscript{185} The implementation of agricultural sector policy reforms led to a steady increase in the average growth rate of the sector, rising from an average of 3.6 percent during the 1993 to 1997 period to an average of 4.9 percent in the 2013 to 2017 period.\textsuperscript{186} The additional biomass resulting from the growth in productivity is a key input into Ghana’s emerging bioeconomy.

Alongside agricultural biomass, Ghana’s policymakers have also sought to increase renewable biomass from the forestry sector. In 2015, the GoG initiated the establishment of woodlots and forest plantations on 500,000 hectares (ha) of degraded land, to be cultivated by 2040.\textsuperscript{187} As a strategy to promote a bio-based renewable energy agenda, more biomass would be produced from forest residues as off-cuts from timber and as a by-product of the processing of timber or agricultural products. Under the Ghana Forest Plantation Strategy of 2016 to 2040, the country aims to ensure biomass availability from forest residues by:

- Establishing and managing planted forests,
- Promoting forest plantation investment,
- Creating employment and sustainable livelihoods, and
- Increasing investment in research and development.
3.2 Deploying climate change policies to foster bioeconomy

In 2013, MESTI introduced the National Climate Change Policy (NCCP). The NCCP looks to integrate a response to climate change, build resilience, and harness the opportunities of green growth across five focus areas: agriculture and food security; disaster preparedness and response; natural resource management; equitable social development; and energy, industrial, and infrastructure development. Updated in 2015, the NCCP outlines specific policy actions for ten multisectoral areas in order to address the multifaceted impacts of climate change across the country and to operationalize the effective development of NCCP objectives. MESTI works on sectoral climate issues with the Ministry of Trade and Industry, MoFA, metropolitan, municipal, and district assemblies, the Ministry of Fisheries and Aquaculture Development, and CSIR; together they lead the implementation of the NCCP’s eight specific sector programs. The Climate-Smart Agriculture and Food Security Action Plan (CSAFSAP), for example, is led by MoFA. It outlines the implementation framework necessary to mainstream climate resilience and adaptation planning into agriculture and food development activities. Totaling US$950 million of both government and international donor funding, the CSAFSAP outlines eight programs and activities: strengthening national climate research and educational services, developing innovative and climate-smart production techniques and systems for agriculture and fishing, supporting smart water management, de-risking the food and agricultural sector, and improving the productive capacity of farmers and rural communities. Proposed activities include developing extension services; financing research on climate-smart agricultural technologies and processes; expanding sustainable water harvesting, storage, and irrigation systems; and establishing insurance schemes. The CSAFSAP is further bolstered by the publication of Ghana’s Nationally Determined Contributions (NDCs). In 2021, Ghana submitted its revised NDCs document, in which it highlighted the expected mitigation co-benefits in the agriculture and health sectors delivered through climate-smart agricultural and sustainable land management practices, ecotourism, the Green Ghana initiative, and disease surveillance and climate early warning systems.

3.3 Waste management and recycling

Ghana’s Solid Waste Management Strategy (SWMS), under the Ministry of Sanitation and Water Resources, seeks to achieve progressive, high quality, and cost-effective SWM service delivery such that it provides environmental, public health, and economic benefits to all. This strategy is built around seven pillars: strengthening sector governance; increasing private sector participation; optimizing service delivery and infrastructure; creating positive social action on SWM; enabling effective waste recovery, re-use, and recycling; ensuring effective sector monitoring and evaluation; and establishing sustainable sector financing mechanisms. In line with the second pillar, the Accra Compost and Recycling Plant was established to recycle solid and liquid waste to produce organic compost. This has led to the creation of 500 direct and indirect jobs and a daily capacity of 100 mt of compost.

Biomass waste to energy

In 2010, the Ghana National Energy Policy was promulgated; it seeks to enhance the transformation of waste (including agricultural waste and other biomass) into energy through various technological approaches. To ensure sustainability, the policy offers various bioeconomy opportunities for investments in the renewable energy subsector. Ghana’s Renewable Energy Act, 2011 (Act 832) was particularly effective; it enshrined a feed-in-tariff (FiT) scheme that was instituted for electricity generated from renewable energy sources such as biomass. It was designed to support the target of 10 percent renewable energy in the national energy mix and to ensure that investors obtained a good return on their investments. In 2020, as a result of these interventions, four biomass-fired cogeneration plants were operating in Ghana, with a combined installed capacity of 4,034 kW and an average annual production of 12.3 GWh. Another important initiative to support the development of the bioeconomy was the GoG’s program to install biomass/waste-to-energy power plants by 2020, with capacities ranging from 50 to 100 MW. As part of this strategy, by 2014 the Ministry of Energy had installed 49 institutional biogas systems.

4. PROGRAMMATIC INTERVENTIONS

A number of Ghana’s existing programmatic interventions support the development of a bioeconomy. These programs focus on a wide range of sectors including agriculture and climate change, energy, biodiversity, and water and sanitation. The following sections present a review of such interventions in Ghana.

4.1 Ghana Agriculture Sector Investment Program

The Ghana Agriculture Sector Investment Program (GASIP) contributes to bioeconomy development through agricultural investments in increased biomass production. GASIP is a six-year program...
Cassava is a major staple crop in Ghana and it has the advantage of being able to produce economic yields even under marginal production conditions. The crop accounts for approximately 50 percent of all root and tuber production in the country and is second only to maize in terms of area planted. It is consumed in all regions and by all ethnic groups, and is therefore considered to be a primary food security crop. Cassava starch can be converted into ethanol production, which is a key ingredient in alcoholic drinks and in pharmaceuticals such as hand sanitizers. The Presidential Special Initiative on Cassava that was commissioned in 2003 was aimed at developing industrial cassava starch production for both the domestic and international markets; it aimed, in the process, to also improve the socioeconomic conditions of Ghana’s smallholders. A new factory, Ayensu Starch, was commissioned in 2004 to supply a growing domestic and global market for starch, in turn creating a market for cassava growers. The firm, however, was plagued with high operational costs and technological challenges which on two occasions culminated in temporary shutdowns, thus necessitating a more focused and sustainable operational strategy. In 2012, in order to revive the program, the GoG introduced a concessionary excise duty waiver for manufacturers who used local raw materials. Within six months, Ayensu Starch signed an exclusive supply agreement with Guinness Ghana Breweries Limited (GGBL) to supply high quality cassava starch, which the brewery uses to produce one of its brands of beer for the domestic market. This was soon followed by the production from cassava starch of Accra Brewery’s own beer brand, Eagle Lager. Cassava starch has since also found a market in the production of biscuits and other household products. About half of the Ayensu Starch Factory’s cassava is grown on its own farms, while the rest is sourced from about 400 smallholder outgrowers who are issued quality guidelines that they must meet. Waste products from the process of extracting starch, such as peels and pulp, are then sold on to local livestock enterprises, which earns the company additional revenue. The simple intervention to attract private sector players in the use of cassava and starch has kickstarted a revolution in Ghana’s cassava sector, with its products and by-products featuring in food processing, baked products, paperboard manufacturing, domestic plywood outputs, and bioethanol and biogas.

4.3 Biogas Technology and Business for Sustainable Growth

Biogas Technology and Business for Sustainable Growth (BTBSG) was a 2013 to 2016 program to assist Ghana’s green industries. It was implemented by UNIDO in partnership with the Ministry of Trade, Industry and Energy (MoTIE) of Korea and the Korea Institute of Energy Technology Evaluation and Planning (KETEP). The BTBSG program builds on empirical evidence on the state of biogas industries in Ghana and on lessons drawn from past and current biogas initiatives in the country. The program’s two main aims are to enhance access to clean energy via the promotion of industrial-scale biogas technologies in the form of an integrated technology transfer, and to support the development of biogas enterprise in Ghana. A number of biogas plants have been created at abattoirs, homes, health and educational institutions, and at various other locations across the country.
5. CONCLUSION

Ghana’s economy is largely driven by agriculture, and the export of processed wood and raw produce, all of which result in the generation of huge volumes of biomass waste. This waste is usually disposed of by burning, which releases harmful greenhouse gases into the environment. Meanwhile, the availability of these large stocks of biomass makes the country highly suitable for setting up bio-industries and a thriving bioeconomy. Although Ghana, like many countries in Africa, still has no explicit policy on bioeconomy, many past and present government policies and programs—particularly in the agricultural, energy, and forestry sectors—contain components that promote various aspects of a bioeconomy. The development of strategic bioeconomy blueprints will not only help prioritize investments and government interventions in Africa; it will also guide a policy agenda for bio-based economic growth and sustainable development.

Ghana’s current institutional frameworks, policies, and programs that are closely related to bioeconomy development are often linked to agricultural, energy, forestry, technology, and innovation strategies. In order to take advantage of opportunities in emerging bioeconomy sectors, Ghana must make necessary targeted investments in research and innovation, enhance capacity at the institutional level, and improve general governance. For example, as Ghana’s biobased industrial activities and enterprises grow, so will the demand for institutions and services to oversee quality management. There is also an urgent need to build stronger linkages between actors in the innovation ecosystem and entrepreneurs who scale the production of outputs from the bioeconomy. This will help ensure that the benefits that accrue from innovations reach end users and support the financing efforts of research institutions. At the same time, greater internal collaboration among institutes would also attract more projects, deliver greater impacts, and enhance financial sustainability. Although MESTI has proposed an apex statutory body to coordinate and harmonize the new policy and other national STI programs, the Presidential Advisory Council on Science, Technology and Innovation is not yet operational. Such a council can be an important voice in advancing the development of Ghana’s bioeconomy, and ensuring that the benefits realized from the bioeconomy contribute to sustainable economic growth. It can also support efforts to raise public sector budget allocations to R&D from the current 0.3 percent of GDP to 1 percent, as set out by the African Union.
1. INTRODUCTION

Namibia is endowed with exceptional natural resources and a diverse range of species and habitats. It is one of the world’s few dry-land countries that has internationally recognized biodiversity hotspots. Biodiversity and the natural environment are critically important to Namibia and offer high potential for the country’s socio-economic development. Unique land and seascapes, abundant wildlife, and rich mineral resources attract both tourists and investors. Namibia’s population is directly dependent on natural resources for income, food, medicinal and health needs, fuel, and shelter.203 The natural resource-based sectors of mining, fisheries, agriculture, and tourism are therefore the basis of the Namibian economy. The Government of Namibia has recognized the importance of nature for the economic wellbeing and food security of its citizens. This is reflected in its strong commitment to the sustainable use of natural resources, including biomass, and its robust contribution to bioeconomy development efforts as manifested in its drafting of the current national bioeconomy strategy. Commitment to bioeconomy development is visible at institutional, policy, and programmatic levels. Namibia displays a relatively high level of innovation and manufacturing capacity, which demonstrates its readiness for bioeconomy development. This case study analyzes some key institutional and policy innovations and programmatic interventions that support the development of a thriving bioeconomy in Namibia.

2. INSTITUTIONAL INNOVATIONS

Several government institutions and private organizations directly or indirectly support bioeconomy development in Namibia. These include the Ministries of Agriculture, Water and Land Reform; and the Ministry of Environment and Tourism, as well as their respective directorates; the National Planning Commission, and research institutions. Development of the bioeconomy is also supported by the Namibia Biomass Industry associations such as N-BiG and the Namibia Charcoal Association (NCA), the Environmental Investment Fund of Namibia, and a number of civil society organizations.

2.1 Raising the production of renewable biomass: Ministry of Agriculture, Water, and Land Reform

The Ministry of Agriculture, Water, and Land Reform (MAWLR), together with other ministries such as the Ministry of Higher Education, Training and Innovation (MHETI) through the National Commission on Research, Science and Technology (NCRST), plays an important role in bioeconomy development. It aims to develop Namibia’s prosperity through transforming the agricultural, water, and forestry sectors to contribute to efficient and sustainable socio-economic growth. In line with the overall objective of the bioeconomy, it advocates the sustainable and equitable use of agricultural, water, and forest resources to improve livelihoods, wellbeing, and wealth for all. Within the MAWLR, this aim is supported by the Department of Agriculture Development, the Directorate of Agriculture Research and Development (DARD), and the Directorate of Agriculture Production, Extension and Engineering Services (DAPEES).204

DARD oversees research and knowledge development; this includes:

- Conducting crop and livestock research;
- Carrying out programs for the conservation and preservation of plant and animal genetic material;
- Conducting rangeland management and pasture research;
- Improving the management of research plans, programs, and projects at all levels;
- Implementing research agendas and priorities in line with the needs and demands of both communal and commercial farmers;
- Facilitating access to information and appropriate technology for all stakeholders and customers.205

DAPEES has several objectives that are relevant to bioeconomy development, including capacity building and information dissemination.206

- Provision of Agricultural Extension Services in the form of communication, advisory and training services;
- Promotion of technology development, adaptation, adoption and information dissemination in the agricultural sector;
- Identification of technological needs and requirements for agronomy, animal husbandry, soil conservation, and water supply;
- Provision of plant health services and enhancement of production and marketing safety through ensuring conformity to regulations and policies on plant and animal health, agrochemicals, and animal fodder quality.

The Directorate of Forestry (DF) aims to practice and promote sustainable and participatory management of forest resources and other woody vegetation, in order to enhance socio-economic development and environmental stability. Its objectives include:

- Ensuring that forests, including woodlands, are established, managed, utilized and conserved for human benefit;
• Providing forestry extension services in the form of communications, advisory and training services;
• Providing robust scientific research support in order to effectively manage and develop the potential of Namibia’s forest resources.207

2.2 Ministry of Environment, Forestry and Tourism

The Ministry of Environment, Forestry and Tourism (MEFT) is mandated to ensure the preservation of ecosystems, essential ecological processes, and biological diversity, and to promote the sustainable utilization of living natural resources. All of these support bioeconomy development and the preservation of Namibia’s natural environment. In partnership with other ministries, and international development partners, MEFT ensures the protection of biological diversity and biological/ecological support systems. MEFT is also in charge of overseeing standard controls with regard to environmental pollution. Furthermore, it conducts and promotes environmental education, extension, and awareness programs.208 Within MEFT, bioeconomy development is supported by the Directorate of Wildlife and National Parks (DWNP) and the Directorate of Scientific Services (DSS). DWNP’s main objectives include sustainable management of Namibia’s Protected Areas, regulation of the use of renewable natural resources, and enforcement of national wildlife protection legislation, including prevention of wildlife crime. DSS is the scientific branch of MEFT; it supports protected area management by providing technical information and support for conservation and resource management programs.209

Moreover, the Sustainable Development Advisory Council (SADC), situated within the MEFT’s Department of Environmental Affairs, is mandated to promote coordination and cooperation on environmental issues related to Namibia’s sustainable development. With respect to a bioeconomy development in Namibia the SADC advises the Minister on policies and strategies for the management, protection, and use of the environment; and on the conservation of biological diversity, access to genetic resources, and the use of components of the environment in a way and at a rate that does not lead to the long-term decline of the environment, thereby maintaining its potential to meet the needs and aspirations of present and future generations. It was inaugurated in 2013 under the Environmental Management Act of 2007. The Minister is mandated to appoint the Council’s eight members. Four of the members must represent the interests of the State, while the other four members must represent the interests of organizations, associations, or institutions concerned with environmental matters.210

2.3 National Planning Commission (NPC)

The National Planning Commission (NPC) was established in 2013 as the dedicated institution for setting the priorities and the direction of national economic development, including the mission to support bioeconomy-related policies and strategies. Housed within the Office of the President, the NPC develops monitoring and evaluation (M&E) mechanisms to ensure the effective implementation of the country’s National Development Plans (NDP), while it also coordinates the development of all government socio-economic policies for consistency. Moreover, the NPC mobilizes, manages, and coordinates international development cooperation.

In 2019, and as part of an inter-ministerial committee spearheaded by the Ministry of Fisheries and Marine Resources, the NPC coordinated the Development of the Namibia Sustainable Blue Economy Policy. The policy aims to implement a blue economy governance and management system that sustainably maximizes economic benefits from marine resources and ensures equitable marine wealth distribution to all Namibians. Furthermore, it will provide an institutional framework that facilitates inter-ministerial consultation and joint decision-making concerning various cross-cutting issues in the blue economy.211

2.4 Namibia’s National Commission on Research, Science, and Technology (NCRST)

Namibia has also emphasized the need for knowledge development in the creation of an enabling environment for a thriving bioeconomy. Namibia’s National Commission on Research, Science and Technology (NCRST) was established in 2012 under the MHETI to coordinate, monitor, supervise, and to provide policy guidance to the national research, science, and technology innovation system. At NCRST, the Natural Sciences Research Division (NSRD) coordinates natural sciences-related research and emerging technologies in line with national development priorities. NSRD also facilitates the development and management of national research facilities to support the implementation of the National Programme on Research, Science, Technology, and Innovation (NPRSTI). NCRST also plays a leading role in the formulation and implementation of policies relevant to the bioeconomy.212

Currently, NCRST is working closely with the Food and Agriculture Organization (FAO) to build a cohesive national Sustainable Bioeconomy Strategy, in collaboration with various affiliated sectors in Namibia.213 The overall objective of this collaboration entails stocktaking and analysis to establish the baseline of the bioeconomy landscape in Namibia, stakeholder engagement and workshop organization,
and finally drafting of the strategy. Among the accomplishments thus far (at the time of writing in April 2022) is the establishment of a working group named the Bioeconomy Multisectoral Working Group (BMWG), which consists of 24 entities including nine government ministries, five private companies, and 10 non-governmental organizations, public enterprises, and higher education institutions. The BMWG identified and endorsed the strategic focus areas and priorities for Namibia in the bioeconomy from 2021 to 2026 based on the results of a survey. Agriculture, health, natural resource management, and cross-cutting bioeconomy issues are among them. In 2021, nationwide stakeholder engagement was conducted, with ten regional workshops held. The goal was to present the work of the NCRST and the BMWG, and attendees were invited to contribute by listing challenges they had identified in their respective sectors. The strategy is expected to be fully developed and implemented by the year 2026.

Moreover, at NCRST, a Genetically Modified Organisms (GMOs) testing laboratory was established in 2018 under the NSRD. The laboratory is dedicated to the production of bioproducts and the provision of testing services for GMOs as required by the Biosafety Act, 2006. The Biosafety Act later provided measures to regulate activities involving the research, development, production, marketing, transport, application, and other uses of GMOs and of specified products derived from GMOs. It ensures that only GMO products that are approved for use in Namibia are commercialized with the possibility of traceability along the whole supply chain.

2.6 National Forest Management Standard

Namibia developed its National Forest Management Standard (NFSS) in 2017 based on Version 5 of the Forest Stewardship Council (FSC) Principles and Criteria. The FSC is a global, not-for-profit organization dedicated to the promotion of responsible forest management worldwide. The FSC national standard development process for Namibia was set to take effect in 2020. The design process of the NFSS was based on a participatory model, including six representatives from across social, environmental, and economic interest groups to assist with the process of adapting the requirements to the national context along with engaging local stakeholders during the development process. The NFSS aims to provide a holistic approach to the responsible management of Namibia’s forest resources while conserving and restoring the ecosystem and protecting workers’ rights. The scope of the FSC standard includes natural forests (inclusive of bush thickening species) and non-timber forest products such as venison products and Marula fruit. It applies to large industrial forest organizations, medium-scale farm owners/managers, smallholders, and community-managed forests, and approximately 700,000 hectares (ha) of forest area are currently certified.

2.7 Namibia Biomass Industry Group (N-BiG)

N-BiG was established in 2015 as a result of a cooperation between the Government of Namibia and the Federal Republic of Germany via the Bush Control and Biomass Utilization Project, which was implemented by the MEFT and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). N-BiG represents a diverse range of members from the private sector, as well as academic and research institutions, active in Namibia’s bush-biomass sector. The group drives innovation and technology development while also providing technical expertise on biomass value chains. Its mandate includes the exploration of market opportunities and the promotion of industry diversification. It also supports capacity development through an advisory service by providing training and mentorship programs on sustainable bush control and biomass utilization.

In 2016, the De-bushing Advisory Service (DAS) was formed as a capacity-building division of the Namibia biomass industry Group (N-BiG). DAS is a national information platform and a focal point for questions including on bush encroachment, bush thinning, and value addition to the bush. DAS addresses the skill, knowledge, and information needs of potential actors in the industry. The DAS service portfolio aims to develop structured capacity development programs empowering farmers, workers, contractors, and Small
and Medium Enterprises to effectively implement sustainable bush control and biomass utilization. It provides environmental advice by assisting in raising awareness of forest policies and regulations. It also provides knowledge of bush encroachment and bush control, and advice to the government on unsustainable or ineffective bush control practices. DAS conducts Monitoring & Evaluation of bush encroachment on national de-bushing efforts and facilitates research such as product development research and technical research. It also advises on appropriate harvesting techniques, equipment, and value chains, and facilitates the development of new bush-related value-added products and opportunities. In addition, it ensures the development of demonstration/training sites for rangeland management, bush control, value chain, and aftercare training standards and the development of training materials on bush encroachment, bush control, and value addition. Furthermore, it shares information on potential funding opportunities and engagement with funding sources including referrals to financial services providers and advisory services.

2.8 The Namibia Charcoal Association (NCA)

The Namibia Charcoal Association was formed to formalize and strengthen the charcoal industry, as well as to support the needs of its industry participants. Formerly known as the Namibia Charcoal Producers Association (NCPA), NCA is a non-profit voluntary membership association for the Namibian charcoal industry. Charcoal production is an important activity for managing bush encroachment in a sustainable manner. The NCA’s mission is to support the initiatives and operations of its stakeholders in order to contribute to the economic growth of this important sector in a responsible manner, taking into account the environment, economic impact, and social aspects of its stakeholders.

2.9 Civil society organizations

Civil society organizations (CSOs) play an active and important role in bioeconomy development, including the Namibia Nature Foundation (NNF) and The Namibian Chamber of Environment (NCE). The NNF works closely with the MEFT and other government institutions in the promotion of sustainable development, the conservation of biological diversity and natural ecosystems, and the ethical use of natural resources. The NCE, is an umbrella organization for advocacy and lobby organizations in the environment sector. In fact, the NNF is a member of a consortium of nine Namibian CSOs that work together to support, promote and strengthen community-based natural resource management (CBNRM). The Namibian Association of CBNRM Support Organisations (NACSO) was formed in the late 1990s to serve a core coordination function within the national CBNRM program that was being established at that time, following reforms to law and policy in 1995/96 that created the basis for the establishment of communal conservancies. Since then, NACSO has played a key role in the development of Namibia’s CBNRM program, which has expanded to deliver a growing suite of critical conservation, rural development, tourism investment, and economic diversification functions. NACSO’s key functions are to coordinate the delivery of technical
support services related to CBNRM - originally focused on the conservancies but now broadened to include community forests and a more holistic set of natural resource management issues - to rural communities, as well as to provide a collective action body for influencing policy and engaging with government. It performs a key monitoring, informational and communication function, including drawing up its annual or bi-annual report on the state of community conservation in Namibia, and maintaining an information database, which covers different CBNRM impacts and on which the report draws. One of NACSO’s member organizations is the Kyaramacan Association (KA). All of its members live within Bwabwata National Park’s Multiple Use Area with the agreement of the MEFT. The KA works to maximize the livelihood options of the approximately 5,000 historically marginalized people who live in the area to manage and benefit from their own natural resources. The KA employs 63 staff, making it the largest employer in the park. A craft center was set up, to sell traditional Khwe baskets and other crafts. A further bioeconomy-related income stream for residents is the sustainable harvesting of Devil’s Claw, which is used by the pharmaceutical industry. Devil’s Claw, a tuber with a thorny outgrowth, is organically certified and in high demand. Although full commercialization of the Devil’s Claw in Namibia is still developing, in 2013, income from harvesting was almost US$90,000, with profits going to 562 harvesters, 317 of whom were women.

2.10 Environmental Investment Fund of Namibia

In 2012, the Environmental Investment Fund of Namibia (EIF), created by Act 13 of 2001, was launched to support projects and community initiatives in the sustainable use of natural resources. It aims to achieve a more inclusive approach to natural resource management and to regulate the use of natural resources to prevent wastage, inefficiency, and degradation. The Fund’s Strategic Plan (2018-2022) is designed to complement Namibia’s overall development agenda, including Namibia’s Vision 2030, NDP 5, and the Harambee Prosperity Plan.

The EIF is funded through a government allocation and the mandate to tap into local conservation fees and environmental levies. In fact, the EIF 2018 Investment Plan targets the mobilization of N$570 million (US$36 million) from environmental levies for re-investment in environmental protection during the NDP5 implementation. The investment plan focuses on investment in three strategic areas considered urgent national development priorities: waste management and recycling; biodiversity conservation and ecosystem management, including the development of a Non Timber Forest products factory in; and low carbon and resilient investment. The EIF uses three types of financing tools and mechanisms -

- Concessional loans and credit to support SMEs, local authorities, and the private sector for renewable energy and waste oil recycling, among others;
- Grants and development capital in support of projects oriented towards recycling, resource efficiency, and environmental sustainability;
- Equity instruments and seed and early-stage financing in support of innovative start-ups as an alternative to loans for clean-tech and sustainable new businesses; also provides finds to business incubators and technology transfer.

More broadly, the funds under the EIF are used to invest in the protection of the environment, Namibia’s biological diversity, and ecological life-support functions. The funds are also used to promote sustainable natural resource use for economic development by supporting green and environmental enterprises. The EIF partners with NGOs, government, CSOs, and the business community to ensure that its projects are well-positioned in the socio-economic and environmental tapestry of development, and to guarantee the buy-in of the local and international stakeholders. One of the EIF programs is the Sustainable Utilization of Natural Resources and Energy Finance (SUNREF) program. The three-year initiative mobilizes commercial banks to finance green technologies in the private sector, including sustainable agriculture, tourism, and renewable energy. To be eligible, activities in the bioeconomy must be streamlined to take advantage of these funding mechanisms and existing partnerships.

3. POLICY INNOVATIONS

Namibia is committed to an economic transformation and advancement that supports bioeconomy development. This commitment takes the form of national development strategies and policies, including its Vision 2030, its Fifth National Development Plan, and its Second National Biodiversity Strategy and Action Plan 2013-2022. The country has also emphasized the importance of knowledge development through the National Science, Technology, and Innovation Policy.

3.1 Namibia’s Vision 2030

In 2004, Namibia launched the Vision 2030 which called for, “A prosperous and industrialized Namibia, developed by her human resources, enjoying peace, harmony, and political stability”. Vision 2030 provides direction to government ministries, the private sector, NGOs, and local authorities. Several of its goals support bioeconomy development
through the promotion of sustainable use of natural resources including biomass. The development of a knowledge-based society is also an objective for the government to guarantee the equity of education through the provision of resources for diversified education opportunities equally in all regions. Through emphasizing individual tenure systems, Namibia promotes equality of access to, and utilization of, the country's natural resources including land, fisheries and marine resources, forestry, and wildlife by emphasizing individual tenure systems. Agricultural modernization is another key objective within the country's vision of supporting the sustainable and equitable growth of its economy. In alignment with the Blue Economy Strategy, Namibia seeks to promote fish harvesting that guarantees the good recovery of fish stocks to maximum sustainable yields by ensuring a continued high growth rate of the sector thanks to research products. This is legally supported by the Marine Resources Act which seeks to conserve and protect Namibia's marine ecosystem by promoting the responsible and sustainable utilization of marine resources.225 Water recycling and cost-effective exploitation of new water sources (including desalination plants) are also promoted in order to meet population and irrigation water demands.226

3.2 National Development Plans

Namibia has developed five-year National Development Plans (NDP) from NDP1 to NDP5 informed by Vision 2030. Several objectives of the NDPs implemented since 2012 support bioeconomy development. The NDP4 (covering the period 2012-2017) included strategic initiatives related to the promotion of conservation agriculture and implementation of debushing for sustainable agriculture and restoration of degraded lands. NDP4 also focused on ecotourism in Namibia; it promoted the development and maintenance of national parks and increased investment in communal areas.227 NDP5, in effect for the current 2017-2022 period, focuses on the structural transformation and modernization of the economy. It identifies game-changing strategies and solutions to create a conducive environment to ensure that current and future generations will benefit in a sustainable way from the country’s natural resources. NDP5 goals also support bioeconomy development. These include investment in renewable energy, infrastructure development, productivity increase in agriculture, especially for smallholder farmers; investment in quality technical skills development; and improvement of value addition in natural resources. Under the natural resource management and use, NDP5 plans to strengthen sustainable land management by achieving land degradation neutrality and optimum land productivity through sustainable management of rangelands, restoration of bush-encroached land, and the expansion of conservation agriculture. It also supports environmental awareness campaigns that cut across the education, health, tourism, and business sectors, and that focus on the skills training and empowerment of local people.228 NDP5 also emphasizes research and innovation, which are key enabling factors for bioeconomy development. It includes plans to establish a research and development center for indigenous plant products that is based on sustainable commercialization and value addition. In addition, it envisions increasing Research & Development investment as a percentage of GDP from 0.35 percent in 2015 to 1 percent in 2022 to provide adequate scientific and technological infrastructure to support the advancement of research, innovation, and development. Finally, it plans to build a strategic partnership to foster innovation and entrepreneurship by stimulating partnerships among government, universities, and industries to foster innovation and entrepreneurship.

3.3 National Biodiversity Strategies and Action Plans

Namibia has shown strong political commitment to biodiversity development. Efforts to preserve biodiversity started at the time of its first National Biodiversity Strategy and Action Plan (NBSAP) during the period 2001-2010.229 This was recognized internationally as being one of the best first-generation NBSAPs; it provided a strong foundation for the sustainable management and use of biodiversity in the country. In 2012, Namibia initiated NBSAP2 to build upon this foundation and to directly tackle the threats and challenges it was facing in this area. The vision of NBSAP2 is for “Namibia’s biodiversity to be healthy and resilient to threats, and the conservation and sustainable use are key drivers of poverty alleviation and equitable economic growth, particularly in rural areas”. NBSAP2 has five key strategic objectives, each of which has a number of targets to be achieved by the end of its timeframe of 2022. First, it addresses the underlying causes of biodiversity loss by mainstreaming biodiversity across all levels of government. Actions towards achieving this include making and communicating the business case for biodiversity with a focus on poverty alleviation, with the aim to improve understanding among decision and policymakers and the private sector of the linkages between biodiversity, poverty, and economic development.230 In addition, NBSAP2 seeks to reduce the direct pressures on biodiversity and ensure the sustainable use of biological resources. For that purpose, it supports the application of the ecosystem approach to fisheries management, and the adoption of
sustainable land and forest management approaches, measures and mechanisms to reduce the impact of pollution and waste on biodiversity. NBSAP2 aims to improve biodiversity by safeguarding ecosystems, species, and genetic diversity. This Strategic Goal will be achieved through increased benefit-sharing with local communities from biodiversity and ecosystem services with a particular focus on the CBNRM program, and on managing wetlands, restoring degraded ecosystems, and capitalizing on opportunities from biotrade and bioprospecting. This includes the sustainable commercialization including the processing and marketing of indigenous natural products such as Marula, Ximenia melon, Hoodia, and Devil’s Claw. NBSAP2 also promotes knowledge management and capacity building of traditional authorities and local communities, with the aim of increasing their involvement in the management and use of biodiversity and other natural resources.

3.4 Promotion of technology and innovation as a key enabler of a bioeconomy

The Namibian government promotes technology and innovation for economic growth and long-term development which is a key enabling factor for bioeconomy development. This commitment dates to the design of the 1999 National Research, Science, and Technology Policy, which was then replaced by the Revised National Science, Technology, and Innovation Policy (RNSTIP) for the period 2021-2030. The RNSTIP aims to promote and foster the development and application of science, technology, and innovation (STI) in all spheres of Namibian society with the goal of advancing socio-economic growth. It envisions transforming Namibia into an innovation-driven, scientifically advanced, and industrialized nation by 2030. The policy has several objectives related to the bioeconomy. First, it aims to improve scientific and technical competencies in the areas of science, technology, engineering, and mathematics (STEM) by investing in post-graduate training and fellowship programs that are relevant to national development priorities. It also seeks to increase the utilization of scientific and technical knowledge for societal advancement by strengthening institutions to facilitate multi-disciplinary scientific research and by establishing technology parks and information centers that are focused on national STI priorities. The culture of science, technology, innovation, and entrepreneurship will also be promoted through strategies such as increasing public understanding of STI and providing incentives to enterprises that procure new ideas and R&D services from research institutions. Research in the areas of technological advancement in Technical and Vocational Education and Training (TVET) will be accelerated by providing incentives to industry to increase bilateral and multilateral capacity-build in cooperation in TVET to enhance high-level TVET skills, resources, facilities, productivity, and international competitiveness in scientific productivity and technological economy. Scientific productivity and technological output will be increased through strategies such as providing support to institutions that harness the use of technology in manufacturing and encouraging small and medium-sized enterprises (SMEs) to use advanced manufacturing technologies.
3.5 Importance of the value of game meat in delivering high-quality food

Recognizing the importance of game meat in the development of the food value chain, in 2015 the Ministry of Industrialization, Trade and SME Development, introduced the Growth Strategy for Namibia's Game Meat Industry and Associated Value Chains. The strategy envisioned:

"[the transformation of] Namibia's game meat industry [into] a recognized role model for sustainable and profitable wildlife use, delivering high quality food products to discerning customers at home and abroad, thanks to successful public-private value chain-promotion activities at the different stages of value addition (farming, harvesting, handling, processing and marketing)".

Several objectives under that strategy promote bioeconomy development. First, the strategy aims to improve the industry's contribution to sustainable wildlife use by creating an enabling environment for professional game farming and harvesting. Interventions included increasing to at least 75 percent the share of game farmers and harvesters who are trained in applying good game-farming, harvesting, and offtake practices. The strategy also supports value chain-specific R&D which promotes productivity gains and sustainable resource use at the primary production level of game farming and harvesting. That objective also includes a plan to support research, knowledge exchange, and technology transfer and adaptation to Namibian framework conditions with regard to game-farming methods; this comprises more efficient land use and the enhanced quality of game population for meat production. To ensure the production of high-quality game meat production, the strategy aims to reach at least 75 percent of the volume of game carcasses being processed in official game-handling facilities by 2020. To that end, the strategy plans to support new investments in game-meat handling and to foster value addition by promoting product and process innovations in the game-meat product industry. It also aims to facilitate national and international knowledge exchange and technology transfer regarding game handling and game-based food production.

4. PROGRAMMATIC INTERVENTIONS

Interest in the development of a bioeconomy is emerging in different sectors including wildlife, agriculture, and marine resources. This has led to the implementation of several interventions promoting bioeconomy uptake.

4.1 Community-Based Natural Resource Management Programme

In 1996, Namibia initiated the Community-Based Natural Resource Management (CBNRM) Programme, which combines policy and legal reforms, including granting of resource rights to local members of communal conservancies. Communal conservancies are run by elected committees of local people, to whom the government devolves user rights over wildlife. This has provided the incentive to sustainably manage wildlife populations in order to attract tourists and big game hunters. Through the promotion of sustainable ecotourism, the CBRNM program establishes a link between biodiversity and poverty eradication. Tourist activities in conservancies and community forests include trophy hunting and wildlife viewing, while income-generating activities include wildlife meat processing, devil's claw harvesting, and non-timber products. Technical assistance in managing the conservancy is provided by government officials and local and international NGOs. Conservancies, through private sector partners, are creating jobs and career pathways by providing training in remote rural areas where such options previously did not exist. Conservancies are also directly contributing to social development through the use of their revenue to fund improvement in schools, clinics, and community water and energy supplies. Other benefits of the program for Namibians include the availability of game meat and improvements in household nutrition that are made possibly by cash dividends. By 2017, Namibia's CBNRM Programme had led to the establishment of 86 conservancies covering more than 18 percent of the country's landmass. They are delivering substantial benefits to communities in the form of income generation from tourism, biotrade (including in game-meat) and employment, while also improving wildlife populations across the country. Harvesters and crafts producers working in conservancies generate incomes through the sale of indigenous plant products and handicrafts. An estimated 69 of the 86 conservancies generated returns in 2017 and 39 were financially self-sufficient, covering their own operating costs. The CBNRM Programme will be further strengthened during the lifespan of NBSAP2 in order to ensure its long-term viability.
4.2 Bush Control and Biomass Utilisation Project

Since the 1950s, plant proliferation has been one of Namibia’s rangeland management concerns. Commonly known as bush encroachment, it affects about 45 million hectares (ha) of the total land area, or close to half the country. Between 2015 and 2021, the Bush Control and Biomass Utilisation (BCBU) Project was implemented by the Namibian Ministry of Environment, Forestry and Tourism in partnership with the German Federal Ministry for Economic Cooperation and Development (BMZ), through the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). The project aimed to ensure economic utilization of biomass from controlled bush thinning of pastureland by:

- Creating a framework for bush control and biomass utilization;
- Strengthening the capacity of the competent authorities to better approve and monitor the extraction of bush biomass;
- Advising farmers and owners of SMEs on finance and sustainable bush-control and biomass-use measures;
- Introducing innovative technologies for the extraction and processing of bush biomass.

Building on this, GIZ organized courses on sustainable bush harvesting. In these courses, farmers and most small business owners were trained on the use of special machines that protect the soil; they also learned where and how much they were permitted to harvest. The training resulted in selective harvesting and processing of bush biomass into various biomass products such as animal fodder, charcoal, biochar, building material, and wood chips. By 2021, 650 farmers and SME owners had been trained in harvesting and processing and 11,000 jobs had been created in harvesting and processing; 300,000 ha of bush are also now being controlled annually. Jobs were created primarily in the production of charcoal for export and increasingly in the production of animal feed. During the drought of 2019, more than 800 farmers were able to feed their herds on bush-based feed. Improvements have also been made to working conditions including the introduction of a minimum wage, better accommodation, and the provision of protective clothing. Standards have also been developed in cooperation with the Forest Stewardship Council (FSC), to ensure that the harvesting and processing of bush biomass meet international criteria for environmental and social compatibility. 1.6 million ha have now been FSC certified.

4.3 Biodiversity Management and Climate Change Project

Between 2017 and 2020, the Biodiversity Management and Climate Change (BMCC) Project was implemented through a partnership between MEFT and Germany’s BMZ. The BMCC Project aimed to support a coherent implementation of biodiversity and climate change-related policies, strategies, and practices in cooperation with other ministries and non-governmental actors. Several activities were implemented through the BMCC Project, including the establishment of a regulatory framework for access and benefit-sharing of genetic and biological resources, with the aim of guaranteeing the fair and sustainable utilization of these resources. The activity also analyzed market potentials for biological resources in order to develop value chains and leverage new sources of income for rural and indigenous populations. The enacting of a dedicated law ensured the self-determination of indigenous communities and their involvement in decision-making processes, while producers of biological resources such as marula oil benefited from the fair sharing of benefits, as did about 14,000 marula oil harvesters.

4.4 Promotion of Business Advisory and Economic Transformation Services

The Promotion of Business Advisory and Economic Transformation Services (ProBATS) program was an important intervention in Namibia that moved the bioeconomy development forward in the country’s processing sector. ProBATS supported the implementation of growth strategies for selected private sector industries including game meat and charcoal; it also ensured that business development support services were improved in line with needs. The project was implemented by the Ministry of Industrialization, Trade and SME Development between 2018 and 2021. That intervention led to the development and introduction of pyrolysis, a thermochemical process that increases the efficiency, capacity, and ecological sustainability of charcoal production. The project also supported the introduction of procedures to control shiga toxin-producing Escherichia coli (STEC) contamination during harvesting and processing; this contributed to the resumption of game meat exports to the European Union (EU) which had been banned between 2013 and 2019 due to STEC contamination.
4.5 Bioeconomy project based on production of succulent plants

In 2019, the Biodiversity Research Centre of the Namibia University of Science and Technology (NUST), in collaboration with the University of Oxford and the Namibian Chamber of Environment (NCE), launched a bioeconomy project based on the production of succulent plants. The project’s goal is to generate biomass by growing succulents on Namibia’s semi-arid and degraded lands. Succulent plants use far less water than most other plants and the biomass produced can be converted into a variety of products, ranging from fodder to proteins and renewable energy. Succulent production has the potential to be a game-changer for the Namibian economy through its introduction of an innovative type of bioeconomy, which could position Namibia as a leader in the diversification of dryland agriculture in the face of impending climate change. Succulent production also has the potential to diversify farmers’ incomes, especially given the warmer and drier climate conditions that are predicted for Namibia as climate change advances. The first phase of the project is research-oriented with a focus on optimizing succulent yield, establishing a carbon baseline, and investigating the potential and type of photosynthesis of a range of indigenous succulents.281

5. CONCLUSION

Namibia has undertaken a number of bioeconomy-related initiatives. Many actors in the country are playing an important role in the development of the bioeconomy; these include government ministries and agencies such as the NCRST, civil society, and universities. In terms of policy, the country has joined forces with the FAO to develop its first bioeconomy strategy, and a number of policies are already in place that support a bioeconomy development. Namibia has also shown strong political commitment to biodiversity development. The conservation of biodiversity is a prominent theme in the country’s Vision 2030, which includes a chapter devoted to the topic of sustainable utilization of natural resources and environmental sustainability. The first National Biodiversity Strategy and Action Plan (NBSAP) was developed for 2001 to 2010; it laid a solid foundation for the country’s sustainable management and use of biodiversity. Namibia is now considering bioeconomy to be a potential transformational path. To achieve that objective, the country needs to pursue its institutional, political, and programmatic commitments to bioeconomy development. To that end, it needs to mainstream a bioeconomy approach into sectoral strategies while taking into account the potential risks, including the conflicts that may arise as biological resources become scarce. Developing the manufacturing sector’s capacity to produce a diverse range of bio-based products will require the provision of a set of critical enablers, including technology training and skills development for value addition, financing of infrastructure, and a supportive policy environment.
1. INTRODUCTION

South Africa is one of the most biologically diverse countries in the world. It hosts an estimated 10 percent of the world’s plant species, 7 percent of its reptile, bird, and mammal species, and about 15 percent of its marine species. This rich diversity is spread over a variety of territorial, freshwater, and marine ecosystems, and much of it is endemic to the country. These biodiverse ecosystems deliver a range of sociocultural, environmental, and economic services. They contribute to job creation, income generation, and inputs across several sectors, including farming and livestock, tourism, health, and industrial development.

Recognizing the potential of capitalizing on its natural wealth, over the last two decades South Africa’s policymakers have developed a portfolio of policies, strategies, and supporting institutions to promote a transition to a bio-based economy. This foresight has placed South Africa at the forefront of continental and global efforts to establish successful bioeconomies; it is currently one of only 15 countries in the world—and the only one in Africa—that has approved a dedicated and comprehensive bioeconomy strategy.

South Africa’s establishment of a vibrant innovation ecosystem has been one of the most impactful aspects of its efforts to catalyze a bioeconomy. In 2019, the country was ranked the highest performer on the Global Innovation Index (GII) among African countries south of the Sahara (SSA). By investing in education, improving collaboration between universities and industry, strengthening its intellectual property environment, and supporting small businesses, South Africa has developed a leading biopharmaceutical and biotechnology sector.

This case study analyzes some of the institutional and policy innovations and programmatic interventions that have propelled South Africa into a leading position in the establishment of a thriving bioeconomy.

2. INSTITUTIONAL INNOVATIONS

2.1 Incorporating bioeconomy across the National System of Innovation

South Africa has invested significantly in developing and institutionalizing a dynamic National System of Innovation (NSI), in turn propelling the country forward in establishing a thriving bioeconomy. Following the adoption of a White Paper on Science and Technology in 1996, several new public sector institutions dedicated to science, technology, and innovation (STI) have been established to deliver a world class bio-innovation environment. Working alongside these are semi-independent institutions such as the Technology Innovation Agency, the Council for Scientific and Industrial Research, National Intellectual Property Management Office, the Agricultural Research Council, and the South African Medical Research Council (SAMRC), which further support the development and growth of South Africa’s bioeconomy. Finally, universities, the private sector, and civil society are also key players in advancing the development of a rewarding and sustainable bioeconomy in South Africa.

Interventions to mainstream the bioeconomy across institutions and stakeholders include investments in research, innovation, and commercializing research outputs, improved linkages between research and the private sector, better coordination among institutions, and fiscal support.

Department of Science and Innovation

The Department of Science and Innovation (DSI) (previously called the Department of Science and Technology) leads the development of South Africa’s bioeconomy. The change in name reflects the broader mandate that followed the merger of the Department of Higher Education and Training with the Department of Science and Technology in 2019. The merger was instituted as a part of an effort to streamline South Africa’s NSI. Among its key strategic goals from 2015 to 2020 were supporting the development of vibrant, equitable, sustainable rural communities (which contribute toward food security for all) and the protection and enhancement of environmental assets and natural resources.

DSI plays three key roles as part of its mandate to establish a responsive and efficient national system of innovation: coordination, capacity enhancement, and programmatic interventions to address strategic gaps or opportunities. DSI aims to mainstream STI across all programs that include technology innovation, international cooperation and resources, research development and support, and socioeconomic innovation partnerships. Although DSI led the formulation of the Bio-economy Strategy, approved by the Cabinet in 2013, it recognizes that the success of the bioeconomy strategy relies on the participation of several other government departments, including the Departments of Trade, Industry and Communications (the dtic); Health; Agriculture, Land Reform and Rural Development (DALRRD); and Environmental Affairs and Forestry and Fisheries (DEFF). DSI is thus responsible for coordinating across the public sector and with other bioeconomy stakeholders.

Bio-innovation Chief Directorate

The Bio-innovation Chief Directorate within the DSI leads the implementation of the bioeconomy strategy. It plays a key role in coordinating partnerships
among stakeholders and strengthening research and innovation capacity, both of which are necessary for the development of a bioeconomy. Previously known as the Biotechnology and Health Innovation Directorate, the Bio-innovation Directorate was assigned responsibility for the Indigenous Knowledge based Technology Innovation unit in 2013. This, in turn, warranted the new name to reflect a strategic shift to one that represented a broader socioeconomic approach from one that previously focused largely on technology development. The role of the newly added unit is to create an innovation value chain within the nexus of indigenous knowledge and other knowledge systems. This includes the promotion of applied research for knowledge generation and technological innovation; the design of inclusive technological innovation and local manufacturing for social and economic development; and the facilitation of community-based technology transfer for manufacturing and commercialization. Together, these contribute to a pioneering approach called ‘Ubuntu-based Bio-Innovation’ which ensures that the benefits from indigenous knowledge reach the community level. By 2020, the Unit had invested in 52 indigenous knowledge projects across the country, and from November 2020 has formalized a partnership to increase the rate of commercialization.

In addition to indigenous knowledge-based technology innovation, the Bio-innovation Chief Directorate ensures that STI is deployed in the agricultural, health, industry, and environmental sectors. Working alongside the DSI are several thematic national research agencies that contribute to the growth of South Africa’s bioeconomy. The South African Medical Research Council (SAMRC), and the Technology Innovation Agency (TIA) support the implementation of the Bio-economy Strategy through the management of specific instruments within the key pillars of the strategy. Programmatic interventions from these instruments are discussed below. Other support agencies of the DSI include the Council for Scientific and Industrial Research (CSIR), National Advisory Council on Innovation (NACI), National Research Foundation (NRF), and South African Council for Natural Scientific Professions (SACNASP).

2.2 Monitoring and evaluation: National Advisory Council on Innovation

The creation of South Africa’s National Advisory Council on Innovation (NACI) followed the adoption of the National Advisory Council on Innovation Act 1997. It is mandated to be the premier source of advice for the Minister of Science and Innovation on promoting and achieving national ambitions through STI. The Council is composed of a representative from the Department of Trade and Industry (DTI) and 16 to 20 experts from any field of STI; this ensures that NACI remains abreast of the latest developments and emerging opportunities in STI. NACI plays a major role in influencing research priorities and is a national monitoring and evaluation institution which informs government planning on STI. It conducted an audit of the South African bioeconomy “sector” in 2020, making it among the first countries in the world to do so. The audit aimed to provide an overview of the sector’s contribution to GDP and performance in relation to other sectors and to create a baseline for future evaluations. Using readily available data on input and output indicators, growth, employment, investment, and exports, the audit found that between 2007 and 2020 the bioeconomy’s contribution to GDP remained relatively consistent at about 8 percent. The food and beverage industry and the agricultural sector together contributed 70 percent to the bioeconomy. On the basis of the existing data descriptions and measures, however, the audit concluded that the implementation of the bioeconomy strategy had not resulted in a clear increase in bioeconomy output. Even so, the audit concluded that the bioeconomy’s contribution to total GDP is valuable, in terms of its ability to create employment across the skills spectrum, having generated between 14 and 16 million jobs between 2007 and 2020.

2.3 Strengthening the bioscience and bio-innovation environment: Council for Scientific and Industrial Research

The Council for Scientific and Industrial Research (CSIR) was established in 1945, making it one of the oldest research councils in South Africa. It is mandated to undertake R&D and technology innovation that is relevant to high-impact industries, thereby supporting South Africa’s reindustrialization and helping increase the prosperity of South Africans. CSIR is overseen by the Minister of Higher Education, Science and Technology.

In order to retain a place at the forefront of innovation, continue to be financially viable, and remain relevant to the NSI, CSIR has undergone four phases of significant restructuring. Although it was initially entirely publicly funded, this became an unsustainable and uncompetitive model. In its second phase in the 1980s, state funding was restricted, and the Council was asked to undertake contract research to earn income. By the 1990s, however, it became clear that this approach had undermined its long-term scientific R&D capacity and had caused it to become focused on short-term outcomes. The third phase therefore re-emphasized its scientific capabilities and sought to restore a longer-term research focus.

With its scientific capabilities re-established, CSIR grew into one of South Africa’s most successful scientific councils. It produced several inventions that have been commercialized and that have gone on to advance global developments in telecommunications, materials...
science, aeronautics, information and communications technology (ICT), biotechnology, and nanotechnology. Among its early formal investments into the bioeconomy was the establishment of a Clinical and Botanical Supplies unit in 1999. The unit conducts laboratory research and clinical trials to support value addition to South Africa’s rich biodiversity and indigenous knowledge. One of its successful commercial products is a mosquito-repelling candle which was produced using the oils of an indigenous plant and is now sold by major retailers across the country. This process was boosted by the signing of a benefit-sharing agreement in 2003 between CSIR and the indigenous owners of the botanical knowledge about the plant from which the oil was derived.

In 2001, CSIR became the first research center in the world to develop a technique for genetically engineering pearl millet to protect it from mildew. In 2012, it produced a clone of eucalyptus with better pulping properties to meet growing demand. These and other bioproducts and biotechnologies developed at CSIR set the stage for the establishment of a Biomanufacturing Industry Development Centre (BIDC) in 2014 and the Biorefinery Industry Development Facility (BIDF) in 2018 (see below).

The fourth and latest phase of restructuring, dubbed Project Synapse, builds on the success of previous adjustments and aims to enhance CSIR’s impact. Initiated in 2017, Project Synapse aims to further strengthen the impact of scientific research on industrial development. To do this, the new strategy emphasizes the commercialization of its technologies, which in turn requires robust relationships with the private sector.254,255 CSIR now receives about 30 percent of its total income from public sources and supplements the balance with contract research. In 2019, about 10 percent of CSIR’s revenue came from the private sector, while the balance was generated through contract research from government and state-owned enterprises.256

The Council has also reorganized itself internally in order to foster greater collaboration across research areas and, for the first time in its 75-year history, it has introduced divisions to provide thematic specialization: (1) Chemicals, Agriculture, Food and Health; (2) Mining, Manufacturing, Defence, and Security; and (3) Natural Resources, Enabling Infrastructure, and Public and Professional Services. Each division comprises three technology clusters, is overseen by a division group executive, and is assigned an executive manager for business development and commercialization.

Under the Advanced Agriculture and Food cluster, CSIR promotes transformative technologies and business innovations for agricultural growth and associated processing industries. Specific focus areas include digital technologies to improve yield predictions, enhance pest and disease surveillance, optimize input use, strengthen food safety, and support decision-making. This cluster also aims to increase the output of high value foods, cosmetics, nutraceuticals, and traditional African medical products. The success of the Advanced Agriculture and Food cluster relies on the availability of multidisciplinary skills at CSIR. CSIR collaborates with the government departments (Science and Innovation; Forestry, Fisheries and the Environment; and Agriculture, Land Reform, and Rural Development); provincial governments; private sector companies; NGOs, state-owned enterprises, and universities and research organizations such as the Agricultural Research Council and the National Research Foundation.257

Working in conjunction with the divisions and their clusters, four cross-cutting research centers leverage existing advanced knowledge and skills in specific areas such as synthetic biology and health science, and energy, and water resource management. In addition to all of these, CSIR also supports the innovation process by offering scientific infrastructure such as laboratory testing facilities and scientific instruments and equipment. The agro-processing pilot facility houses a variety of postharvest equipment and can process up to 1,000 kg of biomass per day.258

Overall, one of the fundamental reasons for CSIR’s success is its excellent human scientific capability. On average, CSIR invests about ZAR150 million to ZAR200 million (US$ 10.6 million–US$ 14 million) per year in human capital development, which is about 0.7 percent of its total annual budget.259 This distinguishing feature of CSIR is also a key reason for its selection as the regional hub for the Southern Africa Network for Biosciences (SANBio), which is, in turn, a regional network for NEPAD’s (New Partnership for Africa’s Development) Centres of Excellence for Science and Technology.

Biomanufacturing Industry Development Centre

In 2013, CSIR launched a ZAR90 million (US$ 9 million) Biomanufacturing Industry Development Centre (BIDC) program as an open-innovation hub. The BIDC’s mandate is to rapidly convert biotechnology-based R&D for industrial, veterinary, and human applications by small, medium, and micro enterprises (SMMEs) into market-ready products and services.260 In 2016, this program was formally converted into the Biomanufacturing Industry Development Centre. BIDC operates like an incubator, providing biomanufacturing facilities, laboratory infrastructure, access to experts in agro-processing and bioprocessing, as well as product development and scale-up. It is funded through the Industrial Innovation Partnership Programme and the Jobs Fund Program at the Department of Science and Technology (now called
DSI). Since its inception, BIDC has advanced over 100 bioproducts in cosmetics, nutrition, and biotechnology along the technology realization chain. Among its success stories is VIDA Pharmaceuticals, which produces accessible and affordable nutritious food products from baobab and maize. BIDC provided VIDA Pharmaceuticals with access to the skills and technology they needed in order to advance from concept stage to a thriving company. VIDA Pharmaceuticals also supports the women who collect baobab fruit in their communities and offers a maize porridge product that has no added sugars or preservatives.  

**Biorefinery Industry Development Facility**

In 2018, CSIR, in partnership with the University of KwaZulu-Natal, launched the ZAR37.5 million (US$ 2.7 million) Biorefinery Industry Development Facility (BIDF) in Durban. BIDF is developing technologies to extract maximum value from biomass waste, particularly waste from forestry. The technologies are expected to reduce waste from pulping, thereby reducing the environmental impacts of forestry waste and improving returns on investment for the industry.  

2.4 Bio-innovation in agriculture: Agricultural Research Council

The ARC is the principal agricultural research institution in South Africa. It conducts primary and applied research aimed at fostering innovation and technology adoption in the agricultural sector, including cash crops, horticulture, and livestock. ARC’s primary research areas for livestock include: breeding and improvement, including management of the national database on animal improvement known as the Integrated Registration and Genetic Information System (INTERGIS); rangelands ecology and forage production; food science and technology; and nutrition. As outlined in the Malabo Montpellier Panel’s 2020 report entitled, *Meat, Milk and More: Policy Innovations to Shepherd Inclusive and Sustainable Livestock Systems in Africa*, one of ARC’s successful interventions was the Kaonafatso ya Dikgomo project which improved breeding, resulting in higher calving rates and growth in herd sizes. ARC also invested in the most advanced genome sequencing and genotyping equipment, offering very high throughput levels. This has propelled the ARC biotechnology platform to a position as the continent’s preeminent facility of its kind. ARC is also leading in conventional and marker-assisted breeding for potatoes and sweet potatoes and has developed new breeds that are pest and disease resistant, and heat and drought tolerant.

Also supporting bio-innovation in the livestock sector is Onderstepoort Biological Products (OBP), a South African state-owned animal vaccine manufacturing company, established in 2000. It is mandated to prevent and control animal diseases that impact food security, human health, and livelihoods. OBP produces affordable vaccines and distributes them widely across the country, to regional partners in Botswana, Namibia, and Zimbabwe, and to East African counterparts.

2.5 Centre of excellence on Bioinformatics: South African National Bioinformatics Institute and universities

Bioinformatics uses and develops digital technologies
South Africa is the leading country in bioinformatics on the African continent, largely due to the successes and influence of the South African National Bioinformatics Institute (SANBI). SANBI was founded in 1996 by a South African computational biologist, Winston Hide, at the University of the Western Cape to conduct cutting edge bioinformatics and computational biology research. SANBI also aims to cultivate human resources in bioinformatics and computational biology through the education system and by mentoring scientists. Initial funding came from the National Research Foundation, the US Department of Energy, and what was then Glaxo Wellcome, a global pharmaceutical company. These then leveraged investments from South African telecommunications companies, Telkom and Thintana, over the following two years.

From then on, South Africa’s bioinformatics field expanded in leaps and bounds. Although initial steps were taken by SANBI, universities and other research institutes across South Africa and beyond quickly joined the budding sector. Africa’s first UWC/SANBI Bioinformatics capacity development unit was established in 2000 with committed funding from the SAMRC. This was followed by the formation of a regional bioinformatics training center at SANBI in 2003, supported by the World Health Organization’s Tropical Disease Research (TDR) Program. The European Molecular Biology Network, and Centre National de la Recherche Scientifique (CNRS) in collaboration with NEPAD also invested and positively influenced the growth and intensification of South Africa’s bioinformatics field. A National Bioinformatics Network was set up in 2003 with 5-year funding from national Department of Arts, Culture, Science, and Technology and later the DST. It quickly became one of the key funding tools for human resource development for bioinformatics. Although the network was disbanded in 2009, elements of it got absorbed into the DST. The Bio-Innovation Chief Directorate at DSI continues to invest in several bioinformatics-based initiatives.

In parallel, bioinformatics teaching grew too. The first four PhD students, two postgraduate and two postdoctoral students were enrolled at SANBI by 2000. By 2014, several universities offered degree programs in bioinformatics, some of which offered cross-learning opportunities between students in computer sciences and mathematics with those in biology. This was combined with various training, conference and workshops support too. Although training initially relied on international educators, there is now sufficient capacity in the country to meet its own needs. DST also enabled the construction of a national backbone of fiber cables with speeds up to 10 Gbps, and the purchase of additional capacity to international networks. The additional internet capacity makes it possible to transfer large datasets internationally.

South Africa’s leading status in bioinformatics has been the result of investing heavily and strategically in human resources and infrastructure capacity. Structuring funding into noncompetitive funding for training and initial infrastructure expenditure, and competitive funding for research, ensured support remains sustainable and impactful. Funding decisions were overseen by an independent and international advisory board to ensure that they serve agreed priorities. The outcome has been an internationally respected center of excellence on bioinformatics. In 2020, SANBI was selected as one of three WHO reference laboratories to support the response to emerging infectious diseases, including COVID-19. It also hosts active and successful programs on pathogen surveillance and drug discovery. It is also an acclaimed facility studying gene expression and host-pathogen disease research, including HIV, Trypanosomes, and Malaria.

### 2.6 Financing the bioeconomy

South Africa has allocated significant funding to catalyzing the development and uptake of biotechnology across the country. Among the earliest investments in bioeconomy was the Godisa National Incubation Programme, which was initiated in 2001 in partnership with the European Union. Located within the then DST, the Godisa program was established to improve the performance and productivity of small enterprises and to enhance technological innovation and uptake. The Godisa Trust was instrumental in the development of the eGoliBio Life Science incubator in Johannesburg and of Acorn Technology in Cape Town. It was also exceptionally effective at reducing the failure rate of SMMEs. Where previously 80 percent of new enterprises had been failing within their first two years, by 2005/2006 the Godisa Trust was able to produce an 85 percent success rate. Its success came from being able to identify correct strategic partners and by incubating SMMEs. In 2006, the Godisa Trust was incorporated into the Small Enterprise Development Agency (SEDA), which reported to the DTI. Since then, the Technology Innovation Agency (TIA) has taken a leading role in financing bioeconomy products and projects.

**Supporting bio-innovation commercialization: the Technology Innovation Agency**

Between 2004 and 2007, the South African government allocated ZAR450 million (US$58 million) to support the implementation of the 2001 National Biotechnology...
Strategy (NBS). This resulted in the formation of a national innovation center for plant biotech (PlantBio) in Pietermaritzburg and three Biotechnology Regional Innovation Centres (BRICs), one in Western Cape (Cape Biotech), another in KwaZulu-Natal (Liferab), and a third in Gauteng (BioPad). The BRICs were mandated to develop and commercialize the biotechnology industry. While Cape Biotech focused on nutracueticals, vaccines, and high throughput bioprospecting, LIFElab provided investments for research that aimed to cure infectious diseases such as malaria, HIV/AIDS, and tuberculosis. BioPAD's investments focused on animal and human health and on the industrial, mining, and environmental biotechnology fields. The BRICs made some headway in investing in the biotechnology sector, actively investing their budget of ZAR450 million (US$58 million) over three years (2004 to 2007); they were, however, short-lived. The publication of the DST’s Ten-Year Innovation Plan (TYIP) (see Policy Innovations below) in 2008 resulted in the creation of the Technology Innovation Agency (TIA), which went on to absorb and reform the BRICs.

TIA is a national public entity that was instituted by the Technology Innovation Agency Act 26 of 2008. Its mandate was to support the commercialization of research and innovations originating from universities and research councils. In practice, TIA is the result of a merger of seven entities and programs which focused on various elements of biotechnology, and provide the basis for its continued emphasis on bioeconomy. Although TIA is primarily publicly funded, it has the flexibility to raise or borrow funds if necessary.

TIA offers financial and non-financial support to accelerate the advancement of technology from proof-of-concept stage to pre-commercialization. This is reflected in the funding streams that it offers, including: a Seed Fund, a Technology Development Fund, and a Commercialisation Support Fund. The agency also provides grants, loans and equity investment in a number of scientific areas. It comprises three “divisions”, one of which is purely for bioeconomy-related projects that support innovations in health, agriculture, and biodesign. Agricultural support is allocated to the Bioeconomy Division at TIA. Equating to 41.7 percent, this was the largest share of total project expenditure. Besides the bioeconomy division, the Sector Funding division also supports bioeconomy development in sectors such as energy and natural resources. This sharp focus on bioeconomy and biotechnology makes TIA the leading agency implementing programs that support the development of a bioeconomy. However, with CSIR’s new focus on commercialization, there may be some overlapping and competing priorities between the two national institutions.

Industry Innovation Partnership Fund

A further indication of South Africa’s commitment to the development of a bioeconomy is the creation of the Industry Innovation Partnership Fund (IIPF) in 2013. Housed at the DSI, the IIPF received an opening allocation of ZAR500 million (US$50 million) from the National Treasury to enhance the competitiveness of various sectors through R&D. Of this, ZAR90 million (US$9 million) was earmarked for CSIR’s work on biosciences, energy, and other related areas of research.

An enabling environment for private sector participation

At approximately 44 percent, South Africa’s public sector is the largest funder of all R&D activities; the private sector’s share of contributions—41 percent—is close in size, and the balance is supplemented by
foreign sources. This is testament to the conducive environment that the South African government has created for both public and private sector participation in R&D. Indeed, since 2011/2012, private sector R&D expenditure in the bioeconomy—primarily by large firms—has surpassed public sector spending. In 2017/2018, the private sector invested approximately ZAR7 billion (US$516 million) in R&D, while higher education institutions spent approximately ZAR5 billion (US$369 million) and expenditure through government funds and science councils amounted to approximately ZAR4 billion (US$295 million). Moreover, The entry of private sector players is further evidence of South Africa’s maturing environment for biotechnology. In 2018, for example, a new biotech incubator called OneBio was launched in partnership with the Cape Innovation and Technology Initiative (CiTi) and the Centre for Proteomic and Genomic Research; its mandate was to support life science entrepreneurs and innovators in their efforts to commercialize and scale biotech startups. The incubator received seed funding from TIA in partnership with the SA SME Fund, a private funding vehicle; in turn, it created a pioneering public-private partnership model for funding biotech incubators. While this is good news for new entrants, the challenge for South Africa’s largely small and medium-sized biotech enterprises will be in accessing appropriate support to scale their operations.

2.7 Protecting intellectual property from publicly funded research: National Intellectual Property Management Office

To protect the value generated from publicly funded research, in 2008 South Africa approved the Intellectual Property Rights from Publicly Financed Research and Development Act (IPR Act). The IPR Act introduced mandatory intellectual property (IP) management of publicly funded research outputs and special benefit-sharing arrangements for IP creators. The legislation also established the National Intellectual Property Management Office (NIPMO) and allocated an Intellectual Property Fund to secure and maintain IP protection across a range of strategic fields such as space science and technology (S&T), energy, bio-innovation, nanotechnology, robotics, photonics, and indigenous knowledge systems (IKSs). NIPMO’s primary function is to provide both financial and non-financial support to universities and science councils in the management and protection of their IP. Where appropriate, it is also empowered to take ownership of publicly funded research and advance its commercialization. The IPR Act also established Technology Transfer Offices (TTOs) to assist institutions engaged in technology transfer. NIPMO is further mandated to support skills development in corresponding fields such as synthetic biology, structural biology, systems biology, and functional genomics, as well as space S&T, energy, bio-innovation, nanotechnology, robotics, photonics, and IKS. An evaluation of the impact of the TTOs, and by extension the IPR Act, revealed that between 2014 and
2018, 292 new IP licenses with commercial partners were secured to further develop and deploy the resulting products, processes or services. In addition, over the same period, 238 IP transactions collectively generated revenues of over ZAR185 million (US$13.5 million) for 17 institutions.296

2.8 Data and communications: Bioeconomy SA portal

In October 2020, DSI launched the Bioeconomy SA portal, a web-based platform that gathers data on bioeconomic activity from a variety of sources and combines it into a user-friendly and interactive information management platform. The portal facilitates access to, and sharing of, information by different actors in the bioeconomy, which is an important step to ensuring that knowledge is driving the enhancement of South Africa’s bioeconomy. The portal is an important source of information on different services, including funding, employment opportunities, literature, and opportunities for collaboration in the bioeconomy; it also brings stakeholders together for further innovation and development.297

2.9 Leading regional biosciences development: SANBio and SAIS298

CSIR’s extensive expertise and experience in developing biotechnologies form the basis for its selection as the regional head of the Southern Africa Network for Biosciences (SANBio). SANBio is one of the regional networks that has been established in Africa under the framework of NEPAD’s Centres of Excellence for Science and Technology. The network aims to develop and promote the region’s research and innovation in biosciences with a focus on health and nutrition, doing so by enhancing human and infrastructure capacity. SANBio stipulates that projects must include three or more countries, thereby fostering opportunities for collaboration across the Southern African Development Community (SADC). CSIR hosts the network and provides it with operational support and financial management.

Initial funding for SANBio’s development of a business plan came from the Canadian International Development Agency and DST. The business plan, in turn, provided the basis for seeking funding for strengthening the network from the Finnish Ministry of Foreign Affairs and the Government of South Africa. Between 2009 and 2012, the resulting joint program, BioFISA, extended ZAR9 million (US$1.2 million) and EUR 3 million to eight projects across six “nodes”, or core themes of research. Between 2015 and 2019, the second phase of BioFISA, BioFISA II, received a further EUR7 million in funding.299

During BioFISA II, the SANBio Secretariat that was based at CSIR benefited from an expansion in staff dedicated to the network; this included the addition of a new hub manager who is responsible for promoting greater collaboration among members.300 BioFISA II also saw an expansion of the funding base to strengthen financial sustainability. In this context, member states are now required to contribute 20 percent of project costs through cash disbursements, and 20 percent through in-kind contributions of, for example, office space, electricity, water, transport, and staff time.301 Although these requirements have not quite met the ambitious targets set for leveraging external funds, they are showing initial signs of paying off.302

South Africa is also a part of the Southern Africa Innovation Support Programme (SAIS), a regional initiative jointly funded by the Ministry for Foreign Affairs of Finland, by the STI Ministries of Botswana, Namibia, Tanzania, and Zambia, and by the Southern African Development Community (SADC).303

3. POLICY INNOVATIONS

South Africa has been embracing a biotechnological transformation since 2001, when it devised an ambitious National Biotechnology Strategy (NBS). The strategy’s overarching aim was to increase the extracted value from biomass by stimulating the growth of biotechnology activities.304 The strategy aimed to modernize and expand biotechnology activities largely through leveraging South Africa’s existing strong research capabilities. The Government of South Africa also embarked on a program of building human resources and developing national capabilities in the development and commercialization of efficient and sustainable biotechnologies. It identified the gaps in the biotechnology sector and provided institutional, financial, and policy recommendations that it felt should be acted upon. The strategy focused on bringing science-based innovation to the health and agricultural sectors of the economy.305 The main success of the 2001 strategy was the creation of the Biotechnology Regional Innovation Centres (BRICs) described above. Each BRIC was designed to manage three to four separate technology platforms and was responsible for carrying out research on new biotechnologies. The NBS was expected to cost ZAR182 million (US$22.6 million) per year, of which ZAR135 million (US$17 million) was allocated to supporting the BRICs and their associated R&D programs, ZAR 20 million (US$2.5 million) went to a venture capital fund, ZAR25 million (US$3 million) was earmarked for to strengthen the link between academia and industry, and ZAR2 million (US$250,000)
was allocated to running a new Biotechnology Advisory Committee. A one-off disbursement of ZAR45 million (US$5.6 million) was also given out to cover the set-up costs of the BRICs. Between 2005 and 2008, the government invested more than ZAR450 million (US$64 million) in biotechnology through the NBS, but this amount was about ZAR96 million (US$13.4 million) less than the budget.

3.1 Strengthening backward linkages in bioeconomy innovation chains: Ten-Year Innovation Plan 2008–2018

Although the NBS had boosted a nascent biotechnology field, the focus on commercialization and returns on investments led to gaps in upstream innovation chains. In response to this, the 2008–2018 Ten-Year Innovation Plan (TYIP) became a key tool for addressing the gaps in knowledge generation and exploitation. The TYIP was the DST’s ambitious framework for enhancing South Africa’s transition to a knowledge-based economy. Driving forward the country’s science and technology systems—including biotechnology, biochemistry, and nanotechnology—is seen as crucial to enabling solutions to existing challenges such as improving health, energy, and food security. In addition to establishing the Technology Innovation Agency, the TYIP focused on developing human capital and a knowledge infrastructure; it aimed to enhance communications and networks in order to improve biotechnology practices, ease of doing business, education and industry training, and financial frameworks. It identified five priority “grand challenges”, each of which had an associated high-level expected outcome by 2018, and all were aligned with national ambitions such as achieving 6 percent economic growth by 2010 and halving poverty and unemployment by 2014. The grand challenges included: “farmer to pharma” (later changed to the Bio-Economy), space science and technology, energy security, climate science, and human and social dynamics. TYIP chose sectors of the bioeconomy on which to focus, where there were existing strengths, including bioprospecting, genomics, and biological sequencing. A new decadal plan was approved by the Cabinet and is currently undergoing further consultation.

3.2 Developing an enabling environment for more stakeholder participation: 2013 Bio-economy Strategy

Both the NBS and the TYIP catalyzed South Africa’s emerging biotechnology sector. They strengthened capacity and infrastructure, developed value chains, and fostered a growing interest in the application of biotechnology to new diagnostics, vaccines and therapeutics, improved crops and livestock, and cleaner and more efficient industries. Their immense success, however, required greater oversight and coordination and an inclusion of other disciplines such as ICT, environmental and social sciences, and engineering. To fill this gap, the DST formulated the Bio-economy Strategy in 2013. Closely linked to the National Development Plan launched in 2012, the updated and comprehensive 2013 Bio-economy Strategy provides a roadmap for advancing a strong bio-based economy that will, in turn, provide a basis for future economic growth. The updated strategy builds on the NBS and takes a systems approach to the adoption and strengthening of South Africa’s bioeconomy. The policy identifies agriculture, health, and industry as the three key sectors that would benefit from a holistic bioeconomy strategy. It also focuses on creating an enabling environment wherein all stakeholders can create value from South Africa’s vast natural wealth, and it identifies areas where public policy can remove barriers, encourage innovation, and improve cooperation between stakeholders. Considered key to the success of the bioeconomy strategy, the policy focuses investment on training and education of the labor force, on building strong regulatory and legal frameworks for addressing the importance of inclusive environmental and ethical aspects in bioeconomic practices, and on enhancing support to infrastructure. Proposed interventions include supporting local research and bioprospecting with the aim of identifying effective biomass and biotechnologies that could help diminish health challenges such as HIV and malaria. Through the strategy, South Africa is also encouraging better wastewater treatment through computerized water flow control.

3.3 Science, technology and innovation for a prosperous and inclusive society

In 2019, the South African Cabinet approved a new white paper on Science, Technology and Innovation. The White Paper sets the long-term policy direction for the South African government to ensure a growing role for STI in a more prosperous and inclusive society. It uses STI to accelerate inclusive and sustainable socio-economic development, enhance competitiveness, and quality of life and well-being. The white paper sets the stage for harnessing the benefits of an economy that is becoming more technologically driven. It also presents the opportunities to address the triple challenge of poverty, inequality and unemployment and to achieve the SDGs. The white paper envisages that innovation will support the modernization of key sectors of the economy (agriculture, mining and manufacturing) by driving competitiveness and productivity improvements and, ultimately, higher GDP contributions; exploit opportunities presented by emerging innovation concepts of the circular and digital economy as new sources of economic growth; harness the capabilities
built by NSI over the years to drive innovation and shape a capable and entrepreneurial state; and respond to the global challenges of climate change and environmental sustainability, future-proofing education and skills; and the future of society.

3.4 Protecting indigenous knowledge

The indigenous knowledge (IK) protection regime in South Africa exists to prevent the exploitation and misappropriation of unique cultural and genetic resources, knowledge, or products that are endemic to a particular region. There are four governmental mechanisms related to the protection of IK: bioprospecting regulation, an innovative IK documentation system, the IP system (described above) and, most recently, the Protection, Promotion, Development and Management of Indigenous Knowledge Act 6 of 2019, (IK Act). The IK Act is a highly unique approach to protecting the rights of traditional knowledge and practices across South Africa. The new policy framework established the National Indigenous Knowledge Systems Office, which aims to manage the rights of indigenous communities, encourage fair and ethical access to traditional knowledge, recognize prior exploitation of knowledge and products, and coordinate indigenous knowledge-based innovation. This regulation is noted to be very important in the bioeconomy’s search for new and innovative knowledge, techniques, and processes, to ensure that traditional communities benefit from new technologies and that the advantages of innovations are shared with those involved.

4. PROGRAMMATIC INTERVENTIONS

To complement the outlined policies and strategies to bolster the success of South Africa’s bioeconomy, several programs have been introduced to target specific bioeconomy initiatives.

4.1 Strategic Health Innovation Partnership

The Strategic Health Innovation Partnerships (SHIP) program was designed in 2013 by the Health Innovation Unit of the Department of Science and Innovation (DSI) in partnership with the South African Medical Research Council (SAMRC). SHIP identifies, manages, and funds multi-disciplinary and multi-institutional product research and development projects of new drugs, treatments, vaccines, medical devices, and prevention strategies from prototype to proof of concept. Within the first year, SHIP established itself as a key enabler in the South African bioeconomy by committing more than US$30 million to a number of product-driven programs. SHIP now consists of a number of DSI funded health research and development initiatives, namely, the South African Malaria Initiative (SAMI), the South African HIV and AIDS Research Platform (SHARP), the South African TB Research and Innovation Initiative (SATRII), the Non-communicable Disease Research Programme, Maternal and Child Health Research Programme, the South African Human Genome Programme (SAHGP) and the Vaccines and Biologics Research Initiative. Through these sub-programs, SHIP has a portfolio of more than 50 projects to develop new drugs, vaccines, and medical innovations. It has also been instrumental in responding to the COVID-19 pandemic, both for the benefit of South Africa and beyond.

4.2 Agricultural Bio-economy Innovation Partnership Programme

The Agricultural Bio-economy Innovation Partnership Programme (ABIPP) is an instrument established in 2017/18 by the Agricultural Biotechnology unit of DSI to implement the agricultural pillar of the Bio-economy Strategy; it is overseen by TIA. The aim of ABIPP is to develop a sustainable agricultural bioeconomy that raises productivity, improves food security, and enhances competitiveness and rural economic development. ABIPP prioritizes strategic investments in bio-innovative products, processes and services within crop and animal improvement, including value chain analyses to identify markets opportunities and value chain development. The program facilitates, coordinates and funds multi-institutional, multi-stakeholder agricultural bioeconomy initiatives that are co-funded by industry and TIA. The program also provides farmers with support and training on innovative techniques, assisting SMMEs and farmers in the development and utilization of bio-based knowledge products and agro-processing/value chain processes, and funding and co-funding agricultural bioeconomy initiatives. Between 2018 and 2020 ABIPP funded agro-processing initiatives in the commercialization of marula, honeybush, and Cape Aloe, which are indigenous and underutilized local crops with valuable medicinal and nutritional qualities. This venture included ABIPP co-funding a ZAR15 million (US$1 million) contract for the technological development of marula, resulting in new markets, employment opportunities, and community benefits. Other strategic partnerships and flagship programs have been formed with the grains and oilseeds industries, the red meat industry, and the cotton industry. Several flagship partnership programs have also been implemented with science councils, universities and farmer development support organizations. In the 2021/22 financial year, a total of ZAR73 million (US$4.5 million) has been leveraged from the private sector partners, the Technology Innovation Agency (TIA) and the Red Meat Industry Research Association (RMIRA).
4.3 Technology Innovation Cluster Programme

TIA’s Technology Innovation Cluster Programme (TICP) is a set of programs that seek to create a collaborative enabling environment for different players in the bioeconomy space. The TICP works to encourage cross-disciplinary and cross-sectoral research and development in areas of national priority such as improving food security, job creation. By connecting partners from higher educational institutions, science councils, government ministries, and the private sector, the TICP leverages comparative expertise in the respective clusters to generate new technological products and services. Different institutions host each cluster and, the TIA manages the TICP clusters and provides funding, business services, and technical support to stimulate knowledge outputs and the commercialization of new products in the coordinated joint initiatives. In 2021, the TICP had six operational clusters on beef genomics, dairy genomics, forestry molecular genomics, active pharmaceutical ingredients, uYilo Electric Mobility, and animal health. The Forest Molecular Genetics cluster, for example, works with forestry companies and researchers to collect wood samples and design innovations that improve tree genetics. The introduction of DNA markers for tree breeding and the creation of a synthetic biology toolkit improved tree health and growth, bringing forth subsequent benefits for South Africa’s forestry bioeconomy through enhanced wood production for paper, pulp, and alternative biomaterials. Between 2018 to 2021, the spending on TICP amounted to over ZAR75 million (US$4.3 million), with more than 19 technology products and services released to market and 18 knowledge innovation products produced (including papers, publications, presentations, policy briefs, and collaborative panels).

4.4 Technology Platforms Programme

Also run by TIA since 2015, the Technology Platforms Programme (TPP) is considered a key pillar for the implementation of the Bio-economy Strategy, investing in and supporting entities for technology development from the initial technology research/identification/concept stage to mainstream development. Since its creation, the TPP has supported over 570 bioeconomy projects with a wide range of technology innovators, including higher education, science councils, SMMEs, private sector players, and international funders. Over the course of the program’s implementation, universities, large organizations, and private individuals have formed the majority of concept initiators. The program mobilizes significant funding and provides specialized training to build long-term technical and strategic expertise in South Africa’s bioeconomy.

To date, the TPP has a total of eight technology platforms; these are: the African Traditional Medicines Platform, Biosafety South Africa, Cape Universities Body Imaging Centre, Centre for Proteomic and Genomic Research, Drug Discovery and Development Centre (H3D), Kwazulu-Natal Research Innovation and Sequencing Platform (KRISP), National Metabolomics Platform, and Bioprocessing Platform. The predominant focus area across all the platforms has remained the health sector, but other areas include agriculture, industrial biotechnology, and food and beverages. Impactful work that has been done through the platforms includes the provision of over 10,000 COVID-19 tests during the pandemic and, through the KRISP platform, the identification of HIV resistance to treatment drug Dolutegravir.

4.5 Strategic Industrial Bio-Innovation Programme

The Strategic Industrial Bio-Innovation Programme (SIIP) is a sub-program of TIA’s Industrial Biotechnology Programme. It is implemented in partnership with the DSI. SIIP leverages investments to coordinate and facilitate industrial bio-innovation and environmental management objectives as outlined in the industry pillar of the South Africa Bio-economy Strategy. The program aims to stimulate sustainable job creation, support new product and process development, support SMMEs in the bioeconomy, and foster green economy initiatives. SIIP concentrates on bio-based activities that encourage and strengthen value chain development for low volume, high value bio-based products. Since its inception, the program has managed over 27 projects, with total investment exceeding ZAR133 million (US$8.4 million). Notable achievements by SIIP include support to Khepri Innovations (Pty) Ltd in its initiative to use black soldier fly larvae to generate nutrient-dense livestock feed. Using unique bioconversion technology, the fly larvae are treated in adapted shipping containers.

4.6 Indigenous Knowledge Based Bio-Innovation

The DSI’s Indigenous Knowledge Based Technology Innovation Unit implements an Indigenous Knowledge-based Bio-Innovation program, founded on the ubuntu-based bio-innovation model described above. The program operates through six sub-programs: traditional medicines (naturoceuticals), cosmeceuticals, nutraceuticals, health beverages, technology transfer and incubation, and commercialization (including branding and marketing). Participating partners include indigenous knowledge-holder organizations, community-based organizations, government departments, universities, science councils, non-governmental organizations, and the private sector. By 2022, the program had supported the development of eight new (improved) products and completed the
commercialization of 25 different products. It had also trained 40 indigenous knowledge-holders in a six-month Entrepreneurship ‘CoachLab’ Programme.

5. CONCLUSION

Over the past two decades, South Africa has made meaningful progress in developing a thriving bioeconomy. It has established a number of institutions that are required for a functional system of innovation such as the Department of Science and Innovation, the National Advisory Council on Innovation (NACI), the Technology Innovation Agency (TIA) and the National Intellectual Property Management Office (NIPMO). In parallel, policy adjustments have ensured that the process is rooted in a clear vision and focused on key sectors (agriculture, health, and industrial sectors). Indeed, careful crafting of the policy and institutional environment combined with past successes have made South Africa an attractive destination for investments in the bioeconomy. The country has also mobilized significant funds, both from public and private sources, and invested heavily in infrastructure for bio-innovation. Indeed, according to DSI’s 2020/21 Annual Report, South Africa leveraged ZAR435 (US$ 26 million) million from the European union alone further strengthening its position in global science, research, and innovation. Systematically initiated programs provide thematic platforms around which stakeholders can coalesce and through which investments can be channeled effectively. At the same time, a conscientious framework to oversee indigenous knowledge and other IP outcomes ensures that no one is left behind in this transformation.

South Africa has embarked on an ambitious pathway to establish a bioeconomy. To maintain the momentum achieved to-date, the country must continue to adjust programs and policies, reflecting what is working and to what extent, and lessons from what has not achieved the desired results. Although the country has made some efforts to evaluate the impact of its interventions, these efforts must be scaled up and broadened so that they can capture more nuanced outcomes. The Bioeconomy SA portal provides an ideal platform for sharing the results from independent impact evaluations. Greater publicity for the successes will attract more students and job seekers to seek out bioeconomy-related fields. Although the country continues to invest heavily in education and training opportunities to sustain the dynamism required in a successful innovation environment, greater focus must be paid to early career research support. South Africa has shown immense aptitude in developing a thriving bioeconomy but sustaining its successes will need continued and intensified interventions to foster a cohort of skilled scientists and business entrepreneurs and to mobilize funding for projects and hard and institutional infrastructure.
1. INTRODUCTION

In the last two decades, Uganda has fashioned a robust and forward-looking trajectory to capitalize on the potential of a bioeconomy. It has taken clear steps toward developing a bioeconomy, including drafting a comprehensive bioeconomy strategy. Biomass is used in all sectors of its economy; nearly all rural households and about 98 percent of urban households use biomass energy for cooking. Agriculture, forestry and fisheries are the core sectors of Uganda's economy, employing 64.3 percent of the working population in 2018/2019 and contributing 21.9 percent of GDP. Uganda is also one of the most successful countries on the continent in terms of establishing a thriving livestock sector, as identified in the Malabo Montpellier Panel’s report *Meat, Milk and More: Policy innovations to shepherd inclusive and sustainable livestock systems in Africa.*

Livestock contributes about 17 percent to the country’s agricultural GDP and 4.3 percent to overall GDP. Despite climate impacts, Uganda’s geography, soil, diverse agroecological zones, and rich biodiversity give it a comparative advantage in the production of biomass, which is a key input into a thriving bioeconomy. Over the last two decades, the government has introduced a collection of laws, policies, and action plans that characterize the bioeconomy as an integral part of national development. Uganda is a signatory to relevant international conventions, including the Convention on Biological Diversity, which also has a bearing on bioeconomy development. These interventions have not only addressed the production of biomass, they have also focused on research and innovation and on the conversion and commercialization of bioproducts. Combined with a well-developed policy and legislative framework for environmental protection and natural resource management, the country has the potential to be a beacon for bioeconomy development in the region. This study reviews the policy and institutional innovations and actions taken by state and non-state actors in maximizing the bioeconomy potential.

2. INSTITUTIONAL INNOVATIONS

The development of a bioeconomy in Uganda is anchored in the growth of its agricultural (including livestock, fisheries and forestry), energy, and health sectors. This growth, in turn, is underpinned by an emphasis on research, science, and technology. Uganda’s Vision 2040 is firmly grounded in the deployment of science, technology, engineering and innovation (STEI), with the goal of creating a competitive upper-middle-income country.

2.1 Investing in agricultural R&D: The National Agricultural Research Organization

Uganda benefits from well-developed research in agricultural science that is promoted by good quality institutions. The key institution leading agricultural research in Uganda is the National Agriculture Research Organization (NARO). Established in 1992 to respond to growing food insecurity and poverty, NARO was adopted into the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) in 2005, with the mandate to coordinate and oversee all aspects of publicly funded agricultural research in Uganda, including research on crops, livestock, fisheries, forestry, agro-machinery, natural resources, and socioeconomics.

With growing national and international financial support, Uganda’s NARO has become one of the most prominent institutions in agricultural research across the region and on the continent. Funding from the government and international donors underpinned steadily increasing agricultural R&D spending to a level that was three times higher in 2014 than it was in 2000. NARO has invested its funds in building a robust physical infrastructure base and in the development of highly skilled human resources, the combination of which has resulted in the emergence of a vast range of new production technologies, improved crop varieties, and products identified for patents, licenses, and commercialization. During the period of the last strategic plan covering 2008/2009 to 2017/2018, research at NARO produced 801 technologies and innovations.

The next 10-year strategic plan for the 2018/19 – 2027/28 period is entitled *Market Oriented Research Spurring Agro-Industrialization.* This plan builds on previous achievements and strives to advance the innovation system beyond research that is driven more by scientific curiosity and opportunities for publication, to one that responds to farmers’ needs and demands. NARO also created an intellectual property (IP) office and a Technology Innovation Support Centre in 2017 to boost the research impact of internally generated IP. The IP office is responsible for identifying, protecting, and commercializing the IP that is developed by the institution and is tasked with seeking out any potential duplication of research efforts. It also oversees the licensing, royalties, and product development of innovations. As an incentive to develop more unique and patentable outputs, NARO has also introduced a reward and promotion mechanism based on IP.

---

1. NARO’s establishment was initially enshrined in the National Agricultural Research Organisation Act 1992, which was subsequently replaced by the National Agricultural Research Act 2005 when the organization was adopted by MAAIF.
2.1.1 Multi-stakeholder collaboration to produce bioproducts

NARO works with universities, the private sector, development partners, and civil society organizations to scale up the adoption of its research outputs. For example, it works with East African Breweries to facilitate the use of cassava in beer production, as a part of the company’s commitment to sourcing all its inputs locally, which boosts local production capacity, supports import substitution, and creates jobs. NARO has also partnered with Kamtech Logistics Uganda Limited to produce ethanol from dried cassava, and it has worked with Serere Sorghum Producers and Processors Association (in collaboration with an NGO) to increase the utilization and commercialization of sorghum in products such as bread, cakes, and flour.333 In 2016, NARO and Makerere University hosted the first Joint Agricultural Dissemination conference to foster collaboration between the two institutions on innovations for agro-industrialization and to create an opportunity for participants to showcase advances in research and innovation that can contribute to the development and transformation of the agricultural sector.

2.2 Ministry of Science, Technology and Innovation, Office of the President

The establishment of the Ministry of Science, Technology and Innovation (MOSTI) is rooted in the Government of Uganda’s recognition that science, technology, and innovation (STI) are the drivers of socioeconomic growth and transformation. Established in 2016, MOSTI provides leadership, an enabling environment, and resources for scientific research and knowledge-based development for industrialization, competitiveness, and employment creation leading to a sustainable economy. In doing so, the Ministry is expected to take the lead on developing a national system of innovation (NSI) and on strengthening the intersectoral linkages with other science, research, and innovation stakeholders at national agencies, universities, and in the private sector. There are currently three directorates under MOSTI: the directorate of science, technology, and innovation regulation; the directorate of science, research, and innovation; and the directorate of “technopreneurship” .334 ** Two affiliated statutory agencies also report to MOSTI; they are the Uganda National Council for Science and Technology (UNCST) and the Uganda Industrial Research Institute (UIRI). UNCST, instituted by the Uganda National Council for Science and Technology Act 1990, oversees national research and innovation, while UIRI, instituted by the Uganda Industrial Research Institute Act 2006, primarily seeks to scale and commercialize innovations (see below). MOSTI provides overall coordination, although at the time of writing it was undergoing a transition to the Office of President.335

Jointly, MOSTI, UNCST, and UIRI are responsible for overseeing and developing policy and legal frameworks in the bioeconomy space. The transfer of the functions of MOSTI to the Office of the President will create synergies and will harmonize interventions on science, research, technology, and innovation across government institutions and will thus avoid duplication of resources.

2.3 Building a leading science, technology, and innovation environment

The UNCST was established in 1990 as a semi-autonomous government agency with responsibility for advising, developing, and implementing policies and strategies for integrating science, technology, and research development into national development policies. Its role was to advise the Government of Uganda on policy matters related to the promotion of science and technology and to coordinate and guide national research and development. Some of these roles were subsequently assigned to MOSTI. Nevertheless, in this role, UNCST led on policy design and advice and managed funding allocations.336 In 2002, UNCST took the lead in formulating what became the National Biotechnology and Biosafety Policy 2008. Working with support from the United Nations Environment Programme’s Global Environment Facility (UNEP-GEF) and financially supported by the Government of Uganda and multilateral and bilateral donor agencies, UNCST implemented a hands-on integrated program to establish the status and potential for biotechnology applications in Uganda. This process and the resulting policy have propelled Uganda to the forefront of being a regional hub for agricultural biotechnology innovations.337 UNCST also formed a strong science-driven approach which is now being introduced into MOSTI.338 This success also set the stage for UNCST’s leadership of the National Science, Technology and Innovation Policy 2009, which sets the legal and regulatory framework for R&D activities in traditional, conventional, and emerging technologies, including indigenous knowledge, biotechnology, nanotechnology, information and communications technology, and microelectronics.

More recently, UNCST has funded research projects on sericulture development in Uganda. The production of silk is a nascent industry in the country, but it has the potential to generate significant employment in all its aspects, including mulberry cultivation, leaf harvesting, silkworm rearing, reeling, twisting, weaving, printing, dyeing, finishing, and silk waste processing. By 2020, mulberry plantations had been established on 601 acres (243 hectares) across ** At the time of writing this report in April 2022, ministries and directorates, including within MOSTI, were undergoing restructuring.
15 localities, with more farmers identified for support in additional locations; state-of-the-art silk yarn processing equipment had been procured for two silk-processing factories located in Sheema and Mukono and the project was employing 450 casual laborers and 63 full-time professional and administrative staff, expected to rise to 2,000 employees once the processing begins. Moreover, the project is expected to scale to 50,000 acres (20,234 hectares) under mulberry plantations, generating 150,000 jobs and producing a minimum of 2,200 metric tons (mt) of silk yarn annually; this will bring a minimum of US$100 million into the economy annually.339

2.3.1 Open Forum on Agricultural Biotechnology in Africa

UNCST facilitates engagements among key stakeholders and policymakers on agricultural biotechnology—specifically on genetically modified crops—through the Open Forum on Agricultural Biotechnology in Africa (OFAB).340 OFAB is a pan-African networking platform that aims to enhance knowledge-sharing and awareness of agricultural biotechnology; its goal is to raise understanding and appreciation of the technology and contribute to the building of an enabling environment for informed decision-making. It supports the development of a bioeconomy by facilitating conversations between key policymakers and the public on the safety and benefits of modern biotechnology. OFAB works in collaboration with partners in Ghana, Burkina Faso, Nigeria, Ethiopia, Kenya, Tanzania, and Zimbabwe.

UNCST was also the leading partner for the first two phases of the East African Regional Programme and the Research Network for Biotechnology, Biosafety and Biotechnology Policy Development (BIO-EARN) from 1999 to 2005. The program was designed with the aim of advancing East Africa’s use of biotechnology in agriculture, industry, and environmental management. It focused on building the human and infrastructure capacity to use advanced agricultural, environmental, and industrial biotechnology and on developing skills for formulating biopolicy and biosafety regulations. The program acted as a platform for collaboration among 35 institutions—including government, academia, private sector, and civil society—and over 100 scientists from Ethiopia, Kenya, Uganda, and Tanzania. With funding from the Swedish International Development Cooperation Agency (Sida), BIO-EARN successfully developed improved varieties of sorghum, cassava, and sweet potatoes, as well as new bioprocesses for wastewater treatment and energy production. In addition, more than 30 PhD students were provided with the opportunity to complete their program between African and Swedish research institutions. These students went on to champion biosciences by training the next generation of PhD and MSc students and by engaging in, and supporting, the development of biotechnology policy. In 2010, BIO-EARN evolved into BioInnovate Africa, which is currently based at the International Centre of Insect Physiology and Ecology in Nairobi, Kenya.341 The change also reflected a reorientation from capacity-building to product development and commercialization.

2.4 Commercializing bio-innovations: UIRI

UIRI was established in 2002 as a competence and capability center to champion innovations, translate applied research results into practical applications that would lead to high quality and efficient industrial products and processes, and create highly skilled human resources. UIRI is composed of directorates that are tasked with the development of products, systems, and innovative technology. It also provides business consulting and advisory services which include guidance on enterprise start-up, business documentation, equipment sourcing, production, business management, ICT, and marketing. The institute also provides networking platforms for entrepreneurs through exhibitions, trade fairs, workshops, and seminars. UIRI also leads on collaborations with international counterparts on technology transfer and capacity enhancement projects in a broad range of sectors, including agriculture. It hosts several pilot plants, a technology development center, and a business incubation program, which oversee technology transfer and adaptation processes and challenges.342

2.5 Investing in research, science, and innovation

Over the last two decades, the Government of Uganda has implemented a variety of grant mechanisms to support science and innovation, including The Millennium Science Initiative (2007–2013), the National Science and Technology Innovation Plan 2012/2013–2017/2018, and the Presidential Initiative on Science and Technology (2010–2020) at Makerere University. By one evaluation, these initiatives have been credited with fueling a 1,200 percent growth in the number of scientific publications from Uganda between 1990 and 2010.343 The findings from this vast wealth of research, however, have rarely been converted into commercial products that could provide a return on investments and contribute to economic growth. MOSTI therefore created the National Research and Innovation Program in 2019, to facilitate a continuous pipeline of high-potential and groundbreaking research and innovations that can be commercialized and scaled to drive Uganda’s development agenda. A corresponding fund was created in 2021 to support innovations in biotechnology, biopharmaceuticals, and life sciences (biomedical engineering, bioinformatics,
biomaterials, and synthetic biology). The National Research and Innovation Fund, draws from the Ministry of Science Innovation Fund, which was set up to encourage youth creativity, to enable ideas to be transformed into innovations or inventions and ultimately into viable companies, and to respond to the needs of financing innovation. In addition to public sector sources, the program also derives funding from development partners, endowment funds, venture capital funds, and contributions from a share of the profits of commercialized national innovations. The program has already supported the translation of a number of R&D outputs into commercial products, services, and processes. These include fully biodegradable sanitary pads made from papyrus reeds; biochemicals and microbes to kill mosquito larvae and prevent malaria; baby foods to fight child malnutrition; wines, juices, and sanitizers from banana and banana by-products; and high quality cassava flour for the confectionary and beverages industries.

2.6 Centers of excellence at higher education institutions: Makerere University, PHARMBIOTRAC and Pharm-Biotechnic

Uganda’s Makerere University plays a central role in advancing the country’s bioeconomy. It contributes to agricultural R&D and innovation, both through its teaching programs and by providing field research capacity. The university hosts one of four centers of excellence, the Makerere University Regional Centre for Crop Improvement, which is supported by the African Higher Education Centers of Excellence Project launched by the World Bank. The university has also benefited from the BIO-EARN program which contributed substantially to the improvement of research infrastructure and equipment across departments, including the Institute of Environment and Natural Resources, and Med Biotech Laboratories. With funds from BIO-EARN, the Faculty of Agriculture was able to invest in a state-of-the-art tissue culture facility. These improvements have boosted the university’s teaching and research programs, which now have a stronger position when competing for international grants.

At Mbarara University of Science and Technology, the Pharm-Biotechnology and Traditional Medicine Centre (PHARMBIOTRAC) provides a regional platform for innovative drug development, including exploring the use of traditional medicines. Launched in 2017, the Centre was subsequently recognized as one of the World Bank-funded African Higher Education Centers of Excellence (ACE II) and is one of 24 such centers of excellence in eastern and southern Africa. PHARMBIOTRAC aims to build a critical mass of specialized and skilled human resources in Uganda and across East Africa to advance the domestication and sustainable use of traditional medicines and biopharmaceuticals for socioeconomic development. Toward this goal, PHARMBIOTAC introduced master’s and PhD graduate training programs to enable research and to create capacity for the commercialization of products in biotechnology and traditional medicine. In order to support the production of high-value science-driven traditional medicines and biopharmaceutical products for uptake by pharmaceutical and herbal medicine industries in the region, graduates...
will be trained in the systematic identification, documentation, mapping, conservation, harvesting, extraction, isolation, characterization, structural elucidation, and modification of active molecules from plants and other life forms. It also offers research grants to strengthen capacity for applied research in collaborations with the private sector and community-based organizations with a view to developing tangible products, prototypes, protocols, monographs, and scientific publications. Since 2020, PHARMBIOTRAC has also hosted the Regional Incubation Centre, which is focused on traditional medicines and biopharmaceuticals. Working in partnership with the Consortium for Affordable Medical Technologies (CAMTech) Uganda, the incubator supports innovators who are seeking to conceptualize, develop, test, and commercialize their ideas on traditional and herbal medicines, natural cosmetics, and natural (herbal) health drinks. Despite its short history, PHARMBIOTRAC has already led the design and production of hand sanitizers in response to the COVID-19 pandemic. It successfully fast-tracked the process, completing an in-depth review of existing literature, trial formulations, critical quality control measures, company formalization, and production, such that quality hand sanitizers authorized by the Uganda National Bureau of Standards were being sold in supermarkets and pharmacies in Mbarara town in only two weeks and at much lower prices than their counterparts.

**2.7 Incubators for agricultural bioeconomy: The Food Technology and Business Incubation Centre**

Makerere University also hosts the Food Technology and Business Incubation Centre (FTBIC) at the School of Food Technology, Nutrition and Bioengineering, which is dedicated to agro-processing. Initiated with funding from the Rockefeller Foundation and supported by the Norwegian and Malaysian governments, its early successes impressed the President of Uganda, who then pledged additional funding through the Presidential Initiative on Value Addition. Between 2009 and 2020, FTBIC received UGX 5 billion (US$1.4 million) per year. The additional funding was used to expand a fruit and vegetable processing pilot plant into a larger space that processed new lines that included meat, fruit, dairy, and cereals; funding was also used to acquire a mobile processor. In addition to R&D services, FTBIC also offers practical training for students and for owners of micro, small, and medium-sized enterprises (MSMEs); it incubates agro-enterprises, which then have access to processing facilities and technical support to help boost their capacity in production, marketing, and business management. At any one time, 20 to 30 firms are hosted in the incubator and are thus benefiting from on-going support to commercialize their improved products. Firms typically stay at the incubator for two to three years on a cost-sharing basis. By 2022, FTBIC had generated more than 70 products and technologies with potential for commercialization, supported over 100 agro-processing enterprises (in-house and virtual), and trained over 2,000 MSME owners across the country who were mainly youth and women. The current model of FTBIC is not self-sufficient; however, it has demonstrated a need for more food- and agriculture-based incubators in Uganda, with emphasis on those that can rapidly commercialize products and scale up operations. Indeed, incubators at both UIRI and at Makerere University are severely oversubscribed and were only able to accept about 7 percent of applicants over the 2015 to 2020 period. Firms also remain for longer at the incubators because there is a dearth of next-stage support systems and because the costs and difficulties of doing business in Uganda can be unacceptably large compared to other countries in the region.

**2.8 National Environment Management Authority**

The National Environment Management Authority (NEMA) is a semi-autonomous organization formed under the National Environment Act (2019). It is the principal environmental management agency in Uganda, responsible for coordinating, monitoring, regulating, and supervising activities related to the environment. NEMA also proposes strategies and policies to the government through the Ministry of Water and Environment. The Act makes key bioeconomy-related provisions, including management of the conservation of biological resources and biodiversity, oversight of biodiversity offsets (for example, the negative effects to biodiversity as a result of development activities), oversight and protection of the biological diversity of ecosystems, maintenance of ecosystem services, and the sustainable management of, and access to, genetic resources. Among other activities, NEMA works with partners and government councils to enforce good practices of biowaste management, collection of solid wastes, control of greenhouse emissions through environmental regulations, and biotechnology and biosafety issues. NEMA also conducts research and data analysis and advises the Ministry of Water and Environment as part of the national greenhouse gas inventory. It is therefore central to the promotion and development of a bioeconomy.

**3. POLICY INNOVATIONS**

Uganda’s recent policy updates have set the stage for a comprehensive bioeconomy approach. The country has focused its bioeconomy development on the energy and agricultural sectors, which are
underpinned by environmental and sustainability conditions. In addition, in 2020, a comprehensive policy was drafted by MOSTI.

Bioeconomy has been placed at the center of the Uganda Vision 2040, which envisages that biosciences will play a key role in health, agriculture, energy, and pharmaceuticals with the direct support of the government. Although it does not explicitly mention bioeconomy, key elements of Vision 2040 reflect the government’s ambition to harness the potential of a bioeconomy by developing biotechnology industries, industrializing agriculture, and increasing the deployment of renewable forms of energy including wind, solar, and biogas.

Uganda’s Third National Development Plan (NDP III) 2020/21–2024/25 further expands on Vision 2040, with sector-specific targets for energy, agriculture, and the environment. Recognizing the potential that cuts across the agricultural and energy sectors, NDP III also proposes greater use of new renewable energy solutions such as solar water heating, solar drying, solar cookers, wind water pumping solutions, and solar water pumping solutions. Development in these areas can further accelerate the development of Uganda’s bioeconomy.

3.1 Uganda Green Growth Development Strategy

Green economy development strategies and the transition from conventional economic development models to a green economy have become necessary due to the negative impact of conventional economic development models on the environment, locally and globally. Green growth presents an opportunity to develop a thriving bioeconomy on the basis of resource efficiency, equity and social inclusiveness, low emissions, and sustainable economic growth. The Uganda Green Growth Development Strategy (UGGDS) 2017/18–2029/30 was developed to accelerate the implementation of the Sustainable Development Goals (SDGs), the Uganda Vision 2040, and the Second National Development Plan (NDP II). The UGGDS was therefore developed to operationalize the broad green growth tenets highlighted in the 2030 Agenda, the Uganda Vision 2040, and in NDP II to support the country’s transition to middle-income status on a sustainable pathway. The general objective of the UGGDS is to provide guidance on priorities, strategies, and governance frameworks for implementing the green growth principles within Uganda’s existing framework for sustainable development. It focuses on five core investment areas: agriculture, natural capital management, green cities, transport, and energy, each of which reinforces its capacity to support the development of a thriving bioeconomy. The development of a bio-based economy is directly supported by an emphasis on the use of innovative technologies in agro- and food processing, by the adoption of agroforestry and afforestation under sustainable forestry and natural capital management, by expanding the use of biomass for electricity, and by the incorporation of improved technology for greater efficiency in the use of biomass for domestic and industrial uses. Estimates indicate that full implementation of the UGGDS interventions (a green growth scenario) will enhance national GDP by 10 percent more than the business-as-usual target, deliver an additional four million green jobs and reduce greenhouse gas emissions by 28 percent relative to the conventional growth pathway.353

The UGGDS also seeks to build further synergies to accelerate growth prospects and minimize inefficiencies associated with a duplication of efforts; access unutilized capacity and willingness to learn; and improve efficiency of performance. In order to achieve the greatest impact, it has adopted the multisectoral governance arrangements proposed in NDP II. These governance arrangements consist of the National Planning Authority; the Ministry of Finance Planning and Economic Development; all sectoral ministries, departments, and agencies; and representations from civil society, the private sector, district local governments, and relevant urban authorities.354

3.2 National energy policies

Over the last two decades, energy policies have evolved to have more space for, and expend greater effort on, increasing the share of renewable energy. The Energy Policy 2002 was developed to guide the energy sector in an environmentally sustainable manner. The Renewable Energy Policy for Uganda (2007–2017) is essentially an offshoot of the Energy Policy 2002. The overall goal of this policy was to increase the use of modern renewable energy from 4 to 61 percent of total energy consumption by 2017. It was committed to developing the use of “modern” renewable energy resources in Uganda into a substantial part of the nation’s energy consumption. The Renewable Energy Policy provided a legal and institutional oversight of the renewable energy sector, including the addition of a renewable energy department within the Ministry of Energy and Mineral Development (MEMD). The policy also sought to improve the enabling environment to facilitate investments in renewable energy technologies; it provided a legal basis, a fiscal policy framework, and a context for international cooperation for technology transfer.

The Renewable Energy Policy was followed by the introduction in 2014 of the Biomass Energy Strategy (BEST) Uganda, which was designed to propose approaches to managing the country’s biomass energy sector. Biomass provides more than 90
percent of nationally consumed energy, with the rest split between electrical generation (mostly hydro) and imported fuel used for transport. Under this strategy and the overall energy policies, some government and public-private partnerships have come into existence. Three sugar factories contribute to the national grid with bagasse energy from sugarcane residues, and a new plant worth US$64 million was announced in 2016 and is expected to contribute about 23 MW to the national grid. These ambitions were reinforced by NDP III which aims to reduce the share of biomass energy used for cooking to 50 percent by 2023 and to increase the share of clean energy used for cooking from 15 percent in 2018 to 50 percent also by 2023. The General Energy Transfer Feed-in Tariff (GET FiT) program also operates within the provisions of this policy. Since 2013, the program has facilitated 17 small energy projects, contributing close to 160 MW to the national grid.

The Renewable Energy Policy and the Biomass Energy Strategy also laid the groundwork for a Biofuels Act, 2018 by formalizing the intention to promote the sustainable production and utilization of biofuels. The Biofuels Act requires petroleum products to be blended with up to 20 percent biofuels, set out clear targets for scaling up the use of biogas and efficient stoves and for the improved use of biomass energy from forests, and advocated for greater conversion of municipal and industrial waste to energy. It regulates the production, storage, and transportation of biofuels and provides for the participation of the private sector in bioenergy development under the oversight of the MEMD. On the basis of these objectives, the Biofuels Act aims to increase power generation from municipal waste from 0 to 30 MW by 2017. The policy also aimed to produce 2.1 million m³ of biofuels by 2017, while promoting solar home systems and other energy-efficient renewable technologies. The Act, however, is yet to be operationalized.

3.3 Agricultural bioeconomy

Uganda’s agricultural sector is central to its economic growth, employment, and wealth creation. This is reflected in the priority it is given across both of the previous NDPs and in its sector strategies. Both the 2013 National Agriculture Policy and the Agriculture Sector Strategic Plan (2015–2020) acknowledge the importance of biotechnology as a catalyst for productivity in various agricultural value chains. NDP III, too, presents agro-industrialization as the premier strategy for raising household incomes and improving the quality of life of Ugandans. To achieve these goals, NDP III focuses on raising productivity, improving postharvest handling, and improving agro-processing and value addition for ten selected commodities: coffee, tea, fish, cocoa, cotton, vegetable oil, beef, maize, dairy products, and cassava. All of these activities have a bearing on the progress of Uganda’s agricultural bioeconomy in that they necessitate greater uptake of improved inputs and varieties, as well as increased investment in R&D, extension systems, and processing facilities for the selected commodities and their by-products to produce starch, ethanol, and processed oils. NDP III also aims to expand micronutrient industrial food fortification, research on biofortification and the
multiplication of nutrient-dense food staples such as beans, cassava, and sweet potatoes. These focus areas build on, and enhance, bioeconomy-relevant areas from the Agriculture Sector Strategic Plan (ASSP) that was implemented between 2015 and 2020. The ASSP prioritized, among other things, investment in fertilizer production and marketing; this included biofertilizer use, biofuel production from cassava feedstock, and awareness building on biofortified foods.

3.4 National Bioeconomy Plan 2020

Uganda is one of the few African countries that has drafted a dedicated national bioeconomy plan. Produced by MOSTI in 2020, the bioeconomy plan aims to strengthen bioscience innovation in order to enhance food security, improve nutrition and health outcomes, and increase job creation through the expansion and intensification of the sustainable production of bioresources. It also focuses on translating bioscience research and innovations into industrial and commercial enterprises by facilitating greater private sector participation and, in the process, transforming Uganda into a knowledge-based economy. These objectives have been articulated after multiple highly interactive consultations and dialogues, including with ministerial and other government representatives, academia and research institutes, donors and investors, private sector actors, civil society organizations, and umbrella associations.

The plan presents an institutional framework that addresses the legal and regulatory structures that are required to harness the benefits of a thriving bioeconomy. Once adopted, it is expected that the plan will be implemented by MOSTI in line with the East Africa Regional Bioeconomy Strategy under the East African Science and Technology Commission (EASTECO). MOSTI will also be responsible for stakeholder engagement and coordination and for mobilizing resources to build a thriving bioeconomy.

3.5 Intellectual property rights

Uganda is a signatory to several regional and international IP-related agreements, treaties, and protocols. Under NDP II, the industrial development subsector aimed to promote sustainable industrialization through technology transfer, with the involvement of development partners. Although there is no explicit reference to technology transfer, the National Agriculture Policy (2011) includes the key objective of increasing the productivity and income of Ugandans through greater access to technologies for value addition and agro-processing and by enhancing market access. Uganda’s National Intellectual Policy of 2019 thus sets out to establish an appropriate IP infrastructure that supports innovation and creativity, develops human capital for the IP value chain, and enhances the utilization of IP systems. The IP policy supports the development of a framework to protect traditional knowledge (TK) and traditional cultural expressions (TCES), and to create a digital database of TK and TCES with a view to protecting cultural heritage from unauthorized exploitation. This is a key step towards ensuring that the country’s indigenous knowledge holders benefit from any commercial products that are developed from the knowledge that they hold. The IP policy also provides a platform for greater coordination among institutions, community organizations and individuals who hold the indigenous knowledge. One initiative to strengthen the protection of traditional knowledge is the development of a National Intellectual Property-Related Traditional Knowledge Action Plan. Currently in the process of being drafted, the development of this plan is led by the Uganda Registration Services Bureau (URSB). In July 2017, in order to improve awareness of the issue, the URSB and the World Intellectual Property Organization organized a “Workshop on Intellectual Property and Traditional Knowledge for Economic Development: Empowering Local Communities of Uganda.”

4. PROGRAMMATIC INTERVENTIONS

4.1 The FREVASEMA project

One of UIIRI’s successful outputs has been the development of a new banana variety that can be frozen for six months without losing its taste or aroma. The new variety of cooking banana, called matooke, was developed by Kyambogo University in partnership with UIIRI and others at Afri Banana Products (Uganda) Ltd—an incubator specializing in enhancing entrepreneurial skills in the banana value chain within universities, businesses, and agricultural research institutions. It was developed under the Fresh Vacuum Sealed Matooke (FREVASEMA) project, initiated in 2008 with financial support from the Presidential Support to Scientists. A 20-year patent for the bio-innovation was filed in 2007 at the African Regional Intellectual Property Organization (ARIPO) in Harare, Zimbabwe, and was granted in 2009. The new banana variety was also registered with the U.S. Food and Drug Administration in 2010, thereby opening a large market for export. The technology is protected at the national level and royalties are paid to Afri Banana Products (Uganda) Ltd. The project also developed commercially viable processes for adding value to banana by-products by using them in various products like biodegradable bags, textiles, briquettes, wine, enriched animal feed, and vinegar. The second phase of the project aims to enhance product branding and promotion and to consolidate distribution systems for supplying local, regional, and international markets. It also aims to
support full commercialization of the other value-added products. Exports to the USA and Australia have benefited farmers, project partners, and the economy of Uganda generally through the foreign currency it has garnered and the employment it has generated.363,364,365,366

4.2 Interventions in the energy sector

The Government of Uganda is making some efforts to improve the supply of clean energy. In 2015, Uganda submitted an investment plan under the Scaling-Up Renewable Energy Program (SREP) to the Climate Investment Funds program. The investment plan was positively evaluated and US$50 million was provided to invest in catalyzing investments in geothermal, solar PV net metering, mini-grids, and wind power. An initial US$100 million injection to the GET FiT program leveraged an additional US$35 million from public and private sources. The financial boost has resulted in the emergence of smaller renewable energy projects which contribute over 150 MW to the national grid, and employ more than 11,000 Ugandans.367 At more micro levels, development partners continue to encourage the uptake of energy-saving cookstoves that consume far less biomass.368 Mass take-up of energy-saving cookstoves, however, remains low and promoters may need to incentivize take-ups such as free testing options and warranties.369 There is no clear government policy or program that encourages the use of energy-saving cookstoves, so these efforts remain only in the private sector.

4.3 Waste management

The capital city of Kampala alone generates an estimated 1.2 million metric tons (Mmt) of waste per year and has only one large landfill. Efforts to open a more efficient landfill are underway through a public-private partnership between the city council and private companies that is being funded by the World Bank.370 USAID is also funding another public-private partnership that handles medical waste.371 Current waste collection and management systems are mainly public-private partnerships; however, studies have indicated that most residents in slum areas cannot afford the collection fees.372 In the meantime, increasing e-waste from electronics and electric equipment has created a new and more pressing challenge in addressing the country’s waste management. Uganda is estimated to have generated 17,000 mt of e-waste in 2018,373 which was generally not disposed of in an environmentally friendly manner. To counter this increasing threat to the environment, in 2016 the government established an e-waste management facility and developed
regulations for the proper disposal and management of e-waste. The World Bank and the Kampala Capital City Authority are conducting a study to explore the ‘willingness to pay’ for new waste facilities and waste collection modalities.

Another dimension of waste management is livestock waste. The potential for livestock waste to be converted into bioenergy (biogas) has been highlighted by several researchers and yet most abattoirs across Uganda’s major urban areas do not have proper waste management facilities. A lot of livestock waste from abattoirs therefore ends up in Lake Victoria, causing water pollution. With funding from Sida, a pilot plant was set up at the city abattoir which generated biogas from the daily waste produced there. Staff report an almost 90 percent saving in the amount of diesel fuel being used to run the generators, and it is projected that more energy will be generated as the technology becomes better established. The Kampala Capital City Authority seeks to expand this project to other abattoirs in the city and to scale it up for implementation across the country.

5. CONCLUSION

A bioeconomy is central to Uganda’s Vision 2040 and to its National Development Plans, especially in terms of the country’s aspiration to reduce its dependence on biomass energy and increase clean energy. Bioeconomy offers Uganda the potential to modernize traditional economic sectors with the adoption of new technologies such as biotechnology and nanotechnology. The country has made some efforts to advance bioeconomy development through specific value chains and industries in its agricultural and energy sectors. Lessons learned from these efforts can be scaled out to other value chains and other parts of the economy to achieve sustainable growth.

A number of policies and acts of parliament have created an enabling environment to accelerate the development of a bioeconomy. The country has also demonstrated some success in developing bio-innovations in its agricultural sector. Overall, there is evidence of the potential to create a vibrant multidimensional bioeconomy which enables closed-circuit loops in the agricultural, livestock, and energy sectors for bioenergy production. As scientific evidence mounts, the government has developed multiple policies and regulations to guide innovation, attract funding, and scale up on-going pilots and small projects.

However, challenges remain. First, while it is clear that there is a vibrant innovation environment in the country, the current institutional structure for fostering the development of biotechnologies and biosolutions risks duplication of efforts and inefficiencies. Greater oversight and coordination of research and innovation projects, perhaps through a central body would reduce duplication and ensure that the pathway from idea to commercialization is efficient and rapid. Second, there is clearly a large demand for incubators to support the conversion of innovations into commercial products and thriving enterprises. Investing in the required STI infrastructure—such as science and technology parks, technology transfer centers, and incubators—must be matched with efforts to improve the operating environment for new businesses such that they are able thrive once they have graduated from incubation. This includes strengthening backward and forward linkages between actors in the innovation ecosystem in order to exploit the opportunities arising from synergies in their activities. Third, while the country aspires to increase renewable and clean energy, efforts must be made to diversify the sources of finance and scale the investments being made in these industries. The UGGDS, national climate change policies and science, technology and innovation plans can all be deployed to achieve these ambitions. Uganda’s green growth strategy is an ambitious program to reorient the country’s development pathway to a low-carbon and sustainable one. Achieving this is expected to cost approximately US$1.8 billion per year until 2030. If bioeconomy objectives are integrated more explicitly into the UGGDS, there is a significant opportunity to realize multiple goals.
8. CONCLUSION

Although African countries are still in the early stages of developing bioeconomies, they are a part of a growing global movement seeking to build more sustainable production and consumption practices. More than 60 countries globally have already drafted bioeconomy-related policy strategies. And, as this report shows, this includes several African countries too. At the time of writing, fourteen countries across Africa are in the process of drafting the first generation of bioeconomy and bioeconomy-related strategies, while the East African Community is set to complete its regional strategy.

This report comes at a time of socio-economic pressures; over two years into the COVID-19 pandemic and war in Ukraine, coupled with climate change, population growth, and increasing resource scarcities, matters of vulnerability and resilience are at the top of governments’ concerns and agendas.

Bioeconomy - defined as the application of science, technology, and innovation to the sustainable production and use of biological resources to create innovative products, processes, and services for all economic sectors – presents an enormous opportunity for African countries to address multiple challenges simultaneously and accelerate progress toward its continental and global development commitments.

Bio-based innovations not only offer technological solutions to many of the economic, social, and environmental challenges facing the continent; the use of renewable biological resources, primarily from the agricultural sector, provides a platform from which to extend the benefits of a growing and sustainable economy across both rural and urban parts of the continent. A vibrant bioeconomy can increase agricultural productivity and support the expansion of agro-industries, both of which are vital for sustainable economic growth, enhancing economic competitiveness, and employment generation, especially for Africa’s youth. Meanwhile, greater uptake of biotechnology can also effectively increase food availability and raise its nutrient content, while promoting new food (and non-food) value chains; it can also improve food safety. There are also opportunities for protecting, conserving, and restoring biodiversity, and climate change mitigation.

The experience of four African countries that are at the forefront of innovative actions and leadership at the institutional, policy, and programmatic levels, thus offers a wealth of lessons for replication and scaling up and out across the continent.

Ghana’s bioeconomy-related activities are currently focused on agriculture, forestry, energy, and waste management. Promoted by the Council for Scientific and Industrial Research and COCOBOD, the country has transformed the cocoa sector with biosciences and technology and established a wide range of industries for cashew, shea, and their by-products. The country has also successfully integrated herbal medicines into standard healthcare delivery, supported by public and private sector actors, as well as research and financial institutions. Science, technology, and innovation thus play a central role in Ghana’s socio-economic development and in the development of its bioeconomy. This, in turn, provides a strong foundation for scaling up its emerging bioeconomy to other sectors. The last two decades have seen renewed interest in enhancing the role of tertiary institutions in advancing their science and technology outputs. These higher education institutions are well-positioned to contribute to the Ghanaian bioeconomy.

Namibia has launched a number of bioeconomy-related initiatives, and its multistakeholder approach to bioeconomy development, including government, civil society, and universities, plays a critical role in its efforts to scale across sectors. Namibia is in the process to develop its first bioeconomy strategy, and a number of bioeconomy-related policies are already in place. The country also specifically promotes technology and innovation for economic growth as a key enabler for bioeconomy development. In addition, the government uses/makes use of the biomass it derives from controlled bush thinning of pastureland for economic opportunities, value chain development, and job creation. Finally, Namibia supports the sustainable management and use of biodiversity with the development of the National Biodiversity Strategy and Action Plan (NBSAP), which was recognized internationally as one of the best first-generation NBSAPs.
South Africa’s policymakers have developed a portfolio of policies, strategies, and supporting institutions to develop a thriving bioeconomy. The Department of Science and Innovation, the National Advisory Council on Innovation (NACI), the Technology Innovation Agency (TIA), and the National Intellectual Property Management Office (NIPMO) form the basis of an impactful system of innovation. Policy adjustments in parallel have ensured that the process is rooted in a clear vision and focused on three key sectors: agriculture, health, and industry. By investing in education, improving collaboration between universities and industry, strengthening its IP environment, and supporting small businesses, South Africa has developed a leading biopharmaceutical and biotechnology sector, and evolved to an attractive destination for investments in the bioeconomy. The country is now at the forefront of continental and global efforts to establish successful bioeconomies; it is currently the only one in Africa that has an approved, dedicated and comprehensive bioeconomy strategy.

Uganda has, over the past two decades, fashioned a robust and forward-looking trajectory to capitalize on the potential of a bioeconomy. Its geography, soil, diverse agroecological zones, and rich biodiversity give Uganda a comparative advantage in the production of biomass, which is a key input into a thriving bioeconomy. The country has drafted a comprehensive bioeconomy strategy and approved a green growth strategy which provides a platform to intensify the development of a bioeconomy. Uganda has become a hub of excellence on agricultural R&D; its National Agricultural Research Organization and universities have become a beacon for advancing food and agricultural biotechnology, in turn earning a position on the coveted African Higher Education Centers of Excellence Project by the World Bank. While the incubators at Makerere University (Food Technology and Business Incubation Centre) and the Uganda Industrial Research Institute provide a valuable launchpad for bio-enterprises, PHARMBIOTRAC at Mbarara University is rapidly building a critical mass of skilled human resources to promote the domestication and commercialization of traditional medicines and biopharmaceuticals.
The Malabo Montpellier Panel has identified a set of five actions summarized below that if adopted could make a significant contribution for Africa to leapfrog into bioeconomy:

1. **Identify gateway sectors through which to initiate the development of transition to a bioeconomy.**

   The development of a bioeconomy can be initiated via selected ‘gateway’ sectors. These sectors would ideally match those that form the focus of long-term national development plans, align with broader food security and resilience ambitions, provide clear innovation opportunities such as clean cooking fuels, the reduction of plastic pollution, bio-based materials for sustainable construction, and biopharmaceuticals, or which represent a comparative advantage or complementary approach. Working with a shortlist of sectors or challenges allows policymakers to model context-specific approaches prior to mainstreaming a bioeconomy strategy across other sectors.

2. **Strengthen links to R&D and markets for new bioproducts and biosolutions.**

   Energizing the national innovation system necessitates investments in education, research, and development. STEM subjects, sustainability education, and indigenous knowledge are critical components of a curriculum that is designed to empower students and young people to participate meaningfully in the development of a bioeconomy. Closer collaboration between higher education, national research institutions, and the private sector can be facilitated via incubators, competitions, and challenges. Enhancing the financial sustainability of national research institutes with hybrid funding models that accommodate private sector services and international development partners can enhance bioeconomy research outcomes and impacts and can further strengthen collaboration across sectors and among stakeholders.

3. **Develop demand for bioproducts and biosolutions.**

   Public awareness campaigns, public procurement, and industrialization and trade strategies can facilitate a bioeconomy market and can drive demand for bioproducts and biosolutions. At the same time, the introduction of recycling and biofuel mandates or of bans on single-use plastic products can provide low-hanging fruits with which to kick-start innovation in the bioeconomy.

4. **Regulate for sustainability incentives and to manage trade-offs.**

   The use of geographical indications, standards, and certification schemes ensures the realization of maximum benefits and gains from developing a bioeconomy. Policymakers across Africa can customize a vast range of existing (voluntary) guidelines and frameworks; while carefully crafted intellectual property (IP) regimes can protect Africa’s domestic research outputs and indigenous knowledge while creating an attractive and innovation-driven environment for private sector investments in the bioeconomy.

5. **Set up independent national advisory boards to inform and guide the development of bioeconomies.**

   Given the complexity and multisectoral nature of the bioeconomy, the central task of the bioeconomy advisory board or council—whose expertise would cover all aspects of the bioeconomy—would be to keep abreast of emerging developments in science, research and innovation and identify those that are relevant to national development.
ENDNOTES


bessanova_siani_brief_161027.compressed1.pdf
33 SIANI 2016 op. cit.
34 HLPE 2021 op. cit.
42 FAO 2020 op. cit.
43 FAO 2017 op. cit.
44 SIANI 2016 op. cit.
49 FAO 2017 op. cit.
50 FAO 2017 op. cit.
51 FAO 2017 op. cit.
60 FAO (Food and Agriculture Organization of the United Nations), A profile of the South African egg industry market value chain. Department of Agriculture, Forestry and Fisheries, Republic of South Africa, 2013.


72 Rosa 2021 op. cit.


75 O.J. Oguntuase, Biorefinery for Sustainable Development in Africa–State of production determinants and future directions, AgEcon Search (2020). ISSN 2083-3725; eISSN 2451-182X.


77 Global Bioeconomy Summit Communiqué 2020


81 https://www.afronomicslaw.org/download/file/10


83 J. Rose, Biopiracy: When indigenous knowledge is patented for profit, The Conversation, 2016. https://theconversation.com/biopiracy-when-indigenous-knowledge-is-patented-for-profit-55589#. -text=Biopiracy%20happens%20when%20researchers%20or%20affluent%20countries%20left%20marginalised%20people.&text=This%20%20more%20commonly%20used%20legally%20and%20respectfully%20manner.


85 Gold 2007 op. cit.

86 Gold 2007 op. cit.

87 https://www.afronomicslaw.org/download/file/10

88 Graff 2020 op. cit.


95 Science & Technology 2013 op. cit.

96 Science & Technology 2013 op. cit.

97 http://archive.abs-biotrade.info/fileadmin/media/Knowledge_Center/Publications/FNI/FNI-R0612.pdf


103 El-Chichakli 2016 op. cit.


108 Virgin 2016 op. cit.

109 Ecuru 2016 op. cit.

110 Morris 2016 op. cit.

111 Nuts & Bolts: Strengthening Africa’s Innovation and Entrepreneurship Ecosystems

112 Nuts & Bolts: Strengthening Africa’s Innovation and Entrepreneurship Ecosystems


161 COCOBOD (Ghana Cocoa Board), Objectives and Functions of the Board: Get to know more about the function of our board in helping us achieve our goals and visions, 2022. https://cocabod.gj/objectives-of-board

162 Essegbey and Ofori-Gyamfi 2012 op. cit.


165 Yusif 2021 op. cit.

166 J. Gockowski, Policy-led intensification and returns to input use among Ghanaian cocoa farmers; Sustainable tree crop program of the International Institute of Tropical Agriculture (IITA), Accra, Ghana, 2012.

167 COCOBOD (Ghana Cocoa Board), Annual reports and consolidated financial statements, 2022. https://cocabod.gj/resources/annual-report


174 Adelina Maria Mensah and Christopher Gordon 2020. op. cit.


195 ECREEE 2015 op. cit.


206 Namibia, Ministry of Agriculture, Water and Forestry n.d. op. cit.

207 Namibia, Ministry of Agriculture, Water and Forestry n.d. op. cit.


249 Republic of South Africa, Department of Science and Innovation, 2020 op. cit.


255 Campbell 2019 op. cit.

256 McLeod 2019 op. cit.


259 McLeod 2019 op. cit.


277 Ramazan Uctu, Hassan Essop, The role of the South African government in developing the biotechnology industry—From biotechnology regional innovation centres to the technology innovation agency, Working paper 19, Department of Economics, Stellenbosch University, 2012.

278 Al-Bader 2009 op. cit.

279 Uctu 2012 op. cit.

281 TIA 2022 op. cit.


285 Joly 2019 op. cit.


291 Madikizela 2022 op. cit.


293 Madikizela 2022 op. cit.


300 SANBio (South African Network for Biosciences), Annual report 2015, 2016.


302 Adelle 2018 op. cit.


305 Hide 2001 op. cit.


310 Durham 2018 op. cit.


315 Republic of South Africa, Department of Science and Innovation, 2020 op. cit.

316 Republic of South Africa, Department of Science and Innovation, 2019 op. cit.


318 TIA n.d.b op. cit.

319 TIA n.d.a op. cit.


321 TIA n.d.b op. cit.

322 TIA n.d.b op. cit.

323 TIA n.d.b op. cit.


325 TIA n.d.b op. cit.

326 Personal communications, Maneshree Jugmohan-Naidu, Director: Agricultural Biotechnology, Department of Science and Innovation, 2022.


338 UNCTAD 2020 op. cit.


342 UNCTAD 2020 op. cit.


348 Mbarara University of Science and Technology, Pharmacy and Traditional Medicine Centre (PHARMBIOTRAC), n.d. https://pharmbiotrac.must.ac.ug/.


350 Document from Dorothy

351 UNCTAD 2020 op. cit.

352 Grace 2020 op. cit.


354 Uganda, Vision 2040 n.d. op. cit.


359 Uganda, National Planning Authority 2020 op. cit.

360 ATPS 2020 op. cit.


362 UNCTAD 2020 op. cit.


377 Mbugua 2015 op. cit.

378 Uganda, Vision 2040 n.d. op. cit.

Copyright 2022 AKADEMIYA2063, Imperial College London, and Center for Development Research (ZEF) University of Bonn. This publication is licensed for use under a Creative Commons Attribution 4.0 International License (CC BY 4.0).

Any opinions stated in this report are those of the author(s) and are not necessarily representative of or endorsed by AKADEMIYA2063, Imperial College London, and Center for Development Research (ZEF) University of Bonn.

Image copyrights: