Bioeconomy as Climate Action: How Ready Are African Countries? 122

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Abstract

Bioeconomy is a new perspective for fighting climate change. Africa is warming faster than the global average, and climate change remains a major threat on the continent for coming decades. The development of sustainable bioeconomy is extremely important in Africa to accelerate mitigation and adaptation to climate change. However, this concept is not well diffused on the continent. The objective

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of this chapter is to present the current state of bioeconomy in Africa and the readiness of the member countries to adopt bioeconomy as climate action, with particular attention to the state of production determinants of a bioeconomy. The main factors and trends (both positive and negative), relating to building strategic capacity towards employing bioeconomy for climate action on the continent, are outlined. The findings and recommendations will assist both the academia and policymakers in Africa to integrate bioeconomy into their national and regional climate change mitigation and adaptation strategies and action plans.

Keywords

Climate change · Climate action · Bioeconomy · Production determinants · Africa

Introduction

Africa is one of the hotspots of vulnerability to the adverse impacts of human-induced climate change (IPCC 2014), with multiple biophysical, political, and socioeconomic stresses interacting to increase the continent's susceptibility and constrain its adaptive capacity (Connolly-Boutin and Smit 2016). Productivity in several African countries depend on natural resources, climate sensitive sectors such as agriculture, fisheries, forestry, and tourism, and climate-sensitive infrastructure such as houses, buildings, municipal services, and transportation networks. Endemic poverty, lack of awareness, and lack of access to knowledge also limit the continent's adaptive capacity to cope with climate change impacts (Fereja 2017; Ford et al. 2015). With increasing temperature, the Food and Agricultural Organization (2019) projected that there will be loss of 2–7% of GDP by 2100 in parts of sub-Sahara Africa, 2–4% and 0.4–1.3% in west and central Africa, and northern and southern Africa, respectively.

Bioeconomy is a set of economic activities, an alternative to our present fossil-dependent model, in which renewable biological resources are sustainably produced to replace fossil fuels in various forms of consumption and production, to produce products (goods and services) for final and intermediate consumption. As a new wave of economic system, bioeconomy combines, in a synergic way, both natural resources and technologies, with markets, people and policies to tackle societal challenges such as natural resource scarcity, fossil resource dependence, climate change, unprecedented waste generation, loss of biodiversity, and food and energy insecurity while achieving sustainable growth.

While the concept of bioeconomy emerged in the twentieth century, it was not until the twenty-first century that it gained wide attention of scientists and policy makers as a political-economic concept which proposes the replacement of fossil resources in order to combat climate change (Asada and Stern 2018). However, bioeconomy has not been adopted by several African countries (Oguntuase 2017).

Accordingly, the objectives of this chapter are to present the current state of bioeconomy in Africa, and the readiness of African countries to embrace bioeconomy as climate action. The chapter will also compare the readiness of African countries to embrace bioeconomy with that of countries having bioeconomy strategies.

Bioeconomy as Climate Action

Bioeconomy has been identified as an opportunity to achieve EU's climate change mitigation targets and reduce dependence on fossil-derived resources (Fehrenback et al. 2017). It also holds significant promise for solving the climate-related problems associated with fossil fuel use in heat, electricity, and transportation fuel production (Banerjee et al. 2018). Likewise, the use of bioenergy, devising smart strategies and value-chain pathways to lock the chain's greenhouse gases emissions, have been identified as a potential means of achieving the ambitious Paris climate target (Honegger and Reiner 2018).

Bang et al. (2009) estimated that industrial biotechnology, biofuels and bioenergy could reduce global greenhouse gas emissions by 1.0–2.5 billion tons of carbon dioxide (CO_2) per year by 2030. The reduction of GHG emissions and reduction in fossil depletion impact by biorefineries was also alluded to by Gnansounou et al. (2015). Similarly, Junqueira et al. (2017) showed that both first generation 1G (in the medium and long term) and second generation 2G ethanol can reduce climate change impacts by more than 80% when compared to gasoline, while Baral and Guha (2004) reported that growing short-rotation woody crops (SRWC) for use in cost-effective biomass-based technologies such as biomass-integrated gasifier/steam-injected gas turbine (BIG/STIG) is a cost-effective strategy to combat climate change.

In other studies, Jørgensen et al. (2015) reported that temporary carbon storage in biomaterials has a potential for contributing to avoid or postpone the crossing of critical climatic target level of 450 ppm; Shen et al. (2012) found that bio-based PET (polyethylene terephthalate) polymer has been found to have the lowest greenhouse gas (GHG) emissions, compared to recycled (partially) bio-based PET, recycled PET, and petrochemical PET; Singh and Strong (2016) demonstrated that biofertilizers improve the activity of methane-oxidizing methanotrophs, thereby enhancing methane oxidation and/or decreasing the production of methane – a most potent greenhouse gas.

Beyond climate change mitigation, there is a large potential for synergies between bioeconomy and climate change adaptation. Climate change is affecting all four dimensions of food security: food availability, food accessibility, food utilization, and food systems stability (FAO 2008), and bioeconomy offers opportunities for the agriculture sector to adapt. Bioeconomy will help improve food security and advance human development through the development of more efficient systems of agricultural production which can significantly increase the production of much healthier and more natural products, compared with the products obtained by intensive modern agriculture (Canja et al. 2017), support crop and animal diversification to produce a variety of foods suitable for health and nutrition (Bazgă and Diaconu 2013), thereby increasing the sustainability of the agricultural sector (Baidala 2016). Specifically, adoption of genetically modified (GM) technologies could help offset the detrimental effects of climate change (Ortiz-Bobea and Tack 2018) by helping to meet targeted yields, nutritional quality, and sustainable production to stabilize and increase food supplies, which is important against the background of increasing food demand in a warming resource-constrained world (Oliver 2014; Qaim and Kouser 2013).

Around 50% of harvest losses caused by environmental factors are down to drought, and it is expected that this proportion will continue to rise as a result of climate change (Linster et al. 2015), because drought stress tolerance of crops was a significant trigger for total yield in the last decades and its significance for yield is supposed to even increase in the future as a result of climate change (Lobell et al. 2014; D'Hondt et al. 2015). Genetically modified (GM) crops have been cultivated to be more resistant to drought and other biotic and abiotic stresses, increase yields by 6–30% on the same amount of land, help produce more crops per drop of water, help transition towards soil conserving farm practices such as low- and no-till systems, which are important for more efficient water use by better trapping soil moisture, and reduce greenhouse gas emissions associated with the application of fertilizers, fuel use, and plowing (ISAAA 2014; Parisi et al. 2016; Svitashev et al. 2016; Fedoroff et al. 2010).

Employing bioeconomy in the forest-based sector has been demonstrated as both climate change adaptation and mitigation methods. Lindner et al. (2017) submitted that while developing a forest-based bioeconomy with more intensive use of forest biomass can support climate change mitigation, active replacement of maladapted species will strengthen adaptive capacity. Kalnbalkite et al. (2017) submitted that products which are produced from wood take important place in the influence on climate change reduction, while Leskinen et al. (2018) found that for each ton of carbon (C) in wood products that substitute non-wood products, average emission are reduced by approximately 1.2 ton C. This corresponds to about 2.2 ton of CO_2 emissions reduction per ton of wood product, depending on the wood product and technology considered, and the method used to estimate emissions.

Buildings and construction related CO_2 emissions have continued to rise by around 1% per year since 2010, to account for 36% of global final energy use and 39% of energy-related carbon dioxide (CO2) emissions, when upstream power generation is included; these are significant causes of climate change (IEA 2017). Life cycle assessment (LCA) of the climate impact of buildings by Peñaloza and Falk (2016) showed that increasing the biobased material content in a building reduces its climate impact even if biogenic exchanges are assessed. A similar study by Pittau et al. (2018) expressed that storing carbon in biogenic construction products and building components can largely contribute to reducing carbon emissions. In another study, Lei et al. (2016) recommend the use of phase change materials (PCMs) in tropical climates to reduce building cooling load and improve energy performance.

Table 1 Bioeconomy-related activities in African countries

Country	Document title	Perspective
Ghana	National Bioenergy Strategy in Ghana (2014)	Bioenergy
Kenya	Strategy for developing the Bio-Diesel Industry in Kenya (2008) National Bioprospecting Strategy (2011)	Bioenergy High tech
Mali	Renewable Energy Strategy (Strategie Nationale de Développement des Energies Renouvelables en Mali) (2006)	High tech
	Biofuel Strategy (Strategie Nationale de Développement des Biocarburants en Mali) (2009)	Bioenergy
Mauritius	Ocean Economy 2013	Blue economy
Mozambique	National Biofuel Policy and Strategy (Politica e Estrategia de Biocombustiveis (2009)	Bioenergy
Namibia	National Programme on Research Science, Technology and Innovation (2015)	Research and innovation
Nigeria	National Biotechnology Policy (2001)	Research and innovation
	Biofuel Policy and Incentives (2007)	Bioenergy
Senegal	National Biofuels Strategy (2006).	Bioenergy
	Letter of Development Policy of the Energy Sector (Lettre de politique de développement du secteur de l'énergie) (2008, 2012)	Bioenergy
South Africa	The Bio-Economy Strategy (2013)	Holistic bioeconomy development
Tanzania	National Biotechnology Policy (2010)	High tech
Uganda	The Renewable Energy Policy for Uganda (2007) National Biotechnology and Biosafety Policy (2008)	Bioenergy
	Biomass Energy Strategy Uganda (2014)	High tech

Current State of Bioeconomy in Africa

Only South Africa has a defined bioeconomy strategy in the continent. Countries such as Ghana, Kenya, Mali, Mauritius, Mozambique, Namibia, Nigeria, Senegal, Tanzania, and Uganda have some bioeconomy-related activities as shown in Table 1.

Production Determinants in a Bioeconomy

The epistemological understanding of production factor as a durable input employed in production activities allows for naming of new variables influencing and employed in the production processes as determinants. Having in mind the essence of bioeconomy, which is transition to low carbon sustainable economy, and the

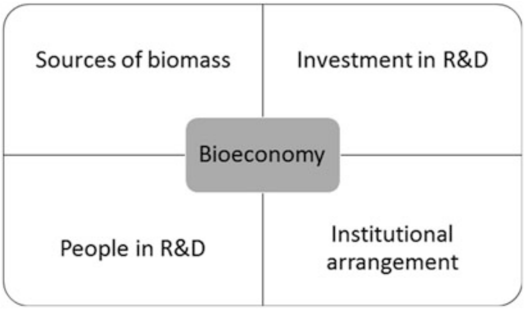

Fig. 1 Bioeconomy production determinants in line with classical view of production function

establishment that bioeconomy is a knowledge-based innovative economy (Lainez et al. 2018; Pyka and Prettner 2018), it needs to be stated that the primary production determinants of the bioeconomy extends beyond those in mainstream economic theory: land, labor, and capital.

This chapter adopts the common definition that bioeconomy is "the knowledge-based production and use of biological resources to provide products, processes and services in all economic sectors within the frame of a sustainable economic system" (German Bioeconomy Council 2013). It is situated in the context that bioeconomy is a knowledge-based economy whose four primary production determinants are the sources of biomass, investment in research and development (R&D), people in research and development, and institutional arrangement. The biomasses (biological resources) are acting as substitutes for other fossil resources. Investment in R&D focuses on the development and commercialization of products and processes within the bioeconomy system. The people in R&D encompass people employed within the bioeconomy system, who have obtained sufficient knowledge to add value across the bioeconomy value chain. Institutional arrangement is connected to the organization of the system which enables implementation of solutions that ensure competitiveness under dynamic changes (Maciejczak 2015; Talavyria et al. 2016) (Fig. 1).

Building a Bioeconomy Readiness Index

Some research findings reveal the need to measure countries' potentials for embracing bioeconomy as climate action. Bagla and Stead (2018) developed BioGreen, a method to assess the potential of bioeconomy in curbing significant climate change and its contribution to attaining Ireland's sustainability goals. Data from the JRC-SCAR Bioeconomy survey by the Bioeconomy Observatory showed that the need to combat climate change is one of the relevant reasons for the development of a bioeconomy in European countries (Langeveld 2015).

Mungaray-Moctezuma et al. (2015) developed the Knowledge Economy Index (KEI) which determined the necessary institutional characteristics of technology and human capital necessary for the knowledge-based economy in Argentina, Costa Rica, and Mexico from the perspective of bioeconomy as part of the economy. In another study, Henry et al. (2017) recognized the role of scientific and technological knowledge as a key driver in a bioeconomy and highlighted the need for every country and every region to identify possibilities and opportunities in order to set its own bioeconomy development agenda, consistent with its conditions, capacities, and needs.

The Organization for Economic Co-operation and Development (OECD 2002) aggregation method is a veritable method for building indices like the one for determining the readiness of a country or jurisdiction to embrace bioeconomy as climate action. The four-step approach to the aggregated indices OECD method as adopted by Schlör et al. (2017) are: (1) the selection of the variables, (2) transformation, (3) weighting, and (4) valuation.

Specific statistical indicators for determining the bioeconomy readiness of a country or jurisdiction are virtually nonexistent at present. The most significant quantifiable indicators representing the production determinants in terms of bioeconomy are shown in Table 2.

The proposed formula for calculating the bioeconomy readiness of a country or jurisdiction is:

$$f\,(\text{BIOMSS}, \text{INV RD}, \text{PPL RD}, \text{IAR})$$

where: BIOMASS = ***f*** (ARL, NBI, FOR)
INV RD = ***f*** (RDE, CSR, PCT, CPI, ALT, QRI, PROD)
PPL RD = ***f*** (ASE, RRD, TRD, QMC, UIC, SCT)
IAR = ***f*** (LAW, FIN, IFR, NCA).

The State of Bioeconomy Production Determinants in African and Selected Countries

Kenya leads African countries in the people in research and development category, performing better than Thailand and Bulgaria. Tunisia follows Kenya in this category and performed better than countries like Mexico, Costa Rica, Argentina, and South Africa, in that order. Mauritania, Lesotho, Liberia, Chad, and Congo are the worst performers as shown in Fig. 2.

An African country, Gambia, leads the biomass production determinant category. The remaining countries in the top ten are Malaysia, India, Costa Rica, Rwanda, Mexico, Sierra Leone, Malawi, Democratic Republic of Congo, and Tanzania. The poor performers are African countries – Algeria, Mauritania, Egypt, Chad, and Cabo Verde as shown in Fig. 3.

Scandinavian countries – Sweden and Finland – have invested in research and development more than other countries. South Africa is ahead of Bulgaria in investing in research and technology, while Kenya, Mauritius, Rwanda, and

Table 2 Possible indicators for measuring the bioeconomy readiness of a country or jurisdiction

Production determinant	Indicators	Explanation
Sources of biomass ***BIOMASS***	Arable land (% of country land area), ***ARL***	Includes land defined by the FAO as land under temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow
	National Biodiversity Index, ***NBI***	Richness in four terrestrial vertebrate classes and vascular plants with adjustments country size
	Forest land (% of country land area), ***FOR***	Forest area is land under natural or planted stands of trees of at least 5 m in situ, whether productive or not, and excludes tree stands in agricultural production systems
Investment in R&D ***INV RD***	Research and development expenditure (% of GDP), ***RDE***	Gloss domestic expenditures on research and development (R&D), expressed as a percent of GDP
	Company spending on R&D, ***CSR***	The extent companies invest in research and development
	Patents applications per million population, ***PCT***	Number of applications filed under the Patent Cooperation Treaty (PCT) per million population
	Capacity for innovation, ***CPI***	How do companies obtain technology; from exclusively from licensing or imitating foreign companies to conducting formal research and pioneering their own new products and processes
	Availability of latest technologies, ***ALT***	To what extent are the latest technologies available
	Quality of scientific research institutions, ***QRI***	Quality of scientific research institutions
	Production process sophistication, ***PROD***	Sophistication of production processes
People in R&D ***PPL RD***	Availability of scientists and engineers, ***ASE***	Availability of scientists and engineers in the country
	Researchers in R&D per million people, ***RRD***	The number of researchers engaged in Research &Development (R&D), expressed as per million
	Technicians in R&D per million people, ***TRD***	The number of technicians engaged in Research &Development (R&D), expressed as per million
	Quality of mathematics and science education, ***QMC***	In your country, how do you assess the quality of math and science education? [1 = extremely poor – among the worst in the world; 7 = excellent – among the best in the world]

(continued)

Table 2 (continued)

Production determinant	Indicators	Explanation
	University-industry collaboration in Research & Development, ***UIC***	The extent to which business and universities collaborate on research and development (R&D)
	Scientific and technical journal articles (2003–2016), ***SCT***	The number of scientific and engineering articles published in the following fields: physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences
Institutional arrangement ***IAR***	Rule of law, ***LAW***	Measures countries' rule of law performance across eight factors: constraints on government powers, absence of corruption, open government, fundamental rights, order and security, regulatory enforcement, civil justice, and criminal justice
	Availability of financial services, ***FIN***	Provision of a wide variety of financial products and services to businesses
	Quality of overall infrastructure, ***IFR***	Quality of overall infrastructure
	Macroeconomic stability, ***ECON***	The extent to which a country's public sector can provide appropriate counter-cyclical measures and invest in projects that the private sector cannot finance

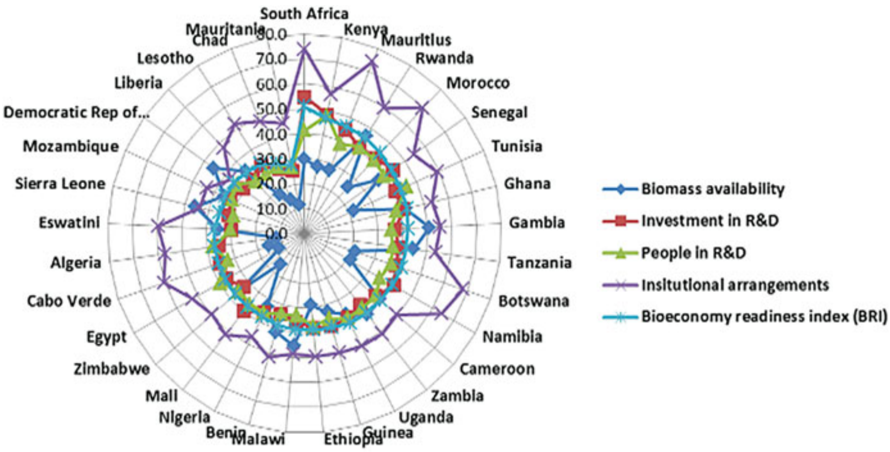

Fig. 2 State of bioeconomy production determinants in African countries

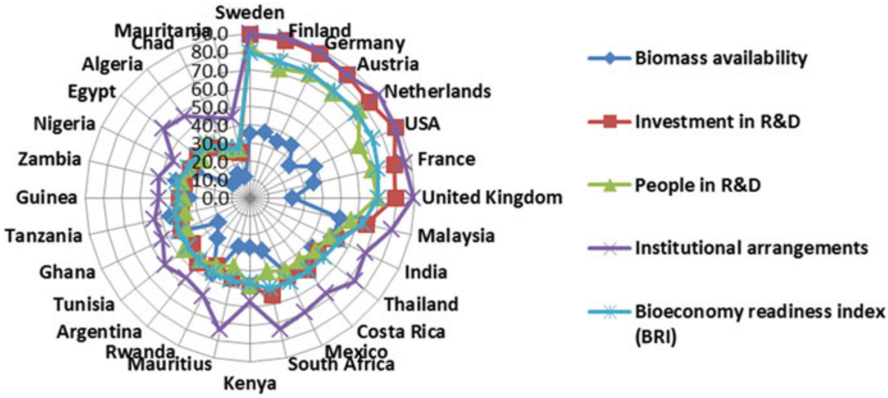

Fig. 3 State of bioeconomy production determinants in selected countries

Morocco perform better than Argentina. Mauritania has the least investment in research and development, followed by Chad, Lesotho, Liberia, and Congo.

African countries perform poorly under the institutional arrangements category. The continent's best performer, South Africa shares the same spot with Bulgaria, ahead of Argentina. Mauritania, Chad, Lesotho, and Liberia remain at the bottom of the log, just as in investment in research and development, people in research and development, and institutional arrangements production determinants.

Bioeconomy Readiness of African and Other Selected Countries

The top African countries in terms of readiness to adopt bioeconomy as climate action are South Africa, Kenya, Mauritius, Rwanda, and Morocco as shown in Fig. 4.

The bioeconomy readiness of African countries' compare to those of countries with bioeconomy strategies (Austria, Finland, France, Germany, Sweden, the United Kingdom, and the United States of America), and those with ongoing development strategies (Argentina, Bulgaria, Costa Rica, India, Mexico, The Netherlands, and Thailand) (Dietz et al. 2018; Sasson and Malpica 2017) as shown in Fig. 5.

Many African countries are endowed with relatively abundant natural biomass, yet they are poorly equipped to adopt bioeconomy for climate action, when compared with countries from America, Europe, and Asia. This is mainly due to the poor state of investment in R&D and dearth of people in R&D. Poor government spending on R&D, lack of patent applications, dearth of researchers and technicians in R&D, absence of latest technologies, poor industrial production process, poor university-industry collaboration, and poor institutional arrangements, especially rule of law and quality of infrastructure, are the key challenges to bioeconomy's development on the continent.

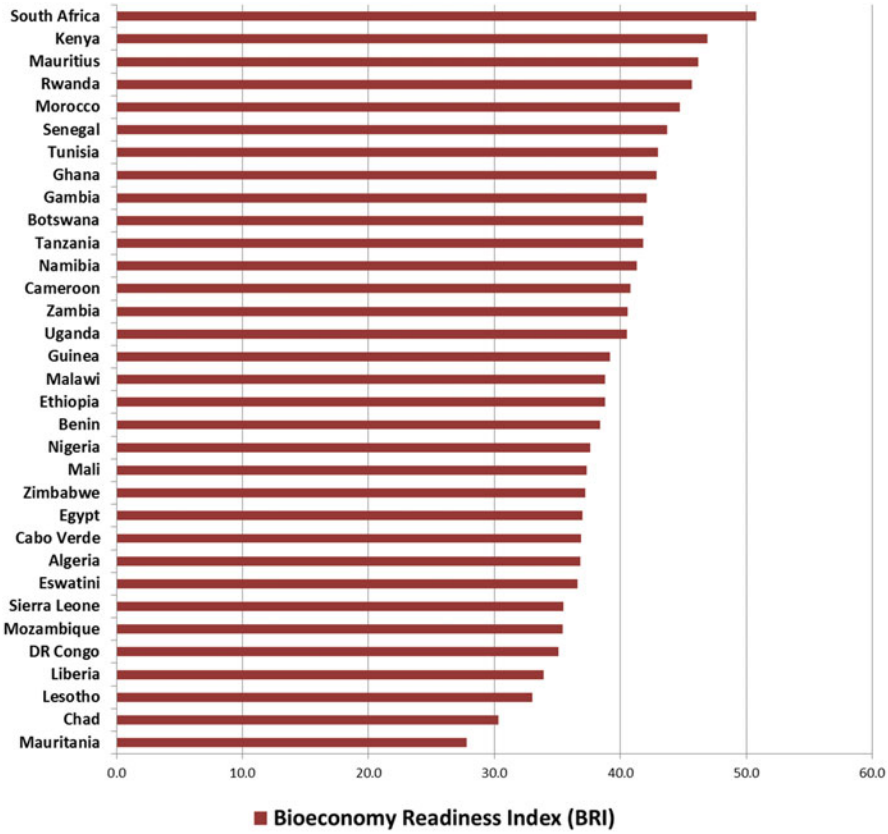

Fig. 4 African countries' bioeconomy readiness

Conclusions

This chapter presents the concept of bioeconomy as a knowledge economy with four production determinants: the sources of biomass, investment in research and development, people in research and development, and institutional arrangement. It introduces the bioeconomy readiness index (BRI) to determine the state of the production determinants of bioeconomy in African countries and other selected countries. Theoretically, countries with higher and better BRI will be better able to employ bioeconomy as climate action.

While there are bioeconomy-related activities in some African countries, it is significant to note that South Africa, the only country with defined bioeconomy strategy in Africa, has the best bioeconomy readiness index (BRI) on the continent. The possible policy implication of this is that formulating a dedicated national bioeconomy strategy, an integral part of national development agenda as applicable in South Africa, will help

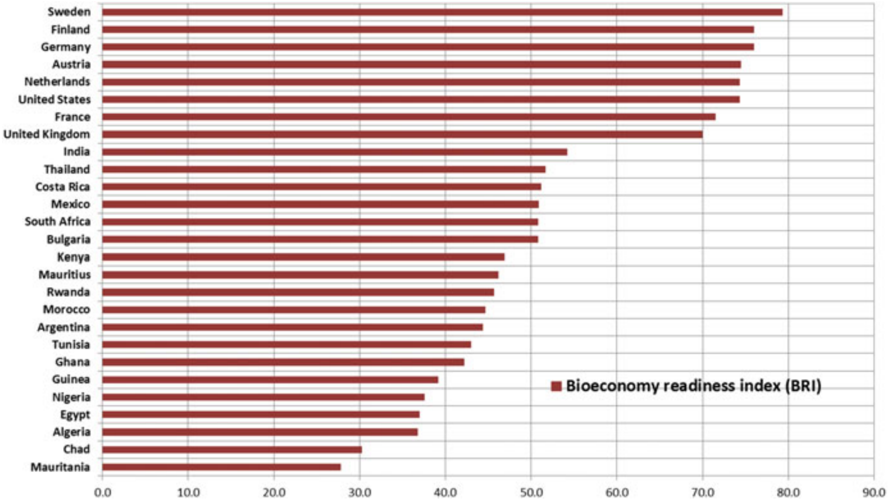

Fig. 5 Bioeconomy readiness of selected countries

improve the state of bioeconomy production determinants in Africa thereby increasing the continent's potential to employ bioeconomy as climate action.

Strategies to promote the bioeconomy in Africa must focus on targeted investments to support R&D activities; building efficient innovation system; improving the level of education, training, and skills of the populace; and supporting market development to enhance competiveness. Furthermore, African countries must improve general governance, the quality of their infrastructure, and the rule of law, to attract foreign investment in the bioeconomy sectors.

While this chapter shows important findings on the state of bioeconomy in Africa and the readiness of African countries to adopt bioeconomy as climate action, further studies are recommended in the specific areas of each production determinants to shape public policy decisions towards development of sustainable bioeconomy on the continent.

Incomplete datasets and nonavailability of comparable data remains major limitations in Africa underscores the urgent need to develop and sustain a data collection and management system on the continent to overcome the challenge of dearth of data in the bioeconomy system and related sectors. In the absence of quality data, it is difficult to formulate good strategies and scale up innovations for sustainable bioeconomy on the continent.

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