INSIGHTS INTO REGIONAL DEVELOPMENT
ISSN 2669-0195 (online) http://jssidoi.org/IRD/
2023 Volume 5 Number 1 (March)
http://doi.org/10.9770/IRD.2022.5.1(7)

ENTREPRENEURSHIP AND SUSTAINABILITY CENTER

Publisher
http://jssidoi.org/esc/home

CIRCULAR BIOECONOMY IN EGYPT: THE CURRENT STATE, CHALLENGES, AND FUTURE DIRECTIONS*

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Received 15 December 2022; accepted 15 March 2023; published 30 March 2023

Abstract. The concept of circular bioeconomy or bio-based circular economy is an integrated concept of circular economy and bioeconomy. In other words, it alludes to a systematic approach to economic growth that makes use of cascading biomass production from biological resources. In order to fulfil the objectives of sustainable development and the circular bioeconomy in Egypt, it is recommended that the bioeconomy be focused on as an economy of societal value in this article. It also discusses future directions and actions that can be used in this regard. This paper presents the current situation of the development of circular bioeconomy in Egypt and discuss future directions and measures that can be exploited and recommends focusing on the bioeconomy as an economy of societal value, enabling the achievement of the goals of sustainable development and the circular bioeconomy. Although there is no specific strategy for the bioeconomy, there are numerous government initiatives aiming to benefit from it in the future.

Keywords: circular economy; bioeconomy; circular bioeconomy; bio strategy; Egypt

Reference to this paper should be made as follows: Piccinetti, L., Rezk, M.R.A., Kapiel, T.Y.S., Salem, N., Khasawneh, A., Santoro, D., Sakr, M.M. 2023. Circular bioeconomy in Egypt: the current state, challenges, and future directions. *Insights into Regional Development*, 5(1), 97-112. http://doi.org/10.9770/IRD.2023.5.1(7)

JEL Classifications: O10, O55

Additional disciplines: biochemistry; ecology and environment; environmental engineering

Funding: This research was supported by the project MC2 EU project EuropeAid Programme (ENI/2019/413-557).

1. Introduction and literature review

The concept of circular bioeconomy refers to the systemic method for economic development that incorporates the cascading use of biomass from biological resources (Leong et al., 2021). A circular economy seeks to reduce reliance on (new) natural resource extraction while extending the amount of time resources spend via alternate

* *This research was supported by the project MC2 EU project EuropeAid Programme (ENI/2019/413-557*

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2023 Volume 5 Number 1 (March)
http://doi.org/10.9770/IRD.2022.5.1(7)

usage cycles. The bioeconomy, a concept that can include economic activities connected to the creation, development, production, and use of biological products and processes for energy, materials, and chemicals, can supplement the circular economy (Biofuture Platform, 2018).

The bio economy encompasses all fundamental modes of production, including industrial and economic sectors that use biological resources and techniques to create bio-based products and services while also establishing new businesses and jobs. (Aworunse et al., 2023). Bioeconomy is an emerging field that focuses on the sustainable use of biological resources to create economic value. It is a rapidly growing sector, driven by advances in technology, policy changes, and consumer demand for sustainable products. In recent years, there has been a surge in interest in bioeconomy as a way to create economic growth while preserving the environment.

The term bio economy in the1980's, was used to depict a solar energy-driven sustainable economy, which fits within the confines of ecology without the permanent constraint to grow. In the 1990s, a redefinition of the bio economy was advanced. It was described as an ''economic sector that makes use of new biological knowledge for industrial and commercial purposes''. This definition, alongside the corresponding establishment of the 2002 Strategy on Biotechnology sets the stage for the ''Knowledge-based Bio economy'' (KBBE) in 2005 (Gawel et al., 2019).

According to a European Commission (EC) conference report, the KBBE is a sustainable economy based on renewable resources that will not only contribute to the development of more environmentally safe production systems and the expansion of scientific frontiers. (Birner, 2018). The European Commission (2018) recently defined the bio economy as an economy that uses renewable biological resources from land and sea (for example, animals, crops, fish, forests, and microorganisms) to produce energy, food, and materials. (D'Adamo et al., 2022). Modern bio economy should not focus only on biomass and substitution of fossil fuels with sustainable and renewable alternatives but should be targeted towards ''biologisation'' of the economy via disruptive innovations that convert bio resources into food, feed, products, and services that integrate sustainability (Global Bioeconomy Summit, 2020).

The bioeconomy is an essential component for connecting and organising people to achieve the SDGs (Reim et al. 2019; Ranjbari et al., 2022). Sustainable development is defined as development that meets the needs of the current generation without risking future generations' ability to meet their own needs. (Brundtland Report, 1987). The three primary aspects of sustainable development are well articulated in the SDGs global framework, launched by the United Nations in 2015, and have become important indicators in the pursuit of sustainable development. (Kardung et al., 2021). The work of Heimann (2019) identified SDGs 1 to 3, 6 to 9, and 12 to 15 to be affected by bioeconomy activities.

Circular bioeconomy is a rapidly growing field that has been gaining traction in recent years. It is an interdisciplinary field that combines biology, economics, and technology to create sustainable solutions to produce food, energy, and materials.

The goal of bioeconomy is to create a more efficient and sustainable way of producing goods and services while minimizing environmental impacts. One of the most significant trends in bioeconomy is the shift towards using renewable resources such as plant-based materials and bioplastics instead of traditional petroleum-based materials. This shift has been driven by consumer demand for more sustainable products and by government policies that incentivize the use of renewable resources. Companies are increasingly investing in research and development to develop new bioproducts and bioprocesses that can replace traditional petroleum-based materials.
Another trend in circular bioeconomy is the increasing use of digital technologies to improve efficiency and reduce costs. Digital technologies such as artificial intelligence (AI) and machine learning (ML) are being used to optimize production processes, reduce waste, and improve product quality. Additionally, digital technologies are

ISSN 2669-0195 (online) http://jssidoi.org/jesi/
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being used to track raw materials from source to end product, allowing companies to better manage their supply chains and ensure sustainability throughout their operations.

There has been an increase in public-private partnerships (PPPs) between governments, businesses, universities, and other stakeholders to promote research and development into bioeconomy solutions. These PPPs have enabled companies to access funding for research projects that would otherwise be difficult or impossible to finance on their own. Additionally, these PPPs have enabled governments to provide incentives for companies that invest in circular bioeconomy solutions such as tax credits or grants. Generally, there has been a significant increase in interest in circular bioeconomy over the past few years due to advances in technology, policy changes, consumer demand for sustainable products, and increased public-private partnerships. As this trend continues, it is likely that more companies will invest in developing new bioproducts and bioprocesses while governments continue to provide incentives for those who invest in bioeconomy solutions.

The national waste plan in Egypt has set aside 20% of the country's 26 million tonnes of garbage annually to produce energy, 60% for the production of fertilizers and alternative fuels, and 20% for burial. The entire amount of investment potential for implementing waste-to-electricity projects is around $974 million, and the total amount for implementing fertilizer and alternative fuel production projects is approximately $319 million (Ashour, Sally, 2021).

This article provides a critical overview of current policies that determine and influence the development of a circular bioeconomy in Egypt. It also discusses the current state of the circular bioeconomy in Egypt, the role of local players in the adoption of the circular bioeconomy, the future directions, opportunities and challenges of the circular bioeconomy, measures that can be leveraged, and discusses how to focus on the bioeconomy in Egypt as an economy with social value and capable of achieving the Sustainable Development Goals.

2. Methodology

The methodology depends on reviewing the existing literature on circular bioeconomy in Egypt, including studies on the current state of circular bioeconomy in Egypt, challenges faced by stakeholders, and potential future directions. In the current paper, the data have collected from relevant stakeholders, including government officials, industry experts, and academics. These data included information on the current state of circular bioeconomy in Egypt, challenges faced by stakeholders, and potential future directions. The findings were used to draw conclusions about the current state of circular bioeconomy in Egypt, challenges faced by stakeholders, and potential future directions for research and policymaking. Finally, based on our findings from the analysis of the collected data and literature review, we provided recommendations for research and policymaking related to circular bioeconomy in Egypt. These recommendations were tailored to address specific challenges faced by stakeholders as well as provide guidance for future research directions related to this topic.

The paper is limited to the Egyptian context, and thus the findings may not be applicable to other countries. It does not consider the potential economic and environmental impacts of implementing a circular bioeconomy in Egypt, which could provide further insight into the feasibility of such an approach. The paper also does not address potential policy interventions that could be implemented to facilitate the transition to a circular bioeconomy in Egypt as it does not consider the potential social implications of implementing a circular bioeconomy, such as changes in employment patterns or access to resources for certain populations.

3. Status of circular bioeconomy in Egypt

The service sector makes up around 56% of Egypt's GDP, followed by industry (32.6%) and then agriculture, forestry, and fisheries (11.8%). The Sustainable Development Strategy (SDS) 2030, the Sustainable and Green

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Growth Strategy, the National Action Plan for Sustainable Consumption and Production (SCP), and the National Solid Waste Management Program (NSWMP). all indirectly support the concept of the Circular bioeconomy Additionally, the Egypt 2030 plan, which is built on three pillars—economic, environmental, and social—defines objectives that specifically address circular economy in fields including solid waste management, agriculture, and business. The economic pillar of the Egypt 2030 also encourages Circular Economy activities in the industrial sector by promoting the idea of a "green economy," which aims to preserve the environment and use energy more effectively and cleanly. The environmental pillar seeks to protect and utilize natural resources effectively (Nada Maamoun, 2021).

Several international bodies have developed comprehensive blueprints and adopted the circular bioeconomy as a viable approach for enabling new opportunities for economic development and innovation, as well as achieving the SDGs (FAO, 2018; Pandey, 2021). As a well more than 50 countries now developing bioeconomy action plan (Aguilar et al., 2019). While some African countries have a well-defined bioeconomy strategy. When compared to countries in Asia, Europe, and America, a number of African countries have abundant biomass resources but are poorly to implement the bioeconomy. Gambia is the country with the highest biomass production. Rwanda, Sierra Leone, Malawi, the Democratic Republic of the Congo, and Tanzania round out the top ten. Algeria, Mauritania, Egypt, and Chad are the poorest performers in this category (Oguntuase & Adu, 2021), Egypt is still lagging, despite abundant biomass resources (see Figure 1 below)..

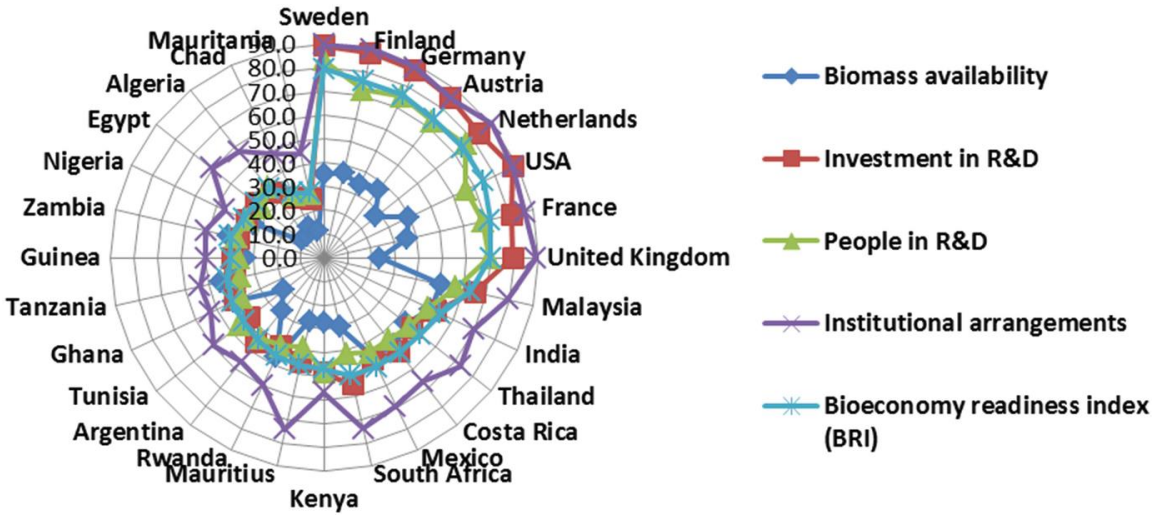

Fig. 1. State of bioeconomy production determinants in selected countries
Source: Oguntuase & Adu, 2021

Egypt has a long history of using natural resources to produce food, energy, and other goods, despite the many challenges that Egypt's bioeconomy faces, including water scarcity, land degradation, and climate change. The bioeconomy in Egypt is a rapidly growing sector that is becoming increasingly important to the country's economic development. In recent years, the Egyptian government has taken steps to promote the development of the bioeconomy to create jobs and spur economic growth.

Agriculture is one of the most important sectors of the Egyptian economy and is a major contributor to its GDP. The country has a long history of agricultural production and has been able to maintain its position as one of the world's leading producers of wheat, cotton, rice, corn, vegetables, fruits, and other crops. In recent years, Egypt

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has seen an increase in investment in agricultural research and development (R&D) to improve yields and reduce costs. This has resulted in increased productivity and efficiency in crop production.

Biomass, a major emerging alternative to fossil resources, can provide a variety of products and energy. As a result, biofuel is critical to sustaining a knowledge-driven and environmentally safe bioeconomy that reduces global warming and climate change (Antar et al., 2021). Egypt could harness agricultural, crop residues and municipal wastes as a possible feedstock for the sustainable production of bioenergy (Abdelhady et al., 2014, Wafiq & Hanafy, 2015, Abdulrahman & Huisingh, 2018).

According to a recent analysis of bioenergy in Egypt that were analyzed include crop and livestock residues to produce heat, power or combined heat and power (CHP) (FAO and EBRD 2017), In terms of crop residues, maize stalks, rice straw, sugarcane bagasse and cotton stalk are the most readily available. Maize stalk, rice straw and cotton stalk are most present in the Middle Delta region, while sugarcane bagasse is most present in the Upper Egypt region, in terms of livestock residues, the availability is very limited due to the reported availability shares (0 percent for chicken manure, 25 percent for cattle manure).

CHP (both from direct combustion and anaerobic digestion) can contribute approximately 7 percent to Egypt's overall renewable energy. If all biomass from agricultural crops, sewage sludge, municipal solids, and animal waste is available, the maximum theoretical potential energy will be 416.9 potential energy. Table 1, representing 92.6% of the total production in all installed power plants in Egypt nowadays (Said et al., 2013)

Table 1. Theoretical potential energy from biomass residues in Egypt

Biomass type	Theoretical potential energy (PJ)	Percentage of total energy (%)
Agricultural crop residues	185.75	44.6
Animal wastes (cows and buffalo)	40.61	9.7
Sewage waste (sewage sludge)	16.74	4.0
Municipal solid waste	173.80	41.7
Total	416.9	100

Source: Said et al., 2013

Biotechnology is another key component of Egypt's circular bioeconomy, which has seen significant growth over recent years. Biotechnology is considered as the foundation of the bio economy where bio economy involves the large-scale usage of biotechnology (Aguilar et al., 2019). Innovations including DNA sequencing, high-throughput molecular operations, modify genomes and metabolic pathways to improve organisms with wholly synthetic genomes, and nanotechnology have significantly increased the probability of biotechnology to drive the bio economy (Frisvold et al., 2021).

The government identified biotechnology as deserving of special support in the early 1980s, but it was not until a decade later that concrete steps to initiate such support were taken. The Academy of Scientific Research and Technology established a focal point for genetic engineering and biotechnology in 1991. Concerned about over-reliance on the advanced industrial countries for the development of this sector, senior policymakers turned to local experts and skilled expatriates from around the world to develop a national agenda. The 'National Strategy for Genetic Engineering and Biotechnology' resulted from these efforts.

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The government allocated long-term funding as part of the strategy to introduce biotechnology to universities and public research institutes, as well as to establish new centers of research excellence, including three pilot plants for scaling up technology. In addition, the government funds training and fellowships in advanced industrial countries and has led several technical and trade missions around the world to promote exports (Abdelgafar et al., 2004). The country has established several research centers dedicated to biotechnology research, which focus on areas such as genetic engineering, tissue culture techniques, plant breeding techniques, food processing technologies, pharmaceuticals production processes etc. These centers have helped Egypt become a leader in biotechnology research and development (R&D) in Africa with several successful projects being completed over recent years.

4. Egypt's national initiatives supporting circular bioeconomy

Egypt is a country that has been actively investing in the development of its circular bioeconomy. The country has implemented a number of national initiatives to support the growth of this sector, which is expected to play an important role in the country's economic development. These include the Bio-Economy Strategy, which was launched in 2018 and aims to create an enabling environment for innovation and investment in the sector. The strategy focuses on four main areas: research and development, technology transfer, market access, and policy implementation. It also seeks to strengthen collaboration between public and private sectors, as well as promote public-private partnerships (MIIC, 2018).

In addition, the government has launched several programs to support bio-based industries. These include the Bio-Industry Development Program (BIDP), which provides financial support for research and development activities related to bio-based products and services; the Bio-Innovation Program (BIP), which provides funding for innovative projects related to biotechnology; and the Bio-Energy Program (BEP), which supports renewable energy projects using biomass resources.

Egypt plans to implement 3 projects in circular bioeconomy, with a total value of $1.250 billion. The first one is a project to extract algae oil for use in biofuel production, with a production capacity of 350,000 tons annually, with investments amounting to $600 million, to reduce 1.2 million tons of carbon dioxide annually. The second project is the production of biodegradable plastic with a production capacity of 75,000 tons, and with investments amounting to 600 million dollars, to reduce 45,000 tons of carbon dioxide annually, while the third project, is a project to convert plastic waste into oil to be used as a raw material for the manufacture of polyethylene, with a production capacity of 30 thousand tons annually, and investments amounting to 50 million dollars, to reduce 63 thousand tons annually of carbon dioxide (Ministry of petroleum, 2022).

In 2022, Praj Industries, an Indian industrial biotech company, signed an agreement with Egyptian Sugar and Integrated Industries Company (ESIIC) to accelerate bioeconomy in Egypt. The agreement aimed to develop infrastructure, help formulate policy framework, and create awareness for bioeconomy. Sugarcane bagasse and rice straw were envisaged to be feedstock for ethanol production (ETEnergyworld.com, 2022).

Here are some examples of Egypt's national initiatives supporting circular bioeconomy: One initiative is a plastic recovery scheme that rewards informal recyclers through digital credits. Egypt's government and several multinational companies back the scheme, and it helps reduce plastic pollution, create income opportunities, and improve waste management. Another initiative is a project that converts rice straw into biogas and organic fertilizer. Egypt's Ministry of Agriculture and Land Reclamation support the project and it helps reduce greenhouse gas emissions, enhance soil quality, and provide renewable energy. A third initiative is a program that promotes sustainable agriculture practices such as organic farming, integrated pest management and water conservation. The program is implemented by Egypt's Ministry of Environment and several NGOs, and it helps improve food security, biodiversity, and climate resilience (Iskandar, 2021).

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The Ministry of Environment-affiliated Bioenergy Foundation for Sustainable Development expanded its efforts in utilizing agricultural waste in 2022 by setting up biogas units, developing hybrid solar-electric power systems to lower the cost of electricity produced, and developing systems for producing biogas from biological waste other than human and animal waste. In the governorates of Gharbia and Beni Suef, 154 units were installed, making a total of 1843 units that treat 49,000 tonnes of biological waste and produce 1.9 million cubic meters of biogas yearly, or the equivalent of 65,000 gas cylinders. Out of which 9,000 are residents, 31 startups were founded, creating 72 direct jobs and 93 indirect jobs (Ministry of Environment, 2022).

Finally, Egypt is actively promoting international cooperation in this field through its participation in various international organizations such as G20's Global Bioeconomy Initiative (GBI) and African Union's African Bioeconomy Alliance (ABA) (Chavarria et al., 2020). Egypt is making significant efforts to develop its bioeconomy sector by implementing various national initiatives that provide financial support as well as promote collaboration between public and private sectors. This will help create new jobs while also contributing towards sustainable economic growth in Egypt.

5. The role of local actors in the deployment of circular bioeconomy

The deployment of circular bioeconomy is an important step in the transition to a more sustainable future. The role of local actors in this process is essential, as they are the ones who can bring about the necessary changes on the ground. Local actors can play a variety of roles in promoting the circular bioeconomy and contributing to its success.

First, local actors can provide valuable insights into the needs and preferences of their communities. They are often well-informed about local resources and potential opportunities for bioeconomy development. This knowledge can be used to identify suitable locations for circular bioeconomy projects and to develop strategies for their implementation. Local actors also have a better understanding of the social, economic, and environmental context in which these projects will take place, which is essential for successful deployment. (Egea González and Torrente, 2022)

Second, local actors can be instrumental in mobilizing support for circular bioeconomy projects from other stakeholders such as governments, businesses, and civil society organizations. They can help create awareness about the benefits of circular bioeconomy and build consensus among different stakeholders on how best to deploy it. Local actors may also be able to provide access to financing or other resources needed for project implementation.

Third, local actors can act as facilitators between different stakeholders involved in circular bioeconomy projects. They can help ensure that all parties are working towards a common goal and that any conflicts or disagreements are addressed quickly and effectively. This is especially important when it comes to projects involving multiple stakeholders with different interests or objectives (Calvert et al., 2017).

A bioeconomy is an economy where renewable biological resources are used to produce food, energy, and industrial goods. Local actors are non-state actors that operate at a sub-national level, such as communities, families, or individuals (Lemard-Marlow and Wilt, 2019).

Local actors can can play a role in improving the circular bioeconomy by reducing waste, promoting sustainability, and creating value from biological resources and serve as ambassadors for circular bioeconomy initiatives by promoting them within their communities and encouraging others to get involved (Wiebke et al.,

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2019). This could include activities such as organizing public events or providing information about available resources or opportunities related to circular bioeconomy development.

The Sustainable Consumption and Production Strategy aims to foster sustainable communities and cities in Egypt by encouraging sustainable consumption and production. It prioritizes sectors such as energy, water, solid waste, and agriculture. Furthermore, the new waste law, which was adopted by Egypt's parliament in 2020, aims to directly address the activities of the circular bioeconomy, as well as to regulate and promote waste management-related operations and to encourage waste management investments.

The circular bioeconomy is an emerging sector of the global economy that is based on the sustainable use of renewable biological resources. It is a rapidly growing field that has the potential to revolutionize the way we produce and consume goods and services. As such, it is essential for countries to ensure that they are adequately prepared to take advantage of this new economic opportunity (Kumar & Kumar, 2020). Technology readiness is essential for any country looking to capitalize on the opportunities presented by the circular bioeconomy. This includes having access to advanced technologies such as biotechnology, nanotechnology, and artificial intelligence (AI). These technologies can be used to develop new products and services, improve existing ones, or create entirely new markets. Additionally, they can help countries reduce their reliance on non-renewable resources and increase their efficiency in producing goods and services (Kumar& Sharma, 2020).

In order to ensure that a country is ready for the circular bioeconomy, it must have access to these advanced technologies as well as a skilled workforce capable of utilizing them effectively. This means investing in research and development (R&D) in order to stay ahead of the curve when it comes to technological advancements. Additionally, countries should focus on creating an environment conducive to innovation by providing incentives for businesses looking to invest in R&D or create new products or services related to the circular bioeconomy.

Countries should also look into developing public-private partnerships (PPPs) in order to facilitate collaboration between government agencies, private companies, universities, and other stakeholders in order to maximize the potential of their circular bioeconomy initiatives. PPPs can help ensure that all parties involved have access to necessary resources while also allowing them to share knowledge and expertise with one another (Kumar& Sharma, 2020).

6. Future opportunities and challenges

Circular bioeconomy is an emerging field that focuses on the sustainable use of biological resources to create economic value. It is a rapidly growing sector, driven by advances in technology, policy changes, and consumer demand for sustainable products. In recent years, there has been a surge in interest in bioeconomy as a way to create economic growth while preserving the environment.

One of the most significant trends in circular bioeconomy is the shift towards using renewable resources such as plant-based materials and bioplastics instead of traditional petroleum-based materials. This shift has been driven by consumer demand for more sustainable products and by government policies that incentivize the use of renewable resources. Companies are increasingly investing in research and development to develop new bioproducts and bioprocesses that can replace traditional petroleum-based materials.

Another trend in circular bioeconomy is the increasing use of digital technologies to improve efficiency and reduce costs. Digital technologies such as artificial intelligence (AI) and machine learning (ML) are being used to optimize production processes, reduce waste, and improve product quality. Additionally, digital technologies are being used to track raw materials from source to end product, allowing companies to better manage their supply chains and ensure sustainability throughout their operations.

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Generally, there has been a significant increase in interest in circular bioeconomy over the past few years due to advances in technology, policy changes, consumer demand for sustainable products, and increased public-private partnerships. As this trend continues into the future it is likely that more companies will invest in developing new bioproducts and bioprocesses while governments continue to provide incentives for those who invest in circular bioeconomy solutions.

The global bioeconomy market is expected to grow at a compound annual growth rate (CAGR) of 8.2% from 2020 to 2027, reaching $1.7 trillion by 2027. This growth is driven by increasing demand for renewable energy sources, such as biomass and biogas, as well as advances in biotechnology that are allowing for more efficient production processes. Additionally, the increasing focus on sustainability has led to increased investment in bio-based products and services (IEA, 2021).

One of the most significant trends in the circular bioeconomy is the rise of bioplastics. Bioplastics are plastics that are either made from renewable resources ('bio-based'), are biodegradable, are made through biological processes or a combination of these. Bioplastics are made from renewable resources such as corn starch or sugar cane instead of petroleum-based plastics. They are becoming increasingly popular due to their lower environmental impact compared to traditional plastics and their ability to be recycled or composted (Renee Cho, 2017). In addition, bioplastics have a wide range of applications including packaging materials, medical devices, automotive parts, and consumer products. Some examples of bioplastics are polylactic acid (PLA), polyhydroxyalkanoates (PHA), starch-based plastics, cellulose-based plastics, and bio-polyethylene (bio-PE). Bioplastics have some advantages over conventional plastics such as reducing greenhouse gas emissions, saving fossil resources, enhancing composting and recycling options, and improving biocompatibility. However, they also face some challenges such as higher production costs, lower performance and durability, limited availability and scalability, and potential competition with food crops (Rosenboom, et al., 2022).

Another trend in the circular bioeconomy is the development of new technologies for producing renewable energy sources such as biomass and biogas. These technologies are becoming increasingly efficient and cost-effective which makes them attractive alternatives to traditional fossil fuels. Biomass is organic matter that can be converted into energy through various processes such as combustion, gasification, pyrolysis, fermentation, etc. Biogas is a mixture of gases (mainly methane and carbon dioxide) that is produced by anaerobic digestion of organic waste such as manure, sewage, food waste, etc. These technologies are becoming increasingly efficient and cost-effective because they can use various types of biomass feedstock (including waste), reduce greenhouse gas emissions, enhance energy security and diversity, create jobs and income for rural areas, and support circular bioeconomy principles. However, they also face some challenges such as technical barriers, environmental impacts, social acceptance, policy support, market development, etc. (Antar et al., 2021; Qureshi et al., 2022; Adil, et al., 2022).

Additionally, advances in genetic engineering are a powerful tool that can enhance the performance and diversity of biological resources. It can also enable the development of new products that are not possible with conventional methods and are allowing for more production for efficient processes that reduce waste while still providing high-quality products. Genetic engineering can modify living organisms for various purposes, such as producing biofuels, or creating new materials and can play a key role in developing non-food applications of

ISSN 2669-0195 (online) http://jssidoi.org/jesi/
2023 Volume 5 Number 1 (March)
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biological resources, such as nanocellulose from wood, but it is also controversial due to ethical and regulatory issues (Maximilian et al., 2021).Finally, there has been an increase in investment in bio-based products and services due to their potential for reducing environmental impacts while still providing economic benefits.

Companies are investing heavily in research and development related to bio-based products such as biodegradable packaging materials or plant-based meat substitutes. This trend is expected to continue as companies look for ways to reduce their environmental footprint while still meeting customer demands. Circular bioeconomy is a rapidly growing field that has the potential to revolutionize the way we produce and use resources. It is an economic system based on the sustainable use of biological resources, such as plants, animals, and microorganisms, to create goods and services. The circular bioeconomy has been gaining traction in recent years due to its potential to reduce environmental impacts while providing economic benefits.

The circular bioeconomy is an emerging sector of the global economy that is focused on the sustainable production and use of renewable biological resources. There is an increase in investment in bio-based products and services due to their potential for reducing environmental impacts while still providing economic benefits. Bio-based products can help tackle issues such as climate change, dependence on fossil fuels, employment and rural development. The circular bioeconomy is a rapidly growing sector has the potential to create new jobs, reduce environmental impacts, and provide economic opportunities for communities around the world. (Contreras, 2023).

One of the most promising opportunities for circular bioeconomy is the development of new products and services that are more sustainable than traditional methods. For example, bioplastics are made from renewable sources such as corn starch or sugar cane, rather than petroleum-based plastics. These bioplastics can be used in a variety of applications, from packaging to medical devices. Additionally, biofuels are being developed from plant-based sources such as algae or switchgrass, which can be used as an alternative to gasoline or diesel fuel. These new products have the potential to reduce our dependence on fossil fuels and create more sustainable energy sources.

Another opportunity for circular bioeconomy is the development of new technologies that can improve efficiency and reduce waste. For example, advances in genetic engineering have enabled scientists to create crops with higher yields and improved nutritional value. Additionally, biorefineries are being developed that can convert biomass into valuable products such as fuels or chemicals. These technologies have the potential to reduce our reliance on finite resources while creating economic opportunities for farmers and other stakeholders in the circular bioeconomy.

Despite these opportunities, there are also some challenges associated with circular bioeconomy that must be addressed for it to reach its full potential. One challenge is ensuring that new technologies are developed responsibly so that they do not cause unintended environmental or social harms. Additionally, there is a need for better regulations around intellectual property rights so that companies can protect their investments in research and development without stifling innovation or competition. Finally, there must be adequate funding available for research into new technologies so that they can reach commercialization faster and at a lower cost.

Social measures must be implemented to make sure that the poor are not burdened for Egypt to successfully transition to a circular bioeconomy. So that workers employed in areas affected by the shift towards circularity do not become unemployed, new job possibilities as well as potentially training would be required.

ISSN 2669-0195 (online) http://jssidoi.org/jesi/
2023 Volume 5 Number 1 (March)
http://doi.org/10.9770/IRD.2022.5.1(7)

7. Direction for future Circular bioeconomy research in Egypt

Circular bioeconomy is an emerging field of research that focuses on the sustainable use of biological resources to create economic value. It has become increasingly important in recent years as the world faces a growing demand for food, energy, and other resources. As such, there is a need for further research into the potential of circular bioeconomy to provide solutions to global challenges. This article will discuss some of the key areas of future research in circular bioeconomy and how they can be used to address current and future issues.

One area of future research in circular bioeconomy is the development of new technologies and processes that can be used to increase efficiency and reduce waste. This includes technologies such as bioprocessing, which uses biological materials such as enzymes or microorganisms to produce products or services. Other technologies include biorefining, which uses biomass as a feedstock for producing fuels, chemicals, and other materials; bioplastics, which are made from renewable sources; and bioremediation, which uses microorganisms or plants to clean up contaminated sites. Research into these technologies can help reduce environmental impacts while providing economic benefits.

Another area of future research in circular bioeconomy is the development of new business models that can be used to increase sustainability while creating economic value. This includes models such as circular economy, which focuses on reducing waste by reusing materials; collaborative economy, which encourages collaboration between businesses; and sharing economy, which enables people to share resources with each other. Research into these models can help create more efficient production systems while reducing environmental impacts.

A third area of future research in circular bioeconomy is the development of policies that promote sustainable use of biological resources while creating economic value which is a complex and challenging task. It requires balancing the intrinsic value of biodiversity, as well as the ecological, genetic, social, economic, scientific, educational, cultural, recreational and aesthetic values of biological diversity and its components, with the human rights and economic development of peoples and nations (United Nations, 2022, December).

This includes policies such as carbon pricing schemes that incentivize businesses to reduce their emissions; subsidies for renewable energy sources; and regulations that promote sustainable land management practices. Research into these policies can help ensure that biological resources are used responsibly while providing economic benefits for businesses and communities alike. (Bansard & Schröder, 2021, April 15).

A circular bioeconomy is expected to help the Egyptian economy improve. A 1.0% increase in GDP (estimated at €5.2 billion) compared to normal is expected, strongly driven by the increase in investments; In addition to improving the current balance by reducing imports by 685 million euros and increasing exports by 212 million euros, it is also expected to reduce food losses. Also, more than 100,000 additional jobs will be created, which is equivalent to an increase of 0.3%. The increases in employment are concentrated in the agriculture and services sector, largely driven by waste management, construction, and communications, along with distribution, retail, and manufacturing (Ashour, Sally, 2021).

Finally, research into public engagement strategies is needed to ensure that circular bioeconomy initiatives are successful in achieving their goals. It is an emerging and important field of study, and it includes strategies such as public education campaigns about the importance of sustainability; community-based initiatives that involve local stakeholders; and incentives for businesses to adopt sustainable practices. Research into these strategies can help ensure that circular bioeconomy initiatives are successful in achieving their goals while also engaging citizens in meaningful dialogue about sustainability issues. Some of the public engagement strategies that have been proposed or implemented by researchers and practitioners include Supporting bio-based research and

development, innovation, and competitiveness through various mechanisms such as subsidies, tax incentives, regulations, standards, labels, etc. (Brandão et al., 2021).

Implementing awareness-raising campaigns to increase societal participation in bio-based transformation, including more responsible and sustainable consumption. Measuring the degree of circularity of the bioeconomy as well as its contribution to the Sustainable Development Goals using a set of indicators. Studying the transition towards a circular bioeconomy using a systematic literature review on transition studies and existing barriers (Maximilian et al., 2021).

Conclusion

Circular bioeconomy is an emerging field that focuses on the sustainable use of biological resources to create economic value. It is a rapidly growing sector, driven by advances in technology, policy changes, and consumer demand for sustainable products. Egypt is a country that has been actively investing in the development of its circular bioeconomy and the economic pillar of the Egypt 2030 encourages Circular Economy activities in the industrial sector by promoting the idea of a 'green economy'. This work is providing a novel indights about the current situation of circular bioeconomy and its future in Egypt. Egypt has implemented several national initiatives to support the growth of this sector, which is expected to play an important role in the country's economic development. The strategy focuses on four main areas: research and development, technology transfer, market access, and policy implementation. Because of the rising need for renewable energy sources and advancements in biotechnology, the worldwide circular bioeconomy market is anticipated to keep expanding. Due to their potential to have less of an adverse effect on the environment while yet having positive economic effects, investments in bio-based goods and services are anticipated to rise in Egypt. The role of local actors in this process is essential, as they are the ones who can bring about the necessary changes on the ground and can play a variety of roles in promoting the circular bioeconomy and contributing to its success. Circular bioeconomy research in Egypt is expected to help the Egyptian economy improve. Research into public engagement strategies is needed to ensure that circular bioeconomy initiatives are successful in achieving their goals. Public-private partnerships should be created to encourage cooperation between stakeholders as local actors play a crucial role in the deployment of these programmes. To achieve long-term success, the Egyptian government should concentrate on funding R&D and informing customers about the advantages of adopting goods made from biological resources. To ensure that circular bioeconomy efforts achieve their objectives while generating financial value for all stakeholders, research is required.

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Funding: This research was supported by the project MC2 EU project EuropeAid Programme (ENI/2019/413-557).

Author Contributions: The authors contributed equally. All authors have read and agreed to the published version of the manuscript.

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INSIGHTS INTO REGIONAL DEVELOPMENT
ISSN 2669-0195 (online) http://jssidoi.org/jesi/
2023 Volume 5 Number 1 (March)
http://doi.org/10.9770/IRD.2022.5.1(7)