European Perspectives on Green Biotechnology Business Practices

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Edited by

Daniela Zirra and Radu Cristian Toma

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PREFACE

Despite its rapid growth, the relatively new field of green studies is still at its infancy, and even more in Biotech Green Entrepreneurship. Education plays a crucial role in fostering the eco-entrepreneurial consciousness of future Biotech Green innovators, entrepreneurs, and employees in the circular bioeconomy and climate change solutions' finding.

The need for new green skills and attitudes is growing with a growing consumer interest in clean, ethically-sourced products, while at the same time appropriate educational content for the development of such skills in high education is extremely scarce.

This action-oriented book, "European Perspectives on Green Biotech Business", aims to inspire and develop Biotech Green entrepreneurial knowledge, skills and competences of the Life Sciences/Biotech, as well as Business teachers or trainers and learners.

Equally, the book represents a valuable source of knowledge for investors, companies and employees in the green biotechnology industry and can be a welcome support for all parties interested in the development of this field so important for the sustainable development of the global economy.

In the realm of the Green Bioeconomy, fundamental concepts and principles revolve around sustainable development, emphasizing the integration of environmentally friendly practices with economic growth.

Entrepreneurship in the biotechnologies sector within this framework necessitates a keen understanding of specific elements such as innovation, ethical considerations, and the ability to navigate regulatory landscapes.

Local Green Biotech businesses can be effectively navigated through strategic mapping, optimizing resources and fostering community engagement.

Entrepreneurial economic performances within this sector hinge on balancing ecological impact with financial gains, requiring a judicious approach to risk and benefit analysis.

Promotion and business management in Green Biotech call for adept communication of environmental stewardship and responsible practices.

Financial aspects of Green Biotech are integral, with investments directed towards sustainable solutions and long-term viability.

Incorporating ITC technologies and tools into Green Biotech entrepreneurship facilitates efficient data management and innovation.

Numerous programs and platforms support green biotech entrepreneurship, fostering collaboration, knowledge exchange, and resource accessibility. In unison, these concepts form a holistic understanding of the intricate tapestry that is the Green Bioeconomy, where entrepreneurship is not only about profit but also about forging a sustainable future.

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—The Editors

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CHAPTER 1

GREEN BIOECONOMY – CONCEPTS AND PRINCIPLES

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Introduction

Several terminologies are widely used nowadays to highlight the sustainability of economic activities, such as circular economy, green economy, bioeconomy, and the most recent, green bioeconomy. All of them share a common goal: the respect for nature at every stage performed.

Circular economy is, on the one hand, considered from the producer's perspective, and on the other, from the consumer's approach. However, the main purpose is to reduce resource usage as well as wastage, reincorporating by-products into other main processes. Improving the product's lifecycle is another approach. Recycling, refurbishing, and repairing are also a part of sustainable circular economy activities, as well as reusing, sharing, and leasing actions.

In **Green economy** the priority is environmental protection in all economic activities. The goal is to reduce carbon emissions and pollutants' release, enhance energy efficiency, and increase resource value. Following these principles, products and services created in environmentally unfriendly ways are additionally taxed to discourage such practices and products considered detrimental.

Bioeconomy involves giving additional value to renewable biological resources. It is a powerful tool in progressing towards a circular and low-carbon economy.

Green bioeconomy is an economic model that emphasizes the use of renewable and sustainable resources to create goods and services. Green economy and bioeconomy represent concepts that can be applied and were developed to implement sustainable development objectives (Fig. 1.1). Therefore, they support the implementation of sustainable development instead of replacing it, within the context of global environmental changes, mainly referring to climate change and resource deficiency. The prospect of bioeconomy evolved slowly but surely towards inclusion of new elements, key processes, and economic sectors in which this concept could be applied (Łuczka, 2018). Bioeconomy represents an emerging concept with its base point being the sustainable use of renewable resources for the revitalization, development, and creation of economic systems (Aguilar et al., 2019). The bioeconomy policy organization and development perspectives can utilize energy and materials found in biomass, biodiversity, and genetic resources. This concept present both similarities and differences related to green and/or circular economies, which are included in the frame of sustainable development (Trigo et al., 2021).

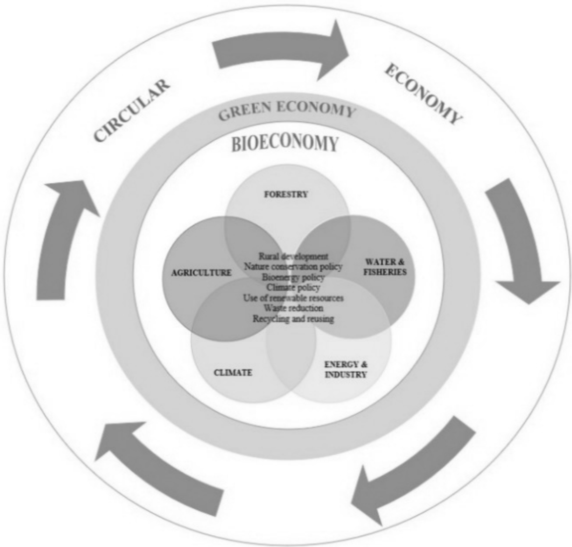

Fig. 1-1 Relationship between circular economy, green economy and bioeconomy

Within bioeconomy, processes are mainly related to those sectors that present channels of supply or demand, related to renewable biological resources, being based on using innovative biotechnology solutions (Łuczka, 2018). Therefore, it is safe to say that bioeconomy binds domains like biotechnology, science, industry, the economy, and society. Furthermore, biotechnology is at the centre of the scientific and innovative starting points of bioeconomy policies that have been established in various countries. Furthermore, the provocations and perspectives of bioeconomy are great, from resource-efficient large-scale production of commodities like materials, chemicals, food products, pharmaceutical products, polymers/biopolymers, fragrances, and flavours to the sustainable and economically obtaining of novel biomaterials and bioenergy for an increasing society globally (Aguilar et al., 2019).

The three pillars on which the development strategy of bioeconomy is based were adopted in 2012 by the European Union and are: (1) Investing Union by providing national and private funds for research in bioeconomy, skills, and innovation, along with synergy development with other activities; (2) stronger policy interlinkage and coordination as well as involvement of stakeholders by establishing the panel for bioeconomy and the bioeconomy observatory; and (3) a developing market and increased competitiveness of sectors related to bioeconomy through sustainable development at primary production (for example, by processing waste into products with added value) (Łuczka, 2018). Also, the increasing and extensive application of technologies related to information and communication must be considered, representing an important asset of the supply chain (Kardung et al., 2021).

In recent decades, policymakers belonging to the European Union (EU) have considered the concept of a durable and circular (bio)economy of high priority, its main objectives being to decrease the imports of natural resources, reduce petrochemicals use, alleviate climate change, on which there is increased dependency, and encourage and develop economies locally. The accent on bioeconomy became obvious after a high number of EU policy initiatives, which have been led, for example, by different research programs, including the European Green Deal. Furthermore, a lot of strategies related to bioeconomy have been developed on both a regional and national level. Most of them were elaborated in Europe, but there has also been interest in other countries like the United States, Thailand, or South Africa, which are also eager to develop their bioeconomies by applying and using different policy means (Kardung et al., 2021).

The food industry, being one of the largest industries worldwide, has a significant impact on the environment. The concept of a green bioeconomy within the food industry refers to the use of renewable and sustainable resources, such as agricultural and forest products, food production, and other related products. Furthermore, sustainable development represents a combination of production and consumption, presenting three major dimensions: economy, society, and the environment (Kardung et al., 2021).

Concepts and principles of Green Bioeconomy in the Food Industry

The concept of a green bioeconomy in the food industry is based on three primary principles. The first principle is related to the use of renewable resources. Historically, the food industry has relied on fossil fuels, which are considered non-renewable or finite resources. Utilising renewable resources, such as agricultural and forest products, for food production is more sustainable and environmentally friendly. Therefore, given the issues of food security and the global environmental changes, there is an increasing necessity for the economy to transition towards renewable resources and to adopt sustainable production and consumption models. This transition leads to a more efficient use and management of bioresources, reducing waste, pollution, and mitigating climate change, while also alleviating the pressures on fossil resources (Łuczka, 2018).

The next principle is related to resource usage efficiency. The food industry has been characterized by significant waste of resources such as water and food products. A green bioeconomy within the food industry emphasizes the efficient use of resources by employing high-end technologies, like precision farming and water conservation practices, to reduce waste and increase efficiency. In recent years, consumers have become more aware of the benefits of adopting a sustainable lifestyle, are highly informed, and tend to favour products that are environmentally friendly. These facts open up the possibility of utilising biomass (derived from agricultural or food waste), enhancing recycling processes, shortening supply chains, and creating alternative raw materials to produce a multitude of products, from fuels and energy to chemical compounds, pharmaceuticals, and biopolymers, among others. Furthermore, innovations in the bioeconomy could lead to significantly positive impacts on sustainability (Trigo et al., 2021). In the bioeconomy, the development of a sustainable supply chain is crucial, based on a circular economy and comprising a closed-circuit product lifecycle. In this concept, it is acknowledged that value is created through the process of reusing waste, which then becomes a resource (for production, operation, or waste recovery) (Łuczka, 2018).

The third principle is the reduction of carbon emissions. The food industry has been a significant contributor to carbon emissions, which have contributed to climate change. The green bioeconomy in the food industry emphasizes the reduction of carbon emissions by utilising sources of renewable energy, such as wind and solar energy, and by reducing carbon footprints in food production and transportation.

The principles of the green bioeconomy in the food industry are founded on multidimensional concepts with clear objectives. These objectives include reducing greenhouse gas (GHG) emissions, employing energy and materials more efficiently, assuming responsibility for consumption, and emphasising both the importance of social inclusion and the relevance of innovation (Trigo et al., 2021).

Sustainable Agriculture: The green bioeconomy in the food industry emphasises the use of sustainable agriculture practices, which contribute to reducing the environmental impact associated with food production. Sustainable agriculture practices encompass the use of organic fertilisers, crop rotation, and cover cropping, all of which help to preserve soil health and decrease reliance on synthetic fertilisers and pesticides.

Sustainable agriculture extends to sustainable food production. Therefore, for a food product to be sustainable, it must generate positive value across three dimensions simultaneously: social, economic, and environmental.

From an economic perspective, for a food system to be deemed sustainable, the activities carried out by each participant involved in its production or provision of support services must be economically viable. These activities should yield benefits or added value for all categories of stakeholders, including worker salaries, government taxes, company profits, and improvements in food supply for consumers.

In terms of the social dimension, a sustainable food system must ensure fairness in the distribution of the added value, while also considering vulnerable groups defined by factors such as age, gender, and race. It is crucial that activities related to the food system contribute to important socio-cultural outcomes, such as labour conditions, preservation of traditions, nutrition and health, and animal welfare.

Regarding the environmental dimension, sustainability is achieved by ensuring that the impacts of activities related to food systems on the natural environment are neutral or positive. This involves considering factors such as biodiversity, soil health, water conservation, plant and animal welfare, carbon footprint, water footprint, food waste and loss, and toxicity (FAO, 2018).

Sustainable Forestry: The green bioeconomy in the food industry also underscores the importance of employing sustainable forestry practices to mitigate the environmental impact of wood production. Sustainable forestry practices encompass selective harvesting, reforestation, and utilizing wood-based products for energy production, all of which contribute to reducing reliance on fossil fuels.

Efficient Resource Use: The green bioeconomy in the food industry emphasises the necessity of utilising resources such as water and energy efficiently to minimise waste and enhance productivity. To optimise resource utilisation, various advanced technologies, including precision farming and water conservation practices, can be employed.

Renewable Energy: Furthermore, the green bioeconomy in the food industry highlights the significance of transitioning to renewable energy sources like wind and solar energy to reduce carbon emissions and diminish reliance on conventional fossil fuels.

In conclusion, within the food industry, the green bioeconomy embodies an economic model that underscores the importance of utilising renewable and sustainable resources to produce goods and services. Sustainable agriculture, sustainable forestry, efficient resource utilisation, and the adoption of renewable energy sources form the foundation of the principles of the green bioeconomy in the food industry. Consequently, the concept of the green bioeconomy in the food industry represents a promising approach to promoting environmental sustainability while simultaneously fostering economic growth within the sector. This marks a crucial step towards realising a more sustainable future.

Concepts and principles of Green Bioeconomy in Agriculture

Global climate change significantly affects agricultural sectors by decreasing crop yields due to extreme temperatures, uneven water distribution resulting in drought and flood risks, as well as increased soil erosion and soil salinity. These abiotic risks exacerbate problems created by pests and diseases, which expand their range or emerge as new virulent strains.

Plant breeding plays a crucial role in mitigating both biotic and abiotic risks and supporting agricultural production, particularly in regions like the European Union where there is low tolerance for GMOs and transgenic plants. Selective plant breeding aims to enhance existing crops, improve food, and feed quality, and enhance resistance to adverse factors (van Elsen et al., 2013). Various aspects are considered in plant breeding beyond yield, including nutritional benefits, resistance to pests and diseases, sustained demand for food and feed, and enhanced utility for sports facilities or ornamental purposes. While selective breeding may seem less directly linked to the green bioeconomy, breeding outcomes offer the opportunity to select plant varieties that are more competitive, require fewer inputs, and consume less energy.

In agriculture, energy savings and reduced carbon emissions can be achieved through the implementation of green bioeconomy practices, including technological advancements and precision farming. Numerous activities can be optimised to reduce energy consumption, minimise input requirements, and produce fewer residues. Additionally, process amendments can enhance precision through automation, leading to quicker and more accurate diagnostics and decision-making. Technical advancements in agriculture result in reduced input requirements and less waste, thus mitigating the negative impact of agricultural products on agroecosystems and biodiversity.

In addition to precision farming, another green approach to reducing the negative impact of agrochemicals is the use of bio-alternative inoculants. Approximately 25% of the active substances approved by the European Commission for plant protection products are biological ingredients. Utilising such bio-inoculants achieves increased sustainability with similar efficacy while reducing the impact on nature and biodiversity.

Despite the undeniable role of chemical products in supporting agriculture, efforts are made to minimise their adverse effects. Even with technical improvements for low- and ultra-low treatment applications to reduce leaching loss, residues may still remain in application machinery. These pesticide residues can be biodegraded within farming facilities if subjected to Phytobac®-like constructions, as certain microbial consortia can naturally degrade collected pesticide waste.

Bio-fertilisers represent another green practice that can reduce the amount of nitrogen required for agricultural production. Additionally, pollutant-intensive industrial processes for nitrogen fertiliser production can be reduced and partially replaced by more sustainable methods, providing appropriate agro-inoculants to sustain plant nitrogen requirements. Azotobacter, Azospirillum, and rhizobia-based inoculants can provide atmospheric nitrogen to support plant nitrogen needs. Microalgae-based biofertilizers are also a sustainable option for green agriculture. In addition to providing nutritional benefits for crops, microalgae-based biofertilizer can replace chemical fertilisers. Moreover, microalgae cultivation allows for CO2 capture, contributing to the circular bioeconomy. Microalgae cultivation can utilise residual waters, further contributing to circular bioeconomy principles.

Microalgae have diverse applications beyond agro-inoculant production. They can serve as nutritional sources for food and feed, dietary supplements, food ingredients, or additives. Lipids extracted from microalgae can also be used for biofuel production, contributing to carbon sequestration during microalgal cultivation and serving as an alternative to fossil fuels.

Biostimulants can replace certain chemical plant protection products, enhancing plants' resistance to adverse abiotic stress and improving nutrient uptake. Biostimulants may include living microorganisms or be derived from algae, plants, or animals. Animal processing by-products can gain high added value if properly recycled, contributing to both the green and circular bioeconomies. Similarly, crop leftovers can be appropriately converted into fertilising biomatter, adding value to agricultural waste.

Cover crops play a role in sustainable agricultural systems by preventing erosion and rehabilitating degraded lands. They can also serve as mulch, green manure, forage, grazing, or raw materials for biofuels.

Agriculture can stimulate the green bioeconomy in various ways. Forests, algae, and certain microorganisms efficiently capture carbon from greenhouse gases. Additionally, carbon emissions from livestock ruminant farms can be capitalised on through biotechnological methods in production units where carbon sequestration occurs.

Concepts and principles of Green Bioeconomy for Environmental Protection

As climate change threatens our future, biotechnology stands out as a key tool for improving industrial practices and processes with more sustainable biological alternatives. It has already made a positive impact on sustainable activities while supporting various green and circular bioeconomy processes. Furthermore, the green bioeconomy delivers tangible results aligned with societal needs while prioritising environmental and biodiversity preservation.

Bioeconomy, circular economy, and green economy concepts have garnered significant attention in policy, business, and scientific research circles, aiming to address social, economic, and ecological sustainability goals (D'Amato and Korhonen, 2021).

According to the United Nations Environment Programme (UNEP), substantial benefits can be derived for the economy and society by ensuring a healthy and clean environment. Implementing sustainable production systems and adopting good practices related to agricultural and industrial waste disposal can lead to enhanced environmental protection, including the preservation of ecosystems and biodiversity. Achieving a low-carbon economy and promoting resource efficiency requires the implementation of specific policies and actions (Morganti et al., 2016).

Numerous companies have already initiated green programs, establishing benchmarks for more sustainable production pathways and related activities. Green practices are employed to enhance carbon efficiency, thereby reducing global CO_2 emissions. Various solutions are now available for this purpose, some of which require ongoing expansion and improvement.

Environmental protection can be pursued across all production sectors. Buildings can be optimised and equipped with eco-friendly climate control systems and energy-efficient lighting. Information dissemination can primarily occur through electronic devices rather than printed formats. Logistics can be redesigned to minimise energy requirements, and non-biodegradable materials can be replaced with greener and less polluting alternatives in a cost-effective manner. Electric machines and vehicles are promoted for their lack of fuel needs, minimal air pollution generation, and reduced noise levels. Fossil fuel use can be curtailed by transitioning to alternative energy resources, such as renewable resources derived from forests or biofuels sourced from agricultural crops like canola and camelina.

In addition to the green bioeconomy, the circular bioeconomy can also significantly contribute to environmental protection, especially when accompanied by green policies and practices.

The future of the Pharmaceutical Biotech Industry is Green

Despite being one of the first industries to embrace the "green" movement, studies have shown that big pharma companies rank as the 25th largest carbon-emitting industry, surpassing even the automotive, semiconductor, and forestry and paper industries, known for their high pollution levels (Belkhir, 2018; My Green Lab, n.d.). A recent report from My Green Lab, a non-profit environmental organization, in collaboration with Urgentem, a climate risk consultancy, revealed that the global pharma and biotech industry has a significant carbon footprint of 197 million tCO_2-e (My Green Lab, n.d.). This study comprehensively evaluated the carbon impact of the biotech and pharma sectors while identifying critical hotspots and practical opportunities to steer the industry towards sustainability.

Transitioning pharmaceutical and biotech companies towards more sustainable practices is a challenging task, requiring an assessment of the environmental footprint of each drug's life cycle, from discovery through production, formulation and packaging, supply chain and logistics, to waste disposal, an emerging global priority. The complexity of molecules used in drugs leads to more manufacturing steps and a higher carbon footprint. Moreover, the long and intricate supply chains of pharmaceutical products make it difficult to measure their sustainability. While sustainable pharmaceutical manufacturing processes were once voluntary targets for companies, formal regulation trends now focus on environmental protection, encouraging the industry to decarbonize its value chain and reduce waste.

Leading companies in the pharma and biotech industries are taking decisive steps to align with the goals of the Paris Climate Agreement. Forty-six percent of companies in this sector have committed to the Race to Zero, implementing programs aimed at reducing emissions by 50% by 2030 (Millar and Connelly, 2022). Additionally, more than 700 labs worldwide have adopted the My Green Lab program, which provides scientific teams with support and strategies for making impactful environmental changes. My Green Lab Certification helps companies implement measurable actions for laboratory sustainability best practices, reducing costs and preserving resources. The associated education program aims to foster a culture of sustainability in the scientific community (My Green Lab, n.d.).

In 2021, eight major pharma companies founded the Alliance to Zero, a non-profit association facilitating the industry's transition to net-zero emissions (BioSpectrum Asia, 2022). Similarly, ten major companies, including AstraZeneca, Pfizer, Merck, Biogen, Sanofi, Novartis, GlaxoSmithKline, Johnson & Johnson, Takeda, and Eli Lily, launched a program supporting the decarbonization of the pharmaceutical value chain. These efforts underscore the industry's commitment to achieving climate-related goals and educating scientists and engineers on selecting more environmentally friendly reagents, solvents, and catalysts, while promoting guidelines and best practices.

The concept of “green chemistry” is a key area of interest for pharmaceutical companies seeking to incorporate eco-friendly manufacturing into their products. Exploring ways to manufacture medicines that reduce the use and production of hazardous compounds during drug development and production and increase the use of green solvents is seen as an attainable goal (Mishcon de Reya, 2020). While sustainably produced small-molecule intermediates or active pharmaceutical compounds remain limited, synthetic biology and enzyme engineering hold promise as biotechnological solutions for green pharmaceutical and biotech companies. The Environmental Factor (E-factor) serves as an accurate measurement of the environmental friendliness of a chemical manufacturing process, defined as the ratio of total waste mass to product mass (ChemBAM, n.d.). While the ideal E-factor value is zero, an acceptable range for the pharmaceutical manufacturing industry is between 25 and 100 (Wikipedia, Green chemistry metrics, n.d.). Achieving an E-factor of zero for drug manufacturing requires innovative solutions to minimize environmental impact during manufacturing and advocating for regulations focused on sustainability.

Moreover, the E-factor concept could be extended to the entire drug life cycle, from discovery to production, formulation, packaging, and disposal methods for unused products.

Pharmaceutical pollution is a global concern, with specific worries surrounding waste from the manufacturing of active pharmaceutical ingredients and during formulation or packaging. Improper disposal practices pose significant environmental and health risks, as many active pharmaceutical ingredients resist metabolic degradation and remain active in the environment as persistent pollutants. While hazardous waste disposal is regulated by governmental agencies, non-hazardous waste, such as expired antibiotics, hormones, or contraceptive pills, still requires specific handling and disposal procedures. Many companies have implemented sustainable environmental measures, such as anaerobic digestion to treat heavily contaminated water waste streams and produce biogas or biomethane, and the use of biodegradable packing materials or technologies that reduce greenhouse gas emissions, such as capsule-based dry powder inhalers (The Medicine Maker, Striving for Sustainability, 2022). Promoting personalized medicine, which uses an individual's unique genetic profile to guide medical therapy, could reduce pharmaceutical waste and improve the efficiency of drug treatment (Vicente, 2020).

Reducing the carbon footprint presents a significant challenge for pharmaceutical and biotech companies. The EU Green Deal, aiming to make the European Union climate-neutral by 2050, has spurred the pharmaceutical industry to respond by reducing greenhouse gas emissions in manufacturing processes, logistics operations, and constructing nearly carbon-neutral factories. Energy-intensive processes such as aseptic manufacturing and cold supply chains can transition to renewable energy sources. Additionally, replacing outdated technologies, such as transitioning from the granulation process to direct compression technology for tablet production, can enhance energy efficiency (The Medicine Maker, Striving for Sustainability, 2022).

However, estimating the total carbon footprint of drug manufacturing remains challenging, as exemplified by the mRNA vaccine against COVID-19. This breakthrough has ushered in a new era in the biopharmaceutical industry, leveraging mRNA approaches that require fewer manufacturing steps than traditional cell culture- or egg-based production methods, thereby reducing the carbon footprint. Nonetheless, RNA manufacturing is a biochemically intricate process involving highly purified ingredients, polymer packaging, waste stream management, and cooling technology-dependent logistics routes. A recent study found that the carbon footprint of a single mRNA vaccine dose administered to a patient range from 0.01 to

0.2 kg CO_2 equivalents, with the estimated ecological impact outweighed by the benefits (Kurzweil, 2021). It is widely believed that the advent of the third wave of biotechnological products and telemedicine will further reduce the carbon footprint per patient (Purohit, 2021).

Primarily, the sustainability challenges faced by pharmaceutical and biotech companies revolve around energy and waste management. However, fostering a positive culture of sustainability within the industry is equally crucial to translate resolutions into actionable initiatives.

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CHAPTER 2

SPECIFIC ELEMENTS OF ENTREPRENEURSHIP IN GREEN BIOTECHNOLOGY

DANIELA ZIRRA

Introduction

The biotechnology industry is a vital sector for sustainable development, for several reasons (Trippl & Tödtling 2007). Firstly, it possesses a strong, innovative character, enabling it to offer relatively swift solutions to the complex challenges facing humanity today, such as pollution and its impact on global ecosystems, the rapid depletion of non-renewable resources, food insecurity, and the emergence of new medical conditions with a high or even extremely high epidemiological degree, akin to the occurrence of the COVID-19 pandemic, which placed continuous and escalating strain on medical systems.

Secondly, the biotechnology industry exhibits high growth potential, exerting a significant driving effect on entrepreneurial activity within this field.

Thirdly, it presents a wide array of investment opportunities, as newly established biotechnology businesses have a notable multiplier effect.

A noteworthy subset of entrepreneurship in biotechnologies falls within the realm of green businesses. Green Biotech Entrepreneurship (GBE) entails the creation and dissemination of innovative biotechnology products and technologies that are sustainable and have a positive impact on the environment (Agarwal et al., 2021). These products and technologies may encompass ecological alternatives to pesticides or chemical fertilisers, the development of plants resistant to extreme climatic conditions, or more energy-efficient production processes. Given recent global developments, GBE warrants special attention, particularly considering its potential to provide solutions for urgent global challenges.

This chapter explores various aspects of GBE, including different definitions, specific characteristics, underlying principles, sector typology, financing and support programmes for new and existing businesses, essential steps for establishing a green business, diverse business models, and illustrative success stories. Additionally, we will endeavour to offer insights into the future evolution of entrepreneurship in this domain and draw pertinent conclusions.

Defining entrepreneurship in the green biotechnology sector

There are numerous ways to define or characterise entrepreneurship in biotechnologies. For instance, it is considered a unique field as it fosters the creation of specialised and highly innovative products and/or technologies (Shimasaki, 2009). Alternatively, some opinions suggest that entrepreneurship in biotechnologies facilitates the transformation of research processes in this field by bridging the gap between fundamental research and entrepreneurial ventures (Acs et al., 2009, p. 35), which is crucial for the success of any biotechnology startup.

On the other hand, Green Biotech Entrepreneurship (GBE) can be understood as the process of launching and growing a business in the biotechnology sector, with a focus on developing environmentally sustainable solutions. This may involve leveraging biological processes and organisms to create new products and services aimed at reducing waste, conserving resources, and safeguarding the environment. Several authors have made significant strides in understanding the complexities of the GBE sector, addressing aspects such as its definition, key challenges and opportunities, the importance of networking, and the social and environmental responsibilities of green biotech entrepreneurs.

Some established definitions of GBE (D'Amato & Korhonen, 2021) incorporate elements such as biotechnology (utilising living organisms to develop new products and services), sustainable development (ensuring present-day needs are met without compromising the ability of future generations to meet their own needs), and the green economy (an economic system based on principles of sustainability, environmental protection, and social justice). Another notable perspective in the GBE field emphasises the role of complexity theory in harnessing biological systems to address complex environmental problems (Kauffman, 1992).

In essence, GBE utilises biotechnology to devise and implement sustainable solutions to environmental issues, with the primary goal of promoting sustainability. Consequently, the focus of GBE is on devising innovative solutions to environmental challenges such as pollution, climate change, and resource depletion. These solutions may include the development of biodegradable materials, biofuel utilisation, sustainable agricultural practices, or the creation of water and soil purification technologies employing microorganisms, among others.

Specific features and typology of Green Biotech Entrepreneurship

Considering that GBE is a distinct field of Biotech Entrepreneurship (BE), it naturally possesses specific features that differentiate it both from the rest of the industry and from other types of entrepreneurship. Firstly, GBE is focused on environmental sustainability through the creation of particular goods and services that promote the concept of sustainable economic development. Therefore, the primary objectives of companies in this sector are to reduce waste, conserve resources, and protect the environment.

Secondly, GBE relies on scientific research and development activities as its foundation. Within these types of companies, significant resources are allocated to the creation of innovative solutions that address environmental problems.

Thirdly, GBE necessitates close interdisciplinary collaboration (biology, chemistry, engineering, business, etc.), without which it would not be possible to manifest and develop. The success of companies in this field stems from the development of networks and partnerships between scientists, entrepreneurs, and investors to help bring new green biotechnological products to market (Sutton & Hargadon, 1996).

In this field, open innovation is strongly promoted, with an emphasis on sustainability and clean technologies (Chesbrough, 2019), underscoring the importance of collaboration and knowledge sharing in stimulating sustainability-oriented innovation.

Fourthly, we must consider social responsibility and ethics as two extremely important aspects guiding the activity of enterprises in the green biotech category. This involves promoting goods and services that respond to the needs of a large number of consumers. Moreover, it is imperative that these economic goods are produced sustainably, protecting the environment and conserving resources. From this perspective, the concept of a triple bottom line approach to sustainability, introduced by Elkington (1998), is GBE's main priority. This means that businesses must prioritize social and environmental responsibility alongside economic profitability.

Furthermore, GBE is heavily regulated by government agencies in all countries where it is practiced. Primary regulations address environmental preservation, user/consumer safety, and health.

The unique characteristics of GBE also align with how entrepreneurship is facilitating the shift to a low-carbon economy, as promoted by Hockerts & Wüstenhagen (2010). For instance, identifying market niches and pursuing disruptive innovation to create new opportunities for green entrepreneurs is crucial for the GBE field.

In this context, identifying unmet needs or gaps in the market and developing biotechnological solutions to address them is essential. However, it is crucial for green entrepreneurs to create value by developing innovative business models that capture economic and environmental benefits. This may involve developing new revenue streams, leveraging partnerships, and adopting circular economy principles in the biotech sector.

Moreover, entrepreneurial ecosystems play a vital role in supporting and nurturing green entrepreneurs. These ecosystems consist of various stakeholders, such as research institutions, investors, policymakers, and industry associations, who collaborate to provide resources, knowledge, and networks to foster entrepreneurial activities.

Finally, supportive policies and regulations aimed at encouraging start-ups and the development of GBE are crucial. This includes incentives, subsidies, and regulations that promote the development and adoption of green biotech innovations, as well as policies that facilitate market access and international collaboration.

Table 2-1 Examples of specific GBE activities

No	Activity	Content
1	Development of biodegradable plastic and other sustainable materials	Products that can replace petroleum-based products
2	Creating new biofuels and bioproducts	Products intended to replace fossil fuels and reduce carbon emissions
3	Development of sustainable agricultural practices	Activities that reduce environmental impact, such as using biotechnology to produce more efficient crops with lower inputs of water, fertilizers, and pesticides
4	Development of new wastewater treatment technologies	They aim to reduce pollution and promote water reuse
5	Development of bioremediation technologies	It uses microorganisms to clean contaminated or polluted sites with various substances

Source: Grand View Research-Market Research Reports, 2022

GBE has a wide range of applicability, from the creation of innovative renewable energy technologies to the development of sustainable agricultural practices. Some examples are summarized in Table 2-1.

Also, very rarely can a field of activity be classified according to all criteria, and GBE is no exception. However, specific typologies of GBE can be identified either according to the considered sustainability field (as shown in Table 2-2) or in relation to various sustainable archetypes (Schaltegger et al., 2016), which are applicable to entrepreneurs seeking to engage in green economic activities, among other areas.

As seen, the typologies presented in Table 2-2 are not mutually exclusive and overlaps between them can occur. It can be said that GBE often integrates multiple approaches to address complex environmental issues and stimulate the use of sustainable practices across all economic and social areas. Another intriguing perspective on the typology of entrepreneurship begins with the concept of sustainable archetypes promoted by Schaltegger et al. (2016).

Table 2-2 GBE typology according to the areas underlying sustainable development

No	Typology	Content
1	Sustainable Agriculture	Focuses on developing biotechnology solutions to enhance agricultural practices, improve crop yields, reduce chemical inputs, and promote sustainable farming methods. It includes areas such as genetically modified crops, precision agriculture, biofertilizers, and biopesticides.
2	Renewable Energy	Involves biotech entrepreneurship in the fields of renewable energy generation and biofuels. It includes developing biotechnological processes to convert biomass, algae, or other organic materials into biofuels like biodiesel or bioethanol. It may also involve the genetic engineering of microorganisms to improve their efficiency in producing bioenergy.
3	Waste Management	Green biotech entrepreneurship in this area focuses on developing biotechnological solutions to tackle environmental challenges related to waste. This includes developing bioremediation techniques to clean up contaminated sites, bioconversion of waste materials into useful products, and bioplastics production from organic waste.
4	Environmental Monitoring	Involves the use of biotechnology to monitor and assess environmental conditions. It includes the development of biosensors and bioreporters that can detect pollutants, pathogens, or other environmental factors. These technologies can help in the early detection of environmental issues and enable timely intervention.