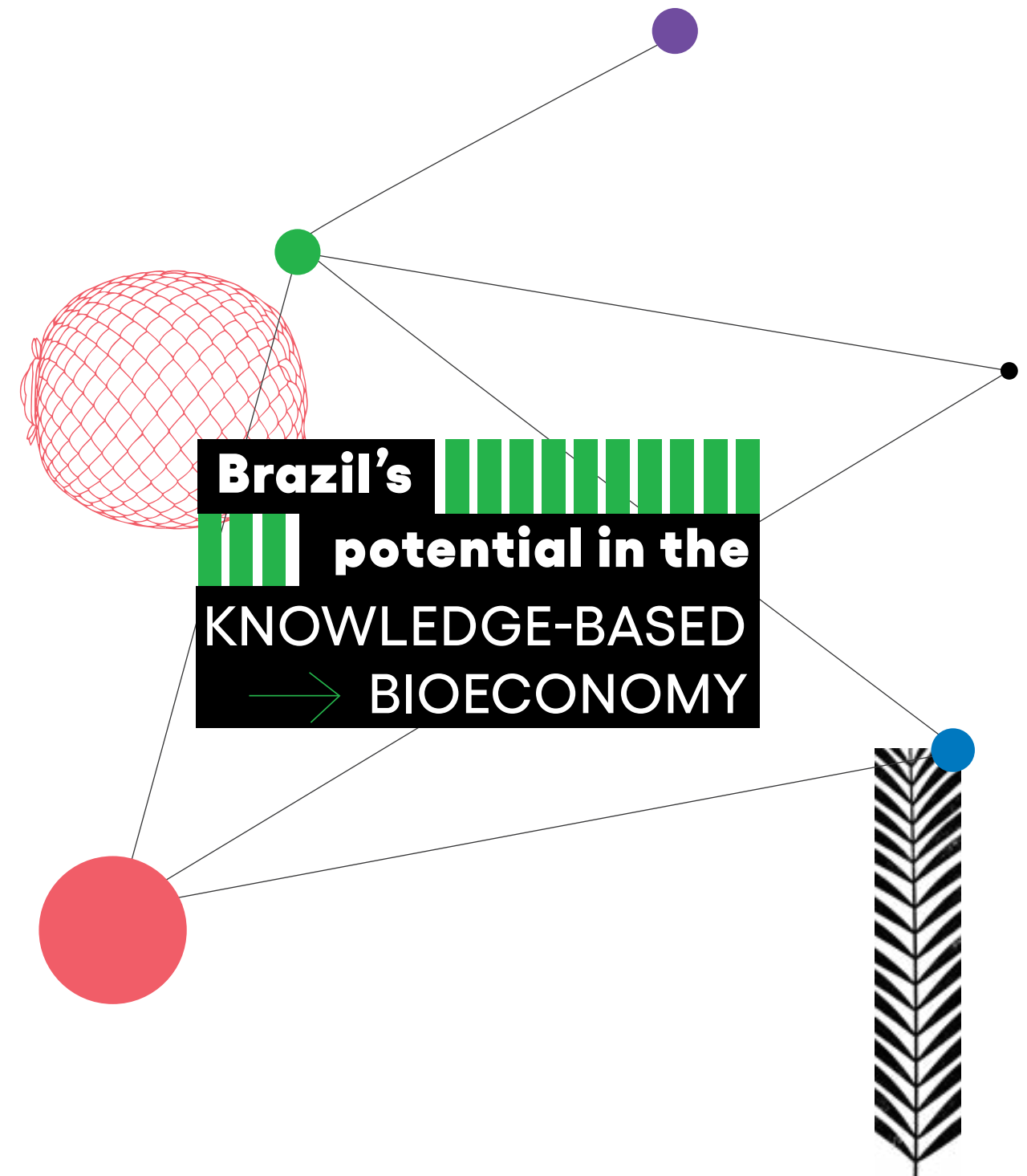


in technical
partnership
with Systemiq
and Emerge

Brazil's
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Presentation

This study starts from a paradox: if, on the one hand, Brazil is one of the countries with the greatest potential to lead the global transition towards a green economy, based on science, technology and the sustainable use of biodiversity, on the other hand, national debates on bioeconomy have focused on the agendas of agricultural and biofuel-related commodities. Even though very relevant, these fields do not represent the entire capacity of the Brazilian bioeconomy. Aiming at contributing to this debate, this study offers reflections on what we call the “knowledge-based bioeconomy”.

The knowledge-based bioeconomy is a branch of bioeconomy that emphasizes the strategic roles of scientific, technological and traditional knowledge in generating value. More than resource extraction, it proposes to activate a new economy based on research, innovation, development of high-value-added products, respect for sociobiodiversity, and a commitment to sustainability. This is an agenda that converges economic potential, industrial opportunities, environmental conservation and solutions to global challenges such as food security, health and climate change.

Despite its relevance, this agenda lacks instruments, strategies and agreements that allow its potential to be realized.

How can we generate value from Brazilian biodiversity? How can we recognize, respect, and value traditional knowledge in the search for scientific and technological advances? How can we distribute wealth and foster innovation in diverse territories, often marked by historical inequalities?

Answers to these questions do not come from a single actor or sector. The knowledge-based bioeconomy requires an approach based on a sextuple helix of stakeholders, encompassing government, academia, the productive sector, investors, civil society and nature as a living active source of innovation. Only through the collaboration of these actors will it be possible to create sustainable, inclusive, and competitive models that position Brazil as a global leader in this field.

This study focuses on investigating Brazil’s potential, the main barriers to innovation, and possible paths to boosting the country’s knowledge-based bioeconomy. To achieve that, it mapped international benchmarks, analyzed emerging technologies and identified ongoing success stories in Brazil. Lastly, the study offers specific recommendations for each stakeholder in the production chain.

More than a technical report, this study is a call to action. It is a collaborative proposal that seeks to contribute to the construction of a new paradigm for national development, based on knowledge, diversity, equity, and sustainability.



The knowledge-based bioeconomy is a strategic development within the field of bioeconomy, standing out for the intensive application of scientific, technological and traditional knowledge aimed at innovation.

Acknowledgments

The environmental agenda is one of the greatest global challenges of our times. Limiting global warming to 1.5°C and reversing biodiversity loss will require a profound shift in current production and consumption models, and a new approach to environmental preservation. To achieve this, we need a broad framework of initiatives, such as technological innovations, robust implementation of carbon markets, and strengthening of Nature-Based Solutions (NBS), among others. Within this framework, biodiversity is a crucial asset, and the bioeconomy is a mechanism for keeping standing forests and building an ecosystem that rewards conservation and brings economic and social benefits to local communities.

As Brazil boasts the greatest biodiversity in the world, our associates challenged us to consider how to unlock the bioeconomy agenda so that it can effectively drive the development of a green economy for our country. This study emerged from this challenge, which aims not only to provide figures and analyses but also to serve as a roadmap for building an ecosystem of better public policies and incentives, integration with local communities, and the development of robust markets.

The results of this study clearly demonstrate Brazil's potential, but also highlight the need to continue striving to achieve Brazilian leadership in the bioeconomy. Despite having the world's greatest biodiversity, we know and catalog very little of it. Although there is robust scientific and research activity on the topic, very little is translated into products with scale and market demand. To reach these goals, we need to invest in research and create public policies and new investment mechanisms to overcome the so-called valleys of death of innovation.

All these challenges can be overcome with even closer collaboration between the public sector, aca-

demia, businesses, and local communities. The stakeholder engagement that gave rise to this study is in itself a very positive example of this: our work was only possible thanks to strong collaboration with the Brazilian Ministry of the Environment and Climate Change's Bioeconomy Secretariat (special thanks to Secretary Carina Pimenta, Director of Genetic Heritage Henry Novion, and the entire team), ensuring that the results could concretely contribute to the National Bioeconomy Strategy. Furthermore, the development of this study involved the engagement and dedication of over one-hundred (100) people who generously shared their time, knowledge, and experience throughout the process. This impressive number not only demonstrates the growing interest in the strategic agenda of the knowledge-based bioeconomy but also highlights available technical qualifications in Brazil to lead this field.

The study was made possible with the support of the sponsoring institutions — ICC, Fundo Vale, Itaú, Natura and Nestlé — whose trust and commitment to a future-oriented agenda were fundamental.

Finally, we would like to thank the teams at Emerge and Systemiq, who led the technical development of this project. Their deep experience and technical knowledge in this field enabled us to deliver a truly unique project.

We hope the content provides relevant information that will be of value to decision-makers in the private and public sectors, experts, and society as a whole.

Happy reading!

Gabriella Dorlhac

- EXECUTIVE DIRECTOR OF ICC BRASIL

Credits

THIS STUDY RESULTS FROM A PROJECT WHICH WAS DEVELOPED AND EXECUTED BY A WORKING GROUP OF OVER 100 PARTICIPANTS WHO GENEROUSLY SHARED THEIR TIME, KNOWLEDGE AND EXPERIENCE THROUGHOUT THE PROCESS. ITS CONTENT DOES NOT NECESSARILY REFLECT THE INDIVIDUAL OPINIONS OF THOSE WHO PARTICIPATED IN ITS PREPARATION, BUT RATHER THE VIEWS OF ICC BRASIL.

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ICC Brasil, one of the national chapters of the International Chamber of Commerce (ICC), was created in 2014 aiming at bringing the private sector to the center of the international trade agenda and amplifying voices of the Brazilian business community with governments and international organizations. It develops projects for economic and social development and aims at improving the business environment. This ability to connect public and private sectors sets ICC apart as a unique institution, responding to the needs of a wide range of stakeholders involved in international trade and related issues, such as innovation and sustainability. One of our missions regarding the sustainability agenda is to mobilize the private sector to lead discussions on sustainability, the environment, and related topics, such as bioeconomy. We recognize that bioeconomy is essential for the sustainable use of natural resources, promoting biodiversity, and mitigating climate change, in addition to being a strategic component for Brazil's sustainable economic development.

Technical report



Systemiq and Emerge would like to thank all institutions, experts, and leaders who contributed to this report. This publication results from a collective effort to position the knowledge-based bioeconomy as a new strategic frontier for Brazil, capable of generating value from biodiversity, leveraging national competitiveness, and positioning the country as a global provider of 21st-century technological and industrial solutions.

Testimonials from supporters



"ICC Brasil's knowledge-based bioeconomy report offers pertinent insights into the enabling environment needed for a thriving bioeconomy, inviting businesses to contribute to socioeconomic development and environmental sustainability.

We warmly welcome this valuable contribution to the COP30 offered by the ICC, as the official UNFCCC private sector focal point and institutional representative of more than 45 million businesses in more than 170 countries."



"Fundo Vale is a development organization that generates positive social and environmental impact, driving solutions for a more sustainable, fair, and inclusive economy. It works towards catalyzing impact businesses, mobilizing catalytic capital, promoting knowledge and innovation, and building capacity. The organization is at the forefront of social and environmental investment in Brazil, with an emphasis on the bioeconomy as a driver of sustainable development."



"We consider this a unique moment to boost the Brazilian bioeconomy in the global scenario. This topic is strategic for the country, given that our strength lies in our rich biodiversity and natural resources, a particular trait that sets us apart. The challenge lies in portraying the potential of the bioeconomy in the transition to a more sustainable economy to the market sector. Studies like this are extremely valuable for measuring this potential and unlocking the necessary capital."



"Natura proudly supports ICC Brasil's 'Knowledge-Based Bioeconomy' study. We believe in the bioeconomy as a lever for generating value and driving sustainable and regenerative solutions. We see a significant opportunity for developing an economic model based on the valuation of nature, combined with climate solutions, social inclusion, and innovation, benefiting traditional peoples and communities. This is a strategic opportunity for Brazil and the entire value chain."



"We believe in the power of food to improve quality of life. This belief fuels our commitment to using our global scale, resources, and expertise to contribute to a healthy future for people and the planet. Nestlé has committed to achieving net-zero emissions by 2050. We are proud of the progress achieved so far, but we also recognize that there is still much work to be done. Creating Shared Value is our way of doing business, and addressing global and local issues is our priority today, as it has been for generations."

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Methodological notes and engagement process

This study's methodology is based on three complementary pillars: expert engagement, secondary data analysis and creation of scenarios to guide decision-making processes. The objective is to model plausible projections that can support strategic decisions (by governments, companies and other institutions) and that have legitimacy and acceptance among the stakeholders involved.

The expert engagement process lasted approximately four (4) months and brought together more than one hundred (100) stakeholders who contributed to validating hypotheses and premises. This process was designed to ensure diversity of perspectives, promote active listening, and foster the collective construction of solutions through successive cycles of consultation and validation. The project included two forms of engagement: recurring participation in technical committees and interviews.

Six (6) technical committees were established: one for each sector under analysis (productive, academic, public, civil society, and entrepreneurial, as well as a cross-cutting financing committee. More than thirty (30)

experts participated in the meetings, which took place over four (4) different sessions. On these occasions, the team discussed the main challenges facing the sectors, validated hypotheses about barriers and opportunities, and tested projections of the potential of the knowledge-based bioeconomy. The consolidated recommendations from stakeholders, which are the final product of these consultations, conclude this report.

Evidence gathering was based on the analysis of more than 150 technical documents, market studies, institutional reports and national and international academic publications, originating from universities, business associations, non-governmental organizations, public institutions and companies. Additionally, fifty-seven (57) technical interviews with experts from different sectors allowed the team to qualify the findings in the literature, explore specific nuances of the subsectors and delve deeper into technical issues in poorly mapped segments.

The analyses were geared towards projecting the potential of the knowledge-based bioeco-

nomy in Brazil by articulating hypotheses and premises validated by experts. The goal is to estimate Brazil's potential as a global provider of knowledge-based bioeconomy solutions. In the specific case of market projections, the adopted approach combined secondary analysis of global growth projections and market share estimations of what Brazil could internationally capture by 2032, considering its comparative and competitive advantages and the current state of production chains and technological pathways in each sector. The concept of fair share (fair contribution) was used as a reference, calibrated by technical premises established by the committees.

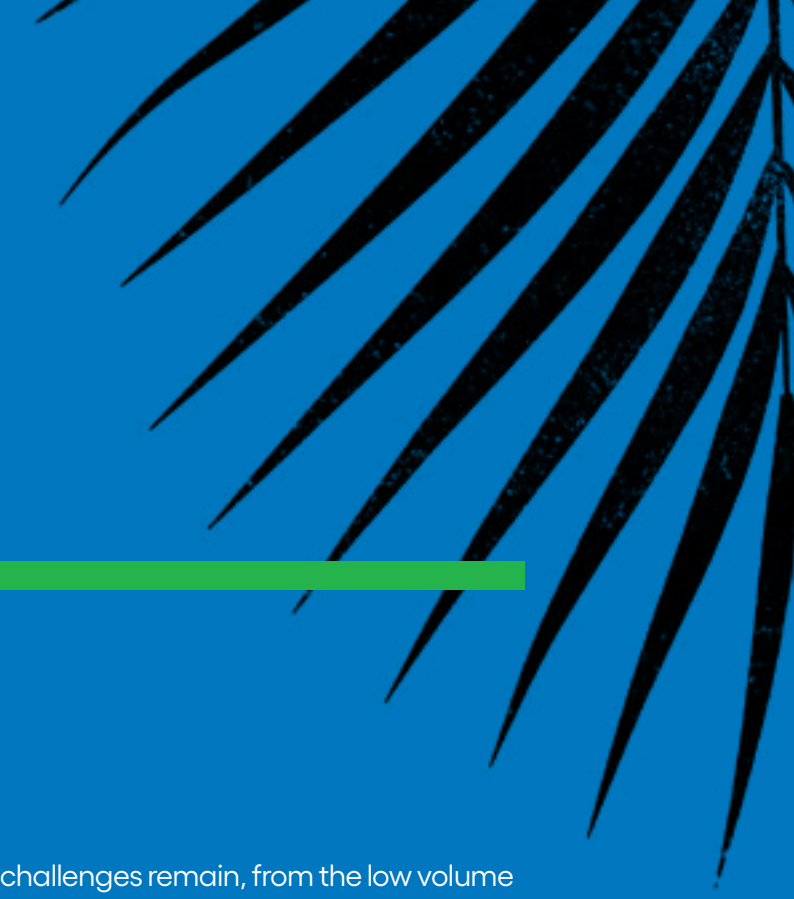
The prioritization of strategic subsectors of the knowledge-based bioeconomy was based on the main challenges faced by each sector. This diagnosis considered production bottlenecks, regulatory barriers, technological dynamics, and demand transformations, aiming to understand the conditions for Brazil's sustainable and competitive insertion into global value chains.

Based on this analysis, concrete solutions that the knowledge-based bioeconomy can offer were mapped, considering their impact, technological applicability, and implementation feasibility.

This entire process was supported by a methodological triangulation of market data, expert interviews, and real-world cases, enabling a practice-based and evidence-driven analysis. This approach sought to ensure that the recommendations presented in the report were technically sound, strategically relevant, and applicable to the realities of the sectors involved.



Preface



This study reflects the national ambition to contribute to leading the world in an aspect of the knowledge economy.

The bioeconomy is often viewed simplistically. In the case of the Amazon, it's often confused with primitive extractivism—no society has prospered this way, and we won't be the first.

As an investor, I have been exploring the intersection of the Amazonian bioeconomy with science and the place where human capital meets biodiversity. Many have made similar, disaggregated efforts; initiatives like these, while important, will always suffer from discontinuity and lack of scale and scope. This study provides the necessary intellectual foundation for us to be able to create coherent and effective policies to achieve the knowledge-based bioeconomy in less time, with fewer errors, and fewer resources.

Brazil is recognized for its vast natural heritage, from its biodiversity to its environmental resources. This heritage can only be unlocked by highly qualified human resources. Over the past few decades, we have developed many of the necessary aspects of this human capital. We also have parts of the necessary infrastructure, from clean energy and connectivity to sector regulation.

However, a significant number of challenges remain, from the low volume of accumulated knowledge to the limited transformation of science into innovation. From volatile funding to low scale, from the lack of services necessary for entrepreneurship to regulatory complexity and uncertainty.

This work goes beyond identifying problems. Here, we take the next step, offering solutions and identifying opportunities with their respective recommendations to embrace areas of natural national potential that remain underexplored.

It is our goal to lead the world in providing bioeconomy solutions. The biomes under our sovereignty, especially the Amazon, call upon us to develop ways to generate abundance and prosperity amid conservation.

Denis Minev

CEO OF BEMOL AND COP30 SPECIAL ENVOY FOR THE AMAZON
PRIVATE SECTOR



1

The potential of the knowledge-based bioeconomy in Brazil



1.1 Knowledge-based bioeconomy

- A Path to Positioning Brazil as a Provider of Green Solutions

INCORPORATING SCIENTIFIC, TECHNOLOGICAL, AND TRADITIONAL KNOWLEDGE TO THE BIOECONOMY CAN DRIVE THE DEVELOPMENT OF HIGH-VALUE-ADDED PRODUCTS AND CONSOLIDATE BRAZIL AS A PROVIDER OF GLOBAL SOLUTIONS TO SECTORAL CHALLENGES. AS A RESULT, THERE WOULD BE COST REDUCTION, INCREASED PRODUCTIVITY AND DECARBONIZATION OF VALUE CHAINS.

Brazil defines bioeconomy as a model of productive and economic development based on the principles of justice, ethics and inclusion¹. This model seeks to efficiently generate products, processes, and services, promoting the sustainable use, regeneration, and conservation of biodiversity by prioritizing synergies between scientific and traditional knowledge. Thus, the bioeconomy is an essential way to add value, generate jobs and income, promote sustainability, and contribute to resilience and climate balance².

The knowledge-based bioeconomy is a strategic development of the field of bioeconomy, which involves the application of scientific, technological and traditional knowledge focused on innovation. Unlike the conventional bioeconomy, which encompasses the extraction and pre-processing of products, the knowledge-based bioeconomy incorporates scientific and technological advances in the creation of new products and processes³. This approach can transform entire sectors, making them more efficient, sustainable, and competitive in high-value-added markets.

¹. BRAZIL. Decree No. 12,044 of June 5, 2024. Institutes the National Bioeconomy Strategy. Available at:https://www.planalto.gov.br/ccivil_03/_ato2023-2026/2024/decreto/D12044.htm. Accessed on: February 5, 2025.

². Ibid.

³. WORLD ECONOMIC FORUM. Accelerating the tech-driven bioeconomy. Geneva: World Economic Forum, 2024. Available at:<https://www.weforum.org/reports/accelerating-the-tech-driven-bioeconomy>. Accessed on: May 27, 2025.



Figure 1 illustrates how knowledge-based bioeconomy is present in everyday life through innovations in strategic sectors such as health, materials, food, cosmetics and agriculture

In the pharmaceutical sector, the extraction of pilocarpine from jaborandi for the treatment of glaucoma and the use of agricultural waste in the production of heparin demonstrate how knowledge about biodiversity can be applied to develop advanced medicines and treatments. In the field of materials, buriti fibers are being used as a sustainable alternative to styrofoam, and orange pulp is transformed into polyols for the production of foams used in furniture, reducing dependence on synthetic chemicals and expanding the use of agro-industrial waste.

In the food sector, the internationalization of the açai food culture through its transformation into an ice cream-like product, and the development of whey protein from whey discarded in the dairy industry are examples of how science adds value to existing products. In cosmetics, the use of oils from biodiversity to produce soaps and shampoos, as well as the application of peptides to intensify collagen synthesis, reinforce the potential of biotechnology to create innovative and sustainable products. In agriculture, biofertilizers produced from sugarcane bagasse and genetically modified crops engineered to resist pests represent advances that contribute to more efficient production and reduced dependence on chemical inputs.

These innovations demonstrate that the knowledge-based bioeconomy has transformed various sectors, making them more sustainable and competitive

FIGURE 1.
Examples of products derived from the knowledge-based bioeconomy

					
TECHNOLOGICAL ASPECTS	PHARMACY	MATERIALS	FOOD	COSMETICS	AGRO
NEW CHAINS (Identification, cultivation, management and value generation from new Brazilian biological assets, naturalized and/or cultivated)	Extraction of pilocarpine from jaborandi for the treatment of glaucoma	Buriti fibers that replace Styrofoam	Internationalization of açai food culture	Essential oils from Brazilian species such as açai and chestnut	New sugarcane cultivars with resistance to the sugarcane borer and glyphosate
EXPANSION OF CHAINS BY ADDING VALUE (Adding value through industrialization, ecosystem regeneration and transformation of waste from large chains into high value-added products)	Use of agricultural waste for heparin production	Production of polyol from orange pomace to produce foams used in furniture	Whey protein from whey discarded from the dairy industry	Extraction of grape residues for the production of soaps, shampoos and others	Biofertilizers made from sugarcane bagasse
TRANSFORMATION THROUGH BIOTECHNOLOGY (New bioactive inputs, new molecules, microorganisms, gene editing for high-value markets)	Gene editing to create new antibiotics	Production of lightweight and structurally resistant materials from mycelia	Cultured meats	Application of the peptide to intensify collagen synthesis for rejuvenation	Genetic modification of seeds

SOURCE: Systemiq and Emerge analysis, based on expert interviews

This report systematizes the knowledge-based bioeconomy into three major innovation axes (see Figure 2). The first is the creation of new production chains based on novel biological assets. The richness of Brazilian biodiversity offers a range of opportunities to identify, cultivate and manage new species -whether native, naturalized or domesticated- which can generate products with high commercial value. Science plays a central role in this process, enabling the development of new

agricultural and forestry crops, bioinputs, and innovative ingredients for the pharmaceutical, cosmetics, food, agribusiness, and materials sectors.

In addition to creating new production chains, the knowledge-based bioeconomy can add value to established production chains. The industrialization and transformation of waste from agribusiness and the forestry sector, for example, can generate advanced bioproducts and inputs for multiple sectors of the economy. Instead of being discarded, agricultural and forestry waste are now used as raw material for the production of biomaterials, bioplastics, and biochemicals, promoting the transition to a circular economy based on the efficient reuse of natural resources.

The third axis of the knowledge-based bioeconomy is the transformation of production chains through biotechnology. New techniques, such as gene editing, the use of microorganisms for bioprocesses, and the synthesis of new bioactive molecules, have revolutionized industries worldwide. In Brazil, there is vast potential for innovation in this field, given access to one of the greatest biodiversity on the planet and the country's growing scientific capacity. Companies and research centers use these technologies to develop new pharmaceuticals, natural cosmetics, biofertilizers, and biopesticides, thus fostering sustainable, high-value-added markets.

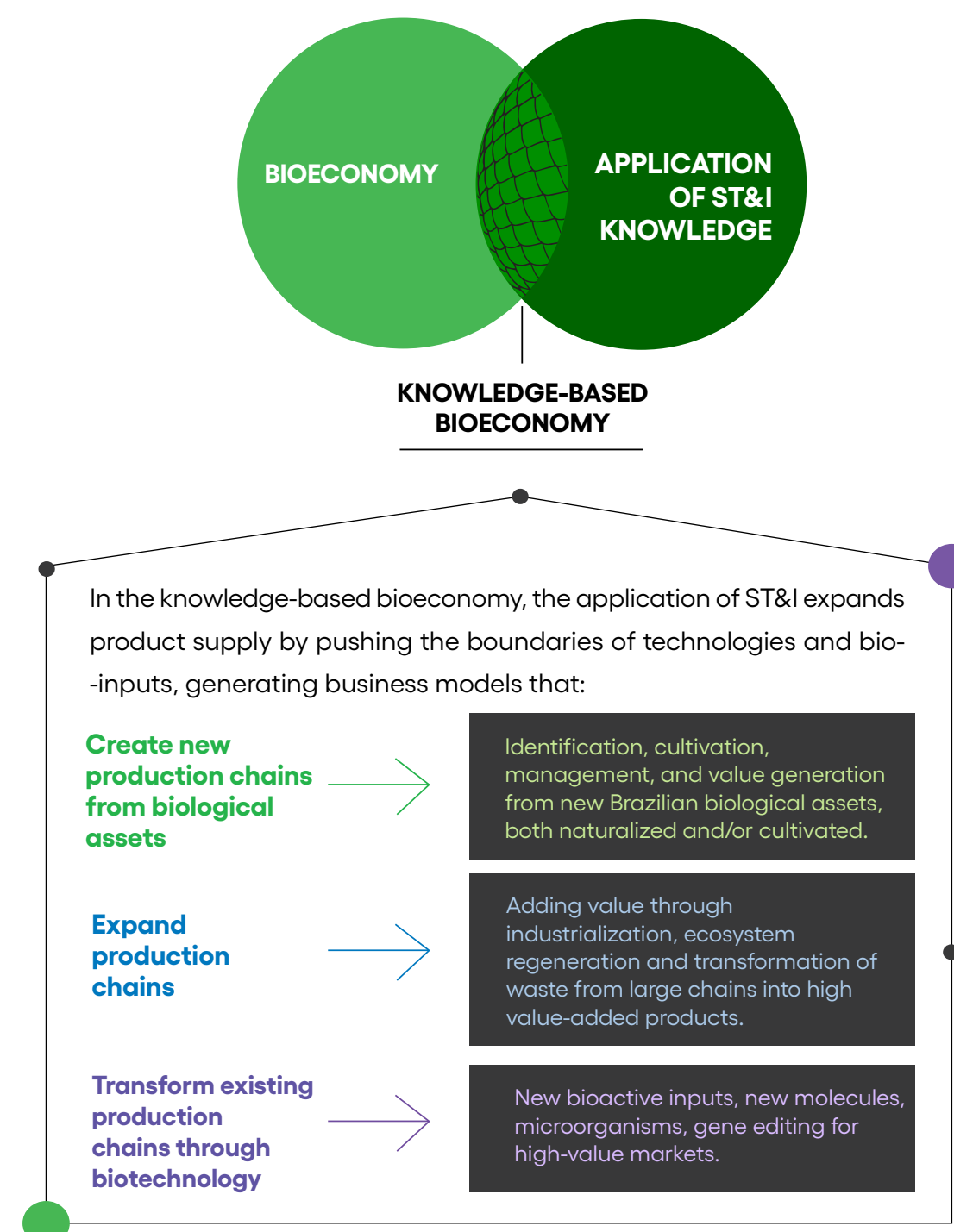
By integrating science, innovation, and biodiversity, the knowledge-based bioeconomy can position Brazil as a leading player in offering sustainable solutions to global challenges.

The country possesses some of the necessary elements to lead this transformation: abundant biodiversity, scientific infrastructure, and a developing regulatory and innovation ecosystem. However, for this opportunity to be fully seized, it is essential that investments be direc-

ted towards research, development, and the scalability of emerging technologies. The combination of structured public policies, financial incentives, and collaboration between private sector, academia, and communities will be crucial to consolidating Brazil as a global leader in the knowledge-based bioeconomy.

FIGURE 2.

The knowledge-based bioeconomy is a segment of the bioeconomy that adds value based on scientific, technological and traditional knowledge.



Therefore, the bioeconomy must be seen as a priority for the future of sustainable development in the country. With the ability to create production chains, add value to traditional sectors, and revolutionize industries through biotechnology, this economic model can position Brazil at the forefront of global innovation, promoting economic growth combined with biodiversity conservation, climate resilience, and social inclusion.

Next follows an analysis of Brazil's comparative advantages in the knowledge-based bioeconomy, highlighting its broad biodiversity, accumulated intellectual capital, established production chains, growing investments in the sector, clean energy infrastructure, and evolving regulations.

1.2 Brazil's comparative advantages in the knowledge-based bioeconomy

1.2.1 The greatest biodiversity on the planet

Brazil can have a prominent role in the global knowledge-based bioeconomy, and biodiversity is one of its greatest competitive advantages. The country is home to the greatest biodiversity on the planet, with a wide variety of fauna and flora species. Approximately 57% of the flowering plant species found are endemic, that is, found exclusively in Brazilian territory⁴. Figure 3 shows that, globally, Brazil represents 24% of freshwater fish, 17% of birds, 13% of amphibians, 12% of plants, 12% of mammals and 11% of ants, reinforcing its role in the conservation of global biodiversity⁵. Brazil is the leader in cataloged plants, with more than 34 thousand species⁶.

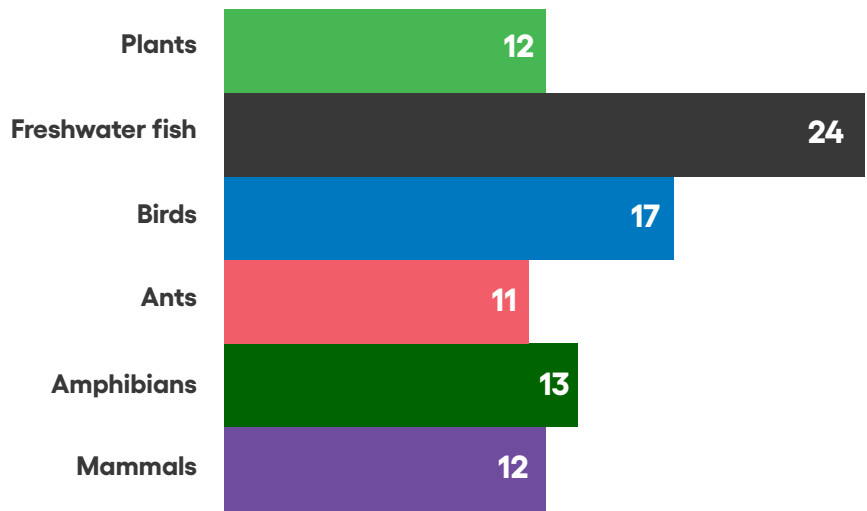
Beyond the economic potential of these assets, preserving them is an ethical issue for three central reasons: intergenerational responsibility, socio-environmental justice, and respect for life.

4. ROYAL BOTANIC GARDENS, KEW. The Brazilian List: Scientists compile country's first official list of native flora. Available at: <https://www.kew.org/read-and-watch/brazilian-list>. Accessed on: April 14, 2025.
5. MONGABAY. Platform presents unpublished data on Brazilian biodiversity.2021. Available at:<https://news.mongabay.com/2021/08/platform-presents-unpublished-data-on-brazilian-biodiversity/>. Accessed on: February 10, 2025.
6. WORLD RAIN FORESTS. Total number of plant species by country. 2023. Available at: <https://worldrainforests.com/03plants.htm>. Accessed on: February 10, 2025.

Future generations have the right to inherit a functioning planet, with healthy ecosystems and available resources. Furthermore, environmental degradation disproportionately affects communities that depend on biodiversity for subsistence, exacerbating inequalities and social vulnerabilities. Furthermore, all species have intrinsic value, and their extinction caused by human actions interrupts millions of years of evolution.

FIGURE 3.
Brazil concentrates 24% of the global biodiversity in classes of living beings

Contribution of Brazilian biodiversity to global biodiversity, in %



Amazon

It is the largest tropical forest in the world and is home to 73% of mammal species and 80% of birds in Brazil.



Cerrado

It is considered the most biodiverse savanna in the world with 13,000 species of native plants.



Caatinga

It is considered the most biodiverse semi-arid biome in the world, with 5,000 species of plants.



Atlantic Forest

It is one of the 36 biodiversity hotspots in the world.



Pantanal

Considered the most preserved biome in the country, it is home to more than 2,000 species of plants.



Pampas

It houses 3,000 species endemic to the region.

SOURCE: Mongabay (2021). Platform presents unpublished data on Brazilian biodiversity; MMA (2024). Biodiversity and biomes

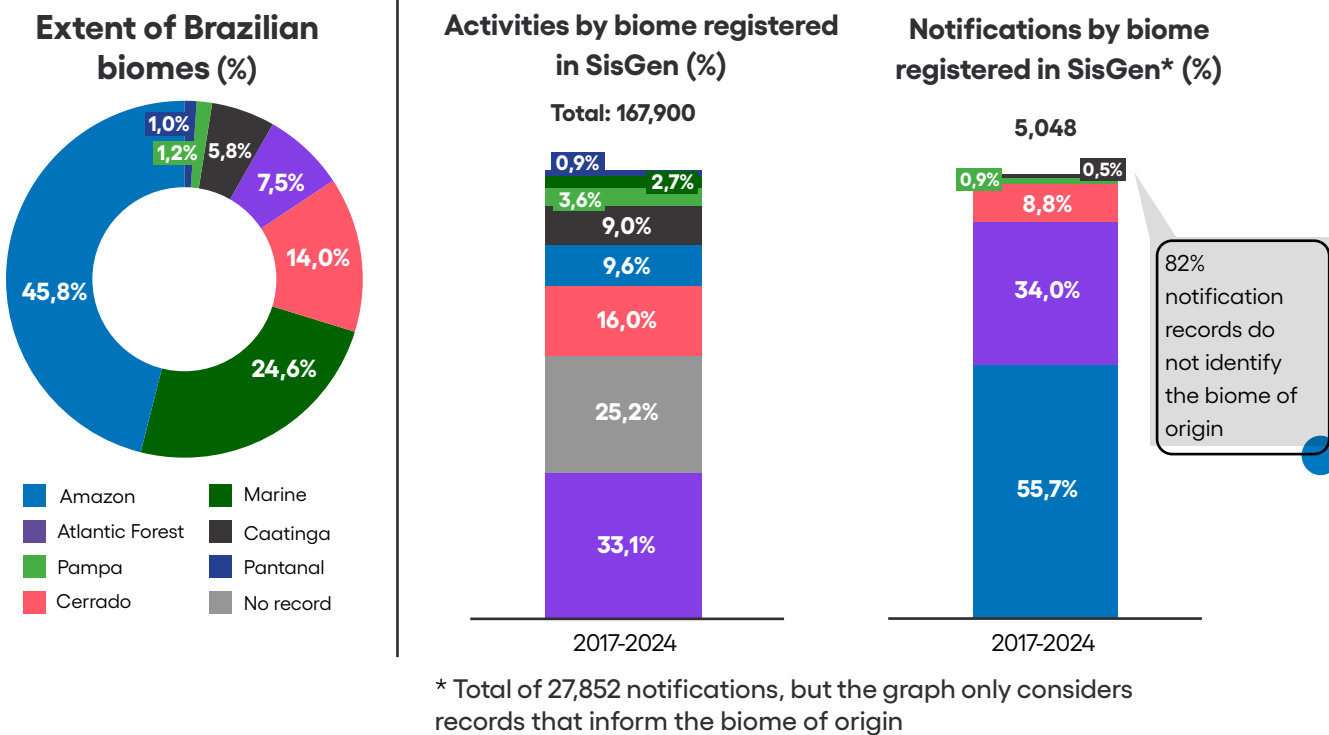
In contrast, biodiversity provides ecosystem services that are essential benefits to society and the economy. These include climate regulation, through carbon absorption and consequent mitigation of extreme events; maintenance of the water cycle, which ensures water quality and availability; pollination, which is essential for agricultural production; soil fertility, which is crucial for productivity; and biological pest control, which reduces the cost of chemical pesticides. The degradation of these services compromises production chains and increases environmental and human health risks. This, on the one hand, affects people's quality of life and, on the other, results in operational costs for governments and industries.

Analysis of records from the National Genetic Heritage Management System (SisGen) highlights a contrast between the territorial extent of Brazilian biomes and the volume of scientific activities carried out in each of them⁷. The Amazon, which represents approximately 46% of the country's territory, has less than 10% of its activities registered in the system. This indicates that its biological potential is not being fully utilized. However, this biome leads in the number of registered notifications⁸, which suggests a growing interest in research and the development of new products derived from its biodiversity. This data reinforces the need for additional investment to transform the region's biological wealth into applied innovation.

On the other hand, the Atlantic Forest stands out as the biome with the highest number of activities registered in SisGen, but with a lower volume of notifications than the Amazon, ranked third. The Caatinga, ranked fourth in terms of activities, has a significantly lower volume of notifications, ranking fifth, suggesting that there is significant untapped potential for new products and biotechnological applications in these biomes. This imbalance highlights an opportunity for public policies that encourage the advancement of research and innovation in historically

less studied biomes, such as the Pantanal and marine ecosystems. The data also indicates the need for greater connections between the productive sectors and academia to increase the conversion of knowledge into innovation in regions with studied biomes, such as the Caatinga.

FIGURE 4.
Brazilian biomes have high potential for new discoveries





The Amazon accounts for ~46% of the national territory. However, it represents less than 10% of the activities registered in SisGen. The biome ranks first in notifications with registered biomes, **indicating high potential for creating new products. This demands greater investment in research and activities.**



On the other hand, **there is untapped potential for reporting in the Atlantic Forest**, which is the region of greatest activity recorded in SisGen, and **Caatinga**, ranked 4th in number of activities and 5th in number of notifications.

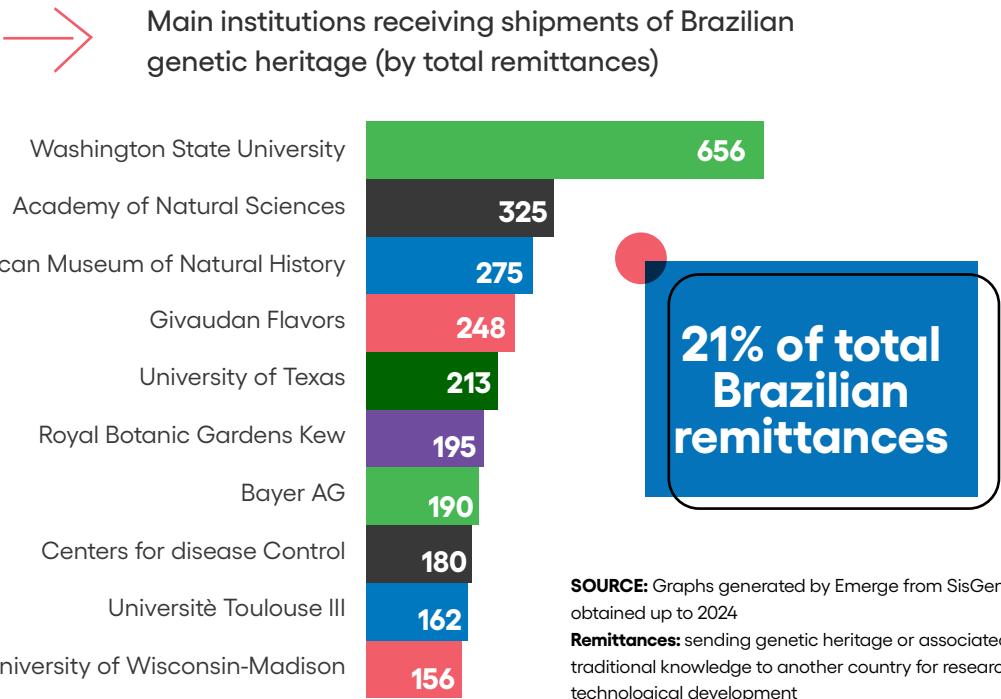
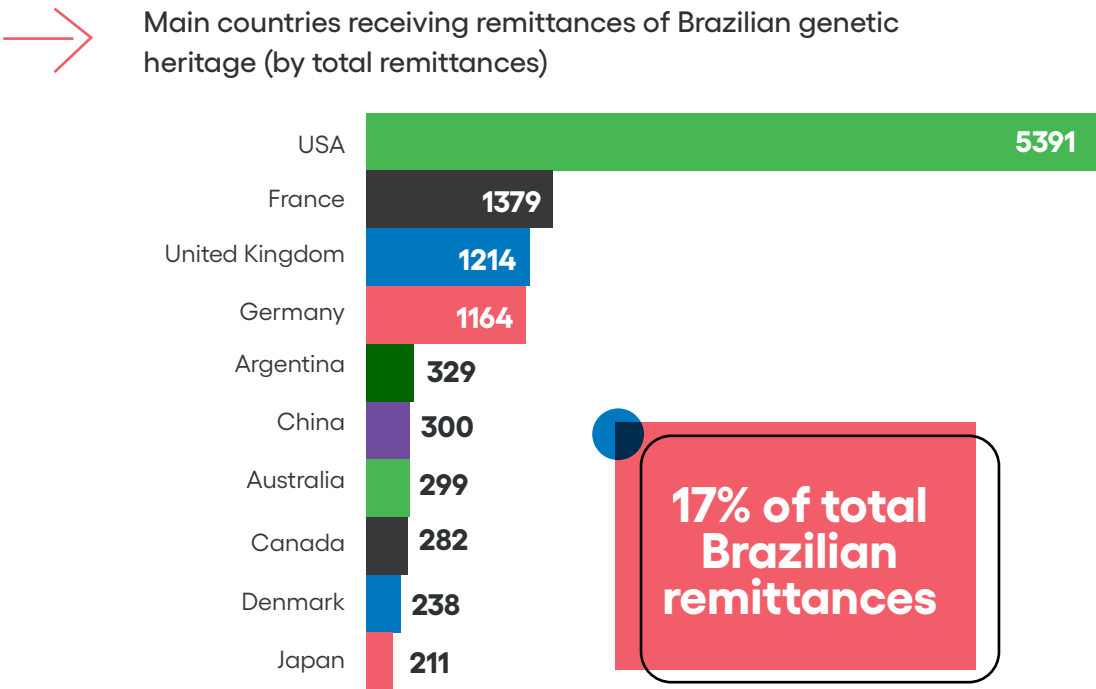
7. Activities: access to genetic heritage or associated traditional knowledge
Shipments: sending genetic heritage or associated traditional knowledge to another country, to carry out research or technological development
Notifications: communication to the government of products developed from genetic heritage or associated traditional knowledge

8. BRAZIL. Ministry of Environment and Climate Change.Database of the National System for the Management of Genetic Heritage and Associated Traditional Knowledge (SisGen). Available at:<https://sisgen.gov.br>. Accessed on: February 5, 2025.

SOURCE: Brasil. Ministério do Meio Ambiente e Mudança do Clima. (2024). Registros de acesso ao patrimônio genético no SisGen – 2024.
Activities: Access to genetic heritage or associated traditional knowledge
Notifications: Communication to the government of products developed from genetic heritage or associated traditional knowledge
* Total notifications of 27,852, but the graph only considers records with the biome of origin reported.

The world also knows this potential. SisGen data indicate that 12,925 shipments of genetic material were made abroad between 2017 and 2024. In this period, United States, France, United Kingdom and Germany received the greatest number of derivatives of Brazilian biodiversity.

FIGURE 5.
Remittances of Brazilian genetic heritage registered in SisGen by country and recipient institution

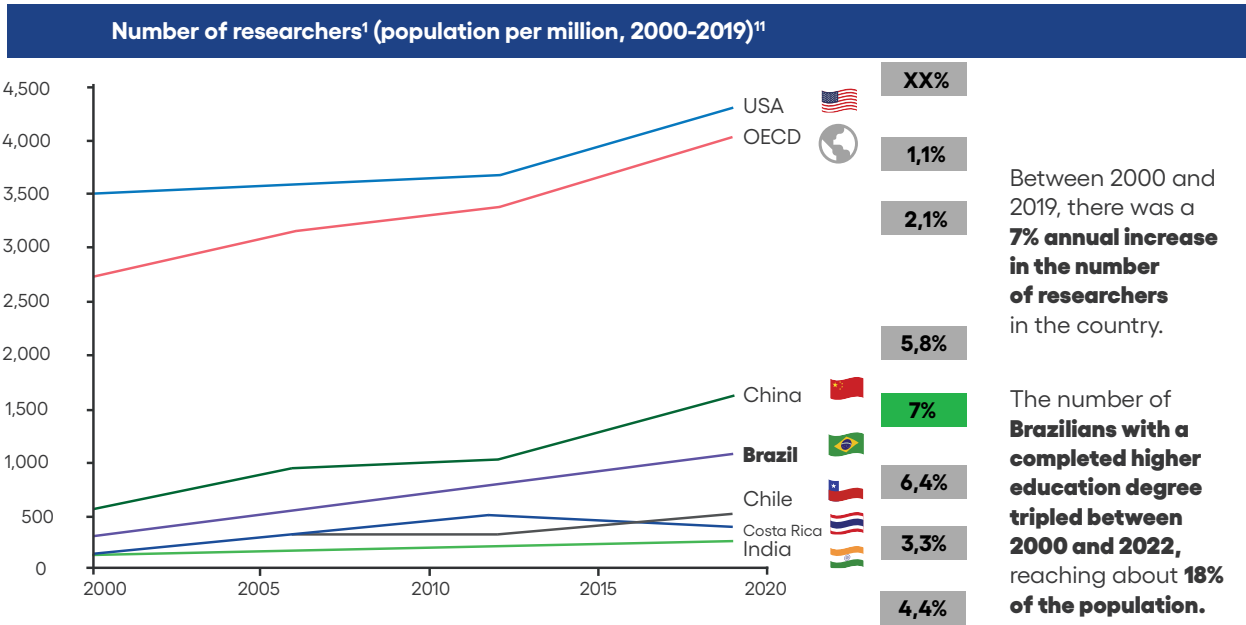


SOURCE: Graphs generated by Emerge from SisGen data obtained up to 2024
Remittances: sending genetic heritage or associated traditional knowledge to another country for research or technological development

1.2.2 Intellectual capital in Brazil stands out among developing countries

In addition to biodiversity, Brazil's scientific base sets it apart from other developing countries. Despite ranking well below developed countries, Brazil occupies a significant position among developing countries due to its growing number of researchers. Between 2000 and 2019, there was a 7% annual increase in the number of researchers in the country⁹. Furthermore, the number of Brazilians who completed higher education tripled between 2000 and 2022, encompassing approximately 18% of the population¹⁰.

FIGURE 6.
Increase in the number of researchers highlights Brazil among developing countries.



Brazil also stands out in scientific production on its biodiversity and leads in the number of academic publications in this area¹². Brazilian science and technology institutions play a central role in research and innovation. These institutions are the main registration agents in SisGen¹³.

⁹. WORLD BANK. Researchers in R&D (per million people). Available at: <https://data.worldbank.org/indicator/SP.POP.SCIE.RD.P6?view=chart>. Accessed on: February 5, 2025.
¹⁰. O GLOBO. Brazilians with higher education triple in 22 years, but a third of the population did not complete elementary school. Rio de Janeiro, February 26, 2025. Available at: <https://oglobo.globo.com/brasil/educacao/noticia/2025/02/26/brasileiros-com-ensino-superior-triplicam-em-22-anos-mas-um-terco-da-populacao-nao-terminou-o-fundamental.ghtml>. Accessed on: February 27, 2025.
¹¹. The number of researchers engaged in Research & Development (R&D), expressed per million inhabitants. Researchers are professionals who conduct research and improve or develop concepts, theories, models, techniques, instrumentation, software, or operational methods. R&D encompasses basic research, applied research, and experimental development (World Bank), 2022).
¹². SCOPUS. Number of scientific publications on Brazilian biomes from the ten main countries between 2012 and 2021.
¹³. BRAZIL. Ministry of Environment and Climate Change. Database of the National System for the Management of Genetic Heritage and Associated Traditional Knowledge (SisGen). Available at: <https://sisgen.gov.br>. Accessed on: February 5, 2025.

FIGURE 7.

Science and technology institutions concentrate the largest number of activities in SisGen

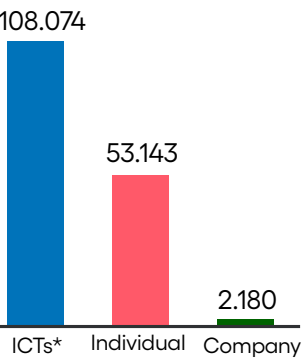
SisGen Records

Activities: access to genetic heritage or associated traditional knowledge

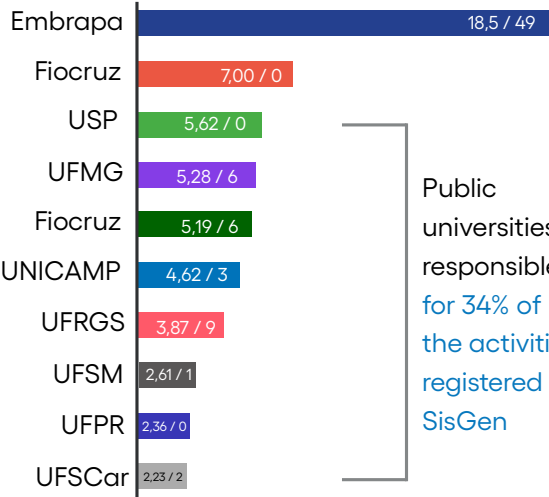
Shipments: sending genetic heritage or associated traditional knowledge to another country, to carry out research or technological development

Notifications: communication to the government of products developed from genetic heritage or associated traditional knowledge

Number of activities recorded in SisGen per agent



* Science, Technology, and Innovation Institutions (ICTs) public administration bodies or entities whose institutional mission includes, among other activities, conducting basic or applied scientific or technological research



Public universities were responsible for 34% of the activities registered in SisGen

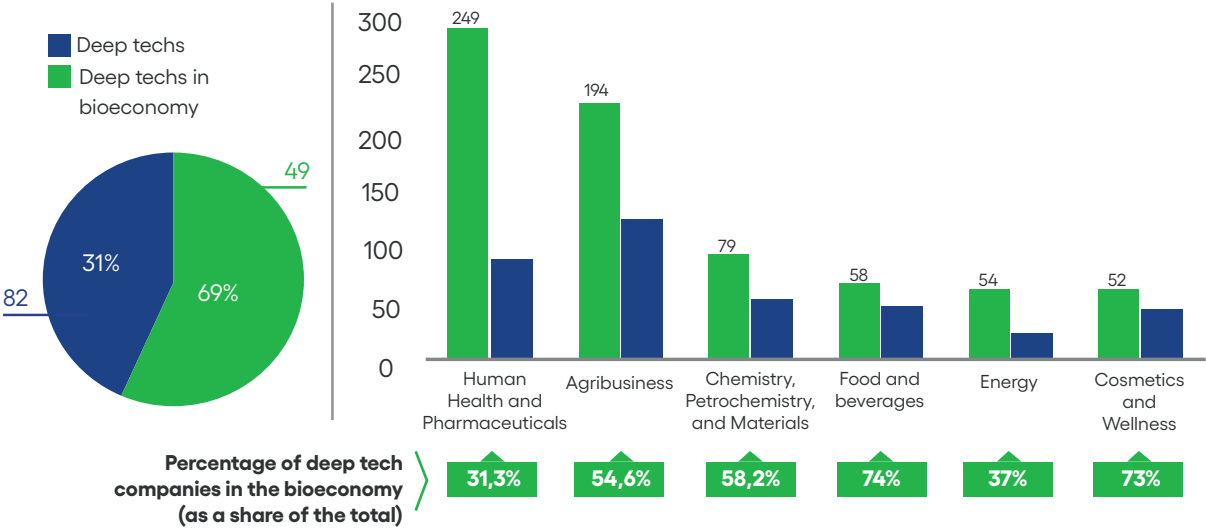
Source: Brazil. Ministry of the Environment and Climate Change. (2024). Registries of access to genetic heritage Sisgen - 2024.

Deep techs in bioeconomy have also gained relevance in Brazil and currently represent 43% of all Brazilian deep techs. This data demonstrates a growing innovation ecosystem aligned with the demands of the knowledge-based bioeconomy¹⁴.

14. EMERGE. Deep Tech Brazil Report. 2024.

FIGURE 8.

Deep techs in Brazil: Comparison between Bioeconomy and other sectors (2018-22)



Of the 876 Brazilian deep tech companies, 43% (382) are focused on the bioeconomy, highlighting its relevance for science-based innovation in the country.

As is the case in the general deep tech landscape, bioeconomy startups are spread across a diverse range of sectors.

SOURCE: Relatório Deep Techs Brasil (Emerge, 2024).

1.2.3 Brazil has a wide range of established bioeconomy chains

Brazil occupies a leading position in several bioeconomy chains. The country is the world's largest producer of coffee, soybeans, sugarcane, oranges, and açai, as well as the world's largest exporter of guarana. It also ranks as the second-largest global producer of cellulose and biofuels, the third-largest producer of corn and cotton, and the sixth-largest producer of cocoa. However, Brazil adds little value to its production. For example, the country has been the world's largest coffee producer for the past 150 years, but it is not the country that generates the most value for the sector. The majority of Brazilian coffee is exported as green coffee beans¹⁵. The United States, Germany, and Japan are among the four largest revenue earners in the sector, yet they do

15. COUNCIL OF COFFEE EXPORTERS OF BRAZIL (CECAFE). March 2024 Monthly Report. Available at: http://www.consorciopecquisacafe.com.br/images/stories/noticias/2021/2024/Mar%C3%A7o/CECAFE_Relatorio_Mensal_MAR_CO_2024.pdf. Accessed on: 25/02/2025

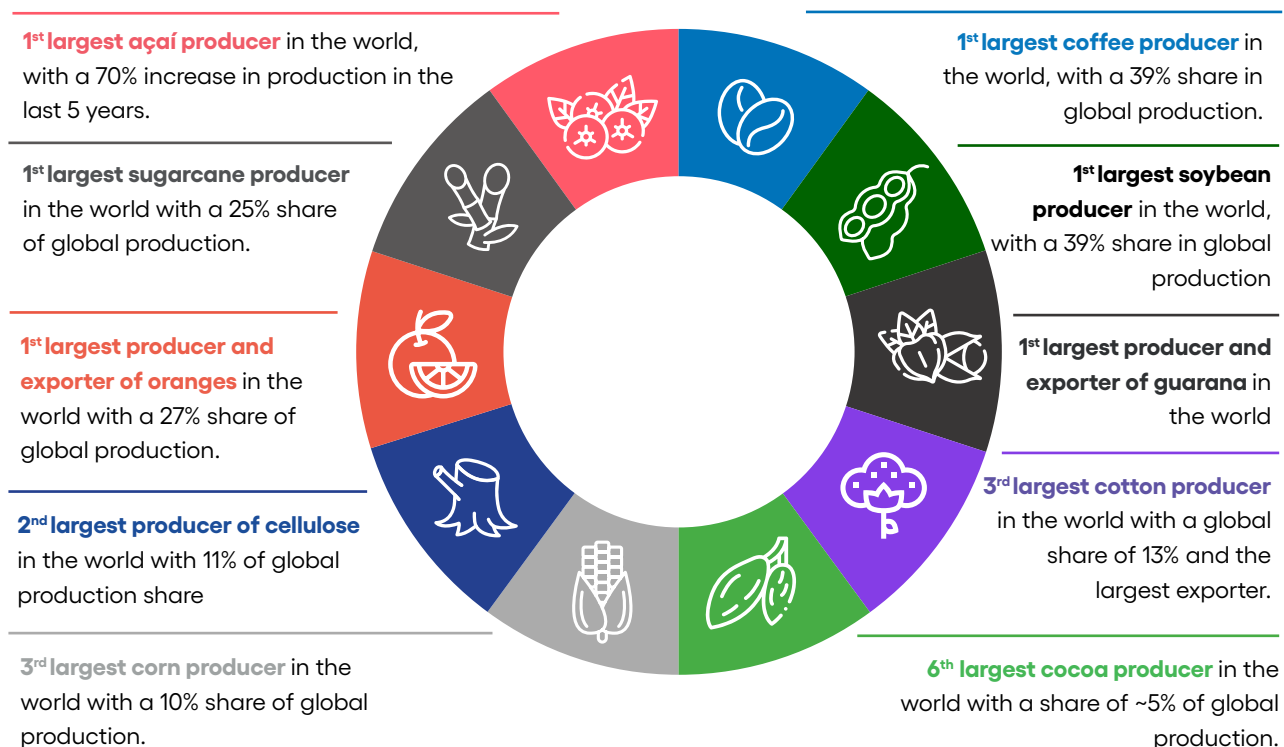
not produce coffee in their territories. These countries are among the largest buyers of Brazilian green coffee and add value to the product through roasting, processing, and distribution to consumer markets.

Furthermore, Brazil's large agricultural production generates waste with high potential for use in the knowledge-based bioeconomy. In 2022, Brazil had around 630 plants that use biomass, with an installed capacity of 16.7 GW; in that same year, 8.55% of the Brazilian energy matrix was produced from biomass¹⁶. Nevertheless, there are opportunities for higher-value uses of this waste, such as feedstocks, fertilizers, and biomaterials. Brazil's accumulated experience in bioenergy production provides it with solid infrastructure, technical expertise, and regulatory incentives, which can be used as a foundation for expanding new segments of the economy.

FIGURE 9.

Brazil leads large established production chains in bioeconomy and agriculture

Brazil's ranking and participation in the global production of bioeconomy and agricultural crops



SOURCE: USDA (2024) ; Allied Market Research (2024), Guarana Market ; Instituto Brasileiro de Árvores ; IBGE

16. MINISTRY OF MINES AND ENERGY. Biomass: waste that is transformed into energy. Available at: <https://www.gov.br/mme/pt-br/assuntos/noticias/biomassa-residuos-que-sao-transformados-em-energia>. Accessed on: February 5, 2025.

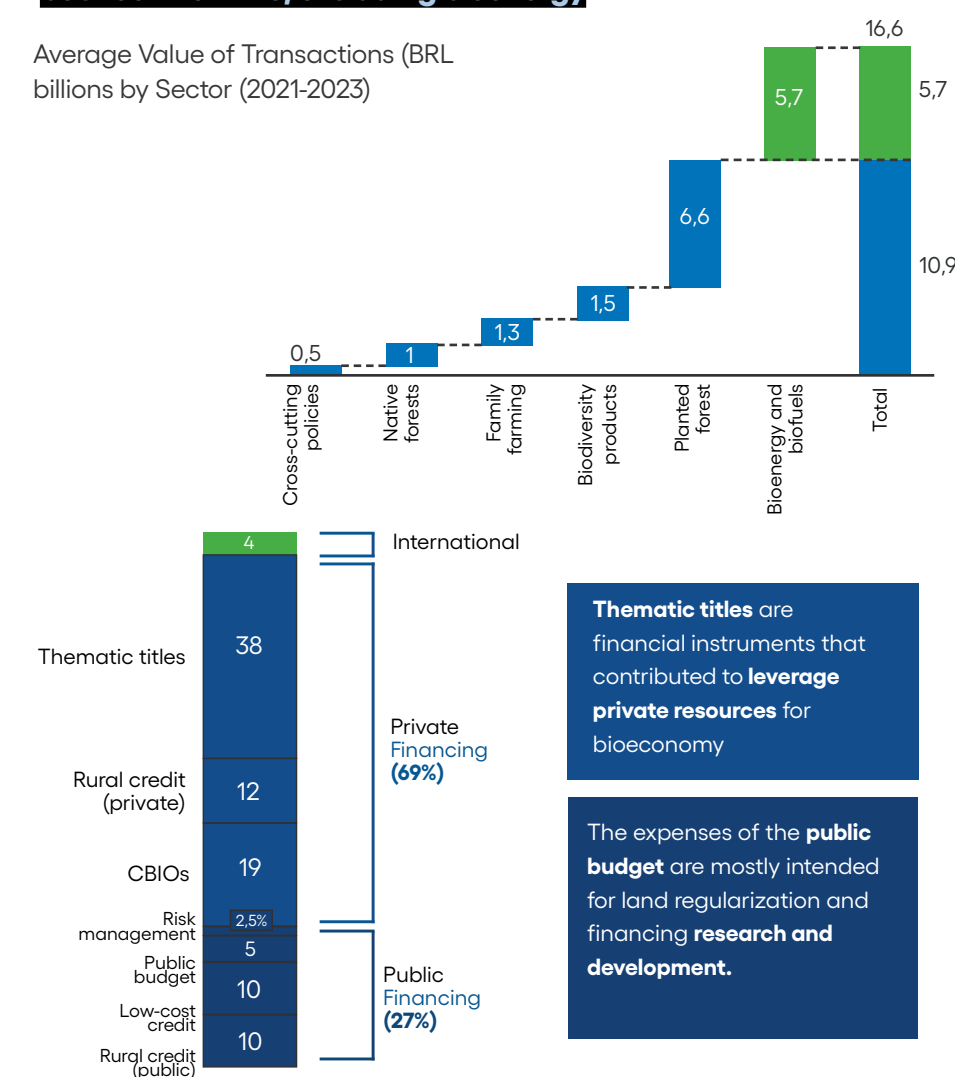
1.2.4 Brazil invests in bioeconomy

The bioeconomy in Brazil generated, on average, R\$10.9 billion (about USD 1.9 billion) per year between 2021 and 2023, excluding bioenergy¹⁷. The planted forest and biodiversity products sectors were the main economic vectors. In this study, we do not highlight the biofuels sector as it has received attention from several institutions and initiatives. Funding for the bioeconomy in Brazil is largely private, with emphasis on thematic bonds, CBIOS, and private rural credit. Furthermore, the public sector mobilizes resources for land regularization and research and development.

FIGURE 10.

Bioeconomy in Brazil has generated R\$10.9 billion per year between 2021-23, excluding bioenergy

Average Value of Transactions (BRL billions by Sector (2021-2023))



SOURCE: CPI (2024). Financiamento para a Bioeconomia no Brasil: Fontes e Destinação dos Recursos

17. CLIMATE POLICY INITIATIVE. Financing for the Bioeconomy in Brazil: Sources and Allocation of Resources. 2024. Available at: <https://www.climatepolicyinitiative.org/pt-br/publication/financiamento-para-a-bioeconomia-no-brasil-fontes-e-destinacao-dos-recursos/#:~:text=Tr%C3%AAs%20quartos%20do%20financiamento%20est%C3%A3o,em%20produtos%20oriundos%20da%20biodiversidade.&text=O%20financiamento%20para%20bioeconomia%20no,ano%20entre%202021%20e%202023>. Accessed on: 02/10/2025

Brazil has a broad network of research funding agencies that play an essential role in financing and promoting scientific and technological innovation. Among the main institutions are EMBRAPA (Brazilian Company for Industrial Research and Innovation), CAPES (Coordination for the Improvement of Higher Education Personnel), BNDES (National Bank for Economic and Social Development), FINEP (Innovation and Research Financing Agency) and CNPq (National Council for Scientific and Technological Development)¹⁸.

The importance of these agencies extends beyond direct funding. They also enhance transparency in resource allocation, by establishing clear criteria for distributing research investments. Furthermore, these agencies play a central role in technology transfer and foster collaboration between universities, research centers, and the private sector, which facilitates open innovation and the dissemination of knowledge. A final key point is their role in aligning academia, government, and the needs of the productive sector, ensuring that scientific research is aligned with the country's strategic priorities.

1.2.5 Developing clean energy infrastructure and digitalization

Brazilian infrastructure plays a crucial role in enabling the bioeconomy, ensuring the necessary conditions for the sector to expand and reach national and international markets in a competitive and sustainable manner.



One of Brazil's main differentiators is its predominantly renewable energy matrix, where 46% of primary energy production comes from sustainable sources, a proportion significantly higher than the global average of 32%¹⁹.

Furthermore, more than 80% of the country's electricity is generated by renewable sources, such as hydroelectric, solar, wind and biofuels,

¹⁸. SIOP. Available at: <https://www1.siop.planejamento.gov.br/>. Prepared by Emerge

¹⁹. BREDARIOL, TOMÁS. "BRAZIL'S OPPORTUNITY TO LEAD THE GLOBAL DIALOGUE ON CLIMATE AND ENERGY." IEA. <https://www.iea.org/commentaries/brazil-s-opportunity-to-lead-the-global-dialogue-on-energy-and-climate?language=pt>. 2024.



which reduces the carbon footprint of productive activities and expands opportunities for the development of industries based on biomass and bioinputs²⁰. Energy infrastructure thus enables the implementation of more sustainable production chains and attracts foreign investment interested in businesses aligned with global decarbonization and ecological transition goals.

Beyond energy, Brazil's logistics and digital infrastructure also stands out as a strategic asset for the bioeconomy, even though it presents challenges. The country has the largest road network in Latin America, complemented by strategic ports like the Port of Santos, which facilitate the flow of products to international markets. Improved infrastructure and the expansion of routes and logistics modalities—such as rail infrastructure—have also contributed to reducing logistical costs and increasing efficiency in the transportation of biomass and agro-industrial inputs.

In the digital realm, the advancement of connectivity with the implementation of 5G, combined with an innovative financial system – with emphasis on PIX and open banking – has accelerated the digitalization of services and expanded access to credit for rural producers and companies in the sector. The availability of land suitable for reforestation and the growing value of the carbon credit market further consolidate Brazil as an attractive hub for the bioeconomy.

²⁰. Ibid.

1.2.6 In Brazil, bioeconomy sector regulation is underway

Brazil has made progress in institutionalizing its bioeconomy with the creation of the National Bioeconomy Strategy, formalized by Decree No. 12,044 of June 5, 2024. This strategy aims to coordinate public policies that promote the sustainable use of biological resources, encourage biodiversity conservation, and strengthen production chains based on scientific and traditional knowledge.

By establishing guidelines for research and development of new products from national biodiversity, the strategy seeks to integrate the public sector, private companies, universities, and local communities in a joint effort to transform the bioeconomy into one of the main drivers of the country's sustainable growth.

The country also has the Ecological Transformation Plan and the Brazil Coalition for Financing Restoration and Bioeconomy, tools for mobilizing financial resources for the sector, with the goal of raising USD 10 billion by 2030. These funds can boost forest restoration projects, biotechnology and innovation in sustainable production chains. The New Industry Brazil program also highlights the bioeconomy as a key axis for the country's industrialization, and has the goal of allocating R\$ 468.38 billion (approximately USD 83.8 billion), including public and private resources, for bioeconomy and decarbonization²¹.

In the regulatory field, Brazil is a signatory to the Nagoya Protocol, an international agreement established within the scope of the Convention on Biological Diversity (CBD) that regulates access to genetic resources and benefit-sharing. The Nagoya Protocol was created with the aim of ensuring that countries that hold genetic resources

²¹. Ministry of Development, Industry, Trade and Services. "Mission 5 of the New Industry Brazil allocates R\$468.38 billion, between public and private resources, for the bioeconomy and decarbonization". <https://www.gov.br/mdic/pt-br/assuntos/noticias/2024/dezembro/missao-5-da-nova-industria-brasil-destina-r-468-38-bi-entre-recursos-publicos-e-privados-para-bioeconomia-e-descarbonizacao>.

and traditional knowledge are compensated when these resources are used, establishing the rules for access and benefit sharing (ABS). With the advancement of biotechnology and the increasing use of digital genetic sequence information (DSI) — such as DNA and RNA data available in public banks — allowing research and innovation without the need to physically access the biological material. The Cali Fund for the Fair and Equitable Sharing of Benefits from the use of Digital Sequence Information on Genetic Resources (DSI) was conceived as an international instrument to enable the voluntary sharing of economic benefits generated by the use of digital genetic sequence information (DSI)²².

Brazil approved the Law on Access to Biodiversity and Benefit Sharing (Law No. 13,123/2015), even before ratifying the Nagoya Protocol. As a pioneer in regulating access to and benefit-sharing derived from the use of genetic resources, this legislation replaced a more rigid and bureaucratic model with a system that seeks to balance biodiversity conservation and fair and equitable benefit-sharing with the need to encourage research and innovation in the sector. However, challenges remain for the full implementation of the law, especially regarding enforcement and the effective sharing of benefits. For Brazil to consolidate its position as a leader in the knowledge-based bioeconomy, it will be essential to improve governance mechanisms, encourage inter-sectoral partnerships, and ensure a regulatory environment that stimulates innovation without compromising biodiversity conservation.



²². CBD. "The Cali Fund launches in the margins of the resumed session of COP16". <https://www.cbd.int/article/cali-fund-launch-2025>

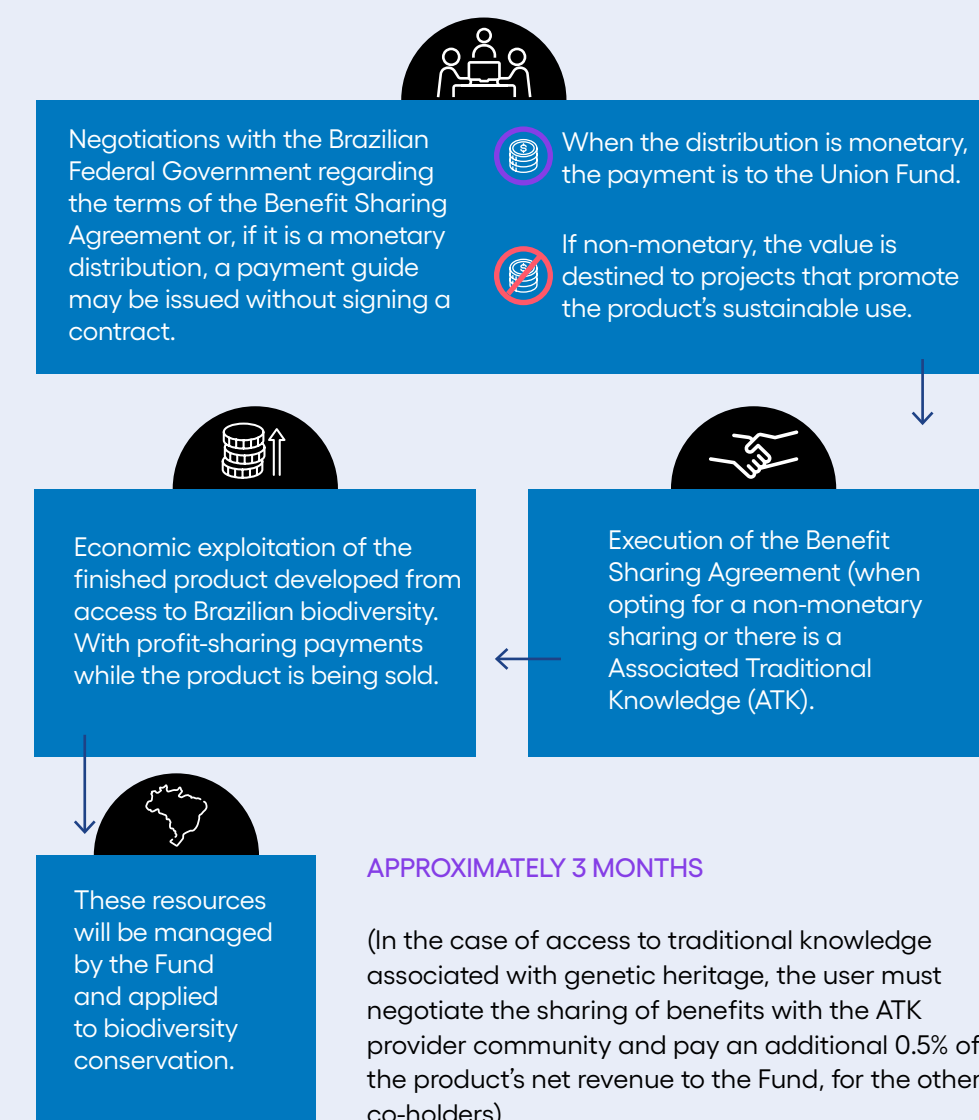
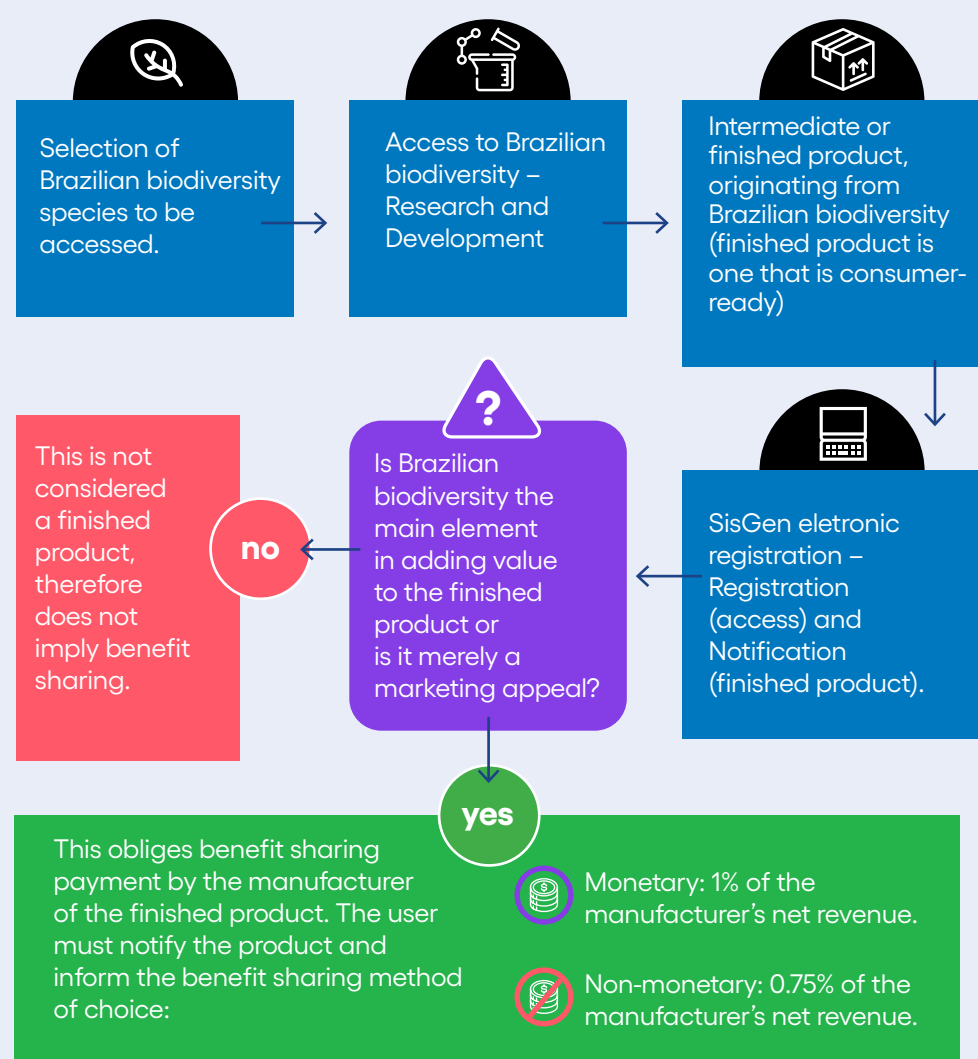
BRAZILIAN BIODIVERSITY LAW REGULATORY BOX

by Anita Pissolito, with contributions from Angela Fey and Giovani Tomasoni

Law 13.123/2015 established the current legal framework for access to genetic heritage and associated traditional knowledge in Brazil. This legal statute revoked and replaced Provisional Measure 2.186-16/2001, which for 15 years regulated this activity in Brazil, requiring prior authorization as a condition for beginning research on Brazilian biodiversity. Law 13.123/2015 now allows access without the need for prior authorization; electronic registration is sufficient, according to current legislation. The flowchart below summarizes the obligations established by Law 13.123/2015:

FIGURE 11.

Obligations established by Law 13.123/2015 regarding access to genetic heritage, protection and access to associated traditional knowledge, and benefit sharing for the conservation and use of biodiversity



SOURCE: Created by Nascimento e Mourão Advogados.

In view of this regulatory procedure, the concepts of access and heritage genetic/traditional knowledge are two pillars supporting the new regime established by Law 13,123/2015 and Federal Decree 8,772/2016. This is because the rights and obligations established by it will only apply if there is access to the sample of the national genetic heritage or to traditional knowledge associated with it.

Genetic heritage is the information of genetic origin of plant, animal, microbial or other species, including substances originating from the metabolism of these living beings, found in conditions on site. That is, whether naturally existing in the national territory or domesticated, if they develop their own distinctive characteristics here, or are kept in

on site conditions in the national territory (according to art. 2, I, Law No. 13,123/2015). In the case of microorganisms, Law 13,123/2015 (art. 2, sole paragraph) establishes a territorial division, providing that the microorganism isolated from the substrate of the national territory will be considered part of the national genetic heritage, which includes substances originating from its metabolism.

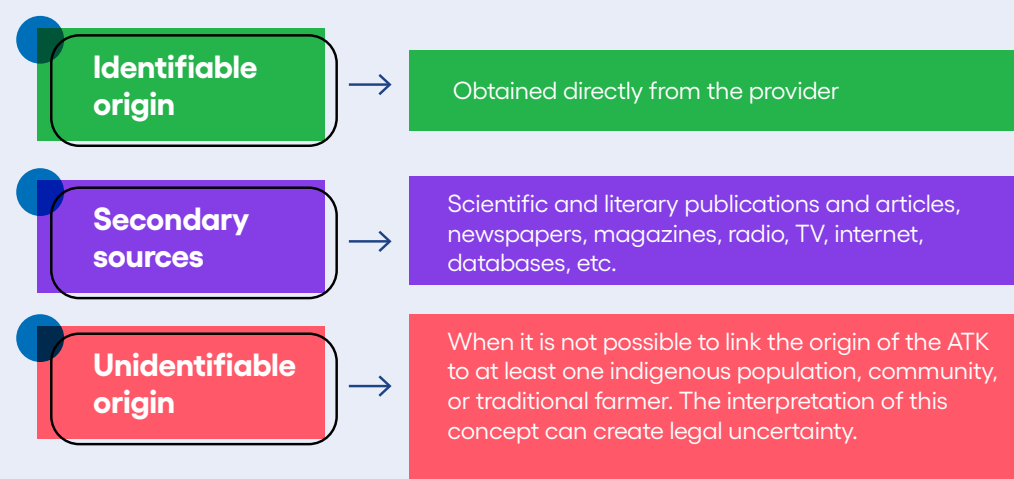
There is an official and complete list of all organisms that fall within the concept of the country's genetic heritage for the purposes of applying Law 13,123/2015. However, there are official lists of exotic and endangered species, which can be used as reference; in addition, lists of reference centers around the world can be consulted. The precise definition of each species' origin requires case-by-case analysis, based on the existing bibliography on the subject and the knowledge of experts, as well as traceability information provided by suppliers of national biodiversity inputs.

When the species used is part of the national genetic heritage, an assessment must be made as to whether access will be granted, that is, whether research or development will be conducted on a sample of the genetic heritage. Access to traditional knowledge is obtained through research or development carried out on traditional knowledge that enables or facilitates access to the genetic heritage. Regarding the latter, the current law established that:

FIGURE 12.

Classification of sources of access to associated traditional knowledge

ACCESS TO ATK = research or development on ATK that enables or facilitates access to genetic heritage.

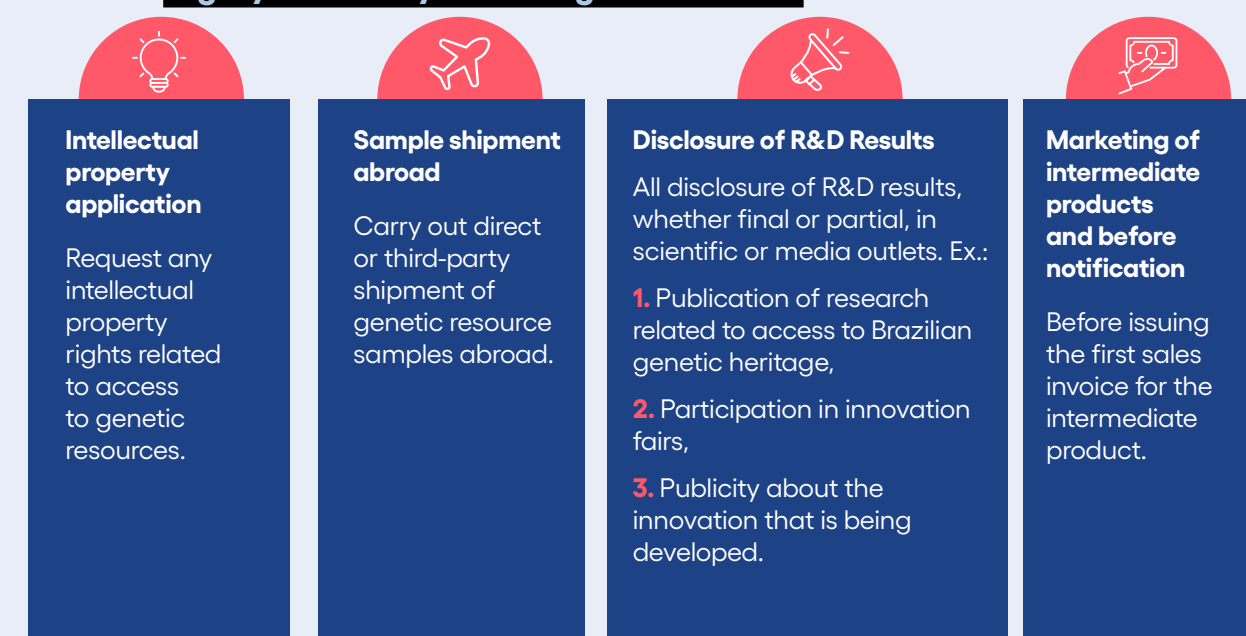


SOURCE: Created by Nascimento e Mourão Advogados.

When accessing genetic heritage or associated traditional knowledge, Law 13,123/2015 eliminated the general requirement for prior authorization from the Genetic Heritage Management Council (CGEN)—with the exception of access by a foreign-controlled company in a national security area. However, it maintained the obligation to obtain prior consent in the case of access to traditional knowledge. Furthermore, the Law provides that access and shipment must only be registered with the Genetic Heritage Management System (SISGEN), an electronic, self-declaratory system, for access and shipment. Registration is only mandatory before:

FIGURE 13.

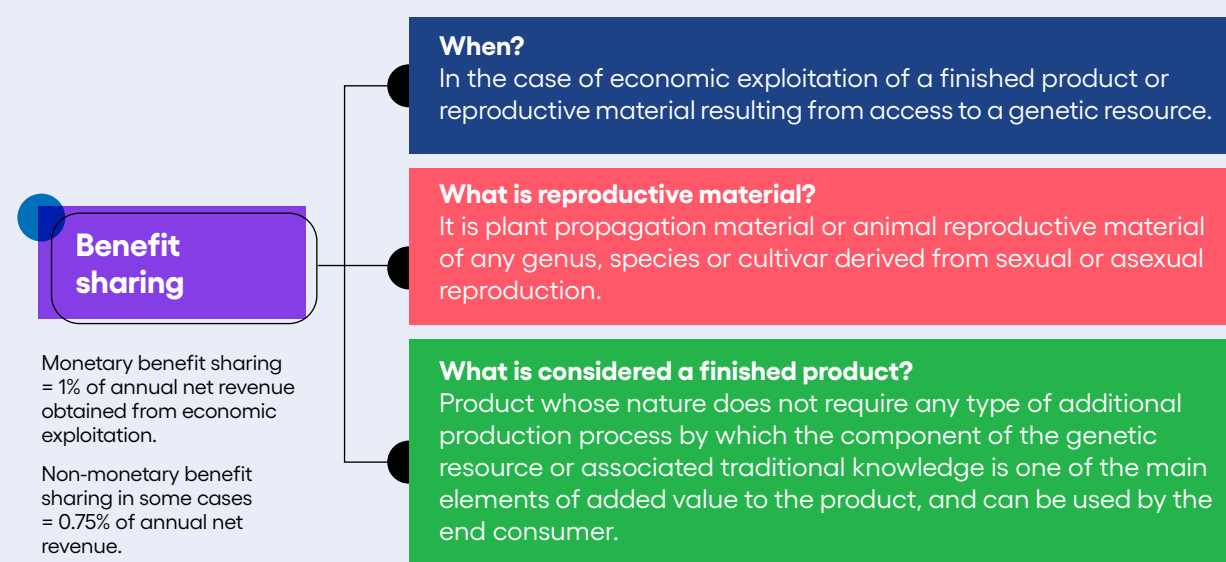
Legally mandatory SisGen registration cases



SOURCE: Created by Nascimento e Mourão Advogados.

The Law also does not require payment of benefit-sharing by all links that access genetic heritage or traditional knowledge. Payment occurs at a single link in the production chain. Benefit-sharing is understood as the sharing of gains earned by the user from access to genetic heritage and associated traditional knowledge. For the agricultural sector (which includes food, beverages, fiber, planted forests, and energy), payment is due at the initial link, the one that produces the reproductive material derived from access (seedlings, seeds, semen, etc.). For other sectors, payment is due only at the last link, that is, the one that manufactures the finished product, ready for use by the end consumer. Below is a detailed flowchart:

FIGURE 14.

Details on benefit sharing

Therefore, if the final product originates from access but does not use genetic heritage as its primary element, it will not be subject to benefit-sharing payments. Furthermore, the benefits to be shared are now pre-established, and negotiation is only possible in the case of access to identified associated traditional knowledge.

Regarding the type of payment to be chosen, in the case of access to genetic heritage, the choice between these modalities is at the user's discretion. In the case of access to associated traditional knowledge of identified origin, this definition will depend on an agreement between the user and the provider; when it comes to access to unidentifiable knowledge, monetary payment is mandatory. In the first case, Law 13.123/2015 allows free negotiation between the provider and user, but requires that a minimum equivalent to 0.5% of the product's revenue be paid to a Fund managed by the Union. In the second case (knowledge of unidentified origin), payment must necessarily be made in monetary form, at a rate of 1% to the Fund. And when access to traditional knowledge is recognized, no payment is due for access to genetic heritage.

Finally, those links responsible for payment must notify their finished products or reproductive material in SisGen to declare the start of their economic exploitation activity, indicating the benefit sharing modality to be established.

REGULATORY BOX - ACCESS AND BENEFITS SHARING (ABS) AND DIGITAL SEQUENCE INFORMATION (DSI)

Anita Pissolito, with contributions from Angela Fey and Giovani Tomasoni

ABS is the acronym for *Access and Benefit-Sharing* (Access and Benefit Sharing), a central principle of the Convention on Biological Diversity (CBD), created in 1992²³.

The idea is that countries holding genetic resources (such as plants, microorganisms, animals, etc.) have the right to use these resources and receive a fair and equitable sharing of the benefits arising from their use – whether monetary or non-monetary benefits.

This principle was operationalized through the Nagoya Protocol²⁴, adopted in 2010 and in force since 2014, to ensure that the acquisition of genetic resources occurs with *Prior Informed Consent (PIC)* and *Mutually Agreed Terms (MAT)* with the provider country. It is worth noting, however, that the Nagoya Protocol did not create rules, but rather introduced facilitation mechanisms so that the bilateral relationship between the “user” and “provider” of genetic resources would be satisfactory and benefit-sharing would be effective.

In this sense, among the main measures are the creation of the *ABS Clearing-house* (art. 14, Nagoya Protocol²⁵), a platform for exchanging information on national legislation; the focal point on the topic in the country; the competent national authority on the topic; checkpoints (internal bodies to report non-compliance); and model clauses.

²³. Text of Article 1 of the Convention on Biological Diversity. Available at: <https://www.cbd.int/convention/articles/default.shtml?a=cbd-01>. Accessed on: July 18, 2025

²⁴. Nagoya Protocol, text available in English at the Link: <https://www.cbd.int/abs/doc/protocol/nagoya-protocol-en.pdf>. Accessed on: July 18, 2025. The text was enacted by Brazil in 2023, through Decree No. 11,865, of December 27, 2023. Available at: https://www.planalto.gov.br/ccivil_03/_ato2023-2026/2023/decreto/d11865.htm. Accessed on: July 18, 2025

²⁵. For more information, visit: <http://cbd.int/abs/theabsch.shtml>. Accessed on: 07/18/2025.

In the context of discussions on Access and Benefit-Sharing, a topic that has gained prominence is how to organize and regulate access and benefit-sharing regarding the use of Digital Sequence Information (DSI). The topic was first addressed under the Convention (CBD) in 2016. Since then, in 2022, with the COP15 decision, it was determined that a multilateral mechanism would be established for benefit-sharing generated by the use of DSI from genetic resources²⁶.

Digital Sequence Information, or “DSI,” is a political term whose definition is under debate and broadly refers to genetic sequence data and other related digital data²⁷. This includes the details of an organism’s DNA and RNA, which determine its unique characteristics and traits.

The use of digital sequences is part of vast areas of current life science research, and its use contributes to significant advances in medicine, conservation, agriculture, and other fields.

During COP16 in Cali, Colombia, in 2024, the development of the mechanism approved at COP15 took on new dimensions. Decision 16/2²⁸, among other definitions, established indicative benefit-sharing rates to be applied to the revenue or profit of DSI user and beneficiary entities. In February 2025, during the second part of COP16, the Cali Fund was launched²⁹. Various stakeholders continue to monitor and contribute to the development of the multilateral mechanism. Brazil has been a key player in guiding these discussions within the CBD by seeking the collective engagement of multidiverse countries with high biodiversity value.

²⁶. CBD. COP15 Decision 15/9. Digital sequence information on genetic resources, p. 4. Available at: <https://www.cbd.int/doc/decisions/cop-15/cop-15-dec-09-en.pdf>. Accessed on: 07/18/2025.

²⁷. DSI Scientific Network. Understanding the use and provision of DSI (p. 4). Available at: <https://dsiscientificnetwork.org/wp-content/uploads/2024/10/Understanding-the-use-and-provision-of-DSI-A-multidirectional-flow-of-information-2024.pdf>. Accessed on: July 18, 2025

²⁸. CBD. 16/2. Digital sequence information on genetic resources. Decision available at: <https://www.cbd.int/doc/decisions/cop-16/cop-16-dec-02-en.pdf>. Accessed on: July 18, 2025

²⁹. CBD. The Cali Fund snacks on the sidelines of the COP16 summary session. Available at: <https://www.cbd.int/article/cali-fund-launch-2025>. Accessed on: July 18, 2025

1.3 Technological convergence

- the digital, biological and sustainable revolution in the bioeconomy

The knowledge-based bioeconomy is driven by technological convergence, in which advances on three fronts — digital, biological and sustainable — open new frontiers for innovation³⁰. This triple revolution creates opportunities for Brazil to leverage its natural, scientific, and productive advantages, consolidating its position as a global hub for biodiversity-based innovation. The country can directly benefit from the application of these emerging technologies by increasing its competitiveness in strategic production chains, expanding value generation from its natural resources, and reducing its dependence on fossil fuels and polluting processes.

FIGURE 15.

The triple technological revolution



³⁰. WORLD ECONOMIC FORUM. Accelerating the Tech-Driven Bioeconomy. 2024. Available at: https://www3.weforum.org/docs/WEF_Accelerating_the_Tech_Driven_Bioeconomy_2024.pdf. Accessed on: February 5, 2025.

The digital revolution has been one of the main drivers of the acceleration of the bioeconomy, with emphasis on the use of artificial intelligence (AI), robotics and automation, and advanced sensing. AI models, including Large Language Models (LLMs), transform the analysis and interpretation of biological data and enable the rapid and efficient identification and optimization of genetic sequences³¹. Advanced sensors and biosensors enable real-time monitoring of variables such as pH and temperature in industrial processes, reducing operational costs and improving the predictability of biological systems³². In addition, robotics and automation have made laboratory processes more accurate, reducing human error and accelerating the development of new products³³. These innovations contribute significantly to reducing the time and cost of research and development in the biotechnology sector, with projections of accelerated growth in these markets through 2030.

At the same time, the biological revolution allows the development of new bioproducts and more efficient production systems. Technologies such as gene editing, nanobiotechnology, and advanced bioprocesses are expanding the possibilities of the bioeconomy. Gene editing, for example, allows for the precise modification of cellular functions, accelerating the development of organisms optimized for industrial production³⁴. Nanobiotechnology enables adjustments at the nanometric scale, ensuring greater control over the physical and chemical properties of bioproducts. Furthermore, precision fermentation and the use of advanced bioreactors create a favorable environment for the large-scale production of high-value-added inputs.

The third piece of this revolution is the sustainable transition, driven by the global need to replace fossil-based inputs, promote circularity, and ensure traceability of products and processes. Companies and governments increasingly invest in solutions that reduce environmental impacts and enhance the efficiency of natural resource use³⁵. Replacing fossil-based raw materials with biomaterials and biopolymers, for example, creates more sustainable production chains.

31. WORLD ECONOMIC FORUM. Accelerating the Tech-Driven Bioeconomy. 2024. Available at: https://www3.weforum.org/docs/WEF_Accelerating_the_Tech_Driven_Bioeconomy_2024.pdf. Accessed on: February 5, 2025.

32. GRAND VIEW RESEARCH. Biosensors Market Size, Share & Trends Analysis Report By Technology, By Application By End-user, And Segment Forecasts, 2025 - 2030. Available at: <https://www.grandviewresearch.com/industry-analysis/biosensors-market>. Accessed on: 02/11/2025

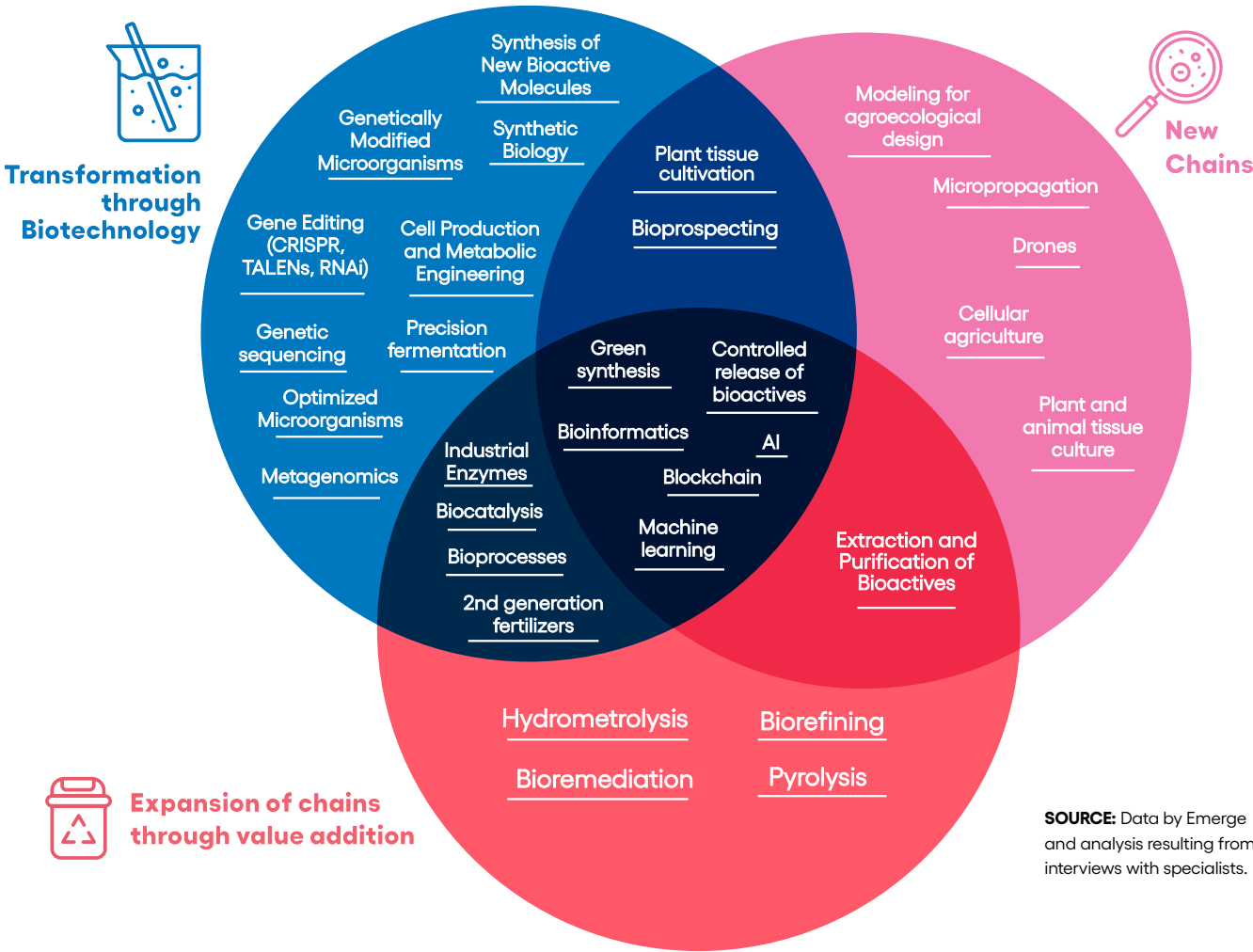
33. MORDOR INTELLIGENCE. Laboratory Robotics Market Size & Share Analysis - Growth Trends & Forecasts (2025 - 2030). Available at: <https://www.mordorintelligence.com/industry-reports/laboratory-robotics-market>. Accessed on: 02/11/2025

34. ROOT ANALYSIS BUSINESS RESEARCH & COMPANY (2024). Genome Editing Market Growth. Available at: <https://www.rootanalysis.com/press-releases/genome-editing-market.html>. Accessed on: 02/11/2025

Digital traceability, combined with smart sensors and artificial intelligence, can strengthen environmental governance and improve the transparency of production chains, ensuring compliance with increasingly stringent international regulations.

The convergence of these three revolutions creates a new paradigm for the bioeconomy. Brazil, with its rich biodiversity, strong scientific base, and growing innovation infrastructure, has a unique opportunity to position itself at the forefront of this transformation. Advances in digital and biological technologies can enhance the country's natural resources, while the sustainable transition drives the adoption of regenerative practices and low-environmental-impact production models. To capitalize on this moment, it is essential that public policies and private investments are aligned to build an ecosystem conducive to innovation and the expansion of the knowledge-based bioeconomy.

FIGURE 16.
Technological advances break barriers to the development and application of solutions based on natural assets



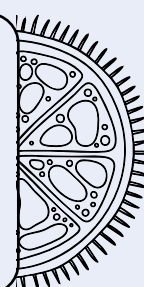
SOURCE: Data by Emerge and analysis resulting from interviews with specialists.

ARTIFICIAL INTELLIGENCE

by Octavio Luiz Franco

Natural proteins have biologically evolved to solve challenges over time, but modern problems require new approaches. AI-accelerated protein synthesis allows for the rapid creation of innovative biomolecules, as demonstrated by the vaccine for COVID-19. Artificial Intelligence (AI) has revolutionized the discovery of new molecules, becoming an essential tool in the pharmaceutical, animal health, and cosmetics industries. Traditionally, identifying peptides with therapeutic applications involves slow and costly processes, with extensive experimental screening.

With AI, it has been possible to accelerate this search by analyzing large volumes of data and accurately predicting bioactivity and molecular stability.



This approach not only reduces time and costs but also enables the creation of innovative molecules with optimized properties for specific applications. AI can accelerate the development of new peptide-based drugs, bioinputs, and biomaterials, enabling rapid screening of candidates and reducing the need for extensive testing. AI in molecule development has revolutionized drug discovery, drastically reducing the time and costs associated with the process.

Traditionally, identifying new assets can take 10 to 15 years and cost billions of dollars, but AI can accelerate this process by up to 90%, as demonstrated by Insilico Medicine, which identified a candidate molecule in just 46 days³⁶. Additionally, AI-powered virtual triage reduces costs by up to 40%. This is demonstrated by examples like Atomwise, which used algorithms to find potential Ebola treatments at a significantly lower cost than traditional methods³⁷. AI also increases accuracy, with

³⁶. MAZIENZA, M. ET AL. Active deep learning approach rapidly identifies potential DDR1 kinase inhibitors. *Nature Biotechnology*, v. 38, p. 1034–1040, 2019. DOI: <https://doi.org/10.1038/s41587-019-0224-x>. Available at: <https://www.nature.com/articles/s41587-019-0224-x>. Accessed on: July 16, 2025.

³⁷. ATOMWISE. Atomwise AI for Ebola Drug Discovery. 2020. Available at: <https://www.atomwise.com/news/atomwise-ai-for-ebola-drug-discovery/>. Accessed on: July 16, 2025.

algorithms that are able to predict molecular interactions with 80–90% accuracy³⁸, and allows for the personalization of treatments, as done by Berg Health, which identified a promising molecule for pancreatic cancer³⁹. Estimates suggest that these technologies have the potential to significantly reduce drug development costs⁴⁰.

Concrete examples, such as the *BenevolentAI*, which suggested a 4-day treatment for COVID-19, and Exscientia, which developed a drug for obsessive-compulsive disorder in 12 months, illustrate how AI transforms molecule discovery into a faster, less costly, and efficient process, enabling new possibilities for treating complex diseases. Furthermore, AI can identify structural patterns that maximize peptide efficiency, thus streamlining the development process. This technology also applies to other biomolecules, such as small-molecules, carbohydrates and lipids, expanding their biotechnological potential. AI also allows target validation (*target-validation*), identifying disease hotspots and preventing side effects by understanding complex molecular networks.

AI has been widely used to select and optimize promising peptides through machine learning algorithms, neural networks, and generative models. These systems are trained on vast databases, allowing them to predict properties such as stability, solubility, and molecular interactions. Models such as deep neural networks and reinforcement learning help generate new peptides with optimized structures. However, experimental validation remains a challenge, as factors such as solubility, stability, and bioavailability can deviate from predictions. A prime example is IBET-762, a BET inhibitor which was initially promising in the treatment of cancer, especially leukemia and lymphoma, and faced challenges in the experimental phase due to unexpected side effects, highlighting the gap between theoretical predictions and practical results.

The transition from AI-discovered peptides to commercial products involves critical steps, from synthesis and structural optimization to clinical trials and regulation. Regulatory matters represent a key

³⁸. ZHANG, Q. et al. Artificial intelligence in drug design: A review. *Drug Discovery Today*, v. 24, n. 5, p. 1241–1250, 2019. DOI: <https://doi.org/10.1016/j.drudis.2019.01.034>. Available at: <https://www.sciencedirect.com/science/article/abs/pii/S135964461930282X>. Accessed on: July 16, 2025.

³⁹. PHARMAPHORUM. Berg utilises AI to aid in pancreatic cancer research. 2019. Available at: <https://pharmaphorum.com/news/berg-utilises-ai-to-aid-in-pancreatic-cancer-research>. Accessed on: July 16, 2025

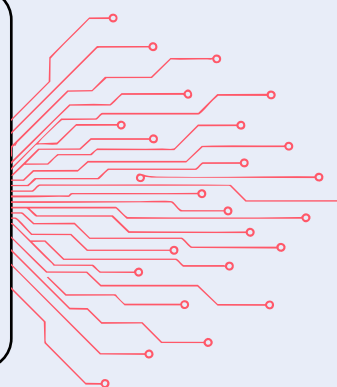
⁴⁰. DREWS, Jürgen. Drug discovery: a historical perspective. *ScienceDirect - Drug Discovery Today*, v. 3, n. 8, p. 411–420, 2000. DOI: [https://doi.org/10.1016/S1359-6446\(00\)01520-7](https://doi.org/10.1016/S1359-6446(00)01520-7). Available at: <https://www.sciencedirect.com/science/article/abs/pii/S0167629616000291>. Accessed on: July 16, 2025.

challenge, with complex requirements and lengthy processes that vary between countries and agencies. The lack of clear guidelines for emerging technologies, such as AI-based therapies or gene editing, creates uncertainty. One example is the biosimilar drug sector, where extensive clinical studies and comparisons with reference products increase costs and risks.

Despite the challenges, collaboration between academia, startups and industries, as well as public-private partnerships, can accelerate regulatory adoption and reduce financial risks. Several sectors can benefit from the advancement of AI.

In the pharmaceutical industry, AI allows identifying peptides with therapeutic potential for diseases such as cancer and metabolic disorders. In animal health, these compounds can be applied in the development of new antibiotics and immunostimulating therapies. In the cosmetics sector, AI facilitates the creation of bioactive peptides for skin rejuvenation, hydration, and protection against environmental factors. Despite advances, barriers such as the need for infrastructure for large-scale production and high initial development costs still persist.

The future of AI in molecular engineering promises to revolutionize drug discovery, with advances such as the integration of quantum computing, which will allow the simulation of molecular interactions with unprecedented precision and speed. This convergence of AI, quantum biology, and big data will allow us to explore previously inaccessible chemical spaces, identifying innovative compounds in a matter of hours. Furthermore, the combination with techniques such as gene editing (CRISPR) and nanotechnology will accelerate the creation of personalized and intelligent therapies, able to treat complex diseases more effectively. In the near future, AI, combined with quantum mechanics, will not only reduce costs and time but also pave the way for precision medicine, transforming global healthcare.



1.4 Brazil as a global provider of new sustainable solutions

Brazil has the capacity to become a global provider of sustainable solutions by using biodiversity and scientific capital to develop innovative products that generate positive economic and environmental impact. The expansion of the knowledge-based bioeconomy can not only drive new high-value-added production chains but also strengthen socioeconomic inclusion through the creation of skilled jobs and the valorization of traditional knowledge. Furthermore, the introduction of new sustainable and competitive products into the global market can increase demand for inputs from forests and regenerative agriculture, strengthening production chains that have a positive impact on the environment and promote local development.

Another crucial factor is the transformative potential of the National Benefit Sharing Fund, which aims to ensure that the value generated from biodiversity is shared fairly with traditional communities, indigenous peoples, and initiatives oriented towards preserving the forest. As more bioeconomy products enter the market, the volume of resources allocated to financing conservation and sustainable development programs could increase significantly. This dynamic reinforces the importance of combining innovation, sustainability, and social inclusion, creating an economic model that benefits both the productive sector and the guardians of Brazil's biodiversity.

However, for this transition to occur effectively and fairly, Brazil needs to act as a bridge between the scientific bench and the market, especially at the technological maturity levels known as TRL 3 to 7. At this stage, many innovations with high potential still do not find structured paths to scalability, remaining restricted to the academic and research



environments⁴¹. Data on patents and scientific publications show that many developments in the sector have yet to reach the market. This may be due to a lack of infrastructure for scaling, gaps in technology transfer, and regulatory challenges, which hinder the conversion of knowledge into commercially viable products or solutions.

Of the science and technology institutions (ICTs) that responded to the 2023 Formict survey, only 45 (16.9%) reported having developed spin-offs since their funding⁴². Only 32% of respondents reported having contracts signed in 2023, demonstrating concentration and a low level of connection with the industry⁴³. Essential activities such as economic evaluation of inventions, exclusive licensing, and minority stakes in companies have implementation rates below 40%⁴⁴. Only 43.8% of ICTs address compensation and leave for employees involved in innovation, which may discourage institutional engagement. To transform this scenario, innovation support programs should be strengthened, new financing models for startups and bioindustries created, and partnership networks between universities, companies and investors established.

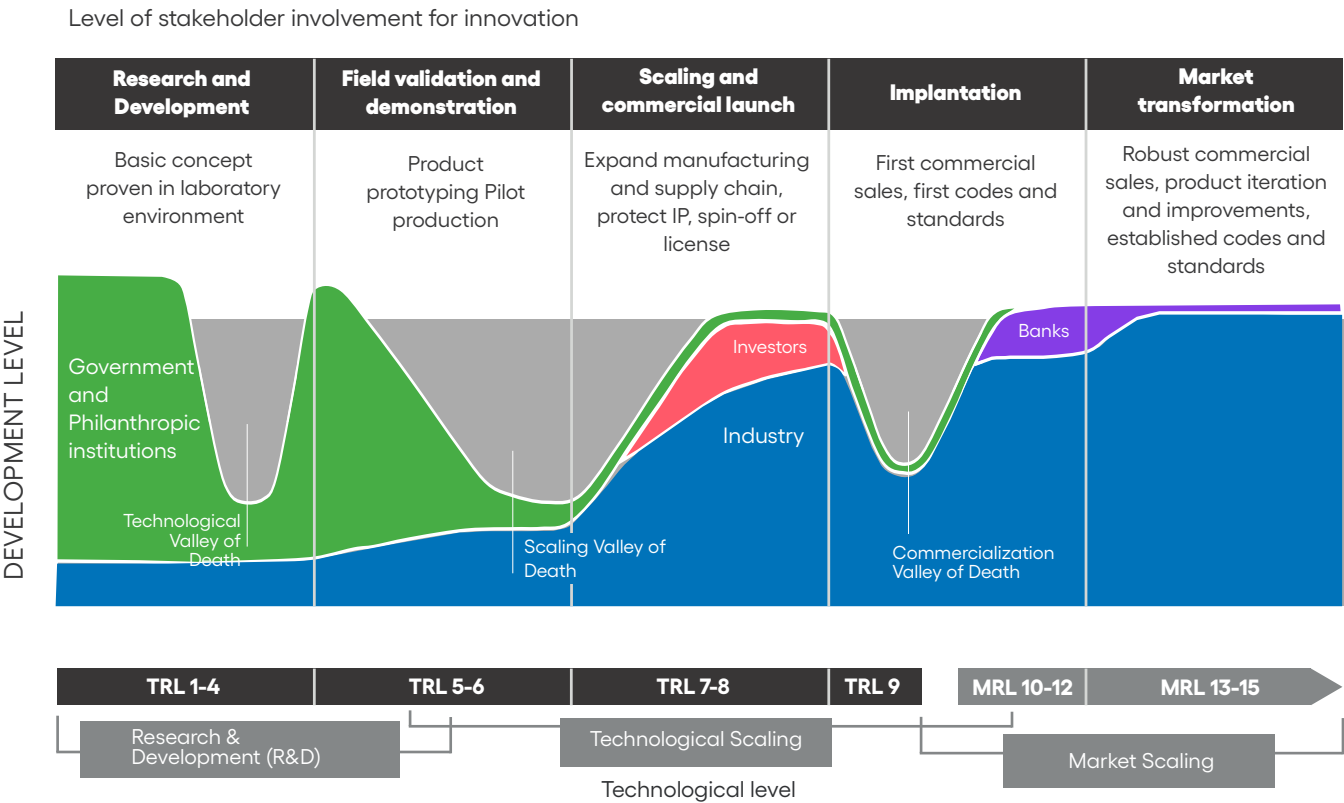
The reduction in DNA sequencing costs, for example, has accelerated bioprospecting and the identification of new bioactive compounds, but this knowledge only becomes a real impact when there is an ecosystem that enables its industrial application. The significant increase in the number of patents registered at the interface between biology and artificial intelligence indicates that a large volume of knowledge is being generated⁴⁵. This reinforces the need for investments in biomanufacturing platforms, specialized incubators, and financial instruments that transition scientific discoveries to commercial applications.

Brazil's success in the knowledge-based bioeconomy will therefore depend on the country's ability to integrate science, technology and the market.

41. SIMÕES, 2018.
42. BRAZIL. Ministry of Science, Technology and Innovation
43. Ibid.
44. Ibid.
45. WORLD ECONOMIC FORUM. Accelerating the Tech-Driven Bioeconomy: Innovation, Investment and Policy Pathways. Geneva: World Economic Forum

Strengthening ties between productive sectors and research centers will be crucial to transforming Brazil's vast biotech potential into an economic reality. By overcoming market, regulatory, and technological challenges, the country can consolidate its position as a global leader in offering sustainable solutions and generating wealth from biodiversity in a responsible, inclusive, and innovative way. The next chapter will address the main barriers that must be overcome to realize the potential of the knowledge-based bioeconomy in the country.

FIGURE 17.
The success of the knowledge-based bioeconomy in Brazil will depend on the country's ability to overcome the valleys of death of innovation.



TRL (Technology Readiness Level); MRL (Market Readiness Level)
* Stakeholders are understood as government and interested institutions, investors, industry and white parties, also referred to as stakeholders

SOURCE: ARUN, Advait. The Project Finance Valley of Death. Center for Public Enterprise, 2024.

2

Challenges to achieving the potential of the knowledge-based bioeconomy in Brazil



BRAZIL HAS THE ATTRIBUTES TO BECOME A BIOECONOMY HOTSPOT: IT CONCENTRATES THE GREATEST BIODIVERSITY IN THE WORLD, IS AMONG THE FIFTEEN LARGEST PRODUCERS OF SCIENCE, AND LEADS GLOBAL PRODUCTION CHAINS SUCH AS AGRICULTURE AND BIOENERGY. STILL, MUCH OF ITS BIODIVERSITY REMAINS UNKNOWN OR UNDERVALUED.

This chapter identifies three barriers to developing the knowledge-based bioeconomy in the country that must overcome. The first is the difficulty in generating strategic knowledge about biomes and translating it into applicable solutions. The second is a financing system that concentrates resources on established sectors and fails to support emerging value chains at critical times. And the third is the fragility of the innovation infrastructure, characterized by regulatory requirements that discourage new businesses.

These obstacles create a vicious cycle: without applicable knowledge, there is no competitive innovation; without innovation and stimulating regulation, there is no capital willing to invest; without capital, the ecosystem remains fragile and opportunities are lost. This chapter delves deeper into these barriers and provides the foundation for Chapter 3, which proposes concrete solutions to transform Brazil into a leader in a regenerative, inclusive, and high-value-added bioeconomy.

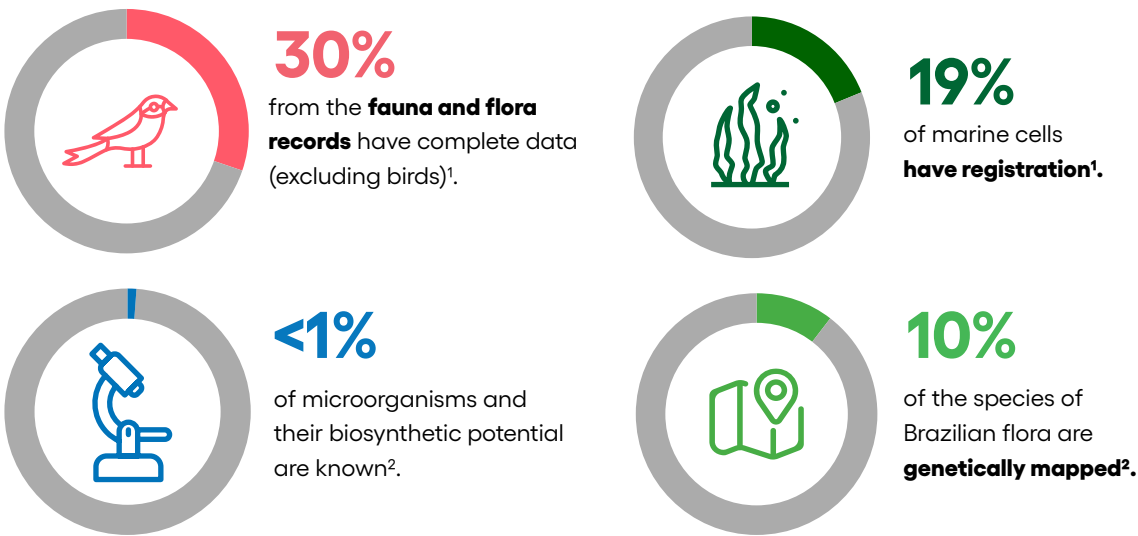
Despite these challenges, Brazil has the capacity to overcome them. The convergence between global demand for nature-based solutions, the maturation of biological technologies, and the strategic repositioning of its production chains opens a unique window for the country to structure a new model of sustainable and competitive development.

2.1 Brazil knows little about the scientific potential of its biomes

Despite its recognition as a megadiverse country, Brazil still has large gaps in knowledge about its own biodiversity. Just 30% of fauna and flora records have complete information⁴⁷ — with the exception of birds —, while only 19% of marine cells have some kind of formal record⁴⁸. When it comes to the potential for economic use, less than 1% of Brazilian microorganisms have their biosynthetic potential known⁴⁹, and 10% of flora species have been genetically mapped⁵⁰. These numbers highlight not only the underutilization of biodiversity as a strategic asset, but also the need for coordinated investments in biological inventory, scientific infrastructure and applied bioprospecting.

FIGURE 18.

Despite having the greatest biodiversity on the planet, Brazil knows little about its biomes



SOURCE: 1. Brazilian Institute of Geography and Statistics. (2023); 2. Interviews with experts.

⁴⁷. BRAZILIAN INSTITUTE OF GEOGRAPHY AND STATISTICS, 2023.

⁴⁸. Ibid.

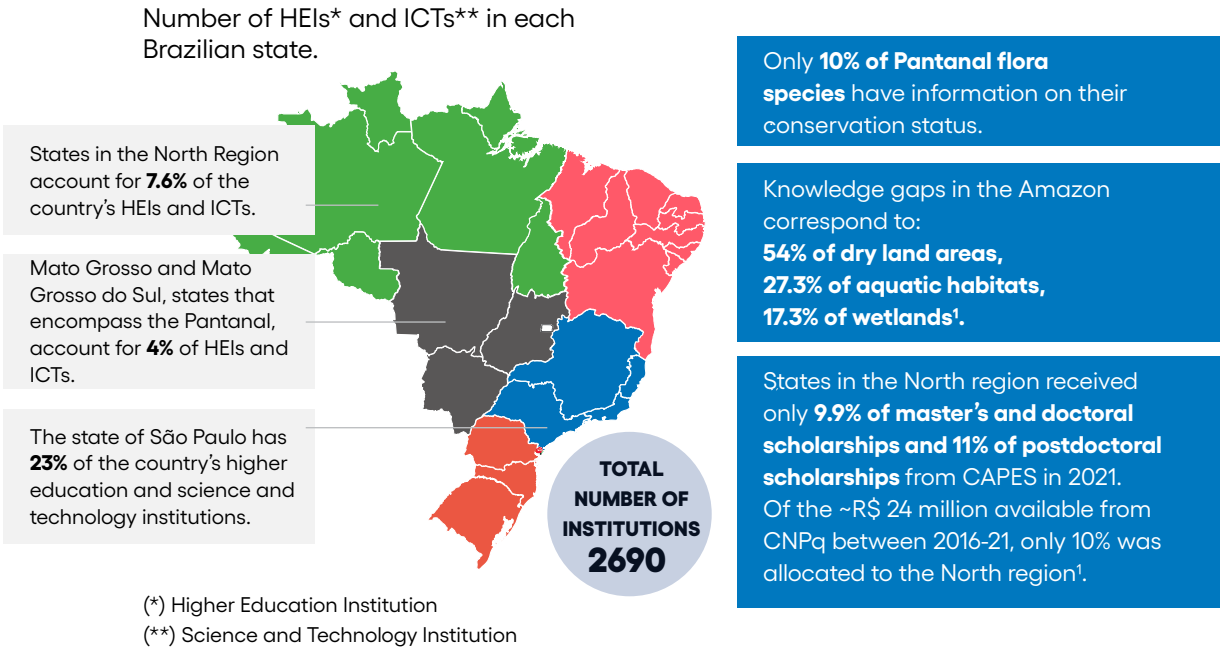
⁴⁹. Interviews with experts.

⁵⁰. Interviews with experts.

The challenge is exacerbated by the low density of research institutions and researchers in key biodiversity regions – such as the Amazon, the Cerrado, and coastal biomes –, along with logistical difficulties and the scarcity of co-development frameworks with local communities.

FIGURE 19.

Knowledge gap is greater in regions with less research infrastructure



Source: 1. Embrapa (2023). Dry land areas in the Brazilian Amazon are poorly studied. 2. Emerge 3. Ministry of the Environment and Climate Change (2024). Biodiversity and Biomes.

The lack of a coordinated national bioprospecting strategy fragments efforts and limits the strategic use of biodiversity. Globally, initiatives offer lessons in this regard. One example is the Indian model of integrated biobanks, which connects research centers, universities, and traditional communities on digital platforms with unified protocols. This network, coordinated by the Department of Biotechnology (DBT) and the Indian Council of Medical Research (ICMR), has integrated more than twenty-five (25) biobanks and cataloged over 500,000 genetic samples⁵¹. As a result, the number of interinstitutional scientific collaborations doubled between 2015 and 2022⁵². Malaysia also moved forward with a *framework* national level in accordance with the Nagoya Protocol, enabling sixty-four (64) formal agreements with local communities by 2022.

⁵¹. DEPARTMENT OF BIOTECHNOLOGY, 2025.

⁵². DBT-ICMR BIOBANK GUIDELINES, 2021

2.2 Knowledge without innovation: the disconnect between science and market

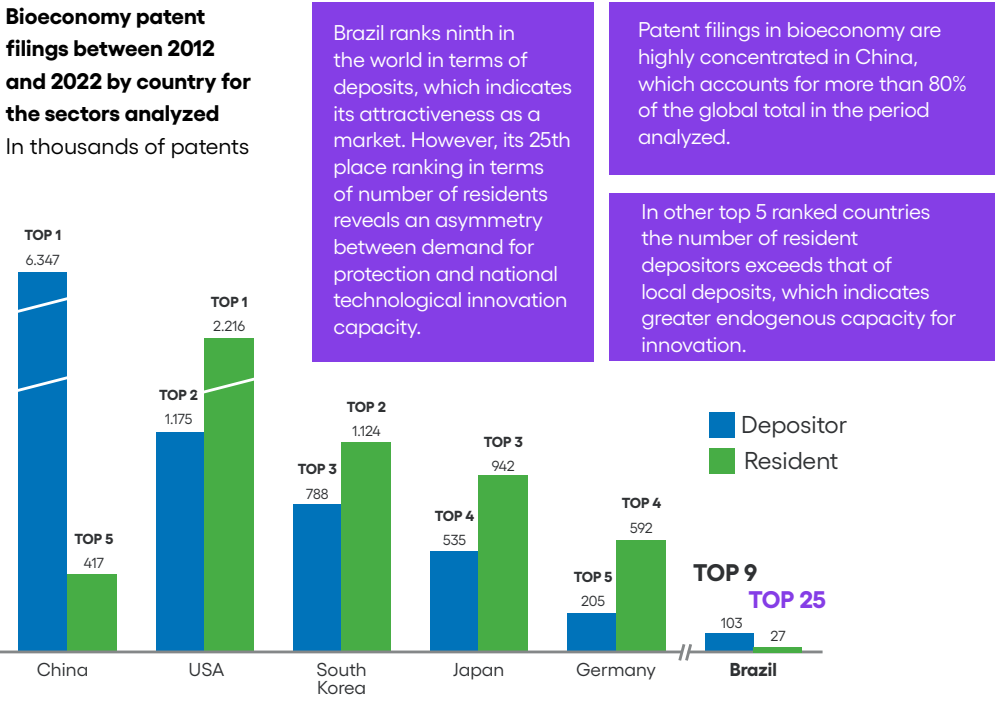
Brazil produces science, but has difficulty converting it into applied solutions and innovative products. The country is among the fifteen (15) largest producers of scientific articles in the world, but ranks 86th in the “Innovation Efficiency” category of the Global Innovation Index 2023. This category measures the ability to transform inputs (education, infrastructure and research) into market outputs⁵³.

The same difficulty is observed when analyzing patent production in the knowledge-based bioeconomy. Although Brazil ranks 9th globally in terms of patent filing volume—which highlights the attractiveness of the Brazilian market for knowledge-based bioeconomy solutions—this position contrasts with its capacity to generate innovation: in 2022, the country ranked 25th among countries with the highest number of resident applicants⁵⁴.

FIGURE 20.

Patent filings in bioeconomy between 2012-2022 by country

Bioeconomy patent filings between 2012 and 2022 by country for the sectors analyzed
In thousands of patents



53. WIPO 2023.
54. ESPACENET 2025.

Between 2012 and 2022, approximately 103,000 patents were filed in the knowledge-based bioeconomy in Brazil, but only 27,000 patents were registered by Brazilian residents in any jurisdiction⁵⁵.

This gap is even more significant when compared to global leaders whose resident volumes exceed those of local deposits, such as the United States (2.2 million resident patents versus 1.2 million deposited), South Korea (1.1 million residents versus 800,000 deposited), Japan (940,000 residents versus 500,000 deposited) and Germany (590,000 residents versus 200,000 deposited), suggesting greater endogenous innovation capacity.

Among the five countries with the highest number of patent filings, four also lead in the number of patents filed by residents, indicating the presence of strong domestic innovation ecosystems.

Such situations are capable of transforming knowledge into intellectual property, a necessary tool for secure knowledge sharing, when supported by public policies and regulatory environments conducive to research and development (R&D)⁵⁶.

China presents an exception to the trend observed among the five largest global leaders: the country has more total patent filings than patents filed by residents. Over 80% of global patents related to the knowledge-based bioeconomy were registered in China, indicating a strong attraction for foreign investment and innovation and demonstrating its strategic leadership in the technological race for knowledge-based bioeconomy solutions. In addition to this attractiveness, the high volume of filings can be attributed to several reasons, including local regulatory requirements for industries to operate and establish partnerships in the country, and innovation incentives for international companies to operate in the country, transfer technologies, and register them locally. This practice is aligned with the government’s industrial and innovation policy, especially “Made in China 2025”.

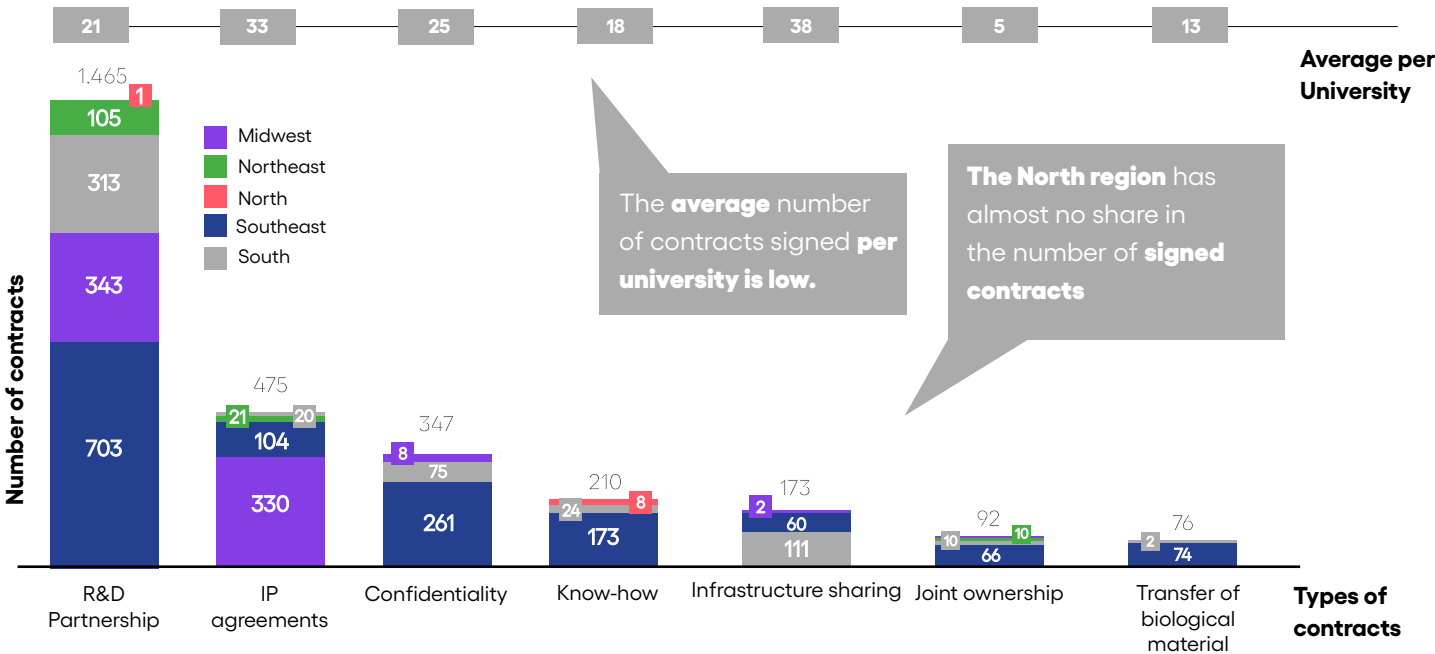
55. Ibid.
56. Ibid.

In the Brazilian agro-biotechnology sector, the disconnect between science and the market is evident: although the country is a world leader in the adoption of transgenic crops, it holds less than 1% of global patents in agricultural genetics⁵⁷. Most of the genetic technologies used in the country are licensed from foreign players, and there is a low number of formal agreements between universities and companies. On average, Brazilian public universities sign fewer than five contracts per year with the private sector, and these contracts are concentrated in the South and Southeast regions⁵⁸.

FIGURE 21.

Collaboration between the productive sector and academia in startup development is low

Contracts signed between universities and companies by type (2023)



SOURCE: Formict (2024)

Among the reasons for this low conversion are the lack of technical and legal support to protect and license technologies, lengthy institutional approval processes for partnerships, and academic incentives still focused almost exclusively on publications. Furthermore, a shortage of structures such as robust technology innovation centers (NITs) and few incubators or seed funds specialized in biotechnology were identified.

57. EMBRAPA, 2024.

58. FORMICT, 2024.

In this sense, South Korean “technology camp” models, such as the Daedeok Innopolis and Pangyo Techno Valley complexes, could serve as benchmarks for Brazil. These complexes integrate research centers, companies, and the government under shared governance, offer incentives for intellectual property, and strongly encourage the formation of *spin-offs*⁵⁹, being responsible for more than twelve thousand (12,000) patents in 2020 and attracting more than USD 2 billion in investments between 2018 and 2022⁶⁰.

Brazil itself has examples of effective public policies to leverage innovation and place the country in a prominent global role, such as the R&D&I clause introduced by the ANP 27 years ago. By 2022, the country had invested approximately R\$ 30 billion (approximately USD 5.4 billion) in the R&D&I clause, a fact that contributed to placing the country as a world leader in the renewable energy matrix⁶¹.

2.3 Immature market: lack of conditions for scaling

The knowledge-based bioeconomy operates outside the national market. There is a lack of technical standards and specific certifications for bioproducts, which hinders access to global supply chains and increases compliance costs⁶². Many Brazilian bioproducts face obstacles to health, environmental, and commercial registration, for example.

Furthermore, bioproducts compete with petroleum-based products. It is estimated that fossil fuel subsidies exceed USD 7 trillion annually worldwide⁶³, which puts bioproducts at a disadvantage.

Brazil, in turn, has an economy based on minimally processed *commodities*: raw sugar in nature represented 40% of all food exports in 2023, while cotton accounted for half of textile exports⁶⁴. In the domestic context, tax complexity, legal uncertainties, and regulatory instability in partnerships with local communities are additional challenges to the advancement of the knowledge-based bioeconomy.

59. Organizations or products created from existing businesses.

60. INNOPOLIS, 2025.

61. See https://www.gov.br/anp/pt-br/canais_atendimento/imprensa/noticias-comunicados/clausula-que-determina-investimentos-em-pd-i-completa-25-anos. Accessed on: July 18, 2025.

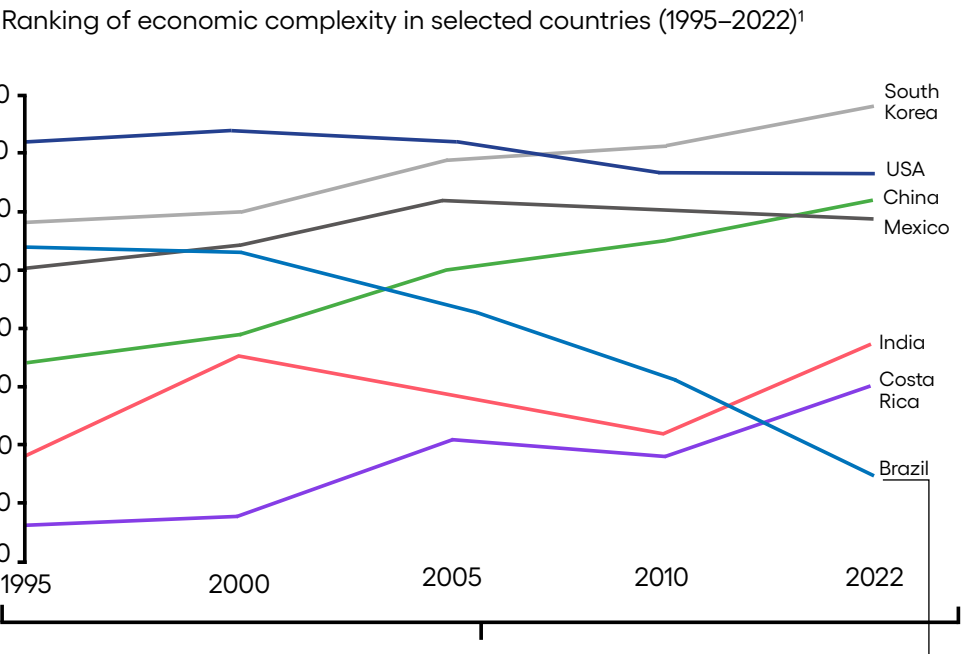
62. ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT (OECD), 2025.

63. PARIS, 2023.

64. DATAVIVA, 2025.

FIGURE 22.

Complexity in Brazil between 1995 and 2022



• **Basket of Brazilian exports in 2023²**

- Soybeans and corn accounted for 20% of Brazilian exports in 2023.
- In food products, raw sugar accounted for 40% of Brazilian exports.
- Raw cotton accounts for about 50% of Brazil's textile exports.
- Aluminum oxide accounted for 23% of chemical exports
- Sawn wood accounted for 22% of timber exports

Brazil fell from the 26th position in 1995 to the 65th position in 2022 in the global complexity ranking...

...and presented a relatively simple export basket in 2023

SOURCE: 1. ATLAS Economic Complexity; 2. DataViva. 3. excluding products of animal and vegetable origin

To achieve economies of scale, the Biotech Campus Delft in the Netherlands serves as a bioproduct validation platform, offering certification protocols, regulatory support, and export incentives. The campus has attracted more than 70 companies, facilitated 20 commercial launches, and mobilized 300 million in capital over five years⁶⁵. This model can inspire policy development and incentive mechanisms in Brazil.

2.4 Concentrated and volatile financing: lack of capital for new models

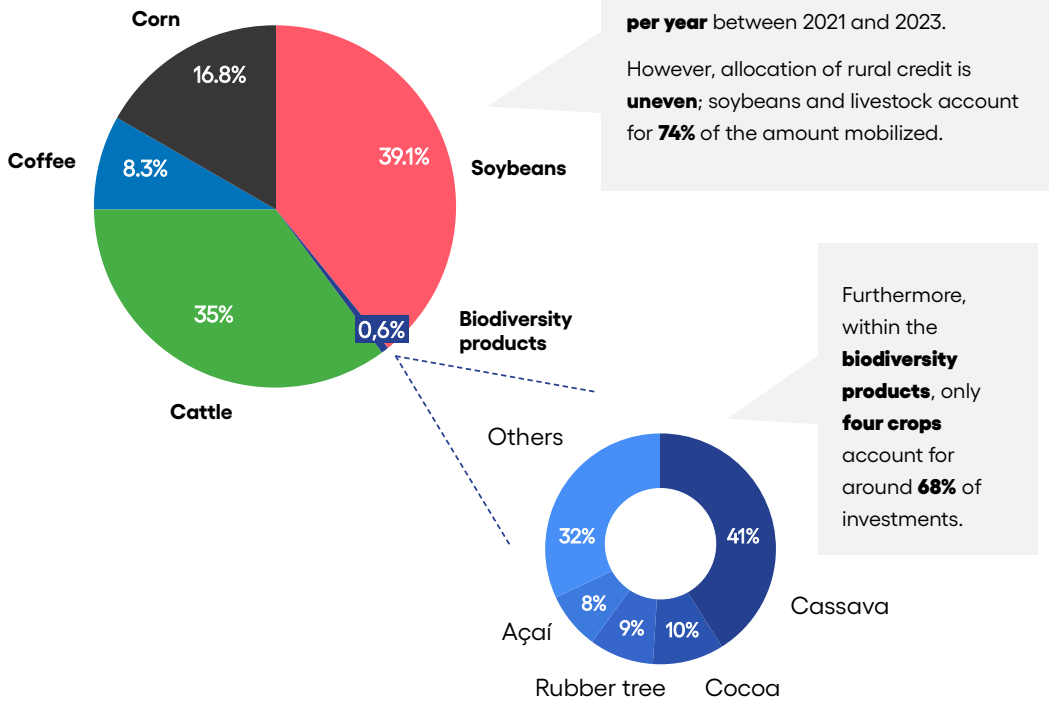
Recent data reinforces the pattern of investment concentration in mature bioeconomy sectors. Between 2021 and 2023, bioenergy and planted forests accounted for 74% of bioeconomy investments, both through public policies and market instruments⁶⁶. Thematic bonds, the main financing modality aimed at the bioeconomy, also allocated most of their resources to these two consolidated production chains.

The second main source of financing, rural credit, followed a similar pattern: 74% of the resources were directed to livestock and soybeans⁶⁷.

FIGURE 23.

In Brazil, soybeans, cattle, corn and coffee account for most investments via rural credit, while cassava, cocoa, rubber trees, and açai are the most significant biodiversity products

Amount in billions of reais, allocated via rural credit between 2021 and 2023



The **rural credit** channeled **R\$ 3.8 billion per year** between 2021 and 2023. However, allocation of rural credit is **uneven**; soybeans and livestock account for **74%** of the amount mobilized.

Furthermore, within the **biodiversity products**, only **four crops** account for around **68%** of investments.

SOURCE: CPI (2024). Financing for the Bioeconomy in Brazil: Sources and Allocation of Resources.

⁶⁵. Netherlands Foreign Investment Agency, 2022

⁶⁶. CHIAVARI, 2024.

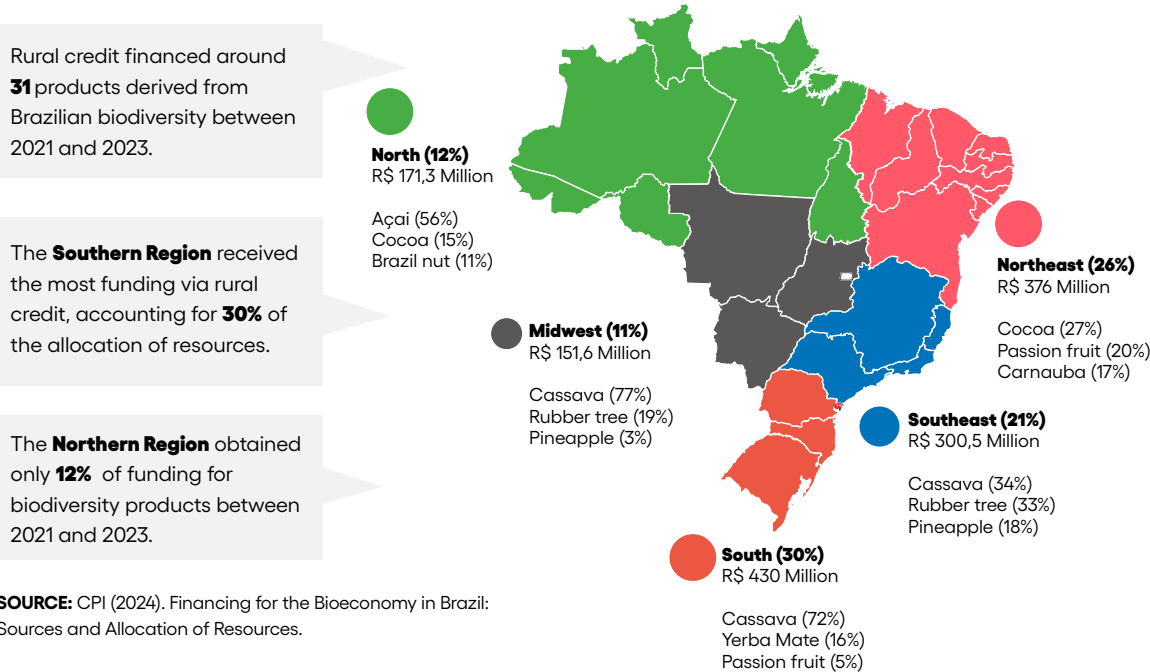
When analyzing the family farming segment, 90% of rural credit was concentrated in four value chains: cattle, coffee, corn and soybeans⁶⁸. This panorama reveals low diversification of financing and the absence of specific incentives for new sectors of the knowledge-based bioeconomy, such as bioinputs, functional foods, or sociobiodiversity assets.

The geography of credit is also uneven. The Southern region received 30% of the resources allocated to biodiversity products, while the Legal Amazon, with its vast biological potential, received only 12%⁶⁹.

FIGURE 24.

The northern region of Brazil received 12% of rural credit financing for biodiversity products

Allocation of rural credit resources for biodiversity products by region



The unpredictability of public funding for science in Brazil is another obstacle to consolidating the knowledge-based bioeconomy. After a cycle of strong growth between 2003 and 2015, resources allocated to the main funding agencies—Capes, CNPq, and FNDCT—saw a sharp

67. Ibid.

68. Ibid.

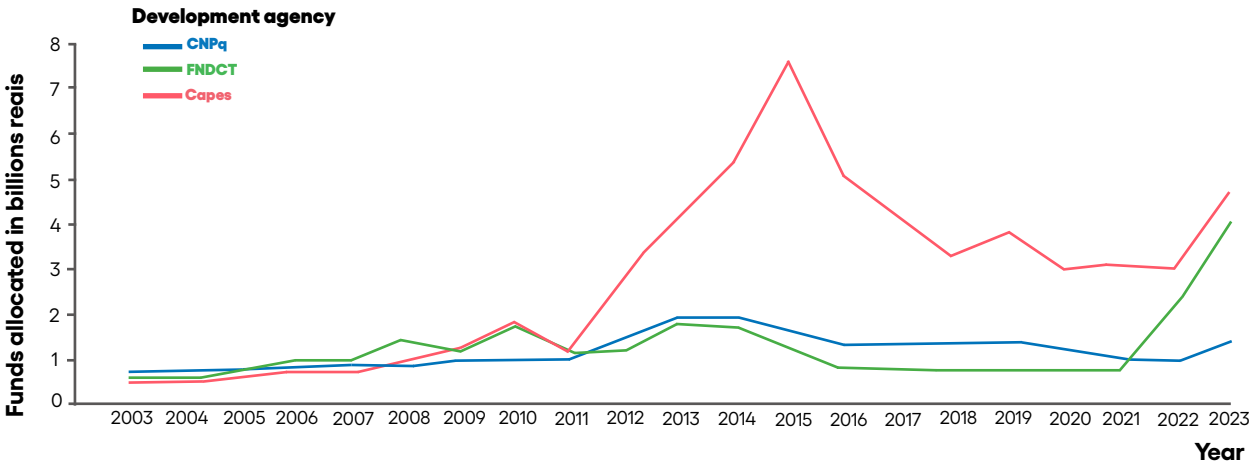
69. CLIMATE POLICY INITIATIVE 2024.

decline starting in 2015, especially in the case of Capes⁷⁰. Between 2015 and 2020, there was a significant decline in investment, followed by a period of stagnation until 2022. Despite a recovery in 2023, historical data reveal a cyclical and volatile pattern that hinders medium- and long-term planning for researchers, universities, and innovation-focused companies. This volatility compromises both the formation of intellectual capital and the continuity of applied research programs and negatively impacts the generation of biodiversity-based solutions.

FIGURE 25.

The history of resource allocation for research funding agencies

Allocation of resources to development agencies in billion reais (2010-2023)



Compared to other emerging and developed economies, Brazil’s performance in Research and Development (R&D) investment as a proportion of GDP has been weak over the past two decades. Between 2000 and 2020, R&D spending per GDP in Brazil grew only 9%, while countries like Vietnam⁷¹ and Colombia increased this investment by 121%⁷². China, in turn, increased its spending by about 170% and South Korea by 126% in the same period.

70. FEDERAL GOVERNMENT OF BRAZIL. Integrated Planning and Budgeting System (SIOP). Available at:<https://www1.siop.planejamento.gov.br/>

71. Consider the years 2002 and 2021 for calculations.

72. World Bank. (n.d.). Research and development expenditure (% of GDP). Available at:<https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS>

Even among OECD countries, highly developed in science and technology, the average growth was 31%⁷³. As a result, Brazil ranks 49th in the global ranking of R&D investment per GDP, positioned behind several developing economies that have used innovation as a vector for productive transformation⁷⁴. Biotechnology *startups* face a particularly adverse scenario.

Funding for the bioeconomy in Brazil is unbalanced throughout the technological development phases. While the initial stages—such as basic research and functional innovation—have greater public resources, grants and angel investors available, the critical phases of scaling and commercial validation face major challenges.

Capital becomes scarce precisely when startups need to prove industrial viability and scale up their production. This gap is exacerbated by the aversion of a significant portion of investors to projects with high technological risk and long maturation cycles, as is typically the case in the knowledge-based bioeconomy. In 2023, programs such as Finep, BNDES and Embrapii contributed around R\$ 14.6 billion (approximately USD 2.6 billion) in funding, with an emphasis on early stages. However, mechanisms to support Stages 3, 4, and 5 — validation, product development, and marketing — remain incipient, hindering the transition from science to the market⁷⁵. The volume of venture capital for this segment is seven times lower than the Latin American average. *Startups* agri-bio and biopharmaceuticals represent less than 3% of venture capital investments in the country⁷⁶.

⁷³. Ibid.

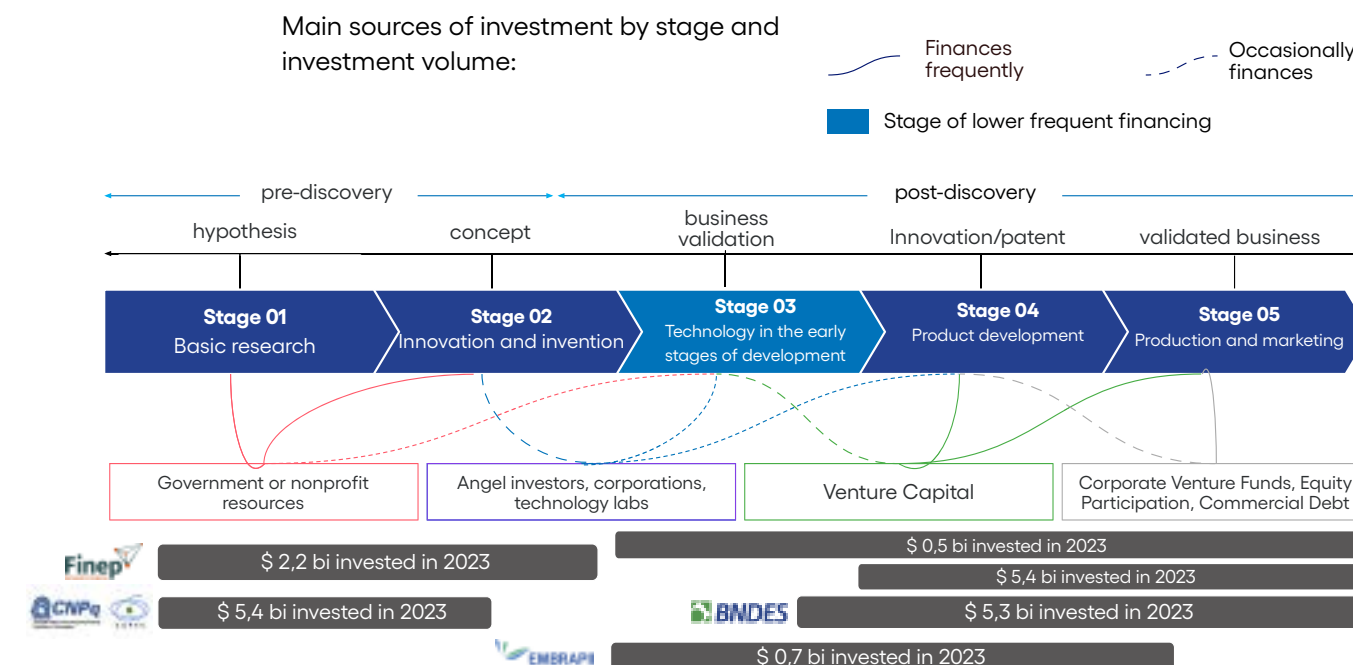
⁷⁴. Ibid.

⁷⁵. KHILJI, 2006.

⁷⁶. ABVCAP & KPMG, 2023.

FIGURE 26.

Capital volume by stage of the innovation chain



SOURCE: Khilji, Mroczkowski, Bernstein. From Invention to Innovation: Toward Developing an Integrated Innovation Model for Biotech Firms (2006); Transparency Portal.

(1) non-refundable investments for science and technology institutes;

(2) non-refundable investment for companies;

(3) refundable investment for companies.

2.5 Ecosystem in formation: insufficient infrastructure and support for entrepreneurship

Despite advances in the creation of technology parks in Brazil, the density of incubated companies is still low and regionally concentrated. The South of the country leads the way: Rio Grande do Sul is the state with the largest number of incubated companies (240), followed by Paraná (143) and Santa Catarina (94), even though the latter has a smaller population than the four most populous states in the country. Most states, especially in the North, have only one or no active incubators focused on the bioeconomy. This inequality compromises the territorial development capacity of the knowledge-based bioeconomy and highlights the lack of a robust national policy to foster innovation environments outside traditional hubs. Furthermore, most existing technology parks do not work with biotechnology or biodiversity assets, limiting their relevance to this emerging sector⁷⁷.

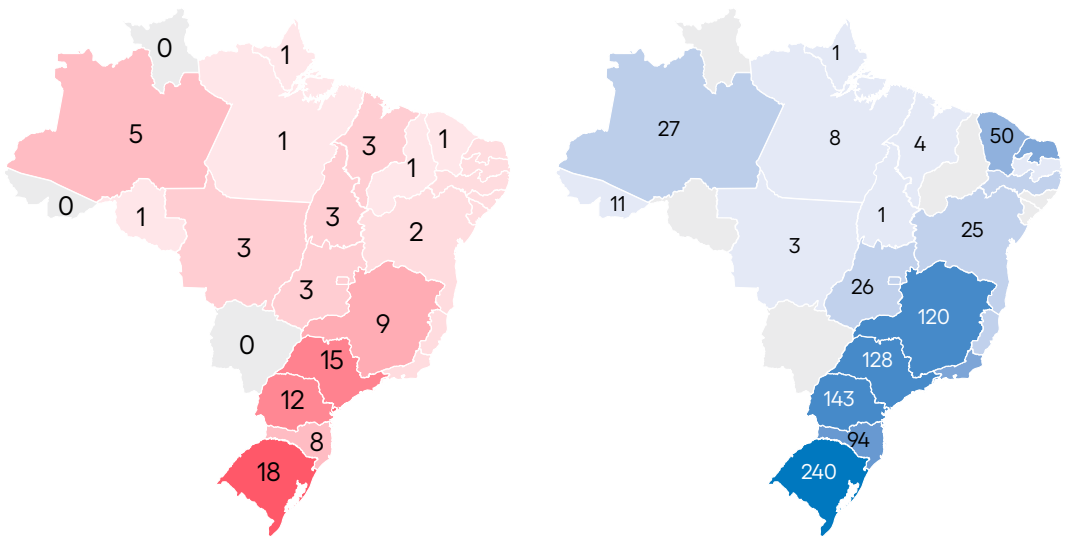
⁷⁷. INOVALINK 2025.

FIGURE 27.

Brazil has developed infrastructure for innovation, but the number of incubated companies is low

Technology parks in operation and under development per state in Brazil, 2025

Number of incubated companies per state, 2025



The innovation system in the Southern region is strong. The region has the highest number of technology parks and incubated companies, followed by the Southeast region.

Rio Grande do Sul is the state with the most incubated companies (240), followed by Paraná (143). Santa Catarina ranks 5th with 94 companies, even though it has a smaller population than the top four states.

SOURCE: InovaLink. (n.d.). InovaLink: The innovative entrepreneurship connection platform. Available at: <https://www.inovalink.org/> (Self-declared data).

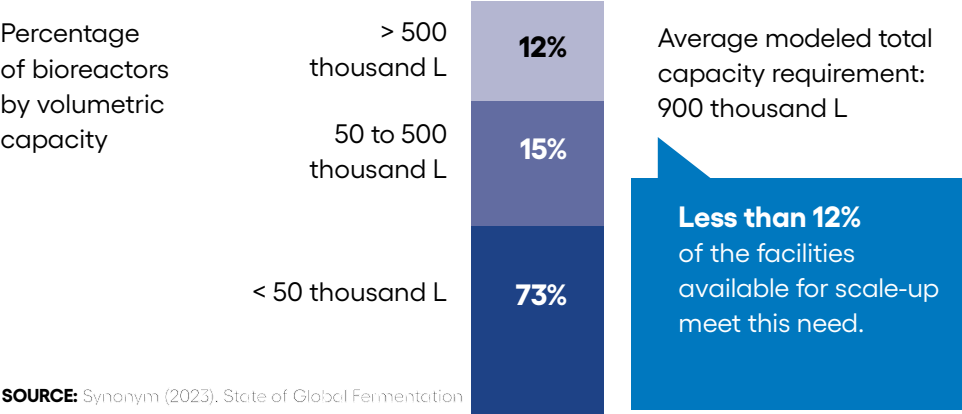
The absence of biofoundries – centers specialized in prototyping and testing biotechnology – is a concrete barrier to startups. Building a medium-scale biofactory can cost between USD 300 million and USD 400 million, which requires shared infrastructure⁷⁸. Centers of excellence such as the Amazon Biobusiness Center (CBA) and the National Institute for Amazon Research (INPA) operate with budgets under R\$ 50 million (approximately USD 8.9 million), an amount that compromises their ability to lead innovation programs⁷⁹.

⁷⁸. SYNBIOBETA.2025.
⁷⁹. BRAZIL. "Decree energizes CBA's operations and boosts biobusinesses in the Amazon".

Shenzhen, China, has created special innovation zones focused on the bioeconomy, such as the Shenzhen International Bio-Valley. Between 2017 and 2022, the city launched more than 500 biotechnology startups and attracted USD 1.8 billion in venture capital⁸⁰.

FIGURE 28.

Less than 12% of bioreactors available for scale-up meet the needs of the modeled projection



SOURCE: Synonym (2023). State of Global Fermentation

→ In total, if every company using Scaler sought an installation to meet its greatest modeled capacity need, it would require more than 10 times the capacity available today in Capacitor.

⁸⁰. Shenzhen Science and Technology Innovation Commission, 2023.





2.6 Complex rules and legal uncertainty: an environment that discourages innovation

Brazil's biodiversity legal framework, while advanced in principle, presents implementation bottlenecks. Applications for access to biodiversity and benefit sharing, and the SisGen system, the main tool for registering access to genetic resources and traditional knowledge, are unintuitive and require qualified professionals, placing a burden on companies and researchers: 48% of registrations fail to indicate results, 37% fail to specify the purpose of access, and 25% fail to record the biome of origin⁸¹. Furthermore, the lack of regulatory stability in the registration of associated traditional knowledge has increased legal and reputational uncertainty, discouraging investment in research and development of national biodiversity assets.

Furthermore, the lack of specific criteria for bioproducts and the current use of evaluation protocols focused on traditional chemistry pose additional regulatory challenges. The average time for approval of biotechnology products in Brazil is among the longest in Latin America. In the case of agricultural bioinputs, the process can take 18 to 24 months, compared to less than six months in markets like the United States⁸².

⁸¹. BRAZIL. Ministry of the Environment and Climate Change. National Management System of Genetic Heritage and Associated Traditional Knowledge – SisGen.

⁸². FAO, 2021.

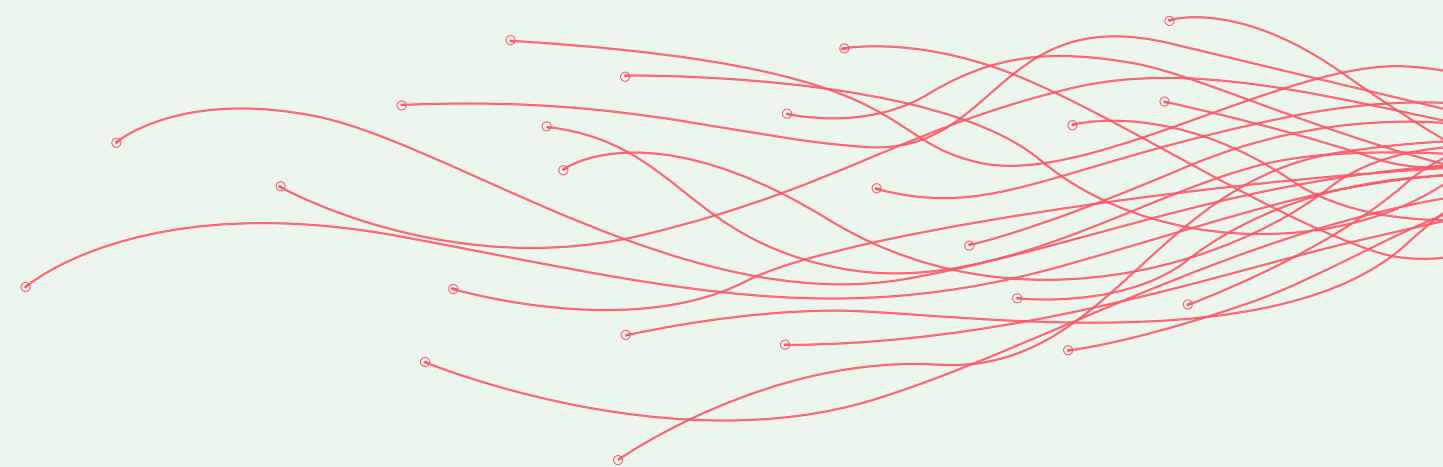
BIODIVERSITY AS A STRATEGIC ASSET: THE RELEVANCE OF INTELLECTUAL PROPERTY TO BOOST THE BRAZILIAN BIOECONOMY

Sergio Bernardo, with contributions from Karina Haidar Müller

Since the establishment of the Convention on Biological Diversity (CBD) in 1992, Brazil developed its legal system focused on biodiversity protection. The CBD, the signing of the Nagoya Protocol, and the enactment of the Biodiversity Law brought internal legal certainty to develop the sustainable economic use of genetic resources and traditional knowledge associated with Brazil's vast biodiversity. Currently, the bioeconomy is an additional factor in driving Brazil's economic growth, especially in regions where biomes and local communities holding traditional knowledge associated with genetic heritage are located.

A robust, effective, secure, and balanced intellectual property system is essential and strategic for Brazil to leverage the actions necessary for the growth of this sector. As a key player in this innovation environment, it is crucial that Brazil strengthen institutions like the National Institute of Industrial Property (INPI), to ensure they can meet demands with efficiency, quality, and speed.

It is also necessary to consider the need for revisions to the legal framework to strengthen the Brazilian innovation ecosystem in the area of biotechnology, including enhancing the capabilities of the INPI. This serves as another pillar to elevate Brazil's position in the international biotechnology innovation scenario and increase the country's attractiveness for investments in the bioeconomy.



3

The transformative potential of key sectors of the knowledge-based bioeconomy



THE KNOWLEDGE-BASED BIOECONOMY IS A CONCRETE OPPORTUNITY FOR BRAZIL TO LEVERAGE A NEW CYCLE OF GROWTH BASED ON THE APPRECIATION OF NATURE, TECHNOLOGICAL INNOVATION, AND THE PROMINENCE OF TRADITIONAL KNOWLEDGE. BY CONNECTING SCIENCE, BIODIVERSITY, AND SUSTAINABLE PRODUCTION CHAINS, THE COUNTRY HAS THE OPPORTUNITY TO BUILD A COMPETITIVE AND REGENERATIVE ECONOMIC MODEL, ALIGNED WITH 21ST-CENTURY DEMANDS IN TERMS OF CLIMATE, INCLUSION, AND FOOD, WATER, AND HEALTH SECURITY.

The knowledge-based bioeconomy in Brazil could generate between USD 100 billion and USD 140 billion in revenue by 2032⁸³. This value derives from the country's ability to lead this agenda by mobilizing science, technology, innovation, and traditional knowledge to transform its biodiversity into industrial assets.

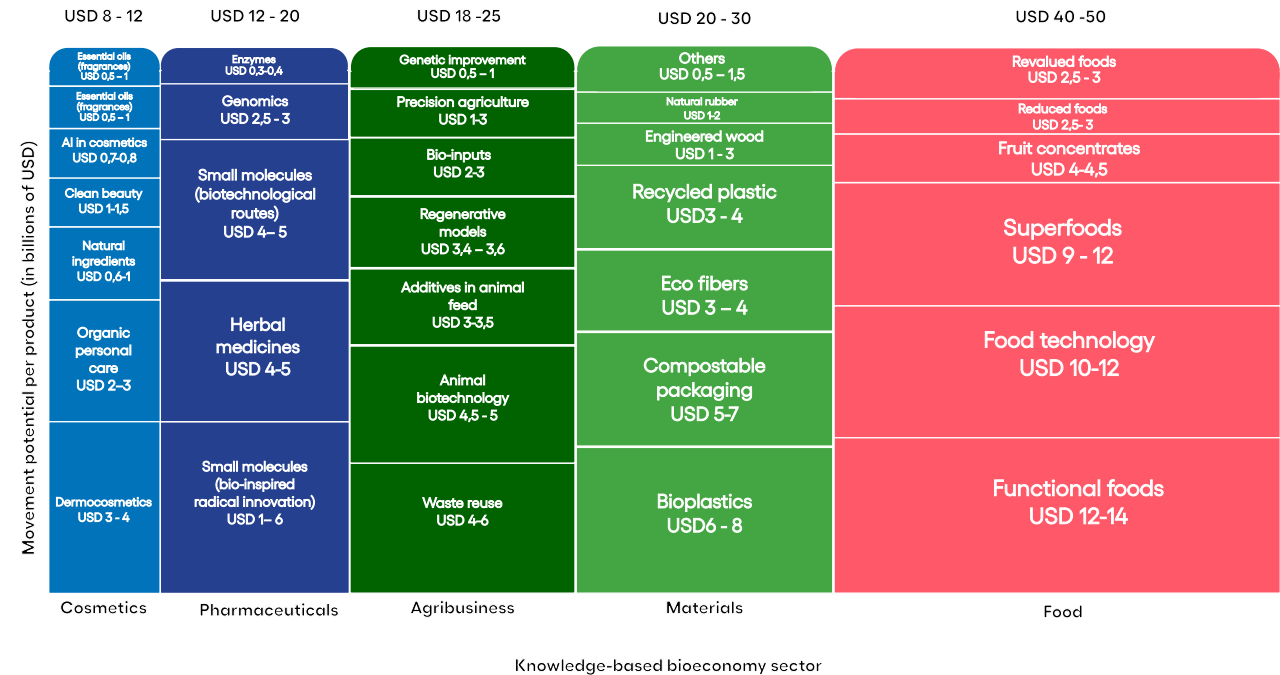
To arrive at the above estimate, five strategic sectors were analyzed: food, agribusiness, pharmaceuticals, materials and cosmetics⁸⁵. Each presents unique opportunities for generating value, strengthening international competitiveness, and promoting sustainable and inclusive production chains.

⁸³. Team analysis, detailed in appendix 1

⁸⁴. For the purposes of analyzing this study, we did not consider the energy and fuel sectors.

FIGURE 29.

The knowledge-based bioeconomy could generate ~USD 100-140 billion in revenue in Brazil by 2032



The volume of activities, notifications and material shipments recorded by companies in SisGen between 2017 and 2024 highlights the intensity of Brazilian biodiversity use by sector⁸⁵. The data underscore the relevance of the analyzed sectors—cosmetics, healthcare, agribusiness, food, and materials—as key drivers of the knowledge-based bioeconomy. The cosmetics sector significantly leads notifications, accounting for 87% of the total (20,104 records), in addition to representing 32% of activities and 29% of shipments of genetic material⁸⁶. In turn, the healthcare sector, although representing only 7% of activities, accounts for 46% of international remittances, which indicates high global interest in the pharmaceutical applications of Brazilian assets⁸⁷. Agribusiness accounts for 37% of activities and 9% of remittances, demonstrating strong dynamism and a strong degree of business mobilization around biodiversity. Food and materials, despite having a smaller relative share (8% and 6% of activities, respectively), also form part of the innovation base with potential for value appreciation⁸⁸.

85. BRAZIL. Ministry of the Environment and Climate Change. National System for the Management of Genetic Heritage and Associated Traditional Knowledge - SisGen.

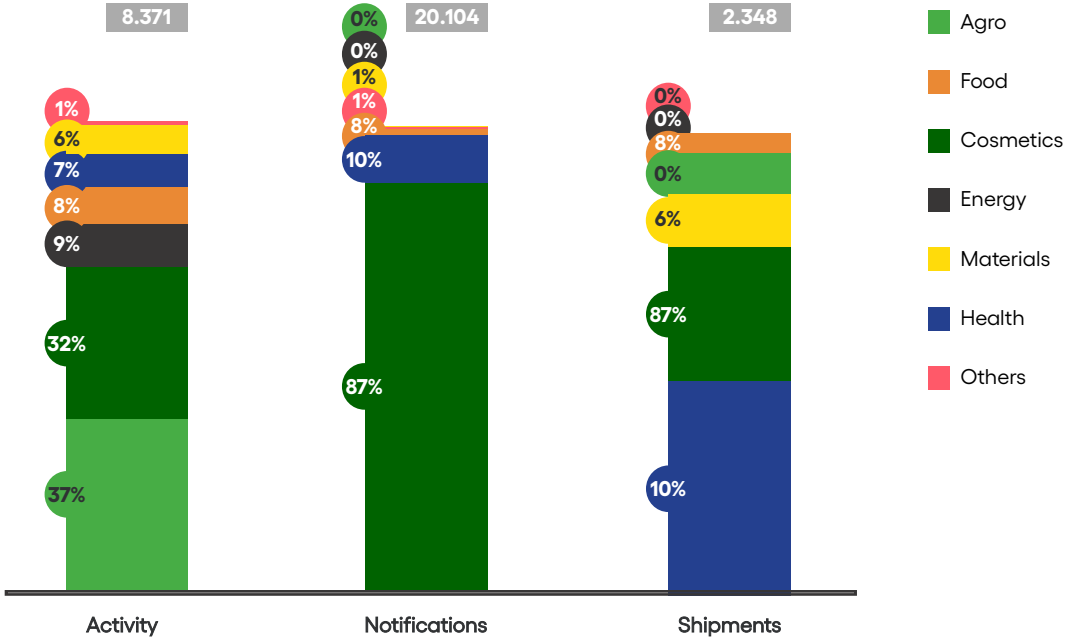
86. Ibid.

87. Ibid.

88. Ibid.

FIGURE 30.

Volume of activities, shipments, and notifications from companies registered in SisGen per sector (2017-2024)



Activities: access to genetic resources or associated traditional knowledge

Notifications: communication to the government of products developed from genetic heritage or traditional knowledge

Shipments: sending genetic material or associated traditional knowledge to another country to conduct research or technological development

SOURCE: BRAZIL. Ministry of the Environment and Climate Change. National Management System of Genetic Heritage and Associated Traditional Knowledge - SisGen. Available at: <https://sisgen.gov.br>. Accessed on: April 14, 2025.

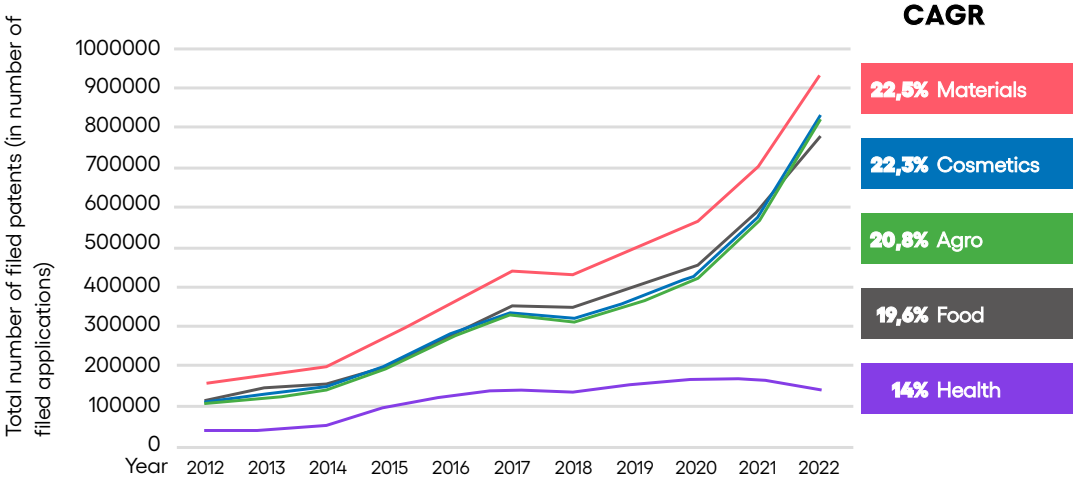
Furthermore, in the five analyzed sectors, the global volume of patents filed in the knowledge-based bioeconomy had a growth rate of 21% per year between 2012 and 2022⁸⁹. Among the sectors analyzed, agribusiness (22.5%) and cosmetics (22.3%) led the way in terms of growth, followed by food (20.8%), materials (19.6%), and healthcare (14%). This movement reflects technological advancement and the growing commercial attractiveness of knowledge-based bioeconomy solutions in global markets. The upward trend in deposits also indicates an increased industrial viability of sustainable alternatives in different production chains.

89. ESPACENET 2025.

However, the participation of Brazilian residents remains below 0.5% in all sectors analyzed (cosmetics, health, agribusiness, materials and food), even though the country holds 1% of global deposits⁹⁰. This mismatch highlights the gap between Brazil’s biological and socio-territorial potential and its capacity for transformation into innovation. This reinforces the need for an agenda that encourages applied research, strengthens the innovation ecosystem, and values the country’s socio-biodiversity assets.

FIGURE 31.
The volume of patents filed in bioeconomy is growing at a rate of more than 20% per year, which suggests a global surge in innovation

Global volume of filed patents on bioeconomy over 2012-2022 for sectors considered in this study



SOURCE: Espacenet.
NOTES: The data refers to patent applications filed by companies with formal ownership in Brazil. Applications filed by subsidiaries abroad are not included, which may underestimate the actual share of Brazilian companies.

90. ESPACENET 2025.

FIGURE 32.
Brazil accounts for approximately 1% of global deposits in the sectors analyzed and less than 0.5% when resident deposits are considered

Industry	China	United States	Brazil	Mexico
Cosmetics	2.999 (83%) / 207 (6%)	499 (14%) / 925 (25%)	48 (1%) / 10 (0,3%)	36 (1%) / 3 (0,1%)
Pharmaceuticals	915 (73%) / 124 (10%)	287 (23%) / 805 (65%)	40 (3%) / 5 (0,4%)	31 (2%) / 3 (0,2%)
Agribusiness	2.914 (82%) / 182 (5%)	454 (13%) / 771 (22%)	36 (1%) / 10 (0,3%)	23 (1%) / 2 (0,1%)
Materials	2.938 (79%) / 196 (5%)	707 (15%) / 1.213 (26%)	48 (1%) / 13 (0,3%)	38 (1%) / 4 (0,1%)
Food	3.609 (78%) / 235 (5%)	539 (14%) / 1.041 (28%)	42 (1%) / 11 (0,3%)	33 (1%) / 3 (0,1%)

SOURCE: Espacenet.
NOTES: The data refers to patent applications filed by companies with formal ownership in Brazil. Applications filed by subsidiaries abroad are not included, which may underestimate the actual share of Brazilian companies.

Below, the knowledge-based bioeconomy is analyzed across these five key sectors. For each sector, the study highlights its value-generating potential, current barriers to its consolidation, emerging technologies with greater applicability, and strategic pathways to realize this potential.



3.1 Food:

Brazil can be a protagonist in the revolution of healthy, functional and regenerative foods

The food sector leads in economic potential within the knowledge-based bioeconomy, with projected revenues of between USD 40 billion and USD 50 billion in 2032⁹¹. This is due to the combination of a consolidated and export-oriented food industry and biodiversity marked by a high number of endemic species with nutritional and functional value.

In 2024, the Brazilian food sector generated revenues of approximately USD 1.26 trillion, representing 10.8% of the national GDP⁹².

The country is the world’s 2nd largest exporter in terms of volume of processed foods and the 5th in terms of value, equivalent to USD 59 billion⁹³. The sector was responsible for 17.6% of Brazilian exports and around 84% of the trade balance surplus.

The global market for knowledge-based bioeconomy applied to the food chain generated around USD 1 trillion in 2024⁹⁴, which represents approximately 14% of the global food market, estimated at USD 7 trillion⁹⁵. This amount reflects the consolidation of a set of highly innovative and, rapidly expanding segments that combine food science, biotechnology, sustainability, and traceability across the entire value chain—from ingredients to final consumer products.

91. Team analysis, detailed in appendix 1.
92. ABIA – BRAZILIAN FOOD INDUSTRY ASSOCIATION. Annual Report 2023.
93. Ibid.
94. Considering the market size of the functional foods, reduced foods, superfoods, food technology, food traceability, fruit concentrate and revalued foods sectors, as detailed in the appendix.
95. RESEARCH AND MARKETS, 2025.

Global challenges and opportunities

The food sector is at the heart of a syndemic caused by obesity, malnutrition and climate change⁹⁶. The annual loss of 14% of the food produced in the world⁹⁷ (equivalent to USD 400 billion), the concentration of 66% of agricultural production in just 9 plants⁹⁸, insufficient consumption of micronutrients by 60% of the population⁹⁹ and the prediction that 50% of the global adult population will be overweight by 2050¹⁰⁰, put pressure on the sector for healthy and sustainable innovation.

FIGURE 33.
The knowledge-based bioeconomy can make food chains more sustainable and resilient



96. SWINBURN, 2025.
97. FAO – Food and Agriculture Organization of the United Nations, 2025.
98. Ibid.
99. The Lancet Global Health, 2025.
100. FUTURE MARKET INSIGHTS, 2025.

The World Health Organization (WHO) establishes guidelines for the composition of a healthy diet: a well-balanced and diverse diet. Brazil responds with public policies such as the Food Guide for the Brazilian Population (2014), the National Food and Nutrition Policy (PNAN), and the National School Feeding Program (PNAE), which are considered global benchmarks. Furthermore, food production regulation is subject to robust registration, inspection, and oversight by MAPA (the Brazilian Ministry of Agriculture, Livestock and Food Supply), as well as the ANVISA (Brazilian Health Regulatory Agency), which recently approved front-of-pack nutritional labeling (effective in 2022).

This has encouraged the Brazilian production market to discuss nutrition and health, making Brazil a global leader in food production and exports.



Additionally, initiatives such as the Voluntary Cooperation Agreements between the Production Sector and the Ministry of Health, led by ABIA (Brazilian Food Industry Association), aim to implement actions aimed at promoting healthy lifestyles. This includes a healthy, balanced, and nutritionally adequate diet, and has resulted in a reduction of 30,400 tons of sodium, 133,000 tons of sugar, and 310,000 tons of trans fat in foods between 2007 and 2023¹⁰¹. Furthermore, the Food Traceability and Monitoring Program (RAMA), led by the Brazilian Association of Supermarkets (ABRAS), monitors food residues for agricultural defensives in fruits, vegetables and legumes and contributes to a healthier diet and greater transparency.

101. ABIA. There's Food, There's Value, 2025.

The knowledge-based bioeconomy adds value along the food chain

The application of science and technology brings solutions such as precision fermentation, biopreservation, green extraction, and the revaluation of agri-food waste, which allow for the creation of foods with fewer additives and greater nutritional density. Patents in this sector have grown at an average annual rate of 20.8% globally over the last 10 years. Despite this, Brazil's share still represents only 1.12% of the total patents filed worldwide related to the sector. Furthermore, the sector also has low representation in SisGen¹⁰².

FIGURE 34. The knowledge-based bioeconomy offers concrete solutions to increase competitiveness in the food sector [NON-EXHAUSTIVE]

Industry challenges	Example of knowledge-based bioeconomy solutions
Diversification of chains	Proteins: use of whey by-product for the production of functional proteins
Development of new chains	Prebiotic fibers: extraction of ingredients from fruit peel to aid intestinal microbiota and reduce sugar
Waste reduction	Natural dyes: application of technology for extracting color from genipap for the development of natural blue dye
Alternatives to ingredients	Reduced glycemic impact: Extraction of sugar with a lower glycemic impact from the yacon plant to replace refined sugar.
	Calorie reduction: application of enzymes to reduce fat content in dairy products
	Reduction for special diets: use of bacteria for partial breakdown of gluten in the fermentation process of bakery products
	Natural preservatives: application of technology to generate natural preservatives from rosemary extracts to replace nitrites and nitrates

SOURCE: ¹GRAND VIEW RESEARCH. Lignin Market Size To Reach \$1.47 Billion By 2030 | CAGR: 4.5%. e STRAITS RESEARCH. Lignin Products Market Size, Share & Analysis 2033 ; ²ALLIED MARKET RESEARCH. Engineered Wood Market Size, Share, Competitive Landscape and Trend Analysis Report, by Type, by Application, by End User Industry e MARKET RESEARCH FUTURE. Engineered Wood Market Research Report – Forecast to 2032; ³FORTUNE BUSINESS INSIGHTS. Bioplastics Market Size e GRAND VIEW RESEARCH. Bioplastics Market Size, Share & Trends Analysis Report By Product ; 4 FONTE ; 5 FORTUNE BUSINESS INSIGHTS. Eco Fiber Market Size, Share & Industry Analysis, By Type e ALLIED MARKET RESEARCH. Eco Fibers Market Expected to Reach \$108.6 Billion by 2032. ; 6 VERIFIED MARKET REPORTS. Global Cellulose Film Market Size By Type, By Application, By End-User Industry, By Thickness, By Material Composition, By Geographic Scope And Forecast

102. BRAZIL. Ministry of Environment and Climate Change, 2024.

The knowledge-based bioeconomy adds value at different stages of the production chain: in the extraction and purification of ingredients, in the creation of cell cultures and microbial and fungal fermentation, in the formulation and texturization of foods, in packaging, distribution, reuse, and revaluation of food waste.

This integrated approach results in market opportunities with significant values, such as functional foods (USD 306 billion¹⁰³), superfoods (USD 188 bi¹⁰⁴) and fruit concentrates (USD 100 bi¹⁰⁵).



In addition, cross-cutting technologies such as foodtech (USD 180 billion¹⁰⁶) which includes diverse technologies, like tracking and tracing, reinforce the importance of innovation in quality control processes and systems¹⁰⁷.

Among the rising subsectors, the following stand out: food technology (USD 180 billion¹⁰⁸), — reflecting investments in automation and AI to optimize the food supply chain —, and the functional foods (USD 360 billion¹⁰⁹), that expand the market scope by responding to the demand for health, inclusion, and food personalization. The expected annual growth rate for both sectors is between 8¹¹⁰-10%¹¹¹ compared to the 5-6% growth rate of the food and beverage sector in general¹¹².

This scenario creates an opportunity to leverage Brazil’s competitive advantages, including a strong industrial base, abundant biodiversity and vast cultural heritage of food knowledge — to gain global prominence in this new frontier of bioinnovation. Investments in research and development, policies to promote the industrialization of natural assets and modern regulatory frameworks will be fundamental for the country to capture a relevant share of this trillion-dollar market.

104. FORTUNE BUSINESS INSIGHTS. *Superfoods Market Size, Share & COVID-19 Impact Analysis, By Type (Fruits, Vegetables, Grains & Seeds, Herbs & Roots, and Others), By Distribution Channel, and Regional Forecast, 2023 - 2030.*
105. MORDOR INTELLIGENCE. *Superfoods Market – Growth, Trends, and Forecasts (2024–2029).*
106. GRAND VIEW RESEARCH. *Fruit Concentrate Market Size, Share & Trends Analysis Report.*
108. GRAND VIEW RESEARCH. *Food Technology Market Size, Share & Trends Analysis Report.*
107/109/111. GRAND VIEW RESEARCH. *Food Technology Market Size, Share & Trends Analysis Report.*
113. INDUSTRY ARC, 2025.

FIGURE 35.

The food sector reached USD 1 trillion (~14% of the global food market) in 2024



SOURCE: KBV Research; Cognitive Market, Research and Markets, Markets and Markets, Business Research Company, Fortune Business Insight, Mordor Intelligence, Grand View Research, Global Market Insights, Allied Market Research
*The delivery sector, responsible for 11% of the sector, is excluded from the market value.

Biodiversity as a strategic asset

Market projections for seven subsectors of the knowledge-based bioeconomy in the food sector point to significant expansion by 2032, reaching approximately USD 2 trillion globally¹¹³.

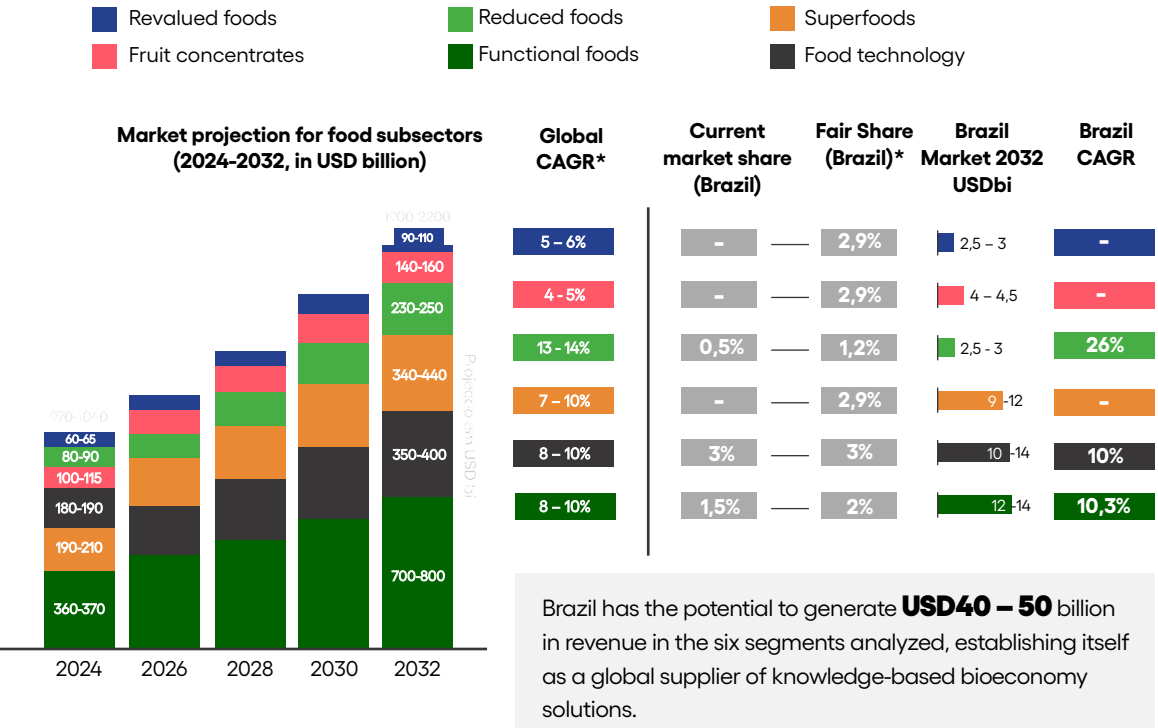
The graph shows the continued growth of categories such as superfoods, functional foods, reduced-fat foods, fruit concentrates, revalued foods and food technologies, all with annual growth rates (CAGR) between 4% and 14%¹¹⁴, driven by the demand for health, functionality and food sustainability.

Based on its current share and expansion capabilities, Brazil could capture around 2% of this global market and generate between USD 40 billion and USD 50 billion in annual revenues by 2032¹¹⁵.

Such performance would position the country as a global supplier of bioeconomy products in food, especially in categories such as functional foods (with a projection of USD 700-800 billion globally by 2032¹¹⁶) and food technology (USD 350-400 billion¹¹⁷).

FIGURE 36.

The six food subsectors are expected to reach USD 1.9-2.2 trillion by 2032, and Brazil could capture 2% of that value



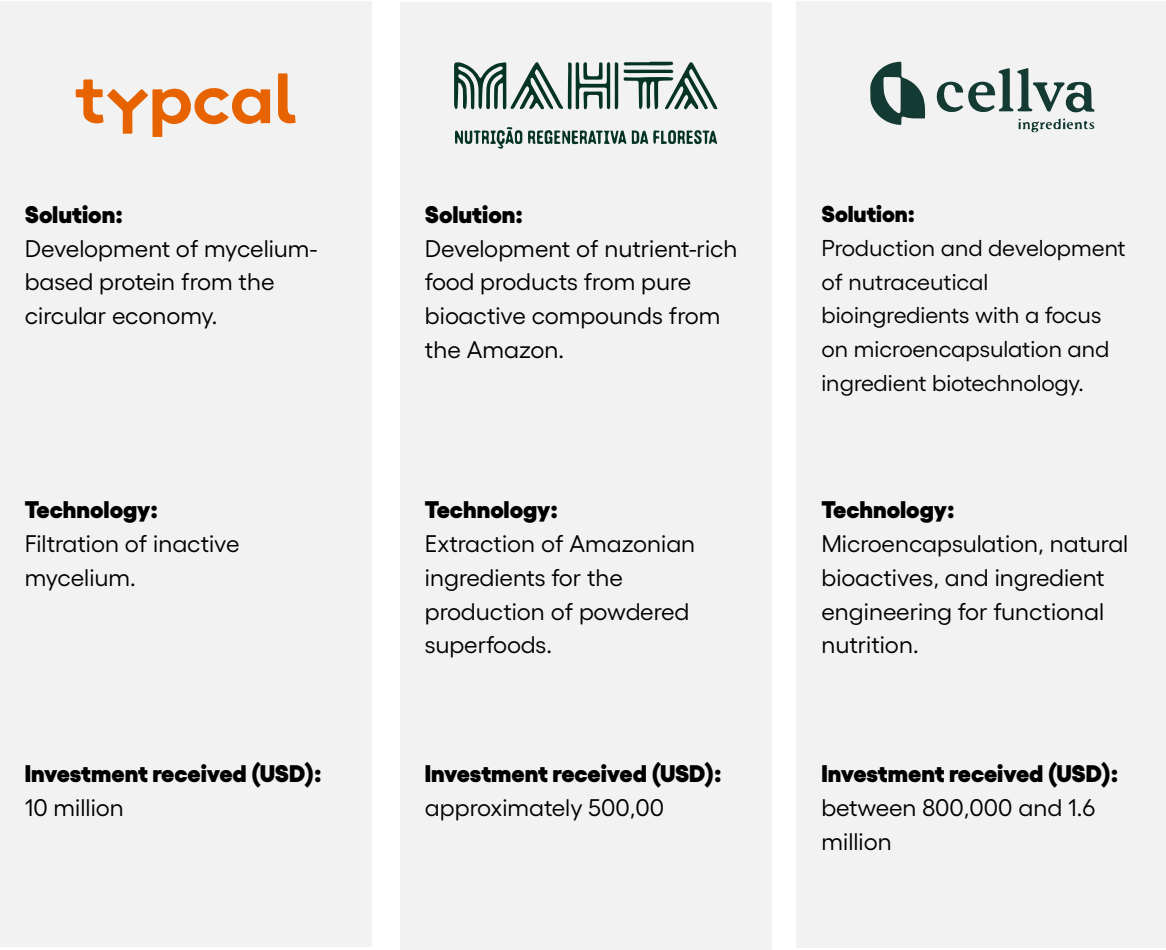
* CAGR = annual growth rate
SOURCE: Global market projection reports; Systemiq/Emerge analysis; expert interviews; expert validation

Innovation ecosystem and emerging companies

There are over eighty (80) Brazilian startups in the food sector¹¹⁸. Notably, Typcal, Mahta, and Celva, were able to mobilize investments ranging from USD 50 million to USD 2 billion. In Latin America, companies like NotCo, Puna.bio, and Bioceres demonstrate the sector’s potential, having raised between USD 25 million and USD 280 million in financing rounds. The country can also draw inspiration from policy examples such as the New Zealand Food Innovation Network¹¹⁹ and the policy of foodtechs of Israel¹²⁰, which structured hubs, labeling standards and incentives for sustainable public procurement to boost their food innovation markets.

FIGURE 37.

The leading startups in the food sector stand out in the study of innovative ingredients | PRELIMINARY |



118. EMERGE BRASIL. Deep Tech Brazil Report 2024. São Paulo: Emerge Brasil, 2024.
119. NEW ZEALAND GOVERNMENT 2025.
120. ISRAEL EXPORT INSTITUTE., 2025.

CIRCULARITY AS A VECTOR OF SOLUTIONS FOR THE FOOD INDUSTRY

Gustavo Alves and Luisa Santiago

The knowledge-based bioeconomy and circularity combined can become a powerful vector of solutions for the challenges of the food sector, such as reducing waste, replacing ingredients and achieving new chains and food health. A circular food economy is based on three principles: (1) eliminating food loss and waste; (2) circulating by-products and waste; and (3) regenerating nature using sustainable agricultural practices. The convergence of these principles with the application of scientific, technological and traditional knowledge to the bioeconomy opens the way for the creation of healthier, more functional and diverse food ingredients and products, designed from its conception to avoid losses and waste, make maximum use of ingredients and their by-products and ensure that each link in the chain contributes to the health of ecosystems.

In 2023, an initiative launched by the Ellen MacArthur Foundation to redesign processed foods based on the circular economy resulted in the creation of thirty-two (32) products from sixteen (16) companies, distributed across four (4) Latin American countries, including Brazil. On average, these thirty-two (32) new food products performed 20% better on indicators such as greenhouse gas emissions, biodiversity loss, and land use change, when compared to the food industry average.

In the challenge, Amazonian startups combined circular design economy with knowledge-based bioeconomy to create more sustainable products that also drive local and diversified value chains. Horta da Terra has designed a portfolio of functional products based on the power of Amazonian biodiversity. There are four functional shots aimed at lack of focus, concentration and low energy. The startup brought diverse ingredients to the products, using sixteen (16) different species for the formulations. By using this wide variety of species grown in agroforestry systems, Horta da Terra contributes to building resilience in the Amazon ecosystem and becomes an alternative to value chains linked to deforestation.

Nutricandies has created the world's first zero-fat chocolate spread from cocoa honey — a byproduct of the chocolate chain — which prevents waste and greenhouse gas emissions. The byproduct used is cocoa honey, generated during the processing of the fruit for chocolate production. The startup uses cocoa from agroforestry systems with the Amazonian peoples. In addition to promoting resilience in the Amazon biome, Nutricandies prevents tons of food from being discarded and greenhouse gas emissions.

Cuica, a plant-based foodtech, launched a plant-based milk made from Brazil nuts, replacing soy with an ingredient which has a lower environmental impact and is sourced from socio-biodiverse chains in the Amazon. By choosing Brazil nuts instead of soy, commonly used as an ingredient in plant-based milks, Cuica delivers the same product with improved environmental performance. This is the result of circular food design that replaces ingredients by prioritizing low impact.



Combining knowledge-based bioeconomy and circularity allows us to leverage national biodiversity to create regenerative food products, while structuring resilient regional chains.

Despite their transformative potential, the bioeconomy and circularity agendas can still be strengthened by improving connections between them, both in public policies and in business strategies. Advancing the integration of the bioeconomy and circularity will require increased investment in R&D, creating incentives for circular design, supporting the transition to regenerative production, and developing policies to enhance the value of ingredients and their byproducts. With its rich biodiversity and established food industry, Brazil is well positioned to lead the global transformation toward a more resilient food industry aligned with planetary boundaries.



3.2 Materials:

Brazil as a strategic supplier of circular and low-carbon materials

The materials sector is another vector of sustainable industrial innovation for Brazil, and could generate between USD 20 and 30 billion per year in revenue by 2032¹²¹, through the development of bio-based alternatives to carbon-intensive inputs. The country is well positioned to develop circular, biodegradable, and low-environmental-impact materials based on its diversified and consolidated industrial base, technical expertise, a predominantly clean energy matrix, and abundant supply of agricultural and forestry waste.

Economic importance and challenges of the sector

In Brazil, the materials sector represented about 15.5% of the national GDP in 2024¹²², equivalent to USD 300 billion, in segments such as mining (4% – USD 0.08), civil construction (3.6% – USD 0.07 tri), paper industry (2.7% – USD\$ 0.06 million), automotive sector (2.5% – USD 0.05 million), textile (0.8% – USD 0.02 tri), and plastics (0.4% – USD 0.01 million).

Although strategic for Brazil, the materials sector faces challenges in reducing emissions and achieving circularity. Due to the fossil-based origin of many inputs and industrial processes, this sector is one of the largest emitters of greenhouse gases globally. Cement production, for example, was responsible for about 6% of all global emissions in 2022¹²³. The materials production chain is also waste-intensive: only 2% to 20% of the plastic waste generated in Brazil is recycled, and around 40% of the weight of processed minerals is discarded.

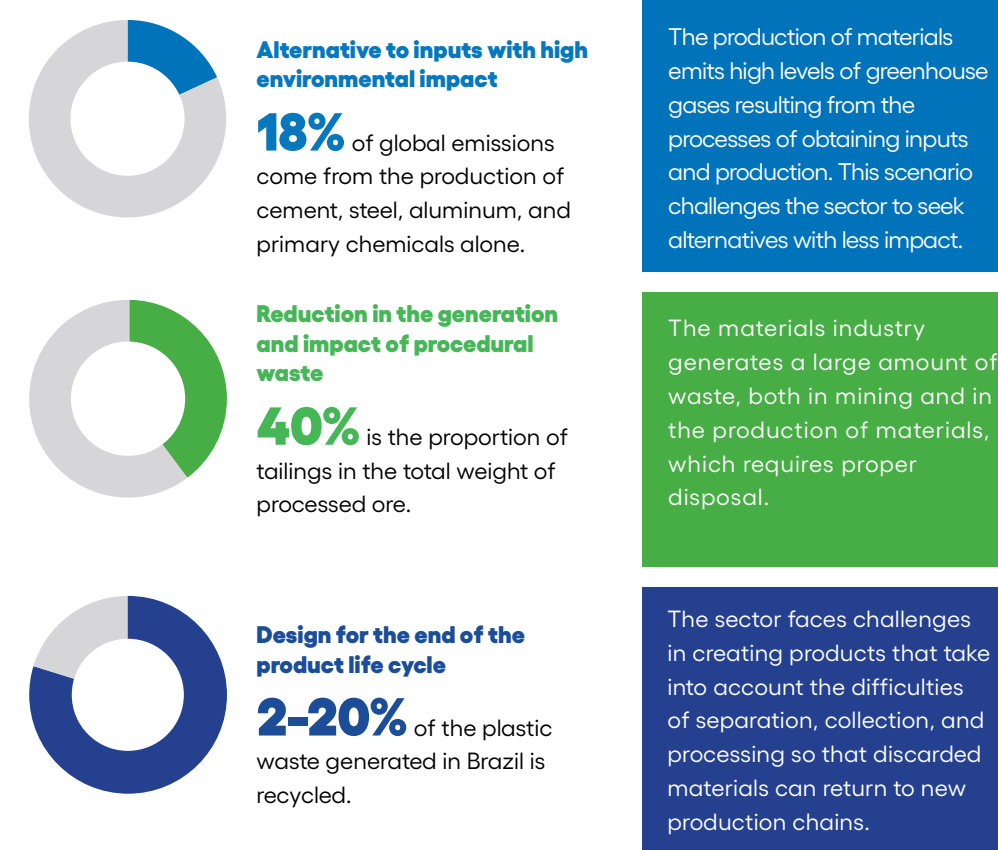
Another factor that makes the sector strategic is its transversality: challenges faced in the packaging materials chain directly impact sectors such as food, cosmetics, and healthcare, which have strin-

gent requirements related to product safety, durability, and efficacy. These regulatory requirements demand materials with high technical performance, often met by conventional plastics and other single-use materials.

While progress has been made, developing alternative materials also faces regulatory challenges. A recent example of progress was the authorization of the use of chemically processed post-consumer recycled (PCR) plastic in contact with food, granted by ANVISA in 2024. To boost the development of new materials from the knowledge-based bioeconomy, the country will need to improve their regulatory structures to make them more agile and aligned with the speed of innovation and the demands of ecological transformation.

FIGURE 38.

The materials sector faces a number of challenges that could affect its competitiveness and sustainability



SOURCE: ¹WORLD ECONOMIC FORUM. Decarbonizing hard-to-abate sectors is possible – here's how. 5 dez. 2024. ; ²FAPESP. What to do with the waste generated by mineral exploration; ³ABIPLAST. Monitoring of Mechanical Recycling Rates of Post-Consumer Plastics in Brazil 2024 e WWF.

¹²¹. A team analysis, detailed in Annex 1

¹²². Brazilian Chamber of the Construction Industry. Economic Indicators – 1st Quarter 2024.

¹²³. WORLD ECONOMIC FORUM. Decarbonizing hard-to-abate sectors is possible – here's how.

¹²⁵. ANVISA. Questions and Answers: Food Macro-theme.

Knowledge-based bioeconomy solutions

The knowledge-based bioeconomy offers solutions to reverse this scenario through the development of materials with greater circularity and lower environmental impact. Technologies allow replacement of petrochemical inputs¹²⁵ by renewable and biodegradable materials; valorization of agro-forestry waste¹²⁶, reducing the extraction of primary resources; production of new materials, such as biocomposites, vegetable fibers, foams and natural resins; circular design¹²⁸, which considers the end of useful life and the reinsertion of materials into production chains.

FIGURE 39.

Knowledge-based bioeconomy solutions for challenges in the materials sector

Industry challenges	Example of knowledge bioeconomy solutions	Global market value (USD billion, 2023)	CAGR (2024-32)
Alternatives to inputs with high environmental impact Reduction in the generation and impact of procedural waste Development of circular materials designed for end-of-life recycling	Lignin: Extraction of residual lignin from the pulp and paper industry for the manufacture of adhesives, resins, bioplastics, and foams in thermal and acoustic insulation.	1-2 ¹	4-5% ¹
	Engineered wood: alternative to concrete and steel due to its lightness, strength, and lower environmental impact.	260-320 ²	5-7% ²
	Bioplastics: creation of biodegradable plastics from organic inputs.	7-16 ³	20-30% ³
	Mycelium: creation of a natural glue for making materials from mycelium	3-3,5 ⁴	6-8% ⁴
	Bioplastic textiles: plastics derived from renewable biomass used in the textile sector	0,9-1 ⁵	8-9% ⁵
	Celluloid films: obtained from the extraction, dissolution, and restructuring of cellulose into ultra-thin sheets to replace conventional plastics.	1,3 ⁶	5-5% ⁶

¹GRAND VIEW RESEARCH. Lignin Market Size To Reach \$1.47 Billion By 2030 | CAGR: 4.5%. e STRAITS RESEARCH. Lignin Products Market Size, Share & Analysis 2033 ; ²ALLIED MARKET RESEARCH. Engineered Wood Market Size, Share, Competitive Landscape and Trend Analysis Report, by Type, by Application, by End User Industry e MARKET RESEARCH FUTURE. Engineered Wood Market Research Report – Forecast to 2032; ³FORTUNE BUSINESS INSIGHTS. Bioplastics Market Size e GRAND VIEW RESEARCH. Bioplastics Market Size, Share & Trends Analysis Report By Product ; ⁴ FONTE ; ⁵ FORTUNE BUSINESS INSIGHTS. Eco Fiber Market Size, Share & Industry Analysis, By Type e ALLIED MARKET RESEARCH. Eco Fibers Market Expected to Reach \$108.6 Billion by 2032. ; ⁶ VERIFIED MARKET REPORTS. Global Cellulose Film Market Size By Type, By Application, By End-User Industry, By Thickness, By Material Composition, By Geographic Scope And Forecast

¹²⁵. Interviews with industry experts, 2025.
¹²⁶. Tunes, S.; Vasconcelos, Y. What to do with the waste generated by mineral exploration.
¹²⁷. ABIPLAST – Brazilian Association of the Plastics Industry.Monitoring of Mechanical Recycling Rates of Post-Consumer Plastics in Brazil 2024 (Base Year 2023).

Over the past 10 years, the number of patents on materials linked to the knowledge-based bioeconomy has grown at a global average rate of 19.6%. Despite this, Brazil represents only 1.05% of the total patent applications related to the sector¹²⁸.

Market potential and strategic assets

Brazil has very favorable conditions for the development of new sustainable materials due to its vast biodiversity and abundance of residual biomass. However, although it is home to approximately 20% of the world's biological diversity of macroorganisms and is among the 17 countries that concentrate almost 70% of cataloged animal and plant species, Brazil's microbial diversity is largely unknown¹²⁹. Microorganisms such as fungi and bacteria with structural or adhesive properties may have promising applications in the materials sector, especially in segments such as construction, automotive, textiles, and packaging, but investment in research and development is needed to foster these discoveries.

Figure 40 presents a comprehensive overview of the knowledge-based bioeconomy segments applied to the materials sector, which move a global market estimated at between USD 480 billion and USD 630 billion in 2024, equivalent to 7 to 9% of the global materials market. This bioindustry is structured along the entire value chain—from the extraction of natural inputs or agroindustrial waste, through intermediate processing, to the manufacture of final products and end-of-life solutions for materials. Segments such as engineered wood (USD 270–320 billion¹³⁰) stand out. Compostable packaging (USD 80–100 billion¹³¹), bioplastics (USD 15–25 bi¹³²), ecofibers (USD 50-60 billion) and recycled plastic (USD 55-75 billion¹³³), lead in volume and industrial application. Furthermore, emerging solutions such as biolubricants, biosurfactants, and green polyol for biofoam production demonstrate the dynamism and technological diversification of this market. The appreciation of natural fibers (such as flax and hemp), mycelium, lignin, and natural rubber demonstrates

¹²⁸. ESPACENET. CPC Browser – Cooperative Patent Classification. European Patent Office, [s.d.]
¹²⁹. EMBRAPA. “Brazilian microbiome project revealing the unexplored microbial diversity challenges and prospects”
¹³⁰. ALLIED MARKET RESEARCH, 2024, MARKET RESEARCH FUTURE. 2024
¹³¹. TOWARDS PACKAGING, 2025, GRAND VIEW RESEARCH. Compostable Packaging Market Size, Share & Trends Analysis Report.
¹³². PRECEDENCE RESEARCH. 2024

the potential for replacing petrochemical inputs with bio-based and circular alternatives.

The growing demand for materials with lower environmental impact and greater traceability creates a strategic opportunity for Brazil to consolidate itself as a global supplier of bioindustrial solutions, combining its biodiversity and agro-industrial expertise to these new economies.

FIGURE 40.

Knowledge-based bioeconomy segments in the materials sector

Stages in the materials production chain

Inputs	Intermediaries	Finals	End of life
Extraction and collection of natural resources or waste from other chains (e.g., agriculture) necessary for production	Transformation of raw materials into materials through chemical, physical, or mechanical processes.	Production of components or final products from processed materials.	Management of products at the end of their useful life. Includes proper disposal or recycling for reintroduction into the production chain.

Sub-sectors of the knowledge bioeconomy and market values in 2024 (USD billion)

Eco fibers: flax, ramie, bamboo, and hemp (USD 50-60 billion) Natural rubber: Obtained from the latex sap of rubber trees (USD 20-30 billion) Green polyol: polyol obtained from renewable sources used as a precursor in the formulation of polyurethanes, other polymers, and foams	Bioplastics: biodegradable and non-biodegradable plastic produced from renewable sources (USD 15-25 billion) Biosurfactants: natural surfactants produced by microorganisms from renewable sources.	Engineered wood: products made from the bonding of wood veneers, particles, fibers, and strips with adhesives to form an artificial composite material (USD 270-320 billion) Compostable packaging: PLA, Cellulose, Bamboo, PHA, wood derivatives (USD 80-100 billion) Biolubricant: produced from vegetable oils and animal fats for the automotive and industrial sectors (USD 3-3.5 billion)**	Recycled plastic: plastic used in packaging, automotive, and electrical and electronic industry applications. (USD 55-75 billion)
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**Included in the "Others" sector in the market projection calculation

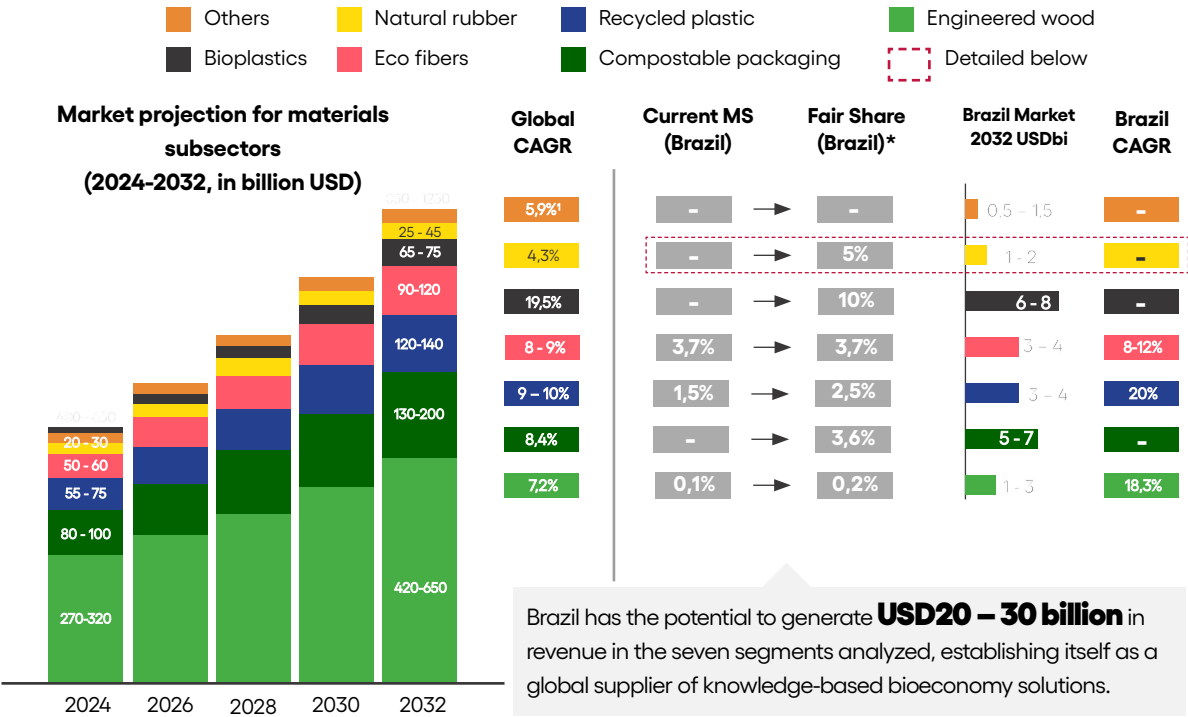
133. GRAND VIEW RESEARCH. Recycled Plastics Market Size, Share & Trends Analysis Report.

The global market projection for seven subsectors of the knowledge-based bioeconomy focused on the materials sector indicates values between USD 850 billion and USD 1.2 trillion by 2032¹³⁴. Despite its incipient share, Brazil could capture approximately 2.5% of this market, representing an estimated annual revenue of USD 20 billion to USD 30 billion.

The segments with the highest market value include recycled plastic, compostable packaging, and bioplastics, all with annual growth rates (CAGR) above 8%, indicating a dynamic and expanding market¹³⁵. Ecofibers and natural rubber present significant opportunities for Brazil. The country can establish itself as a global supplier of sustainable materials solutions by combining biodiversity, biomass, and industrial innovation. Realizing this potential, however, will require coordinated actions in research, infrastructure, regulatory frameworks, and incentives to scale technologies with lower environmental impact and greater added value.

FIGURE 41.

The global market for the seven materials subsectors is expected to reach USD 0.8-1.2 trillion by 2023, and Brazil could capture up to 2.5-3% of this value



SOURCE: Markets and Markets, Fortune Business Insight, Mordor Intelligence, Grand View Research, Allied Market Research ; Towards Packaging . Precedence Research ; Coherent Market Insights ; Foreign Agricultural Services US ; Zion Market Research ; Github Repository ; Market Research Future ; OICA ; *Systemiq/Emerge analysis; Interviews and validation with experts.
TECHNICAL NOTE: ¹ Average of CAGR in contemplated sectors

134. Team analysis calibrated with interviews with experts on global market projections detailed in Annex 1, and methodology detailed in the methodology chapter.

136. Ibid.

Innovation ecosystem and emerging companies

Over forty-six (46) Brazilian startups¹³⁶ operate in the sector of materials linked to the knowledge-based bioeconomy, demonstrating technical and commercial viability. Mush develops products with materials based on mycelium (fungi) waste from the agroindustry. MABE Bio produces biodegradable resins as an alternative to leather and plastic. BVS Green uses industrial waste to develop petrochemical-free packaging. The city produces pine wood structures for buildings as substitutes for concrete and metal beams and pillars.

FIGURE 42.

Leading startups in the materials sector focused on knowledge-based bioeconomy technologies | NON-EXHAUSTIVE |

			
Solution: Transformation of industrial waste into green polyol, aiming to replace petrochemical raw materials.	Solution: Development of products from agro-industrial waste to replace conventional materials with a larger environmental footprint	Solution: Development of plant-based materials as an alternative for industries that use leather and plastic.	Solution: Development of wooden components that perform structural support functions in buildings, replacing concrete or metal beams and pillars, reducing costs and waste.
Technology: Proprietary technology for green polyol development	Technology: Fungal biotechnology in the creation of versatile materials designed for the life cycle.	Technology: Plant biomass polysaccharides derived mainly from angico and residues.	Technology: Engineered wood obtained using Cross Laminated Timber (CLT), Glued Laminated Timber (Glulam), and S4S Urbem Class technology.
Investment received (US\$): ~ 300 and 500 thousand	Investment received (US\$): ~ 200 and 400 thousand	Investment received (US\$): ~ 200mil and 1 million	Investment received (US\$): ~ 18 and 20 million

Despite this, the sector has a low record of activities and notifications in SisGen, although it occupies 3rd place in international remittances (11% of the total by companies)¹³⁷. This indicates growing global interest, but also a concentration of capabilities in a few companies.

136. Emerge Brasil. Deep Tech Brazil Report, 2024.

137. Genetic heritage access records in SisGen – 2024.

Industrial capacity and national references

Brazil has demonstrated its ability to scale biomass-based industrial chains with ethanol. By combining technology, production scale, and efficient regulation, the country has become a global benchmark in biofuels—an example that can be adapted to the materials sector.

Applying this formula to new industry segments can position the country as a strategic supplier of low-carbon materials, aligned with global trends in sustainability, innovation, and the circular economy.



3.3 Agribusiness and animal health

Brazilian agribusiness as a global powerhouse of regenerative solutions

Agribusiness represents 22% of Brazilian GDP and, in 2024, was responsible for 48.9% of exports, which totaled USD 152 billion¹³⁸. Furthermore, it accounted for 84% of the trade balance surplus¹³⁹. Despite this, the model based on intensive use of land, chemical inputs and dependence on climate stability has shown the need for improvement in the sector.

The knowledge-based bioeconomy in Brazil can reposition the agribusiness and animal health sector in the global chain and capture between USD 18 billion and USD 25 billion in annual revenues by 2032¹⁴⁰.

In addition to its rich biodiversity, the country boasts centers of excellence such as Embrapa, a robust production sector, and abundant access to biomass. This creates favorable conditions for Brazil to seek alternatives to imported chemical inputs and to lead the export of biological and regenerative solutions.

138. CEPEA, 2025.

139. BRAZIL. Ministry of Agriculture and Livestock. Institutional portal.

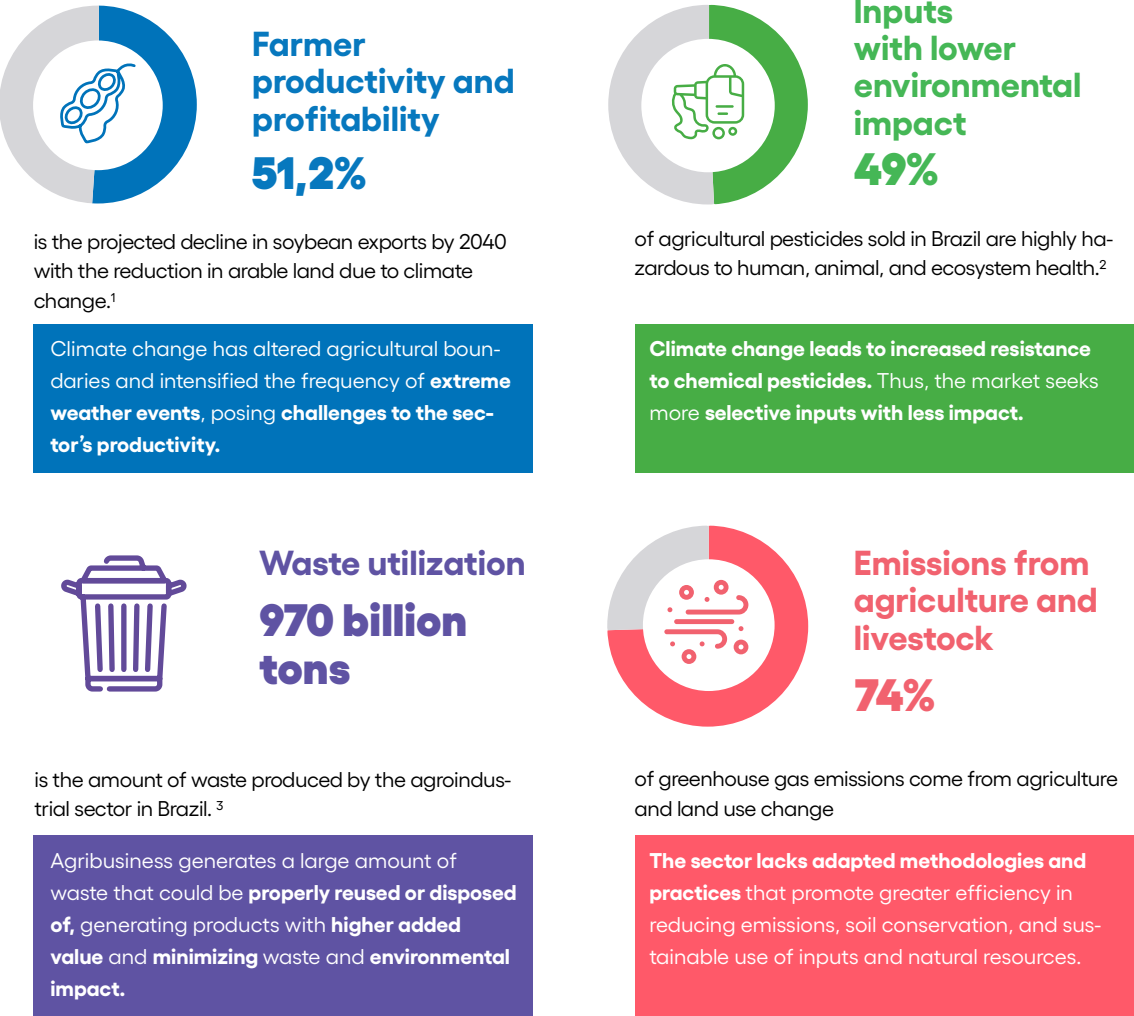
140. Team analysis, detailed in appendix 1.

Global challenges and opportunities

Emissions from agriculture and land use changes accounted for 74% of Brazil's gross emissions in 2024¹⁴¹. It is estimated that between 11% and 25% of native vegetation — equivalent to 60.3 million to 135 million hectares¹⁴² — are at risk of degradation. Global warming also threatens productivity, with soybean exports expected to drop by up to 51.2% by 2040 due to the loss of arable land¹⁴³. Among the agricultural defensives marketed in the country, 49% are classified as highly hazardous, increasing risks to human and environmental health¹⁴⁴.

FIGURE 43.

Brazilian agribusiness faces challenges that could impact its competitiveness and sustainability



¹ JOURNAL OF RURAL ECONOMICS AND SOCIOLOGY. Publications and articles on rural development and agribusiness.
² IDEC – Brazilian Institute for Consumer Protection. Pesticides Atlas. 2025.
³ ABIB – Brazilian Association of Biotechnology Industries. Institutional portal. 2025.
⁴ SEEG – Greenhouse Gas Emissions and Removals Estimation System. Emissions by sector and historical data. 2025.

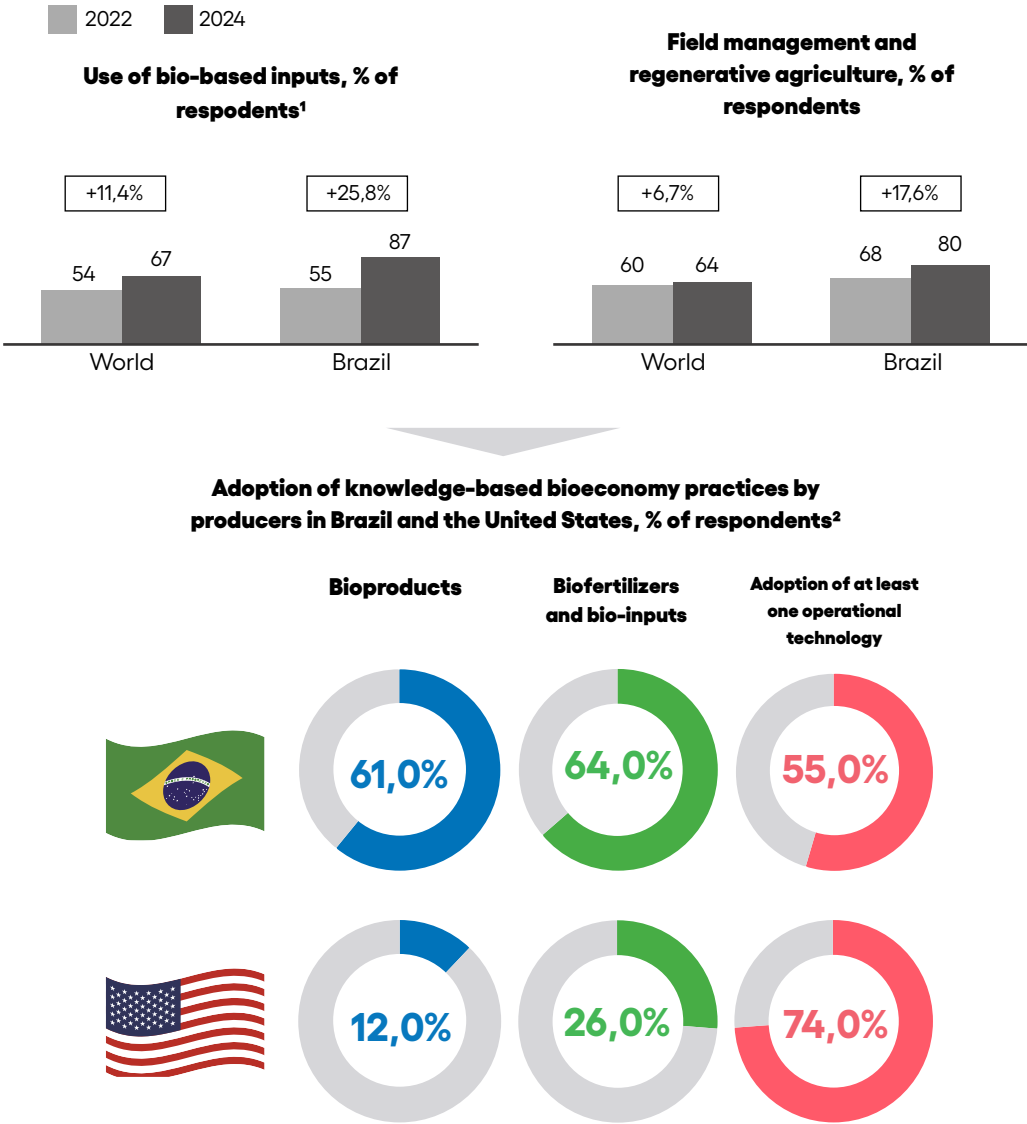
¹⁴¹. SEEG – Greenhouse Gas Emissions and Removals Estimation System. Emissions by sector and historical data
¹⁴². MAPBIOMAS. Up to 25% of Brazil's native vegetation may be degraded.
¹⁴³. JOURNAL OF RURAL ECONOMICS AND SOCIOLOGY.
¹⁴⁴. IDEC – Brazilian Institute for Consumer Protection. Pesticides Atlas.

Knowledge bioeconomy solutions for resilient and sustainable agribusiness

Brazil is a global leader in the adoption of biological solutions in agriculture: 87% of producers use at least one sustainable technology, and 68% adopted biological inputs in 2024, an increase of 17.6% in two years, above the global average¹⁴⁵.

FIGURE 44.

Knowledge-based bioeconomy solutions in Brazilian agribusiness are gaining global recognition | PRELIMINARY |



VAZ JUNIOR, Sílvia. Use of agro-industrial waste: a sustainable approach. Brasília, DF: Embrapa Agroenergia, 2020. 26 p. (Embrapa Agroenergia. Documentos, 31). Available at: <https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/1126255/1/S-VAZ-Aproveitamento-de-residuos-agroindustriais.pdf>. Accessed on: May 20, 2025.

¹⁴⁵. MCKINSEY & COMPANY., 2024.

The knowledge-based bioeconomy offers a robust set of innovations to expand the sustainability and resilience of Brazilian agriculture. In addition to more sustainable bio-inputs, capable of replacing agrochemicals, another promising area is the improvement of cultivars adapted to water stress. This allows for the maintenance of productivity under adverse climatic conditions, such as prolonged droughts—an increasingly common phenomenon due to the impacts of climate change.

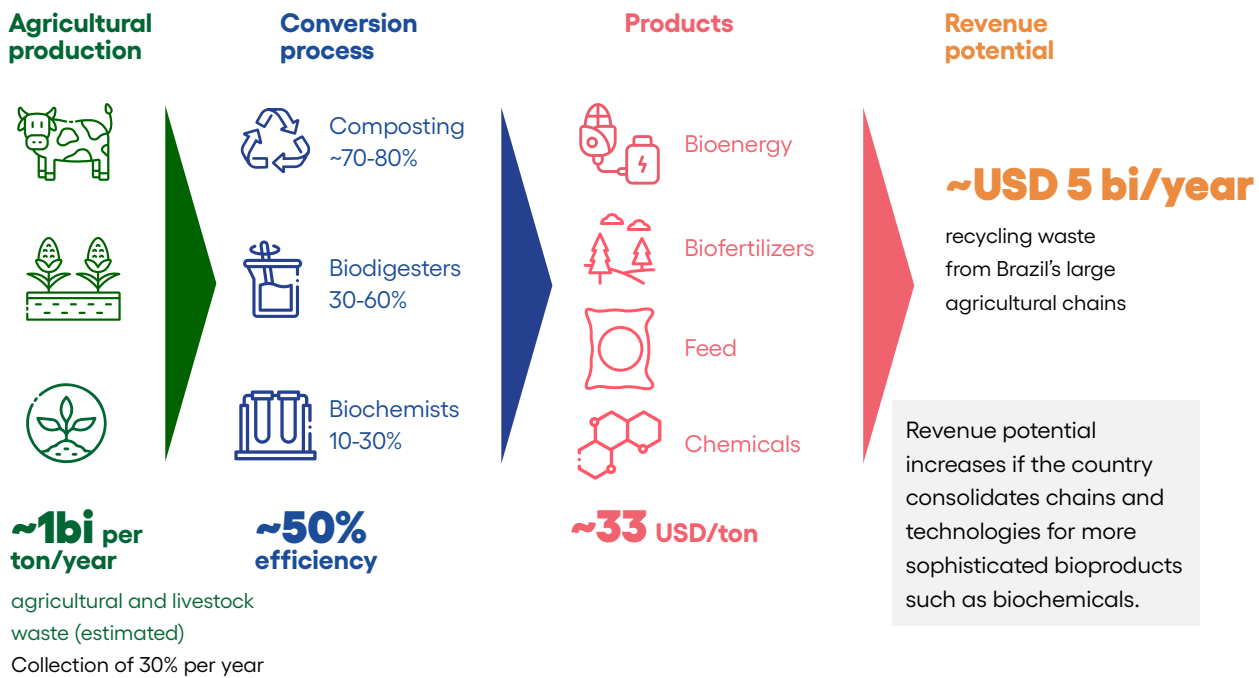
Furthermore, nutritional additives aimed at reducing livestock emissions can contribute to less carbon-intensive animal protein production. At the same time, regenerative technologies focused on soil health are gaining momentum, and are essential for restoring millions of hectares of degraded land and increasing productivity without putting pressure on the expansion of the agricultural frontier.

Precision agriculture complements this set of solutions by enabling more efficient and rational use of inputs through sensors, algorithms, and integrated monitoring systems that optimize agricultural management.

Finally, the use of agroforestry residues as raw material for new bioindustrial products emerges as a concrete opportunity for generating value and income in the field and drives circular and low-environmental-impact production chains.

FIGURE 45.

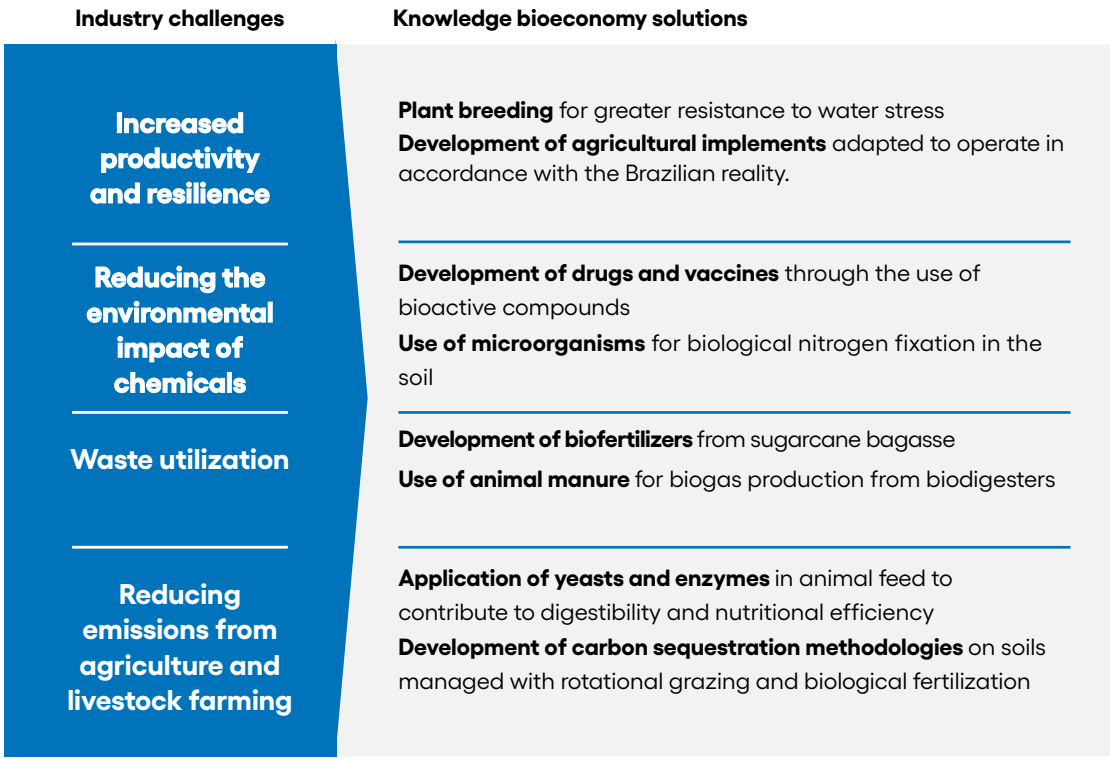
Brazil has the potential to generate USD 5 billion in revenue per year by utilizing agricultural waste



VAZ JUNIOR, Silvio. Use of agro-industrial waste: a sustainable approach. Brasília, DF: Embrapa Agroenergia, 2020. 26 p. (Embrapa Agroenergia. Documentos, 31). Available at: <https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/1126255/1/S-VAZ-Aproveitamento-de-residuos-agroindustriais.pdf>. Accessed on: May 20, 2025.

FIGURE 46.

The knowledge-based bioeconomy offers concrete solutions to increase productivity, profitability, sustainability, and competitiveness in agribusiness



Market potential and innovation

It is estimated that the global bioeconomy market linked to agriculture could reach between USD 265 billion and USD 325 billion by 2032¹⁴⁶. The number of international patents in this field has grown at an average annual rate of 22.5% over the last decade. However, Brazil’s share represents only 1.02% of the global total of patents related to the sector¹⁴⁷.

The knowledge-based bioeconomy represents a significant fraction of global agriculture, generating between USD 120 billion and USD 140 billion in 2024, which is equivalent to 12% of the global agricultural products and services market valued at USD 1 trillion¹⁴⁸. This value is distributed throughout the agricultural production chain—from inputs to waste management—and reflects the consolidation of seven strategic segments with high potential for innovation and impact. Among them, genetic improvement (USD 20–25 billion) stands out¹⁴⁹, followed by bioinsumes (USD 14–15 bi¹⁵⁰) and animal feed additives (USD 36–38 billion¹⁵¹), which together account for almost half of the market. Complementing this ecosystem is animal biotechnology (USD 28–30 billion¹⁵²) and precision agriculture (USD 14–25 billion¹⁵³).

This study also considered solutions for the reuse of Brazilian agricultural waste (USD 4-5 billion¹⁵⁴), which transform environmental liabilities into value-added industrial inputs, and the potential to regenerate degraded pastures with cocoa plantation in agroforestry systems (USD 3.4-3.6 billion).

¹⁴⁶. Team analysis, detailed in appendix 1.
¹⁴⁷. ESPACENET, 2024.
¹⁴⁸. VAZ JUNIOR, Silvio. Use of agro-industrial waste: a sustainable approach. Brasília, DF: Embrapa Agroenergia, 2020.
¹⁴⁹. THE BUSINESS RESEARCH COMPANY. 2024. GLOBAL MARKET INSIGHTS, 2025. FORTUNE BUSINESS INSIGHTS. 2025. MORDOR INTELLIGENCE, 2025..
¹⁵⁰. THE BUSINESS RESEARCH COMPANY, 2024. FORTUNE BUSINESS INSIGHTS, 2025.
¹⁵¹. FORTUNE BUSINESS INSIGHTS. Feed Additives Market Size, Share & Industry Analysis, By Type (Amino Acids, Phosphates, Vitamins, Acidifiers, Carotenoids, Enzymes, Flavors and Sweeteners, Minerals, Antioxidants, and Others), and Regional Forecast, 2023–2030.
¹⁵². MORDOR INTELLIGENCE. Veterinary Biologics Market – Growth, Trends, and Forecasts (2024–2029).
¹⁵³. GRAND VIEW RESEARCH. Smart Agriculture Market Size, Share & Trends Analysis Report
¹⁵⁴. Team analysis.

FIGURE 47.

Segments of the knowledge bioeconomy in the agribusiness sector

Stages of the agricultural production chain

Inputs	Production	Waste management
Biotechnology and genetic improvement	Planting, cultivation, irrigation, pest/disease control	Waste management
Soil preparation and amendments	Food and health management, reproduction, daily care	Reuse of by-products as inputs for new production
	Technical support	
	Regeneration of degraded areas	

Sub-sectors of the knowledge-based bioeconomy and market values in 2024 (billion USD)		
Genetic improvement: Selection, hybridization, mutation breeding, and CRISPR (USD 20-25 billion)	Animal biotechnology: diagnostic tests, biologicals, drugs, nutrition (USD 28-30 billion)	Waste reuse: Collection and conversion of waste from large agricultural chains into simpler products such as bioenergy and biofertilizers, and more complex products such as biochemicals (USD 4-5 billion)**
Bio-inputs: Biostimulants, biofertilizers, and biopesticides (USD 14-15 billion)	Precision agriculture: Precision agriculture, livestock monitoring, smart greenhouses, and harvest, water, and fertilizer management. (USD 14-25 billion)	
Additives in animal feed: Vitamins, antioxidants, amino acids, enzymes, and acidifiers for animal feed and antibiotics (USD 36-38 billion)	Regenerative models (agroforestry cocoa): Agroforestry cocoa production as a strategy for regenerating degraded areas (USD 3.4–3.6 billion)*	

¹ STATISTA. Agriculture – Worldwide. Available at: <https://www.statista.com>. Accessed on: May 20, 2025. ; ² Global Reports and Market Analyses. Available at: <https://www.researchandmarkets.com>, <https://www.thebusinessresearchcompany.com>, <https://www.fortunebusinessinsights.com>, <https://www.mordorintelligence.com>, <https://www.gminsights.com>, <https://www.futuremarketinsights.com>, <https://pharmanucleus.com>, <https://www.sphericalinsights.com>. Accessed on: May 20, 2025. ; ³ EMERGE BRASIL. Team analysis based on secondary data and market projections. May 2025. ; ⁴ Interviews with experts conducted by the Emerge team between March and May 2025 with professionals from the sector. ; ⁵ Validation with experts. Qualitative validation process with external experts, realized in May 2025.
**Potential market value of waste recovery (or recycling/reuse) in Brazil in 2032.
*Potential market value of cocoa production in agroforestry systems in Brazil in 2032.

KNOWLEDGE-BASED BIOECONOMY SOLUTIONS FOR COFFEE

The coffee sector faces increasing climate change-related pressures, with direct impacts on production, costs, and supply chain security. The price of coffee increased by 80% between May 2024 and April 2025, representing the highest inflation in 30 years¹⁵⁵. For four years, Brazil, the world's largest producer, has been facing severe climate impacts, such as frosts and heat waves, which have increased raw material costs by 224% for industry and 110% for end consumers¹⁵⁶.

Projections indicate that the area suitable for growing Arabica coffee — the highest quality, highest value variety — could be reduced by more than 50% by 2050¹⁵⁷. Among the main climate impacts is prolonged water stress, which compromises flowering, impairs grain development, causes damage to fruits, and can lead to plant death¹⁵⁸. This poses risks to productivity, and also to the future of the crop in several producing regions.

The partnership between Nestlé and the Procafé Foundation invested R\$ 5.5 million in the development of a new grain variety, using traditional genetic improvement methods¹⁵⁹. That cultivar has a shorter growing cycle, greater disease tolerance, and lower input requirements, in addition to generating lower carbon emissions.

The results include a 37% increase in productivity, up to 75% larger grains, and a reduction in greenhouse gas emissions of between 36% and 41% compared to conventional varieties, reducing the costs and risks faced by producers¹⁶⁰.

¹⁵⁵. G1. Coffee prices rise 80% in 12 months, hitting highest inflation in 30 years.

¹⁵⁶. Ibid.

¹⁵⁷. NESTLÉ BRAZIL, 2025.

¹⁵⁸. CONFEA, 2025.

¹⁵⁹. NESTLÉ BRAZIL, 2025.

¹⁶⁰. Ibid.

Initiatives like this demonstrate how the knowledge-based bioeconomy is emerging as a strategic path to increasing the sector's resilience. By combining science, biodiversity, and the appreciation of technical and traditional knowledge, it enables the redesign of more resilient, regenerative, and competitive production chains to ensure the sustainable future of food production in Brazil.

According to projections produced for this study, the global market for six key segments of the bioeconomy applied to agriculture analyzed—bioinputs, animal biotechnology, animal feed additives, genetic improvement, precision agriculture, and regenerative models—is expected to reach between USD 265 billion and USD 325 billion by 2032, a significant increase compared to the USD 125–150 billion of 2024¹⁶¹.

Brazil, which currently participates with a modest share in some of these production chains, could capture approximately 5.5% of this global market, which would generate revenues of around USD 15 billion to USD 19 billion per year¹⁶².

Highlights include the animal biotechnology and genetic improvement segments, in which the country can achieve compound annual growth (CAGR) of over 20%. This demonstrates a strong capacity to scale bioeconomy products to address health and production challenges.

The country has several public policies and programs that promote the knowledge-based bioeconomy in the agribusiness sector. Among the main ones are: the National Bioinput Program, structured by the Ministry of Agriculture and Livestock (MAPA), which regulates production, use, registration, and marketing of bioinputs; and the National Bioinput Catalog, also coordinated by MAPA, which gathers accessible and free information on biological inputs for agricultural use.

¹⁶². NESTLÉ BRASIL, 2025.

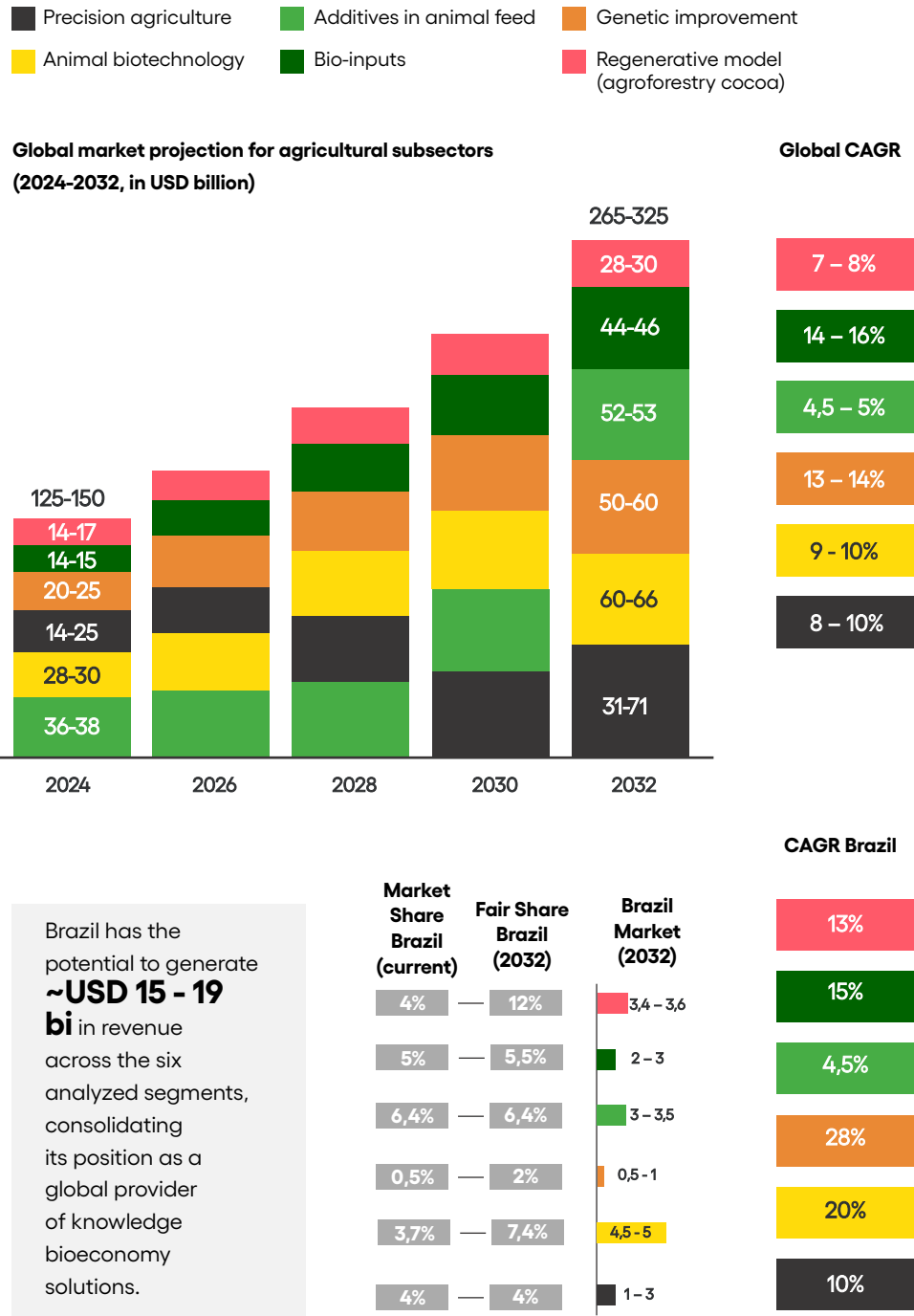
¹⁶³. Ibid.

The Alelo Genetic Resources Platform, developed by Embrapa, is focused on documenting and managing the conservation of animal, plant, and microbial genetic resources of interest for agricultural research, development, and innovation. The National Policy for the Conservation and Sustainable Use of Genetic Resources for Food, Agriculture, and Livestock, structured in partnership between MAPA and the Ministry of Science, Technology, and Innovation (MCTI), aims to expand the Alelo Platform nationally, integrating public and private institutions. Linked to this policy, the National Platform for Genetic Resources for Food and Agriculture seeks to consolidate an integrated database on Brazilian biodiversity, promoting the preservation of plant, animal, and microbial genetic heritage.

Complementary to these initiatives, public policies such as the National Program for the Recovery of Degraded Areas and Reduction of Climate Vulnerabilities (Reverdecer), the ABC+ Program (Sectoral Plan for Adaptation and Low Carbon Emissions in Agriculture), and the National Plan for the Recovery of Native Vegetation (Planaveg) play a fundamental role in the regeneration of degraded areas. These actions seek to promote sustainable practices, such as the restoration of native vegetation, ecological restoration, and the use of integrated agricultural production systems, contributing to climate change mitigation, biodiversity conservation, and increased rural productivity.



FIGURE 48.
National market share in relation to the global market in the six sub-sectors of the agribusiness bioeconomy



¹ STATISTA. Agriculture – Worldwide. Available at: <https://www.statista.com>. Accessed on: May 20, 2025.

² Global Reports and Market Analyses. Available at: <https://www.researchandmarkets.com>, <https://www.thebusinessresearchcompany.com>, <https://www.fortunebusinessinsights.com>, <https://www.mordorintelligence.com>, <https://www.gminsights.com>, <https://www.futuremarketinsights.com>, <https://pharmanucleus.com>, <https://www.sphericalinsights.com>. Accessed on: May 20, 2025.

³ EMERGE BRASIL. Team analysis based on secondary data and market projections. May 2025.

🗣️ Interviews with experts. Conducted by the Emerge team between March and May 2025 with professionals from the sector.

🔍 Expert validation. Qualitative validation process with external experts realized in May 2025.

AGROFORESTRY COCOA AS A VECTOR FOR PRODUCTIVE REGENERATION

Brazil could generate between USD 3.4 billion and USD 3.6 billion per year and capture approximately 12% of the global cocoa market by 2032, with increased productivity and expansion of agroforestry systems (SAFs) across 400-500 thousand hectares¹⁶³. This potential for expansion into degraded areas with agricultural viability will have a more effective impact if accompanied by a consistent increase in productivity.

Cocoa is the main driver of cash generation for crops in agroforestry systems (SAF), due to its good development under shade, adaptability to the Brazilian climate and consolidated demand.

A native species of the Amazon, cocoa is well adapted to the regional climate, soil and biodiversity, presenting high ecological efficiency and being ideal for intercropping with forest, fruit and timber species as it grows well under shade¹⁶⁴. Other crops can be incorporated into SAFs with cocoa, such as açai, banana, and jaborandi, expanding productive diversification and income sources for producers.

In the 1980s, Brazil was the 2nd largest cocoa producer in the world¹⁶⁵, but the disruption of production caused by the witch's broom has led the country to currently rank 6th among world producers¹⁶⁶ and depend on imports to supply the domestic market.

The country has comparative advantages throughout the cocoa and chocolate production chain, with the installed capacity to expand its participation in international markets. In addition to land availability for SAFs and climate and vegetation compatibility, the country has government support programs for the cocoa chain, such as PLANAVEG,

¹⁶³. EMBRAPA, 2023.

¹⁶⁴. EMBRAPA, 2023.

¹⁶⁵. FAPESP AGENCY, 2016.

¹⁶⁶. THE AGRIBIZ, 2024.

Plano Inova Cacau 2030, Cacaucultura 4.0, specialized research centers, industrial infrastructure for processing, and a large-scale domestic consumer market.

The advancement of the knowledge-based bioeconomy can accelerate the technological development of the cocoa production chain. The average Brazilian productivity, currently around 350 kg/ha¹⁶⁷ historically reached levels of 700 kg/ha¹⁶⁸. To increase productivity, programs such as SENAR, Embrapa, and CEPLAC must connect with local training networks to qualify producers and expand the use of best practices.

Investments in genetic improvement, light mechanization, and rural extension are also essential to unlock productivity gains. Public-private partnerships, such as Cocoa Action, help bridge the gap between science and agricultural operations, accelerating the adoption of innovations in the field.

Scaling this model requires greater access to credit. Cocoa SAFs have a syndicated structure and longer payback periods that don't fit into traditional credit models, increasing their perceived risk. This increases collateral requirements and makes access to financing more difficult. Experiences like Pronaf show how financing agreements combined with guaranteed purchases and technical support can accelerate the adoption of regenerative practices, reduce risks, and attract investment. A concrete example is the significant growth of the Pronaf Agroecology line. Between the 2022/2023 and 2023/2024 harvests, the number of contracts increased from 86 to 267 operations, and the amount financed increased from R\$3.4 million to R\$8.7 million¹⁶⁹. Public policies such as legal recognition of cocoa planting in SAFs as part of forest restoration help reduce risks and attract investment, and can facilitate access to climate credits.

¹⁶⁷. THE AGRIBIZ, 2024.

¹⁶⁸. CEPLAC, 2009.

¹⁶⁹. GOV. AGENCY. Pronaf invests R\$59.6 billion in family farming, an increase of 12.1% compared to the 2022/2023 harvest.

Innovation ecosystem and strategic assets

The agribusiness sector accounts for 37% of the activities registered in SisGen and is the most dynamic in terms of biodiversity use¹⁷⁰. Embrapa, the main Brazilian institution in this field, is responsible for 11% of registered activities.

Startups as Biotrop (valued at R\$ 2.8 billion), Gênica (USD 100 million), Peptidus Biotech, Apoena Biotech and Inocas (USD 6 million investment) demonstrate the viability of scaling solutions in biological pesticides, inoculants, veterinary vaccines and recovery of degraded areas through macauba culture¹⁷¹ and attract foreign capital.

FIGURE 49.
Leading agribusiness startups focused on knowledge-based bioeconomy technologies

			
Solution: 100% biotech products for the agricultural and cosmetic markets, reducing market dependence on synthetic chemicals.	Solution: Treatment of diseases in farm animals.	Solution: Bio-inputs, cover crops, biostimulants, and other solutions for Integrated Pest and Disease Management (IPDM).	Solution: Biostimulants, biocontrol, inoculants, and biofertilizers.
Technology: Advanced bioprospecting to isolate microorganisms from Brazilian biodiversity, developing biotechnological ingredients for cosmetics and sustainable agricultural solutions	Technology: Artificial intelligence and molecular modeling applied to the functionalization of Brazilian biodiversity for the development of peptides.	Technology: Isolation of microorganisms and development of bio-inputs from fungi, bacteria, viruses, and certain organic compounds.	Technology: Artificial intelligence for selecting microorganisms and bacteria for product development and scaling up soil health analysis for farmers.
Investment received (US\$): ~ 10 - 50 thousand	Investment received (US\$): ~ 50 - 100 thousand	Investment received (US\$): ~ 10 - 15 million	Investment received (US\$): ~ 10 - 20 million

170. SISGEN – National Management System of Genetic Heritage and Associated Traditional Knowledge. Data available up to 2024.
171. Cocoa for regeneration was used as a specific case for the purposes of this study, but, as demonstrated, it is not the only possible crop.

International references

To accelerate this potential, Brazil can take inspiration from the Netherlands, which, despite its small size, has become an agricultural powerhouse. The country is the second-largest food exporter in the world, exporting around 65 billion euros (about USD 75 billion) per year. This was possible thanks to coordinated investments in Research & Development, biotechnology and digitalization, aligning sustainability with productivity and global competitiveness¹⁷².



3.4 Health:
Brazil as a hub of bioinnovation in health

Brazil can strategically position itself in the global health value chain, with revenues of USD 12 billion to USD 20 billion per year by 2032, through the knowledge-based bioeconomy. Home to one of the greatest biodiversities in the world, consolidated scientific institutions such as Fiocruz and Butantan, in addition to the largest public health system in the world—the Unified Health System (SUS)— the country brings together unique assets to drive a new frontier in bioinnovation in the sector.

The health sector represents about 10% of Brazilian GDP¹⁷³ and is responsible for 20 million direct and indirect jobs, in addition to accounting for a third of national scientific production. The SUS, which serves approximately 70% of the Brazilian population¹⁷⁴, is a central instrument of social inclusion.

The COVID-19 pandemic has highlighted challenges facing global pharmaceutical input production chains. Currently, 80 to 90% of APIs (active pharmaceutical ingredients) are produced by China and India¹⁷⁵. In Brazil, more than 90% of APIs and 95% of vaccine raw materials are imported. Only 5% of the inputs used in drug manufacturing are produced locally. Given this scenario, the need to strengthen the sector and increase investment in technology and domestic production capacity, with a greater emphasis on innovation, was recognized.

172. Government of the Netherlands. Agriculture, 2025.
173. BRAZIL. Ministry of Health, 2023.
174. GOVERNMENT AGENCY, 2024.
175. Comex Bulletin: Strategic Information for the National Pharmaceutical and Active Pharmaceutical Ingredients Sector. Brasília: Ministry of Health, 2024.

In response, Brazil set a goal of producing nationally 70% of SUS needs¹⁷⁶. Countries such as the United States, China, and members of the European Union have been implementing policies to encourage bioinnovation, recognizing the strategic nature of this sector.

Pathways to bioinnovation in health

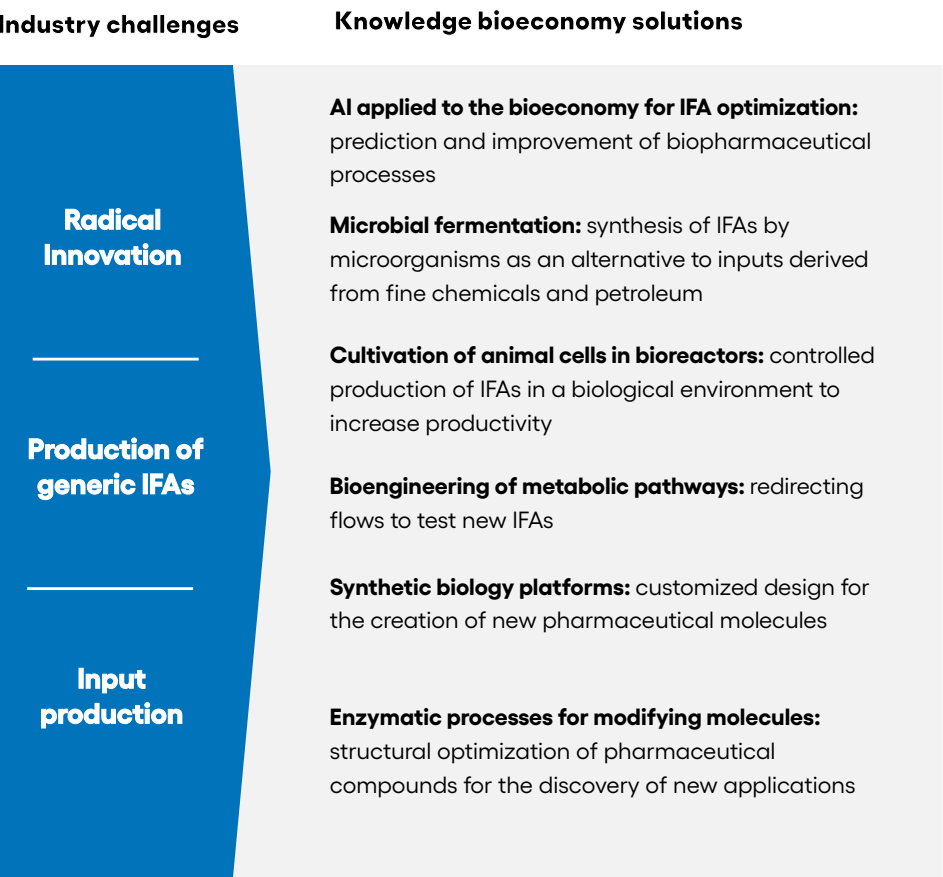
Brazil has a vast natural library of genetic and biochemical assets, with extremely high potential for use in human health. Given that about 65% of the small molecules used in pharmaceuticals were inspired by plants¹⁷⁷, a bioprospecting of medicinal plants, microorganisms and enzymes can meet global demand for new medicines, especially herbal medicines.

Technological advances such as artificial intelligence, genomics, CRISPR and blockchain transform the pharmaceutical industry, accelerate drug discovery, reduce entry barriers and favor the performance of startups. While AI accelerates the identification of bioactives by analyzing large data sets, genomics and personalized medicine develop treatments targeted to genetic profiles. CRISPR and synthetic biology facilitate the development of new therapies. *Crowdsourcing* and open innovation promote collaboration and resource sharing, while blockchain technology increases transparency and traceability in clinical trials and drug supply chains. Partnerships and acquisitions of preclinical-stage assets have proven effective in driving collaborative strategies between large companies and new entrants. Between 2016 and 2020, assets acquired in partnership were twice as likely to be launched when compared to those developed internally by a single company¹⁷⁸. Top-performing pharmaceutical companies concentrated 74% of their acquisitions in the preclinical phase, while lower-performing companies focused 61% of their deals in this phase¹⁷⁹. Both categories of companies increased their preclinical acquisitions by 20% between 2003-07 and 2018-21. This reflects the growing importance of partnerships and early-stage asset acquisitions as a strategy to ensure competitiveness in new

product launches. This scenario offers an opportunity for Brazil to invest in the early stages of the pharmaceutical innovation cycle, which requires a lower volume of investment.

In this context, it is essential to advance the adoption of technologies such as microbial fermentation, cell culture, and synthetic biology to create new bioactives, bioinspired medicines, and innovative therapeutic solutions. Even so, Brazil's share of patents in the knowledge-based bioeconomy in health is only 3.2% of the global total, despite the sector having shown an average international growth rate of 14% over the last ten years¹⁸⁰.

FIGURE 50.
Knowledge-based bioeconomy solutions for challenges in the healthcare sector [NON-EXHAUSTIVE]



SOURCE: Team analysis and interviews with experts.

¹⁷⁶. Brazil. Ministry of Health. Federal Government launches National Strategy for the Development of the Health Economic-Industrial Complex with an investment of R\$42 billion by 2026.
¹⁷⁷. Interview with experts.
¹⁷⁸. McKinsey & Company, 2021.
¹⁷⁹. Ibid.

¹⁸⁰. ESPACENET. CPC Browser – Cooperative Patent Classification. European Patent Office, [s.d.]

The healthcare sector is a market to be developed

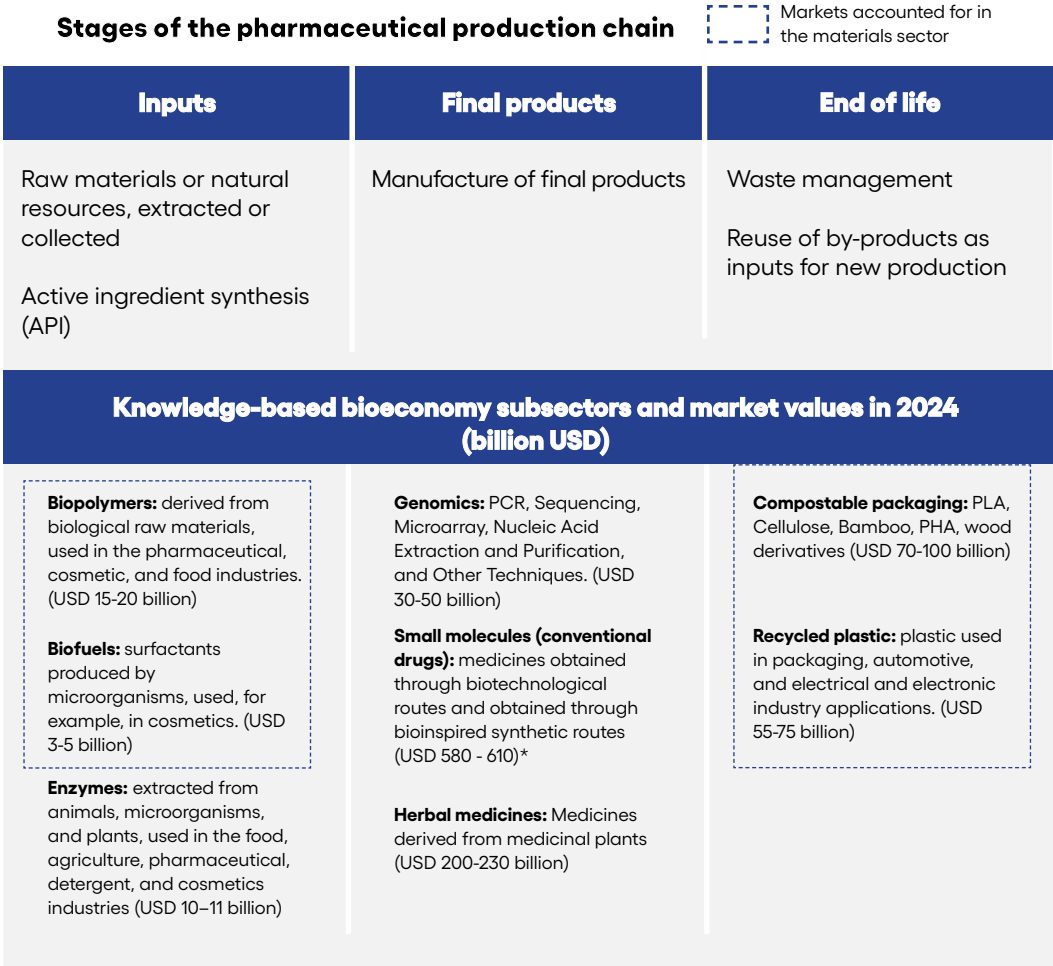
The knowledge-based bioeconomy segments linked to the health sector generate a global market estimated at between USD 820 billion and USD 900 billion in 2024, representing approximately 55% of the global pharmaceutical market, valued at USD 1.6 trillion¹⁸¹. This universe encompasses several stages of the value chain — from the use of natural resources and the synthesis of APIs (active ingredients), to the production of medicines and the management of waste at the end of the useful life of products¹⁸².

Among the main subsectors, phytotherapeutics (USD 200–230 billion) stand out¹⁸³ and bioinspired small molecules – which represent 65% of the small molecule market in 2024 (USD 580–610 billion) – reflecting the role of biodiversity in pharmaceutical innovation¹⁸⁴. Other relevant segments include enzymes, genomics, and those accounted for in the materials sector, such as biopolymers (accounted for under bioplastics) and biosurfactants, all with broad applications, reflecting the growing integration of the healthcare sector with the cosmetics and food sectors. These latter segments reinforce the intersection between health, sustainability, and the circular economy.



¹⁸¹. FORTUNE BUSINESS INSIGHTS, 2025. GRAND VIEW RESEARCH, 2025.
¹⁸². For the calculation, subsectors previously calculated in the materials sectors such as biosurfactants, biopolymers, compostable packaging and recycled plastic were disregarded.
¹⁸³. FORTUNE BUSINESS INSIGHTS. ASTUTE ANALYTICA.
¹⁸⁴. A 65% share of the small molecule market was considered for the calculation, as it is estimated that 65% of small molecules were bioinspired.

FIGURE 51.
Segments of the knowledge-based bioeconomy in the health sector



*The 65% share of the small molecule market was considered for the calculation, as it is estimated that 65% of small molecules were bioinspired.
Source: Research and Markets, Business Research Company, Fortune Business Insight, Mordor Intelligence, Global Market Insights, Future Market Insights, Pharmanucleus, Spherical Insights; Team analysis; Interviews with experts; Validation with experts.

Brazil could move between USD 10 billion and USD 13 billion to reach 1.4% of the global bioeconomy pharmaceutical market, estimated at between USD 730 billion and USD 810 billion in 2032¹⁸⁵.



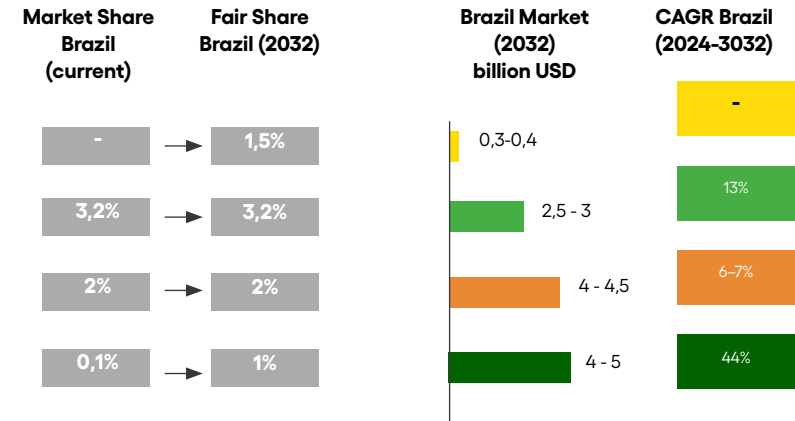
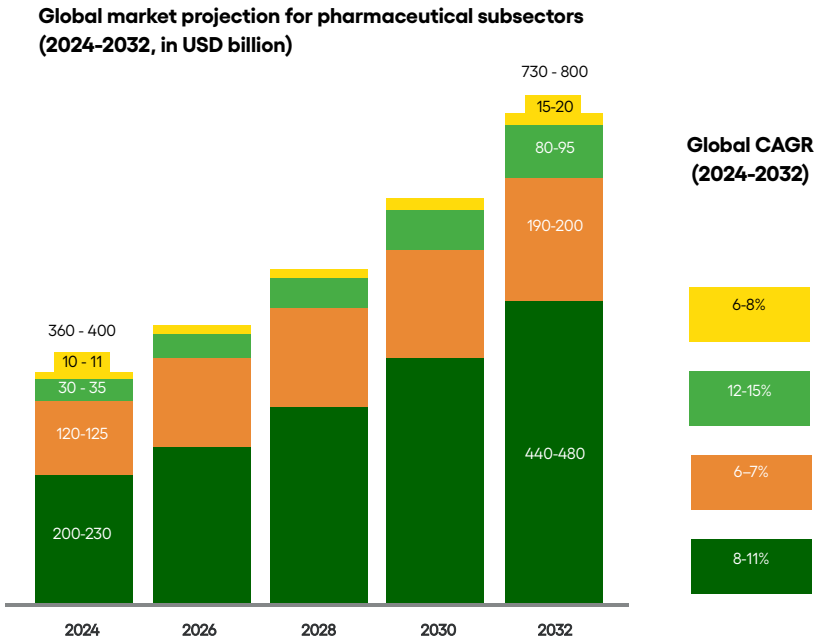
The investment in radical innovation for discovery to preclinical stage of 3 to 5 new bioinspired small molecules could generate USD 1 billion to USD 6 billion in 2032¹⁸⁶. If the country advances to phase 1 of clinical trials, this potential doubles, reaching USD 2 billion to USD 12 billion¹⁸⁷.

¹⁸⁵. Team analysis, detailed in Annex I.
¹⁸⁶. The same.
¹⁸⁷. The same.

FIGURE 52.

National market share in relation to the global market in four sub-sectors within the health bioeconomy

Genomics Enzymes Herbal medicines Small molecules produced via biotechnological routes

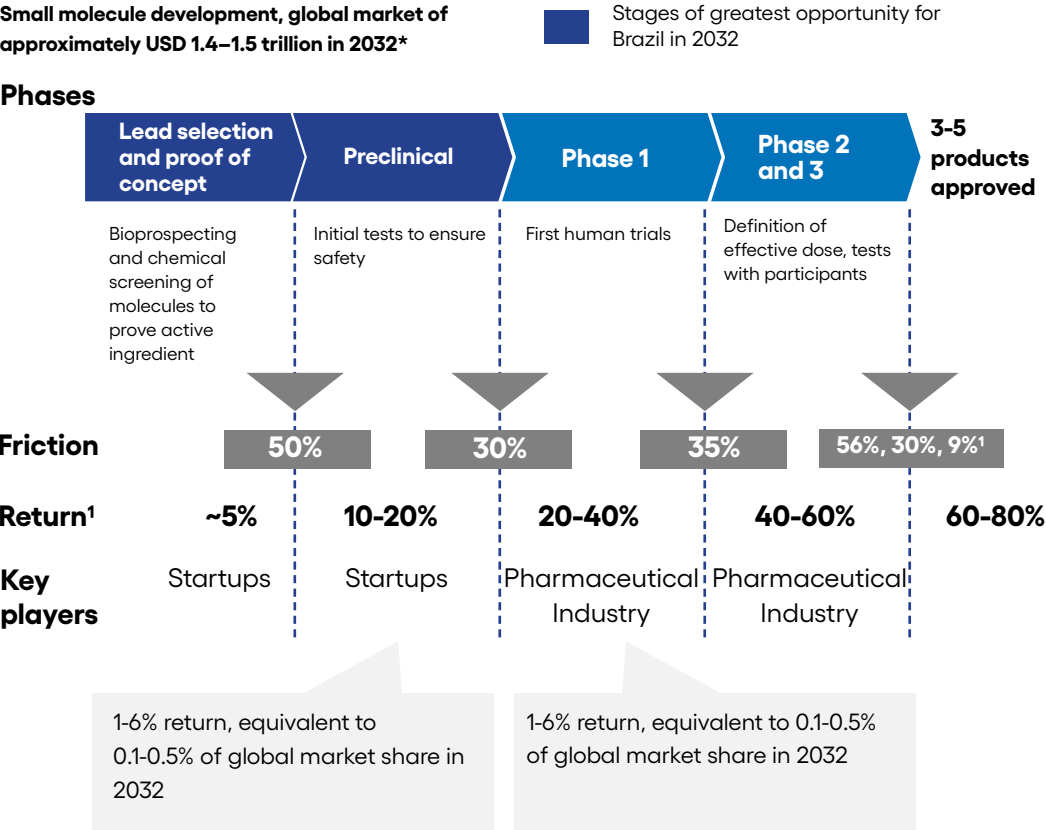


Brazil has the potential to generate **~USD 11 – 13 bi** in revenue across the four analyzed segments, consolidating its position as a global provider of knowledge-based bioeconomy solutions.

*The 65% share of the small molecule market was considered for the calculation, as it is estimated that 65% of small molecules were bioinspired.
Source: Research and Markets, Business Research Company, Fortune Business Insight, Mordor Intelligence, Global Market Insights, Future Market Insights, Pharamanucleus, Spherical Insights; Team analysis; Interviews with specialists; Validation with experts.

FIGURE 53.

Market value projection for the new drugs sector



*Total market values calculated considering that 65% of small molecules were bioinspired
Regarding the value of the final product, based on: WOUTERS, O. J.; KESSELHEIM, A. S.; KUHA, J.; LUYTEN, J. Sales Revenues for New Therapeutic Agents Approved by the United States Food and Drug Administration From 1995 to 2014. Value in Health, v. 27, n. 10, p. 1373–1381, Oct. 2024. Available at: [https://www.valueinhealthjournal.com/article/S1098-3015\(24\)02754-2/fulltext](https://www.valueinhealthjournal.com/article/S1098-3015(24)02754-2/fulltext). Accessed on: Apr. 14, 2025.

In 2022, Brazil ranked 20th in the global ranking in clinical research, participating in only 2% of global studies¹⁸⁸. However, Anvisa’s RDC No. 945/2024 aligns the country with international guidelines and establishes a deadline of up to 90 working days for the completion of the analysis of primary and secondary petitions. Next to the continuous institutional strengthening of the Agency, this regulation can consolidate Brazil as the Latin American reference in early clinical development¹⁸⁹.

The country has comparative advantages that can take it to the 10th global position and attract R\$3 billion in investment (approximately USD 537 million)¹⁹⁰. The low cost of conducting clinical trials compared to benchmark countries such as the United States, Germany, and the United Kingdom, and the ethnic diversity of the Brazilian population stand out, allowing clinical trials to have greater representation and global applicability.

¹⁸⁸. INTERFARMA – PHARMACEUTICAL RESEARCH INDUSTRY ASSOCIATION. Panorama of Clinical Research in Brazil – 2022.

¹⁸⁹. Ibid.

¹⁹⁰. Ibid.

Furthermore, in addition to its healthcare infrastructure and qualified professionals, the country demonstrated its capacity to conduct complex clinical trials during the COVID-19 pandemic.

Brazil also has important public policies and programs aimed at promoting the knowledge-based bioeconomy in the health sector. The Brazilian Genomes Program, structured by the Ministry of Science, Technology, and Innovation (MCTI) in partnership with the Ministry of Health, aims to sequence 100,000 Brazilian genomes, boosting precision medicine, especially in the fight against rare diseases, cancer, and infections. The Brazilian Genomes Production Program Active Pharmaceutical Ingredients (IFAs) and Biotechnological Innovations, led by the Ministry of Health within the scope of the Peixe Rosa Program, seeks to strengthen the national capacity for the production of IFAs, positioning the country as a global reference in this field.

Ecosystem of innovation and use of biodiversity

More than seventy-eight (78) startups Brazilians work at the intersection of biodiversity and health¹⁹¹, such as Nintx, Regenera, and NATiva, which demonstrate the ability to attract capital, develop technologies, and establish international partnerships. The ecosystem, however, still requires R&D infrastructure, specific credit lines, and scalable public policies to mature.

FIGURE 54.

Leading startups in the healthcare sector focused on knowledge-based bioeconomy technologies



Brazil knows little about its biological wealth, but it has public initiatives aimed at mapping and monitoring biodiversity, fundamental to environmental conservation and sustainable development. Notable among these is the Brazilian Biodiversity Information System (SIBBr), coordinated by the MCTI (Ministry Institute of Science and Technology), which integrates data on species, biological collections, and scientific research, serving as the main national platform for open data on biodiversity. The Biodiversity Research Program (PPBio), also part of the MCTI, structures research networks and conducts standardized ecological inventories in various biomes. At the state level, the Açaí Genome Project, led in Pará by BioTec Amazônia, seeks to sequence the plant's genome to identify bioactive compounds with potential industrial use, promoting innovation and adding value to Amazonian ingredients.



191. EMERGE BRASIL. Deep Tech Brazil Report 2024.

The beginning of a bioactive discoveries hub has been consolidating around the National Center for Research in Energy and Materials (CNPEM) in recent years, combining cutting-edge scientific infrastructure, such as the Sirius electron accelerator and integrated screening and structural biology platforms, with a growing ecosystem of corporate partnerships and innovative startups. The focus of this hub is to identify and develop new active ingredients from Brazilian biodiversity, with therapeutic applications in areas such as oncology, infectious diseases, chronic pain and multifactorial disorders. Among the main partners are the pharmaceutical company Aché, startup Phytobios and, more recently, Nintx – a deep tech Brazilian company that has raised over USD 13 million in venture capital (including a USD 10 million Series A round in 2024) to develop drug candidates based on natural products. Initiatives such as the joint CNPEM–Aché–Phytobios program¹⁹², which mobilized R\$ 10 million, and the “Pain Alliance”¹⁹³, with Cristália, show how this hub has attracted significant contributions and given rise to promising innovations in compounds in advanced stages of research. By combining cutting-edge science, artificial intelligence and the country’s rich biodiversity, this hub can place Brazil at the forefront of pharmaceutical innovation based on natural bioactives.

In SisGen, the health sector ranks 2nd in number of notifications and leads in international shipments of genetic material, with 46% of the total, highlighting the global interest in the applications of Brazilian biodiversity¹⁹⁵.



South Korea’s recent experience is an example of how coordinated policies can transform a country into a benchmark for bioinnovation in health¹⁹⁵. Following the COVID-19 pandemic, the country established a National Biohealth Innovation Commission, mobilizing 12 ministries, setting clear global leadership goals, and creating a National Synthetic Biology Initiative. The five-year plan to support the biopharmaceutical

¹⁹². CNPEM – NATIONAL CENTER FOR RESEARCH IN ENERGY AND MATERIALS. CNPEM, Aché, and PhytoBios launch an initiative to discover new pharmaceuticals from Brazilian biodiversity.

¹⁹³. CNPEM – NATIONAL CENTER FOR RESEARCH IN ENERGY AND MATERIALS. CNPEM Semiannual Report – First Half of 2024.

¹⁹⁴. BRAZIL. Ministry of the Environment and Climate Change.

¹⁹⁵. Grand View Research. South Korea Biopharmaceutical Market Size & Outlook, 2030.

sector has positioned Korea as the 10th largest global market, with over 1,000 startups, and average growth of 21.6% per year in R&D investments between 2020 and 2022¹⁹⁶.

Taking inspiration from policies like those of Korea, Brazil can leverage its biodiversity to create a strategic industrial advantage, thereby adding value, generating qualified jobs and positioning itself as a protagonist in the new health economy.



3.5 Cosmetics

Brazilian biodiversity and innovation for sustainable cosmetics

The cosmetics sector associated with the knowledge-based bioeconomy could generate between USD 8 billion and USD 12 billion per year by 2032¹⁹⁷. Home to some of the greatest biodiversity on the planet, an innovative and creative industry, and vast traditional knowledge of natural ingredients, the country can establish itself as a global supplier of bioactives for sustainable, personalized, and high-value-added cosmetics.

Brazil is the world’s 3rd largest beauty and personal care market, behind only the United States and China, with revenues of USD 31.3 billion in 2023. The sector generated 7.1 million job opportunities in 2024, a 7.7% increase over the previous year. In terms of the number of product launches, Brazil ranks 4th globally, standing out as one of the most dynamic countries in the sector¹⁹⁸.

New market demands and challenges

The cosmetics industry is characterized by high competition and constant demand for innovation. The search for more natural, ethical, personalized, and traceable products has reshaped global standards. Consumers demand cosmetics adapted to their microbiome, skin type, and climate, with plant-based ingredients, cruelty-free, vegan, and with a low environmental footprint.

¹⁹⁶. Intralink. 2025.

¹⁹⁷. Team analysis, detailed in Annex I.

¹⁹⁸. ABIHPEC - Brazilian Association of the Personal Hygiene, Perfumery and Cosmetics Industry. Industry Overview 2023.

At the same time, stricter regulations in markets such as the European Union and the United States are restricting the use of potentially toxic ingredients, requiring companies to invest in safety, traceability, and sustainability.

Knowledge-based bioeconomy solutions

The knowledge-based bioeconomy offers concrete answers to this scenario. The combined use of artificial intelligence, bio-informatics, and traditional knowledge can accelerate the identification of personalized bioactives, while the valorization of agroforestry residues and Brazilian biodiversity can foster local, sustainable, and transparent supply chains.

FIGURE 55.

Knowledge-based bioeconomy solutions for challenges in the cosmetics sector [NON-EXHAUSTIVE]

Industry challenges	Example of knowledge bioeconomy solutions
Identification of new assets	Fermented botanical extracts: new biodegradable antioxidants and anti-inflammatories
Circularity	Hyaluronic acid produced via fermentation: alternative to animal extraction that has the potential to increase purity control and minimize allergy risks
Alternatives to petroleum derivatives, synthetic or associated with deforestation	Biopolymers: substitutes for synthetic plastic polymers in functions such as formula stabilizers
Domestic production of ingredients	Vegetable glycerin obtained from vegetable oil by-products: alternative to petrochemical-based glycerin or oilseeds linked to deforestation; provides hydration with a lower carbon footprint
	Biosurfactants: alternatives to synthetic surfactants, enabling emulsions and skin cleansing with lower toxicity and greater biodegradability
	Macauba oil: natural ingredient grown in Brazil with high potential for cosmetic formulations, serving as an alternative to palm oil associated with deforestation in Indonesia
	Oil extracted from coffee grounds: residue transformed into antioxidant oil, which can replace conventional oils (such as almond or argan oil) in cosmetic formulations

Team analysis and interviews with experts

The application of these resources can allow the creation of innovative cosmetic products with bioinspired ingredients and high added value.. For example, macauba oil, native to Brazil, appears as an alternative to palm oil — widely used and associated with environmental impacts¹⁹⁹. As the world’s largest producer, Brazil’s coffee grounds are a valuable residue, containing 15% fatty-acid-rich oils suitable for moisturizers and hair products²⁰⁰.

Over the past 10 years, patents in the cosmetics sector linked to the knowledge-based bioeconomy have grown at a global average rate of 22.3%. Despite this, Brazil’s share represents only 1.32% of total patent filings related to the sector²⁰¹.

Market potential and chain structuring

The study analyzed the main segments of the knowledge-based bioeconomy that make up the cosmetics industry²⁰², which moved between USD 80 billion and USD 120 billion in 2024 — the equivalent of around 15% of the sector’s global market, estimated at between USD 650 billion and USD 720 billion²⁰³. Natural ingredients (valued at USD 6-10 billion), essential oils, used mainly as fragrance ingredients (USD 5-10 billion), dermocosmetics (USD 30-40 billion) and organic personal care were considered, segments driven by ethical, healthy and personalized consumption trends²⁰⁴.

According to projections, Brazil could capture between USD 8 billion and USD 12 billion in revenue by 2032, which represents approximately 4% of this global market.

The segments with the greatest potential for the country include dermocosmetics (USD 3–4 billion), organic personal care (USD 2–3 billion), clean beauty (USD 1-1.5 billion) and essential oils, essential fragrance

199. CAMPOS, Juliana S. et al. Science and technology parks: An overview of the academic literature
200. BRAZIL. Ministry of the Environment and Climate Change.
201. ESPACENET.
202. For the calculation, subsectors previously calculated in the materials or pharmaceutical sectors such as enzymes, biosurfactants, biopolymers (included in the bioplastics market), bioplastics, compostable packaging and recycled plastic were disregarded.
203. Team analysis, expert interviews, and global market projections detailed in Appendix 1.
204. Detailed global market projection reports in Annex 1.

ingredients (USD 0.5-1 billion), reflecting the combination of installed industrial capacities, abundant biodiversity and demand for ethical and sustainable ingredients.

Artificial intelligence applied to the sector (USD 3–3.5 billion) also emerges as a driver of innovation in formulation, personalization, and traceability. From a sustainability perspective, the replacement of ingredients associated with deforestation, such as palm oil, stands out (USD 70–75 billion, with ~16% allocated to the cosmetics sector)²⁰⁵.

The replacement of palm oil (the main ingredient in cosmetic base formulations) with alternatives from Brazilian biodiversity—such as andiroba, babaçu, buriti, copaiba, and pracaxi oils—was also considered. These alternatives offer comparable emollient properties, reduce pressure on palm cultivation areas, currently associated with deforestation in Indonesia²⁰⁶, and have the potential to generate income for local extractive communities.

The market projection for seven segments of the knowledge-based bioeconomy applied to the cosmetics sector is expected to reach between USD 100 billion and USD 140 billion by 2032²⁰⁷. Highlighted segments include dermocosmetics (USD 30–40 billion), emerging trends such as artificial intelligence applied to beauty (USD 3–3.5 billion), and natural ingredients (USD 6–10 billion)²⁰⁸.

All segments show significant annual growth rates. The annual growth rate of AI in cosmetics is in the range of 18–20%, *clean beauty*, in the 14–15% range, and organic personal care in the 7–10% range.

These data signal strong dynamism and market appetite for natural, ethical, and technological solutions²⁰⁹.

205. Ibid.
206. CAMPOS, Juliana S. et al. Science and technology parks: An overview of the academic literature.
207. Ibid.
208. Global market projection reports - detailed in Annex 1 (projection details).
209. Ibid.

FIGURE 56.
Segments of the knowledge-based bioeconomy in the cosmetics sector

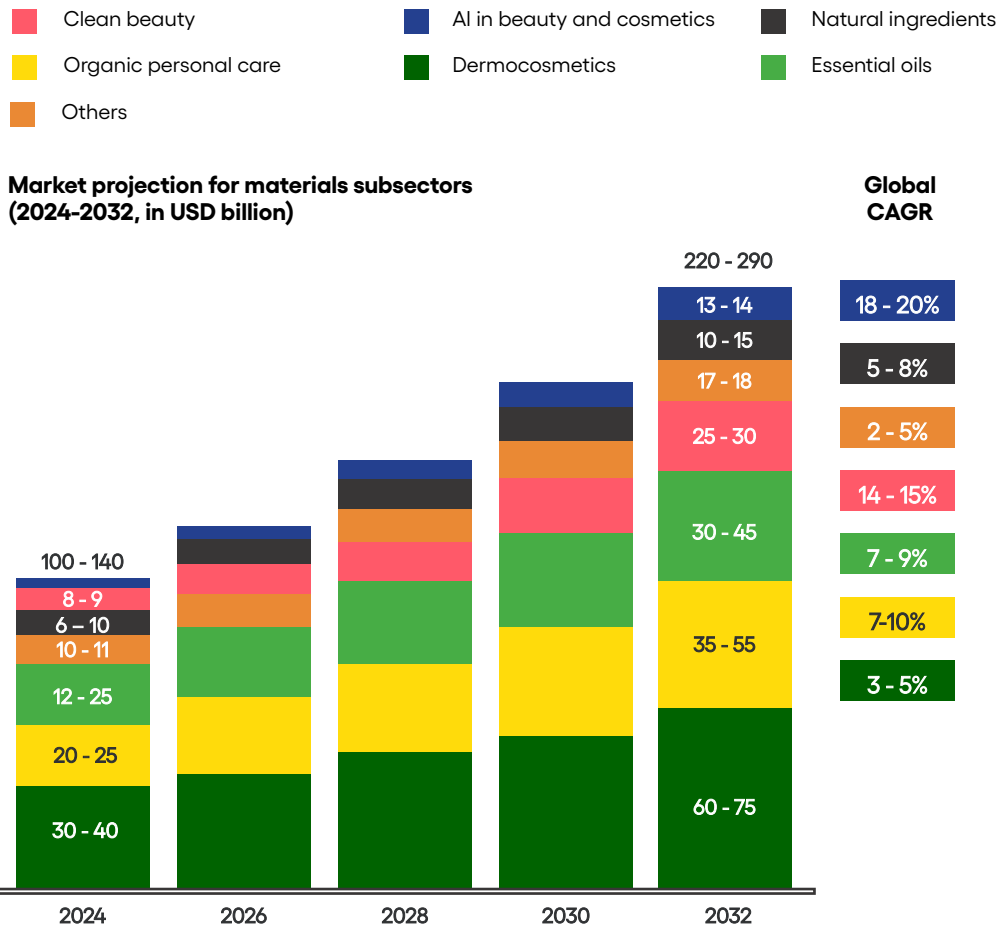
Stages in the materials production chain

Inputs	Intermediaries	Finals	End of life
Raw materials or natural resources that are extracted or collected but still require processing	Raw material processed or derived from inputs that have undergone some type of transformation for use in the manufacture of the final cosmetic product.	Formulation and development of the finished product	Sustainable packaging, logistics optimization, and end-of-life assurance through product design.
Sub-sectors of the knowledge bioeconomy and global market values in 2024 (billion USD)			
Palm oil: Oil widely used in soaps, creams, and conditioners with potential for replacement by oils from Brazilian biodiversity.* (USD10–11 billion) Enzymes: extracted from animals, microorganisms, and plants, used in the food, animal feed, pharmaceutical, detergent, and cosmetics industries (USD 10-15 billion) Biofuels: Surfactants produced by microorganisms. They are biodegradable and used in shampoos and soaps, for example. (USD 3-5 billion)	Natural ingredients: body and facial products and lotions and sun care products made from plants, which do not contain synthetic chemicals such as parabens and petrochemicals (USD 6-10 billion) Essential oils: concentrated plant extracts with aromatic and functional properties widely used in cosmetics for their sensory and bioactive effects (USD 5-10 billion***)	Dermocosmetics: products with therapeutic and aesthetic benefits, which act in the prevention, care, and treatment of skin, hair, and nails. (USD 30-40 billion)** Organic personal care: hygiene and beauty products formulated with natural ingredients free from synthetic chemicals such as parabens, phthalates, sulfates, and artificial fragrances (USD 20-25 billion) Clean beauty: Beauty products free from toxins, parabens, sulfates (8-9bi) Cruelty-free: cosmetic products that have not been tested on animals (USD 15–20)	AI in beauty and cosmetics: AI in product formulation, AI-generated content creation, AI in augmented reality (AR) shopping, smart beauty devices, data-driven personalization, AI in sustainability practices. (USD 3–3.5 billion) Bioplastics: biodegradable and non-biodegradable plastic produced from renewable sources (USD 15-25 billion) Compostable packaging: PLA, PHA Cellulose, Bamboo, wood derivatives (USD 70-100 billion) Recycled plastic: plastic used in packaging, automotive, and electrical and electronic industry applications. (USD 55-75 billion)

**Included in the "Other" sector in the market projection calculation

FIGURE 57.

National market share in relation to the global market in the eight sub-sectors of the cosmetics bioeconomy



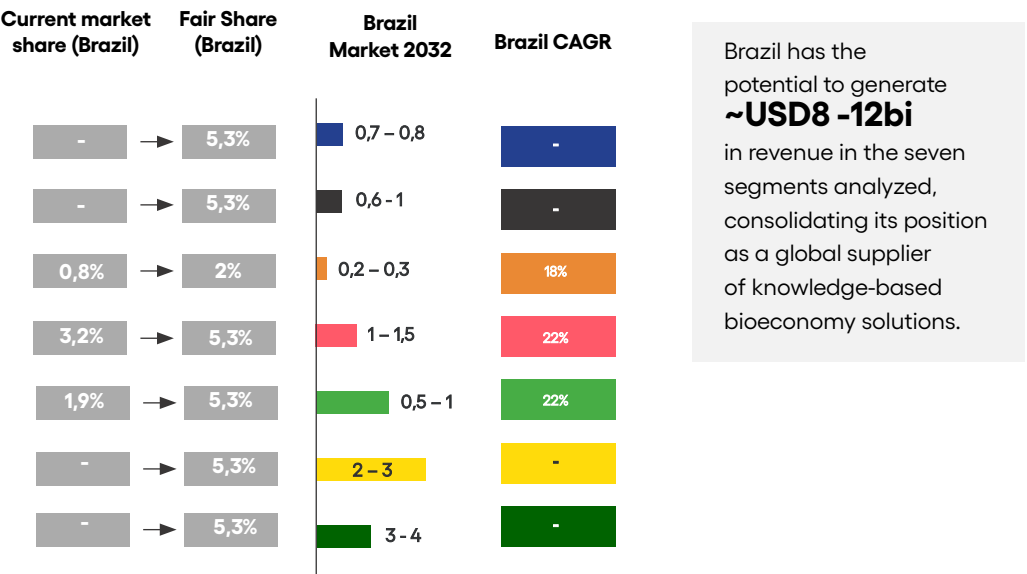
To position Brazil as a global leader in bioeconomy cosmetics, the country needs a coordinated, multisectoral strategy that effectively articulates the strengthening of national production chains, technological advancement, and regulatory improvement. At the same time, it is necessary to expand Anvisa's technical and regulatory capacity, with a special focus on bioinspired active ingredients, ensuring safety, agility, and international recognition. The creation of product development and testing centers will be essential to accelerate innovation and connect science to the market. Furthermore, the implementation of clear public policies to promote research and traceability of inputs derived from sociobiodiversity will help ensure the sustainable origin of the ingredients.

In this sense, public policies and programs have emerged to responsibly promote the knowledge-based bioeconomy responsibly. To ensure quality and sustainability in the production chain, the Amazon Seal for Biocosmetics, granted by the Pará State Metrology Institute (Imetropará), certifies products with traceable and sustainable origins. Furthermore, in the international market, the Organics Brasil program, led by Apex-Brasil, expands Brazil's access to foreign markets by promoting the export of organic and sustainable products, including cosmetics.

Innovation ecosystem and evidence of dynamism

The Brazilian cosmetics sector is a leader in product notifications on SisGen²¹⁰, and is among the first in shipments and registered activities, demonstrating its ability to convert research into commercial innovation. This sector serves as a global reference for integrating innovation, sustainability and socioeconomic inclusion, especially through its supply chains based on sociobiodiversity ingredients.

The entrepreneurial ecosystem is also expanding, with more than 30 startups of mapped cosmetics²¹¹. One example is Nanovetores, which develops nanoparticle technologies to optimize the performance of cosmetic ingredients, having raised an investment in the range of USD 15 million.



SOURCE: global market projection reports; Systemiq/Emerge analysis; expert interviews; expert validation

210. Genetic heritage access records in SisGen – 2024.

211. Deep Techs Brasil Report 2024: Overview of Brazilian Deep Tech Startups

FIGURE 58.
Leading startups in the cosmetics sector focused on knowledge-based bioeconomy technologies

 GLIA INNOVATION	 NANOVETORES	ECOBOTICA
Solution: Active ingredients for high-performance cosmetic products. Technology: Patented technology consisting of a suspension of polymeric nanoparticles decorated on the surface with targeting peptides. Investment received (US\$): Unable to map	Solution: Maximize the performance, protection, and permeability of ingredients through nanoencapsulated active ingredients that enhance formulations for the cosmetics industry. Technology: Prolonged release of active ingredients through six innovative and specific triggers. Investment received (US\$): Between 2 million and 15 million.	Solution: Using nanotechnology, they develop hyperfunctional cosmetic formulations for the market, where skincare can be achieved in 60 seconds. Technology: It offers vegan, natural, and halal-certified products, using nanotechnology to optimize skin care time. Investment received (US\$): Unable to map

International benchmarks: France and South Korea

Brazil can be inspired by models like the French Cosmetic Valley, which has structured an R&D network²¹² and support for internationalization for cosmetics and in 2024 launched a shared laboratory. The “Innovative Cosmetics for CARE” is the result of collaboration between industry and academia: CHANEL, CNRS, ENSCR and University of Rennes²¹³.

The country can also take inspiration from South Korea’s K-Beauty policy, successfully boosted national branding, innovation centers and export stimulus. The results are clear: in 2024, South Korean cosmetics exports exceeded USD 10 billion, surpassing French imports in the US market with USD 1.405 billion and a 22.2% market share.²¹⁴ This growth led to the establishment of more than 4,600 new cosmetics companies that year alone, bringing the total number of brands to over 30,000.²¹⁵.

212. EUROPEAN CLUSTER COLLABORATION PLATFORM.
213. COSMETIC VALLEY. Cosmetic Valley supports research-business collaboration.
214. BUSINESS KOREA. POSCO Holdings Develops New Green Hydrogen Production Technology
215. THE CHOSUN ILBO. POSCO Develops Breakthrough Hydrogen Production Technology.



4

Proposals to boost the knowledge- based bioeconomy market

THE SUCCESS OF THE KNOWLEDGE-BASED BIOECONOMY IN BRAZIL WILL DEPEND DIRECTLY ON THE COUNTRY'S ABILITY TO BUILD BRIDGES BETWEEN SCIENCE AND THE MARKET.. AT THIS INTERSECTION, THE GREATEST RISKS OF DISCONTINUING PROMISING INNOVATIONS OCCUR – A PHENOMENON DESCRIBED AS “THE INNOVATION VALLEY OF DEATH”.

The “valleys of death” represent critical failure points for innovation: the technological valley is where early-stage technologies fail to advance from applied research to a functional prototype. Next, the scaling valley prevents innovations from finding the infrastructure necessary for industrial validation and large-scale production. Finally, the commercialization valley involves regulatory, financial, and demand barriers that prevent products from being competitively inserted into the market.

Overcoming these bottlenecks requires a Brazilian strategy structured around five axes: strengthening the scientific base, consolidating the innovation ecosystem, creating favorable market conditions, strengthening regulation, and creating an integrated financial architecture. Implementing these axis requires specific, mission-guided instruments and mechanisms, derived from consolidated national and international experiences.

The following recommendations are organized into strategic axes and guiding missions, with the aim of promoting systemic and high-impact actions. The missions were defined based on the analyses presented and consensus built with experts in multisectoral technical committees, considering practical experiences, ambition, challenges and installed capacity for the knowledge-based bioeconomy in Brazil.

FIGURE 59.

Areas of action to tackle the three valleys of death in Brazil's knowledge-based bioeconomy ecosystem

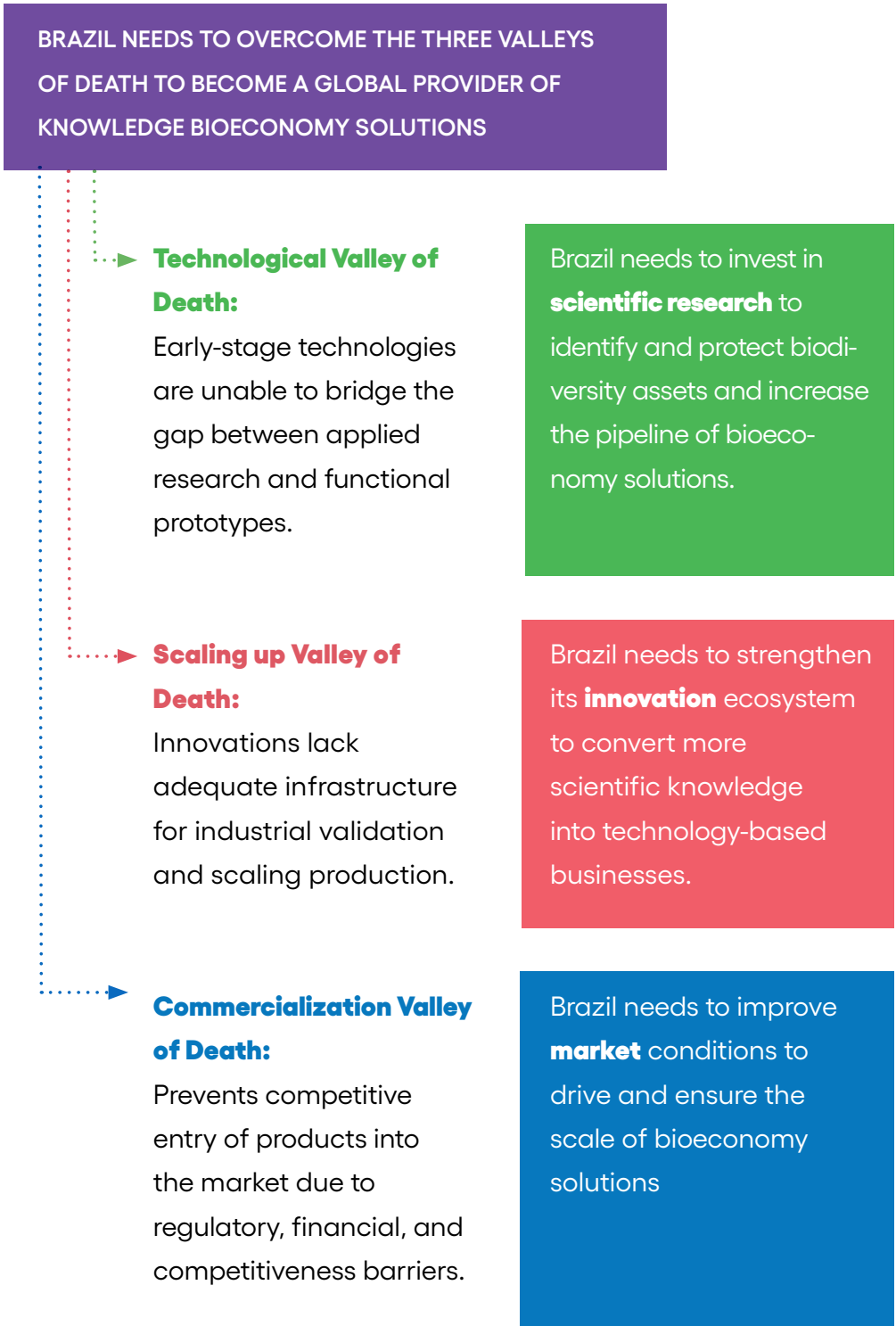


FIGURE 60.

Recommendations to boost the knowledge-based bioeconomy

	Axis	Missions	Suggestions for structural projects
	Brazil needs to invest in its scientific base to identify and protect its biodiversity assets, and increase the pipeline of bioeconomy solutions	Increase genetic mapping of Brazilian biodiversity tenfold over the next ten years	A. National mapping of genetic and molecular assets B. Increase postgraduate programs in strategic areas for the knowledge bioeconomy C. Updating and expanding laboratory infrastructure at universities and research centers
	Brazil needs to strengthen its innovation system to convert more scientific knowledge into technology-based businesses	Increase the number of startups in the knowledge bioeconomy by 20 times over the next 10 years	D. Creation of annual and ongoing programs to promote the research conversion into business within the bioeconomy ¹ E. Expansion of R&D infrastructure and scaling-up plants for the bioeconomy F. Creation of specialized venture capital funds for the bioeconomy through public calls for proposals as anchor capital
	Brazil needs to improve market conditions to drive and ensure the scale of bioeconomy solutions	Achieve a ten-fold increase in the global economic share of the knowledge-based bioeconomy, driven by applied biotechnology and innovation	G. Inclusion of bioeconomy products and technological purchases in public procurement H. Establishment of tax incentives for investments and private purchases of biodiversity bio-inputs ² I. Structuring credit instruments to stimulate production and scaling of value chains ³

4.1 This study’s recommendations for developing the knowledge-based bioeconomy in Brazil

This section brings together recommendations for initiatives and public policies that can boost the knowledge-based bioeconomy in Brazil. The nine proposals below, inspired by the study’s results, are organized into the following areas: science, innovation, market, regulation, and financing. The proposals directly align with the National Bioeconomy Strategy, established by Decree No. 12,044/2024, and reinforce the need for coordination between public policies, science, technology, and innovation that enhance the assets of national biodiversity. These are hypothetical scenarios that aim to overcome current challenges and inspire future actions.

4.1.1 Strengthening the scientific basis

To strengthen the scientific base, Brazil must expand the genetic mapping of national biodiversity by 10 times in the next 10 years. To achieve this, it will be necessary to create a national bank of molecules, microorganisms, and genetic assets linked to patents and innovation.

Furthermore, it is necessary to increase the training of qualified human capital in strategic areas of the bioeconomy, expand cutting-edge infrastructure at universities, and build partnerships with international centers of excellence. These actions aim to attract investment, facilitate technology transfer, and boost the global visibility to Brazilian solutions.

PROPOSAL 1: TO CONDUCT A NATIONAL MAPPING OF GENETIC AND MOLECULAR ASSETS.

DESCRIPTION:
Proposal for a national mapping project of genetic and molecular assets to be led by CNPEM (National Center for Research in Energy and Materials), a private entity that works in partnership with the public sector at the national level, with the capacity for agile, open action and a history sharing. It would be based on the confidentiality of genetic data until the proper formulation of intellectual property and commercialization strategies for the identified bioactive are in place.



OBJECTIVE:

To establish a national genetic mapping infrastructure to protect biological assets and guide the development of new bioeconomy products.



PROJECTED INVESTMENT:

USD 52 million in public capital and **R\$ 3.5 million** in private capital



RELEVANCE:

It would advance the protection and traceability of genetic data, promote partnerships with the productive sector, and enhance the development of innovative solutions based in the knowledge-based bioeconomy



EXPECTED RESULTS:

- Structured national genetic data bank
- Expansion of national research capacity derived from biodiversity



KEY PLAYERS:

CNPEM, Federal Government, national and international private sector, academia, traditional peoples and communities



BENCHMARK:

Chinesische Nationale Genbank (CNGB)



POTENTIAL SCOPE OF ACTIVITIES:

- Genetic and molecular mapping of plants, microorganisms, and animals.
- Development of technologies such as blockchain to ensure traceability and protection of biological data.
- Engagement of companies to use data in product development.
- Inclusion of traditional communities and peoples as mapping agents.

PROPOSAL 2:
TO INCREASE THE NUMBER OF POSTGRADUATE PROGRAMS IN AREAS STRATEGIC TO THE KNOWLEDGE BIOECONOMY.

DESCRIPTION:
Suggested funding for postgraduate scholarships in academic areas related to the bioeconomy. The scholarships should be integrated into projects aligned with the country's interests and also encourage entrepreneurship through programs such as MAI/DAI from CNPq and new business generation programs such as Pipe Fapesp and Catalisa ICT.



OBJECTIVE:

Increase the number of doctoral degrees in critical areas of the bioeconomy and in scientific entrepreneurship, strengthening the country's innovation base.



PROJECTED INVESTMENT:

R\$ 360 million
(over 7 years)



RELEVANCE:

The training of human capital in areas directly linked to the bioeconomy is essential to strengthen the innovation ecosystem. By linking scholarships to the country's interests and entrepreneurship, the project promotes the practical application of scientific knowledge and its conversion into innovation.



EXPECTED RESULTS:

- Training of approximately 20,000 doctoral students in areas related to the bioeconomy
- Increase in technology licensing and creation of startups
- Greater integration of graduate programs with productive sectors



KEY PLAYERS:

CAPES, CNPq, universities, state research funding agencies, PhDs, and technology-based companies



BENCHMARK:

MAI/DAI (CNPq), Pipe Fapesp, and Catalisa ICT.



POTENTIAL SCOPE OF ACTIVITIES:

- Offering 5,000 new doctoral scholarships per year in priority areas
- Promoting internationalization and attracting students from Latin America and strategic countries
- Encouraging the creation of companies and technologies based on dissertations and theses

PROPOSAL 3:
UPDATE AND EXPAND LABORATORY INFRASTRUCTURE AT UNIVERSITIES AND RESEARCH CENTERS

DESCRIPTION:
Suggested allocation of public funds through calls for proposals to modernize university laboratories, prioritizing key technological areas for the knowledge-based bioeconomy. The calls for proposals would explicitly target infrastructure as a platform for open innovation, integrating academia and the market, with provision of services, sharing space between startups and companies, and entering into R&D contracts.



OBJECTIVE:

To modernize and transform university and research laboratories into open innovation platforms that are connected to the productive sector and aligned with the bioeconomy demands.



PROJECTED INVESTMENT:

USD 90 million in public capital and **USD 90 million** in private capital



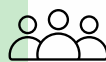
RELEVANCE:

Increasing the experimental and technological capacity of educational institutions focusing on open innovation fosters the connection between ICTs, startups and the productive sector, and reduces costs and risks of generating new business.



EXPECTED RESULTS:

- Modernization of laboratories in priority areas for the bioeconomy
- Expansion of the supply of technological services for the private sector
- Increase in number of collaborative projects between academia and companies
- Higher rate of technology transfer



KEY PLAYERS:

Finep, FNDCT, universities, research institutes, Embrapii, private sector



BENCHMARK:

PRÓ-INFRA (Finep), Embrapii, FAPESP innovation centers



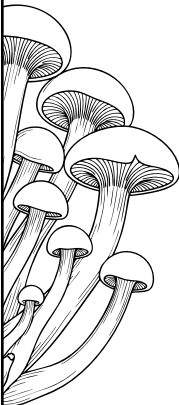
POTENTIAL SCOPE OF ACTIVITIES:

- Launch of calls for proposals related to the modernization of laboratories focused on the bioeconomy
- Establishment of sharing criteria between startups and companies

4.1.2 Consolidating the innovation ecosystem

To strengthen the innovation ecosystem, the goal is to increase by 20 times the number of startups in a technology-based bioeconomy by 2032. This requires enhancing entrepreneurial skills of researchers and founders, and accelerating the viability of conversion of science into viable *startups*.

Implementing specialized centers for scaling biodiversity technologies is strategic for accelerating the industrial production of bioactives and the introduction of solutions into the market. This includes enabling models for the efficient use of biofactories and increasing budgets of innovation centers, as well as forming international partnerships for sharing plants and equipment.



It is also necessary to foster co-development with local communities, whose participation from the outset of projects can facilitate access to biological assets.

PROPOSAL 4:
TO CREATE ANNUAL AND ONGOING PROGRAMS TO PROMOTE THE CONVERSION OF RESEARCH INTO COMMERCIAL BUSINESS.

DESCRIPTION:
Suggested establishment of permanent programs at the national level, aimed at transforming research results into business. In addition to financial support, the model would provide for integration with mentoring networks, technical visits to companies, guidance interviews, and strategic direction led by actors in the productive sector.



OBJECTIVE:
To foster the continuous creation of innovative businesses based on scientific research, strengthening the entrepreneurial ecosystem of the bioeconomy in Brazil.



PROJECTED INVESTMENT:
USD 300 million
(public, over 7 years)



RELEVANCE:
The project would contribute to bridging the gap between academic production and its practical application, driving the transformation of research with high technological potential into viable solutions for the market, fostering entrepreneurship, the creation of startups, and new business models.



EXPECTED RESULTS:

- Creation of up to 1,000 new businesses per year
- Increased success rate of domestic technologies in the market
- Establishment of collaborative networks between science, companies, and investors



KEY PLAYERS:
Finep, state FAPs, CNPq, Sebrae, universities, incubators, private sector



BENCHMARK:
PIPE/FAPESP (Brazil), SBRI (United Kingdom), SBIR (United States), Catalisa ICT (Sebrae), Centelha (Finep), Doutor Empreendedor (FAPERGS/FAPERJ)



POTENTIAL SCOPE OF ACTIVITIES:

- Launch of annual calls for proposals to support science-based projects with business potential
- Direct funding for 1,000 initiatives per year
- Creation of a national network of mentors and experts from the productive sector
- Technical visits and acceleration processes

PROPOSAL 5:
EXPAND R&D INFRASTRUCTURE AND SCALING-UP PLANTS FOR THE BIOECONOMY.

DESCRIPTION:

Suggested creation of infrastructure hubs by expanding existing Scientific and Technological Institutions (ICTs), such as Embrapii units, SENAI centers, and private operators. These centers would function as open innovation environments, offering support for prototypes, validation tests, certifications, and regulatory processes to enable the advancement of research products to the market.



OBJECTIVE:

To create a national network of scale-up and technology validation centers to increase access to specialized services, reduce technical and financial risks, and accelerate the transition of innovations from the laboratory to the market.



PROJECTED INVESTMENT:

USD 90 million in public capital and USD 90 million in private capital



RELEVANCE:

The expansion of scale-up and validation infrastructure fills a critical gap in the innovation cycle. By expanding existing ICTs, it leverages established technical assets and promotes open innovation environments, fostering collaboration between companies, startups, and research centers.



EXPECTED RESULTS:

- Expansion of the network of R&D, scale-up, and validation centers in bioeconomy
- Greater integration among actors in the innovation ecosystem
- Increase in the number of products and technologies validated and launched on the market



KEY PLAYERS:

Embrapii, SENAI, Finep, private operators, startups, large companies in the knowledge bioeconomy sectors



BENCHMARK:

BNDES Criatec, Finep/BNDES/ Butantan Health Investment Fund (2024), Israel Innovation Authority matching capital program, and Bioeconomy Capital fund (USA)



POTENTIAL SCOPE OF ACTIVITIES:

- Launch of public calls for proposal for the implementation of innovation hubs in bioeconomics
- Expansion and modernization of ICTs and private operators
- Structuring of technical and regulatory validation services
- Stimulating private sector co-participation in financing and operation

PROPOSAL 6:
TO CREATE VENTURE CAPITAL FUNDS SPECIALIZED IN BIOECONOMY THROUGH PUBLIC CALLS FOR PROPOSALS²

DESCRIPTION:

Suggested launch of specific public calls for proposals to select specialized venture capital companies. These companies would raise additional funds in the market and structure funds that would invest in startups, bio-based companies, and green technologies aligned with the bioeconomy.



OBJECTIVE:

Foster the continuous creation of innovative businesses based on scientific research, strengthening the entrepreneurial ecosystem of the bioeconomy in Brazil.



PROJECTED INVESTMENT:

USD 120 million in public capital and USD 120 million in private capital



RELEVANCE:

Biotech startups often face barriers to accessing credit and venture capital. By using public resources to attract private investors, the program enables long-term investments in green and biotech technologies, strengthening the innovation ecosystem and expanding the venture capital base in the country.



EXPECTED RESULTS:

- Creation of funds with lines dedicated to the bioeconomy
- Leverage of private capital on a national and international scale
- Increase in the number of bioeconomy startups and companies receiving financing



KEY PLAYERS:

BNDES, Finep, CVM, venture capital funds, specialized managers, private investors



BENCHMARK:

BNDES Criatec, Fundo de Saúde Finep/BNDES/Butantan, Israel Innovation Authority (matching capital), Bioeconomy Capital (EUA)



POTENTIAL SCOPE OF ACTIVITIES:

- Launch of public calls for proposals for the selection of qualified venture capital companies
- Attracting national and international private investment
- Monitoring investments and their impact on bioeconomy companies

4.1.3 Creating favorable market conditions

In the third axis, to improve market conditions, refining the predictability and volume of bioeconomy investment policies is necessary. The goal is to increase by tenfold the share of applied biotechnology and knowledge-based bioeconomy innovation in the global economy.

Fostering the innovation market requires expanding available capital beyond the initial phases, especially for TRLs 3 to 7, with mechanisms that support the transition from research to commercial scale. This involves reducing the perceived risk associated with the maturation and technological complexity of projects, as well as strengthening the taxonomy for bioeconomy investments.

To support such structures there should be effective implementation of planned public programs and direct capital to stimulate the formation of specialized funds and the development of a more robust innovation ecosystem. This includes the greater adoption of knowledge-based bioeconomy solutions in public procurement, which ensures minimum demand and reduces market risks, especially in the early stages. Furthermore, public policies that reduce the cost of biodiversity inputs compared to synthetic alternatives and expand their adoption are essential.

PROPOSAL 7:
TO INCLUDE BIOECONOMY PRODUCTS AND
TECHNOLOGICAL PROCUREMENT IN PUBLIC PROCUREMENT

DESCRIPTION:

Suggested inclusion of sustainability and biological origin criteria in public tenders and technology orders, encouraging the adoption of bioproducts derived from Brazilian biodiversity. The policy could define percentages and/or preferential categories for products and technology orders from the knowledge-based bioeconomy, creating structural demand and strengthening the production chains in the field.



OBJECTIVE:

To create active demand to reduce market risks and attract investments for the consolidation of bioeconomy production chains.



PROJECTED INVESTMENT:

USD 900 million (public)



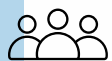
RELEVANCE:

Sustainable public procurement is a strategic tool for boosting new markets and emerging sectors. Encouraging technology and bioproduct orders in government procurement generates predictable and structured demand, reducing risks for investors and accelerating the strengthening of production chains and the entry of new sustainable technologies into the market.



EXPECTED RESULTS:

- Greater adoption of bioproducts and technological orders in public procurement
- Formation of knowledge-based bioeconomy production chains
- Generation of green jobs



KEY PLAYERS:

Federal government, states and municipalities, private sector, cooperatives, startups and technology-based companies



BENCHMARK:

Use of national vaccines in the SUS; family farm foods in school meals; Biopreferred Program (USA); local product purchasing program (Colombia)



POTENTIAL SCOPE OF ACTIVITIES:

- Definition of percentages and/or preferential categories in public calls for proposals for technology orders and bioeconomy products
- Launch of public calls for proposals and purchase requests with bioeconomy criteria
- Launch of technology orders for the knowledge-based bioeconomy

PROPOSAL 8:
TO OFFER TAX INCENTIVES FOR INVESTMENTS AND PRIVATE PURCHASES OF BIODIVERSITY BIO-INPUTS².

DESCRIPTION:
Suggestion that companies that purchase bioinputs – biological products, active ingredients, natural and biotechnological ingredients derived from Brazilian biodiversity – could deduct part of the value of these purchases from the income tax and Social Contribution on Net Profit calculation basis.



OBJECTIVE:

Establish a tax incentive mechanism that stimulates the creation of private demand for sustainable bioinputs, strengthening bioeconomy production chains



PROJECTED INVESTMENT:

USD 1.7 billion (public) and USD 7.2 billion (private)



RELEVANCE:

The creation of tax incentives corrects market distortions, reduces the effective cost of adopting bio-inputs, and encourages the replacement of synthetic and polluting inputs with knowledge-based bioeconomy alternatives.



EXPECTED RESULTS:

- Increase in the volume of purchases of certified bio-inputs
- Expansion of the national market and exports based on biodiversity
- Income generation and strengthening of sustainable production chains



KEY PLAYERS:

Federal Revenue, Ministry of Finance, MAPA, MMA, private companies, bio-input producers



BENCHMARK:

Lei do Bem (incentives for technological innovation in Brazil); R&D Tax Incentive (Australia); tax deductions for green consumption (France)



POTENTIAL SCOPE OF ACTIVITIES:

- Regulation of Law No. 15,070/2024 by executive decree
- Definition of eligibility criteria and tax deduction percentages
- Implementation of a multiplier factor (1.5x) for purchases in the North, Northeast and Central-West regions

PROPOSAL 9:
TO STRUCTURE CREDIT INVESTMENTS TO STIMULATE PRODUCTION AND SCALING UP OF PRODUCTION CHAINS³.

DESCRIPTION:
Suggested creation of new lines of credit with a mandatory allocation of the resources available in rural credit to support projects linked to the production of bioeconomy products, forest management and agroforestry systems.



OBJECTIVE:

To financially enable the development of biodiversity production chains through accessible, targeted and sustainable rural credit instruments.



PROJECTED INVESTMENT:

USD 4.5 billion (private)



RELEVANCE:

Lack of access to credit is one of the main obstacles to the development of the bioeconomy in rural areas. Sociobiodiversity products require longer maturation times and face regulatory and market barriers. By guaranteeing specific credit lines, the project creates the structural conditions for the advancement of emerging supply chains.



EXPECTED RESULTS:

- Expansion of the productive area under Agroforestry Systems (SAFs) and sustainable management
- Largest volume of credit allocated to the knowledge bioeconomy
- Rural income generation with socio-environmental sustainability



KEY PLAYERS:

MAPA, Banco do Brasil, BNDES, credit unions, rural producers, agro-industries and family farming



BENCHMARK:

Eco.business Fund (Latin America and the Caribbean), World Bank bioeconomy programs in Colombia



POTENTIAL SCOPE OF ACTIVITIES:

- Definition of a fixed percentage for rural credit aimed at biodiversity
- Creation of differentiated conditions (term, guarantees, interest) for biodiversity species, agroforestry systems and forest management
- Technical and institutional support for access to credit

4.2 Strengthening regulation

As explained in previous chapters, regulatory adjustments are necessary to enable the knowledge-based bioeconomy in Brazil. Two priorities are standardizing the application of the Biodiversity Law and defining a specific taxonomy for the sector.

The first step is to build a stable, innovation-oriented regulatory environment by consolidating interpretative guidelines and standard documents for applying the Biodiversity Law. This initiative should be conducted with the participation of public agencies, the private sector, and civil society to simplify procedures and ensure legal certainty for companies, researchers, and communities. International experiences, such as those of Colombia, Peru, and the European Union, demonstrate the relevance of similar initiatives to facilitate access and benefit sharing.

The second step is to create a taxonomy that allows for the appropriate classification and tracking of assets and financial flows associated with the bioeconomy. The lack of clear definitions—such as the distinction between fertilizers and biofertilizers, or the classification of products as originating or not from Brazilian biodiversity—makes it difficult to monitor investments and formulate public policies. The development of a specific taxonomy is essential to guide financing, regulatory, and reporting instruments.



4.3 Creating integrated financial architecture

The advancement of the knowledge-based bioeconomy in Brazil requires the use of an articulated combination of financial instruments such as economic subsidies, credit, equity, public procurement and tax incentives. None of these instruments, alone, is capable of meeting all the demands of an innovation chain that ranges from basic research to the global market. Building a solid bioeconomy ecosystem therefore requires a financial architecture that integrates these tools in a coordinated manner, respecting the technological maturity stage (TRL) and risk profile of the projects.

- **Economic subsidy:** essential in the initial phases to support genetic mapping, researcher training and scientific infrastructure.
- **Directed credit:** necessary for the implementation of biofoundries, pilot plants and structuring of production chains.
- **Equity (venture capital):** decisive for scaling startups and emerging companies.
- **Public procurement:** guarantee structured demand in sectors such as health, education and food.
- **Tax incentives:** fundamental to strengthening the competitiveness of bioproducts.

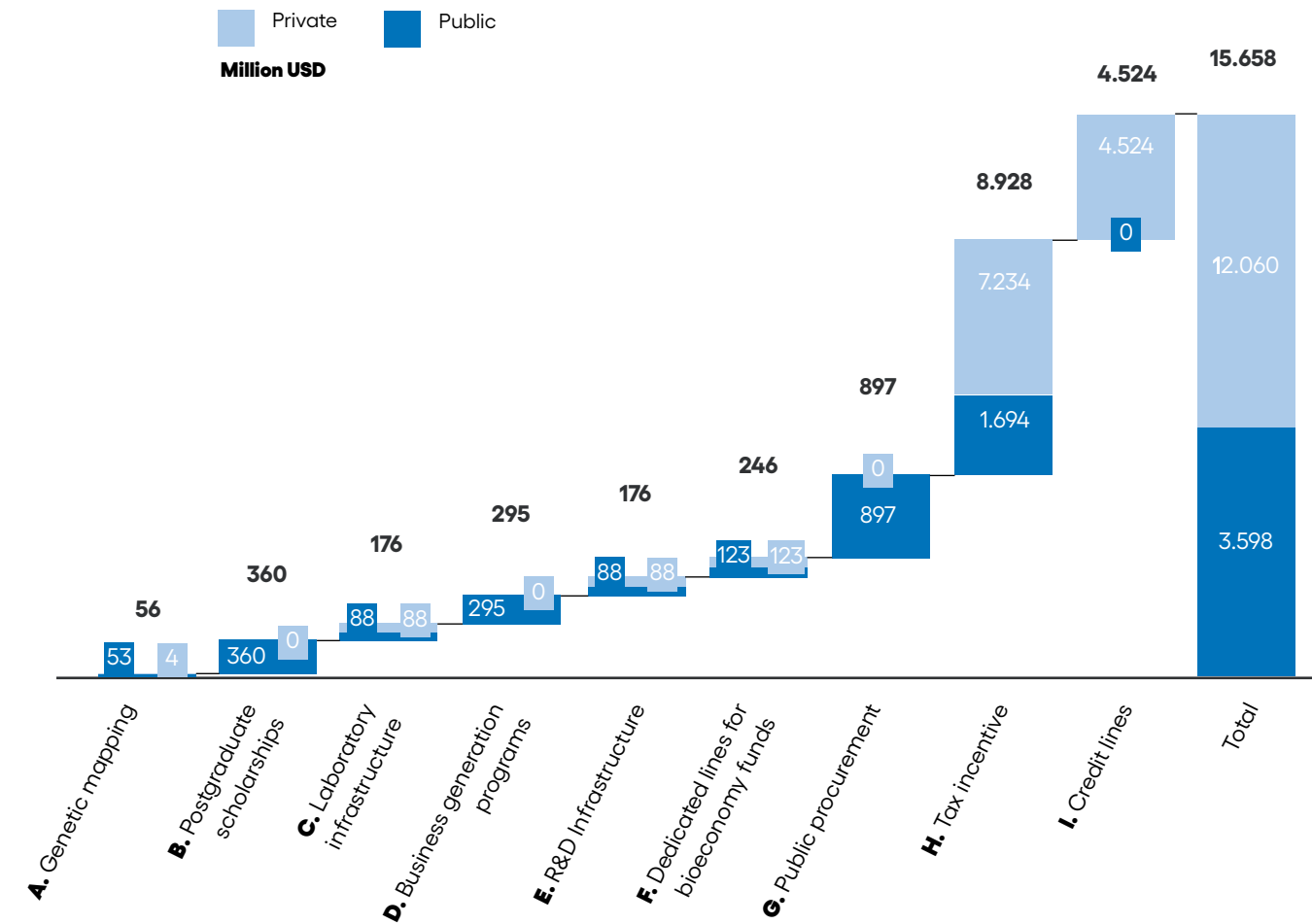
The coordinated application of these financial instruments aims to generate concrete and measurable impacts. The expected results include a significant expansion of genetic and molecular knowledge about Brazil's biodiversity; an increase in doctoral training in strategic areas of the bioeconomy; the creation of up to a thousand new scientific businesses per year; the attraction of private capital for bio-based innovation; the expansion of public procurement of bioinputs and bioactives; the reduction of regulatory barriers related to benefit sharing; and the strengthening of supply chains based on sociobiodiversity, which promote economic inclusion and environmental conservation.

4.4 Necessary investments

The development of the knowledge-based bioeconomy in Brazil will require public and private investments estimated at USD 15.7 billion over the next ten years²¹⁶. This volume is necessary to structure genetic and molecular mapping projects of biodiversity, modernize research infrastructure, expand the training of doctors in areas such as biotechnology, molecular ecology and green chemistry, and create platforms for technological scale-up, such as biofoundries and regional pilot plants. These investments form the basis for transforming Brazilian biodiversity into market assets and positioning Brazil as a global leader in this segment.

These contributions are strategic for accelerating knowledge generation, driving the creation of new scientific businesses, and consolidating a market environment conducive to biodiversity-based innovation. With them, Brazil will be able to unlock a market estimated at USD 100-140 billion by 2032, expanding job creation, income, and social impact. The potential return is significant: in addition to capturing new global markets, these investments will strengthen local production chains and socioeconomic development, increase national competitiveness in high-value-added sectors, and reinforce Brazil’s image as a global benchmark for sustainable solutions.

FIGURE 61.
Investments needed to unlock the potential of the knowledge-based bioeconomy in Brazil



216. Team analysis, detailed in Annex I

5

A Call to Action - Building Pathways to the Knowledge- based Bioeconomy

AS DEMONSTRATED, BRAZIL COULD BECOME A GLOBAL PROVIDER OF SOLUTIONS IN THE BIOECONOMY FIELD AND GENERATE BETWEEN USD 100 BILLION AND USD 140 BILLION PER YEAR BY 2032, IN THE FOOD, HEALTH, MATERIALS, COSMETICS AND AGRIBUSINESS PRODUCTS AND SERVICES SECTORS²¹⁷. REALIZING THIS POTENTIAL REQUIRES INTERSECTORAL COORDINATION, TARGETED INVESTMENTS, AND A CONDUCIVE REGULATORY AND INSTITUTIONAL ENVIRONMENT. THIS INCLUDES INCREASING THE COUNTRY'S CAPACITY TO BRIDGE THE GAP BETWEEN THE SCIENTIFIC BENCH AND THE MARKET, ESPECIALLY IN TRLS 3 TO 7, TO SUPPORT NAVIGATING THE TECHNOLOGICAL, SCALING AND COMMERCIALIZATION VALLEYS OF DEATH.

Advancing this agenda requires a convergence between scientific advancement, industrial transformation, and the protection of ecosystems and traditional knowledge. Collaboration between government, industry, investors, academia, civil society, and nature will be essential to mobilize investment, build legal certainty, expand adoption, and ensure that innovation translates into value for people and nature.

²¹⁷. Team analysis - detailed in appendix 1 (projection details)

5.1 A new governance of innovation: from triple to sixfold helix

Traditionally, the innovation agenda uses the triple helix concept to structure cooperation between the main actors in the innovation ecosystem: government, research centers and companies. The government is responsible for ensuring legal certainty; universities and research centers for training people and advancing knowledge; and companies for producing goods and services. However, to consistently drive socioeconomic development, each of these actors needs to expand their traditional activities.

GOVERNMENTS can promote solid and consistent public policies, such as tax incentives, investments in human capital training, infrastructure, subsidies and specific credit lines for innovation.

UNIVERSITIES AND RESEARCH CENTERS should seek greater proximity with society, encouraging technology transfer and the generation of new businesses based on the knowledge produced in their laboratories.

COMPANIES should invest in research, development and new innovative businesses to gain markets and build sustainable competitive advantages.

The complexity of the knowledge-based bioeconomy requires expanding the model to a six-fold helix, which effectively incorporates three new actors: civil society, investors, and nature. This expansion not only responds to contemporary challenges but is also fully aligned with Decree No. 12,044/2024, which establishes the National Bioeconomy Strategy. New actors also need to expand their traditional operations.

CIVIL SOCIETY: should expand its advisory role to also act as a protagonist in the adoption and collaboration in the development of knowledge-based bioeconomy solutions, contributing local knowledge, valuing sociobiodiversity products and helping to guide innovation.

INVESTORS: should expand their operations in sectors of the bioeconomy mobilizing patient and specialized capital.

NATURE: recognition of nature as a living organism that brings together strategic assets for the country's competitiveness in the field of knowledge-based bioeconomy, being itself a source of innovation.

In the proposed configuration, traditional knowledge is a fundamental part of the bioeconomy. Just as universities and research centers generate academic and technological knowledge, traditional communities and indigenous peoples have accumulated, for generations, practices and understandings about the sustainable use of biodiversity and ecosystem management. This knowledge—empirical, territorialized, and adaptive—must engage with conventional science in contexts such as bio-industries, regenerative technologies, and forest management²¹⁸.

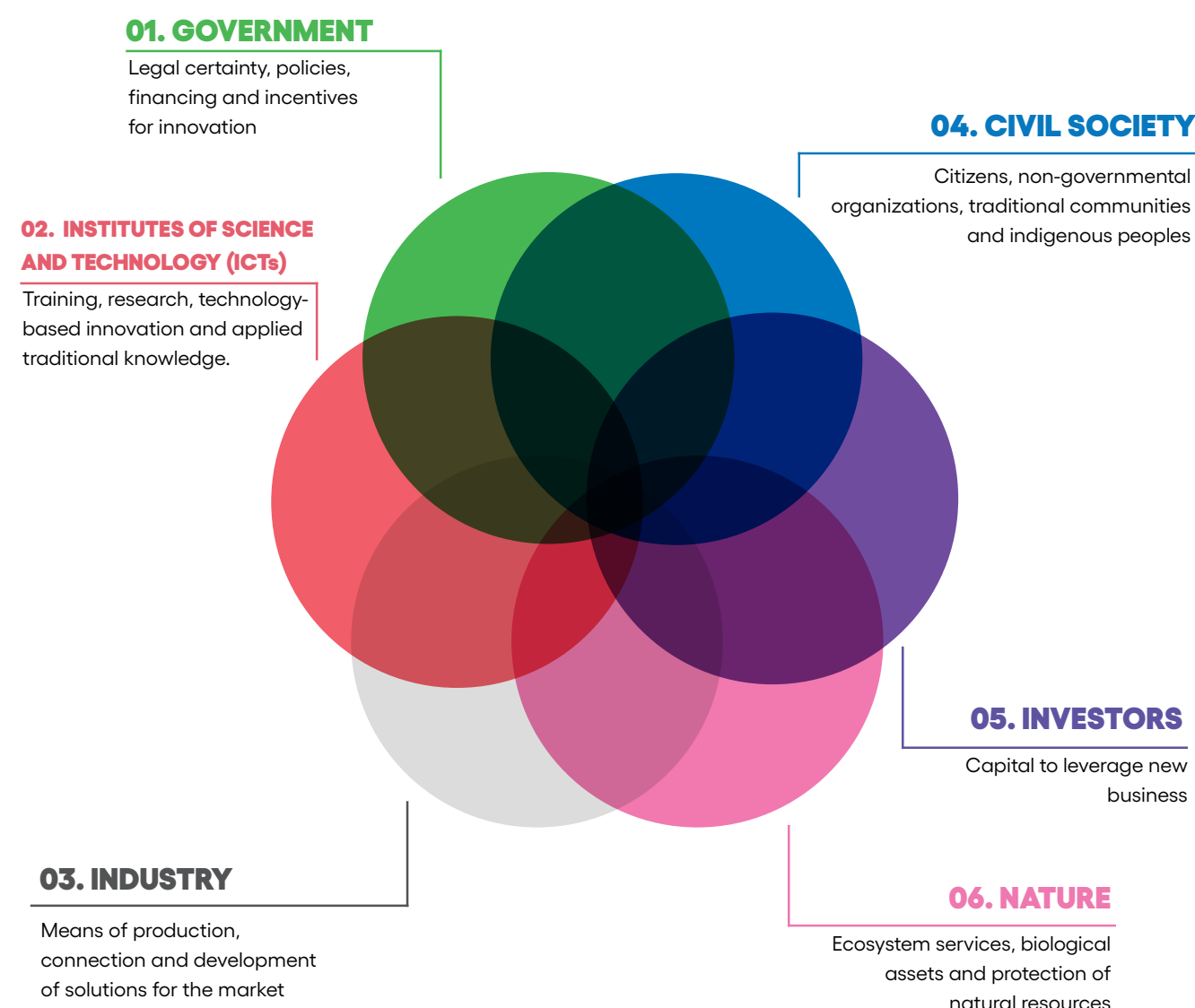
Furthermore, traditional peoples are holders of knowledge, active protectors of nature, and contribute to the conservation of biomes through their ways of life. Their presence in the six-fold helix, therefore, occurs across the board—as producers of knowledge, fundamental actors in civil society, and central agents in environmental preservation. A solid and fair bioeconomy is only possible with their structured, consistent, and respectful participation.

²¹⁸ BRAZIL. Ministry of Science, Technology, and Innovation. Traditional knowledge joins science in the National Innovation System.

FIGURE 62.

Actors in the knowledge-based bioeconomy ecosystem

The success of the knowledge-based bioeconomy depends on the participation of all actors in society



Unlocking the potential of the knowledge-based bioeconomy requires other actors to also expand their traditional operations.

The development of the knowledge bioeconomy in Brazil can no longer be understood solely through the lens of the triple helix. To address the challenges and harness the country's unique potential, it is necessary to adopt a six-fold helix perspective.

FAIR PARTNERSHIPS WITH TRADITIONAL COMMUNITIES — REBALANCING POWER RELATIONS FOR THE BIOECONOMY

Daniel Pimentel and Cristiane Julião Pankararu, with contributions from Renata Amaral

For millennia, indigenous peoples and traditional communities have developed, tested, and transmitted knowledge linked to the ecosystems of which they are a part. Their practices are sophisticated systems of observation, experimentation, and adaptation that have produced banks of knowledge about medicinal and edible plants, ecological cycles, and the properties of plant species, fungi, and microorganisms. This living science, built collectively and based on reciprocal relationships with nature, offers valuable insights into the bioeconomy of the future.



To recognize and value this knowledge is essential to create innovative solutions rooted in Brazil's biological and cultural diversity.

Relations between companies and Indigenous peoples, quilombola communities, and many other traditional peoples and communities (PCTs) have been marked by structural asymmetries, invisibility, unilateral extraction of value, and, frequently, processes of devaluation of their knowledge. Even well-intentioned initiatives can reproduce extractive logics if not guided by clear principles of justice, reciprocity, and self-determination of the peoples involved.

Law n°. 13,123/2015 addresses access to genetic heritage and associated traditional knowledge by mandating **Free, Prior, and Informed Consent (FPIC)** and ensuring the **fair and equitable sharing of benefits**. When it comes to using associated traditional knowledge, non-compliance with established practice is unfortunately common.. In addition to there being no unified procedure for FPIC that ensures the process is conducted in a legitimate and standardized manner, many communities sign contracts without adequate understanding of the terms, with insufficient time for collective deliberation, or under economic pressure.



Although formal consent is required, consultation documents indicate that it is seldom obtained in practice. The failure to secure consent that is truly informed, free from coercion, and prior constitutes a violation of the spirit of ILO Convention 169 and the UN Declaration on the Rights of Indigenous People

FPIC is often treated as an isolated event, but in reality it is an ongoing process of dialogue that must respect the communities' own timelines, organizational structures, and legal systems.

Furthermore, contractual instruments often replicate unequal market logics: there are opaque clauses on profit sharing, secondary use of genetic data, intellectual property rights, and the revocability of consent. Compensation methods are often disconnected from community priorities, and the "benefit" is unilaterally defined by companies. Asymmetric access to legal advice and technical information prevents truly equitable negotiations.

For FPIC to be effectively respected, it is necessary to adopt a clear procedure that goes beyond formal contractual agreements. It is necessary to: i) recognize autonomous community protocols; ii) guarantee adequate time and conditions for collective deliberation; iii) provide independent technical advice; iv) ensure reversibility and monitoring mechanisms; and v) implement pre-established procedures through federal regulations to provide greater legal certainty to all involved. In this sense, the prior definition of formalities that must be

minimally followed would enable greater investments and protection for the communities involved, which is in everyone's interest.

Faced with these challenges, it is essential that any relationship between companies and traditional communities in the knowledge-based bioeconomy be guided by principles, such as:

Principles of fair relations with indigenous peoples, traditional communities and family farmers

1. Self-determination and community time

Respect the collective decision-making mechanisms of each community. It's important to verify whether the community has its own consultation and consent protocol, in addition to considering the community's timeframe for negotiation. Legitimate consent only occurs when there is genuine collective deliberation, not imposition or haste.

2. Clarity and mutual understanding

All proposals must be presented in a comprehensible manner, in accessible languages, and with culturally appropriate materials, including translation services, if necessary, and/or a qualified professional prepared to interact with the community. The community must understand the risks, possible uses, and future implications, including legal and commercial ones.

3. Independent technical and legal advice

To ensure equal conditions, communities must have the support of trusted technical and legal advisors throughout the negotiation process, paid preferably by the company or by external funds, without compromising their independence.

4. Community-defined benefits

Benefit sharing should reflect the community's interests and priorities—which may include education, infrastructure, cultural support, and territorial management, not just financial transfers. Benefits should not be symbolic or conditional on commercial performance.

5. Reversibility and continuous control clauses

Contracts must ensure that the use of knowledge can be reviewed or revoked if there is a misuse of purpose or breach of trust. Governance must be permanent, with monitoring mechanisms, social auditing, and active listening.

6. Building long-term relationships, not one-off transactions

The logic should be one of alliance and co-production of value, not of simple transaction. This includes investments in training, territorial governance, and institutional strengthening of communities. To demonstrate the development of the relationship, it is important to document all stages of the consultation: meetings, decisions, materials presented, questions raised, and responses given. FPIC is not just a document with signatures, but rather a set of documents that demonstrate collective participation.

The advancement of the bioeconomy in Brazil needs to break with the historical cycle of predatory extractivism and the invisibility of traditional peoples and communities.



The relationship must be one of ethical, structuring and strategic pillars. Only with fair contracts, legitimate processes, and shared gains will it be possible to build a bioeconomy that values the standing forest, traditional knowledge, and the diversity of ways of life in Brazilian territories.



5.2 A call to action

TO FOSTER A SOCIALLY JUST, ECOLOGICALLY RESPONSIBLE, AND ECONOMICALLY SUSTAINABLE BIOECONOMY, THE FOLLOWING ACTIONS SHOULD BE PRIORITIZED BY GOVERNMENTS, SCIENTIFIC INSTITUTIONS, INDUSTRY, CIVIL SOCIETY, AND INVESTORS. THE STUDY PROPOSES THE RECOGNITION AND APPRECIATION OF NATURE AS A LIVING PRODUCTIVE SYSTEM.



Federal, state, municipal governments and public agencies

- **Strengthening** conservation policies and valuing nature's services as a supplier of inputs for sustainable industrial chains.
- Promoting legal certainty in the **application of the Biodiversity Access and Benefit Sharing Act**, launching campaigns, informative documents and detailing practical cases and benefit sharing models.
- **Integrating the knowledge-based bioeconomy into national strategies** such as the Ecological Transformation Plan, the National Bioeconomy Development Plan, the New Industry Brazil, and regional development plans.
- Fostering cooperation and open **international markets** for bioeconomy solutions.
- Establishing **enabling governance** to realize the potential of the knowledge-based bioeconomy.
- Increasing the **technical and operational capacity** of ministries and regulatory agencies (such as MAPA, MMA and Anvisa).
- Developing a national **taxonomy** for bioeconomy investments.
- Establishing instruments to **encourage production** based on sociobiodiversity.
- Leading discussions on **the Nagoya Protocol**, advocating for a fair distribution that accelerates innovation for the sustainable use of biodiversity.
- Facilitating the implementation of **public programs** to support innovation, tax incentives, and credit lines for public procurement.



Scientific and technological institutions (ICTs)

- Promoting an **entrepreneurial culture** among faculty and students, including innovation, business, and bioeconomy content in undergraduate and graduate curricula.
- Encouraging partnerships with **international centers** of excellence.
- Encouraging partnerships with **local communities and traditional peoples** as a source of knowledge.
- Training **researchers and managers of innovation centers** in innovation legislation, intellectual property and technology transfer.
- Encouraging **interdisciplinary research** aimed at solving the country's challenges.
- Strengthening **cooperation** with the **private sector**.
- Strengthening the **integration** of databases, equipment and technical services in shared-use networks.
- Strengthening **university incubators and accelerators**, with a focus on startups.



Industry

- Adopting **bio-inputs and bio-ingredients** as alternatives to fossil inputs.
- Integrating **environmental and social criteria into supply chains**, promoting traceability and transparency.
- Including **nature-based innovation goals** in your Environmental Social Governance (ESG) strategies.
- Building knowledge about **legal and regulatory frameworks**, especially in relation to the Law on Access to Biodiversity and Benefit Sharing and the Intellectual Property Law.
- Creating business models that incorporate **community practices**.
- Developing **technical capacity for cooperation with ICTs**, understanding institutional approval processes and adapting R&D schedules to this logic.
- Encouraging a culture of open innovation, actively seeking **partnerships with ICTs and communities** to develop innovative products and business models based on biodiversity and local knowledge.
- Supporting academic incubators and entrepreneurial training programs, contributing with **mentoring and innovation challenges**.
- Contributing to shared **scientific infrastructure** by establishing agreements for the use of laboratories, equipment, and specialized services.



Civil society

- **Valuing products** of socio-biodiversity and the local bioeconomy.
- Supporting **education and communication** initiatives focused on the bioeconomy.
- **Actively participating** in governance spaces, prior consultation and public policy development.
- **Co-creation of solutions** with companies, researchers and governments, from project design onwards.
- Strengthening **community networks** that work with bioeconomy and traditional knowledge.
- Documenting, preserving and disseminating traditional practices linked to the sustainable use of biodiversity.



Nature

- To be recognized as a living productive system, valued as a **strategic supplier of ecosystem services** and inputs for industrial chains of the new biodiversity-based economy.
- Guide the **development of impact metrics** that reflect the value of ecosystem services for economic development, incorporating environmental value into investment, innovation, and public policy decisions.
- Guide the **expansion and consolidation of protected areas**, such as reserves, parks and demarcated lands.
- Guide metrics that ensure that bioeconomy models promote not only sustainable use, but also **ecological resilience and ecosystem restoration**.



Investors

- Including climate and biodiversity loss risks in systemic risk analyses, **anticipating impacts on value chains, regulation, and financial performance**.
- **Demanding transparency and positive socio-environmental impact** as criteria for business evaluations.
- Establishing appropriate criteria for **assessing risk and impact in nature-based innovation**.
- Developing financial mechanisms appropriate to the technological risk of the knowledge-based bioeconomy, such as **blended finance, partial guarantees and flexible credit**.
- Increasing investment in managers with lines **dedicated to the bioeconomy**.
- **Accelerating the training of investment fund** and venture capital managers in the knowledge-based bioeconomy.
- Connecting **bioeconomy entrepreneurs to global investment** and acceleration networks.
- Collaborating with regulators and international financial coalitions to promote standards that accelerate the **transition to low-carbon economies**.



Appendix 1: Chapter 3 Methodology

GENERAL PREMISES

Brazil will defend its share of the current market (Market Share) from the conventional sector to the bioeconomy market in 2032

If the maintenance of this Market Share implies a CAGR greater than twice the global CAGR, a maximum limit of two times the global CAGR will be adopted for the growth of the bioeconomy sector.

In cases where the Market Share of the bioeconomy sector is larger than the conventional sector, the Fair Share projected for 2032 is the same as the current Market Share of that sector.



AGRIBUSINESS

SUBSECTOR Bio-inputs

REVENUE PROJECTION CALCULATION PREMISE FOR 2032

A market value of \$2 billion to \$3 billion was considered for 2032

SOURCES Interview with an expert (Gerson - Gênica)

THE BUSINESS RESEARCH COMPANY. Agricultural Biologics Global Market Report. Available at: <https://www.thebusinessresearchcompany.com/report/agricultural-biologics-global-market-report>. Accessed on: May 22, 2025.

FORTUNE BUSINESS INSIGHTS. Agricultural Biologics Market Size, Share & Industry Analysis, By Type (Biopesticides, Biostimulants, and Biofertilizers), By Source (Microbial and Biochemicals), By Application Method (Foliar Spray, Soil Treatment, Seed Treatment, and Others), By Crop (Row Crops, Fruits & Vegetables, and Others), and Regional Forecast, 2025-2032. Published in jan. 2025. Available at: <https://www.fortunebusinessinsights.com/industry-reports/agricultural-biological-s-market-100411>. Accessed on: May 22, 2025.

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AGRIBUSINESS

SUBSECTOR

Genetic improvement

REVENUE PROJECTION
CALCULATION PREMISE
FOR 2032

It was assumed that the Brazilian CAGR until 2032 would be twice the global CAGR of the plant genetic improvement market.

SOURCES

NATIONAL INSTITUTE OF INDUSTRIAL PROPERTY (Brazil). Gene editing: mapping of patents associated with CRISPR technologies and their applications in agriculture and livestock. Rio de Janeiro: INPI, 2024. Available at: https://www.gov.br/inpi/pt-br/assuntos/informacao/RadarTecnologicoEdioGnica26_06_2024.pdf. Accessed on: May 22, 2025.

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MORDOR INTELLIGENCE. Animal Genetics Market Size and Share Analysis – Industry Research Report – Growth Trends (2024–2029). Published in 2024. Available at: <https://www.mordorintelligence.com/pt/industry-reports/animal-genetics-market>. Accessed on: May 22, 2025.



AGRIBUSINESS

SUBSECTOR

Additives in animal feed

REVENUE PROJECTION
CALCULATION PREMISE
FOR 2032

Brazil's current MS on animal feed additives was used to project the 2032 Fair Share

SOURCES

MORDOR INTELLIGENCE. Feed Additives Market Size & Share Analysis – Growth Trends & Forecasts up to 2030. Published in 2025. Available at: <https://www.mordorintelligence.com/industry-reports/global-feed-additives-market-industry>. Accessed on: May 22, 2025.

FORTUNE BUSINESS INSIGHTS. Feed Additives Market Size, Share, Growth & Industry Analysis, By Type (Amino Acids, Vitamins & Minerals, Antioxidants, and Others), By Animal Type (Cattle, Poultry, Swine, and Others), and Regional Forecast, 2025–2032. Published in May 5 2025. Available at: <https://www.fortunebusinessinsights.com/feed-additives-market-104345>. Accessed on: May 22, 2025.

MORDOR INTELLIGENCE. Brazil Feed Additives Market Size and Share Analysis – Industry Research Report – Growth Trends (2024–2029). Published in 2024. Available at: <https://www.mordorintelligence.com/pt/industry-reports/brazil-feed-additives-market-industry>. Accessed on: May 22, 2025.



AGRIBUSINESS

SUBSECTOR

Waste reuse

REVENUE PROJECTION
CALCULATION PREMISE
FOR 2032

An estimated ~1 billion tons of residues from agricultural and forestry chains were considered. Harvesting, conversion, and final price rates were refined through expert interviews.

SOURCES ABIB – Brazilian Association of Biotechnology Industries. Institutional portal. Available at: <https://www.abibbrasil.org.br>. Accessed on: May 20, 2025.



AGRIBUSINESS

SUBSECTOR

Animal biotechnology

REVENUE PROJECTION
CALCULATION PREMISE
FOR 2032

It was assumed that the Brazilian CAGR until 2032 would be twice the global CAGR

SOURCES GRAND VIEW RESEARCH. Food Technology Market Size, Share & Trends Analysis Report By Component (Hardware, Software, Services), By Application (Delivery, Food Science, Supply Chain, Kitchen & Restaurant Tech), By Industry (Dairy Products, Fish, Meat, and Seafood, Beverages, Bakery and Confectionary, Others), By Region, And Segment Forecasts, 2023–2030. 2023. Available at: <https://www.grandviewresearch.com/industry-analysis/food-technology-market-report>. Accessed on: May 22 2025.

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GRAND VIEW RESEARCH. Brazil Food Technology Market Size & Outlook, 2023–2030. 2024. Available at: <https://www.grandviewresearch.com/horizon/outlook/food-technology-market/brazil>. Accessed on: May 22 2025.



MATERIALS

SUBSECTOR

Bioplastics

PREMISE FOR CALCULATING
REVENUE PROJECTION
FOR 2032

A Fair Share of 10% was considered for the 2032 market, taking into account the current MS of the green polyethylene segment

SOURCES FAPESP RESEARCH JOURNAL. The promise of bioplastics. Pesquisa FAPESP, São Paulo, n. 290, Apr. 2020. Available at: https://revistapesquisa.fapesp.br/a-promessa-dos-bioplasticos/#bioplasticoC_290. Accessed on: May 22, 2025.

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GRAND VIEW RESEARCH. Bioplastics Market Size, Share & Trends Analysis Report by Product (Biodegradable, Non-biodegradable), by Application (Packaging, Agriculture, Automotive & Transportation, Electronics, Textile), by Region, and Segment Forecasts, 2025–2030. Published in october. 2024. Available at: <https://www.grandviewresearch.com/industry-analysis/bioplastics-industry>. Accessed on: May 22, 2025.



MATERIALS

SUBSECTOR

Compostable packaging

PREMISE FOR CALCULATING
REVENUE PROJECTION
FOR 2032

Based on Brazil's current MS for the conventional packaging sector

SOURCES TOWARDS PACKAGING. Compostable Packaging Market Strategic Analysis & Growth Opportunities. Published on February 6, 2025. Available at: <https://www.towardspackaging.com/insights/compostable-packaging-market-sizing>. Accessed on: May 22, 2025.



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FORTUNE BUSINESS INSIGHTS. Packaging market size, share, and industry analysis, by material (plastic, paper and cardboard, metal, glass, wood, and others), by product type (rigid packaging and flexible packaging), by packaging type (primary, secondary, and tertiary), by end-use industry (food, beverages, cosmetics and personal care, chemicals and lubricants, healthcare, consumer goods, civil construction, electronics, automotive, and others), and regional forecast, 2024–2032. Published in May 5th 2025. Available at: <https://www.fortunebusinessinsights.com/pt/packaging-market-110901>. Accessed on: May 22, 2025..

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MATERIALS

SUBSECTOR
Natural rubber

PREMISE FOR CALCULATING REVENUE PROJECTION FOR 2032

Based on Brazil’s current MS of the conventional rubber sector

SOURCES ALLIED MARKET RESEARCH. Natural Rubber Market by Application (Tires, Medical Gloves, Tubes, Footwear, Straps, Rubber Covered Roller – MRO, Molded Rubber Product, Bonding Gum Compound, Conveyors Belts, Extruded Products, Rubberized Coir Product, Rubber Bands, Latex Adhe

sives, Balloons, Rubber Lining, Latex Foam, Latex Thread, Condoms, and Industrial Gloves), by Region (North America, Europe, Asia-Pacific, Latin America, West Africa, and Rest of World): Opportunity Analysis and Industry Forecast, 2024–2034. Published in december 2024. Available at: <https://www.alliedmarketresearch.com/natural-rubber-market-A107974>. Accessed on: May 22, 2025.

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GRAND VIEW RESEARCH. Rubber Market Size, Share & Trends Analysis Report by Type, by End-Use (Automotive, Construction, Industrial, Healthcare, Consumer Goods, Packaging), by Region, and Segment Forecasts, 2024–2030. Published in 2024. Available at: <https://www.grandviewresearch.com/industry-analysis/rubber-market-report>. Accessed on: May 22, 2025.

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MATERIALS

SUBSECTOR
Ecofibers

PREMISE FOR CALCULATING REVENUE PROJECTION FOR 2032

The ecofiber segment in Brazil has a larger share of the global market than the conventional textile segment, therefore the MS of the ecofiber market was considered for the 2032 projection.

SOURCES FORTUNE BUSINESS INSIGHTS. Eco Fiber Market Size, Share & Industry Analysis, By Type (Organic Fibers, Recycled Fibers, Regenerated Fibers, and Others), By Application (Clothing/Textile, Household & Furnishings, Industrial, Medical, and Others), and Regional Forecast, 2024–2032. Published in May 5th 2025. Available at: <https://www.fortunebusinessinsights.com/eco-fiber-market-106356>. Accessed on: May 22, 2025.

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MATERIALS

SUBSECTOR

Recycled plastic

PREMISE FOR CALCULATING REVENUE PROJECTION FOR 2032

Based on Brazil’s current MS for the conventional packaging sector

SOURCES GRAND VIEW RESEARCH. Recycled Plastics Market Size, Share & Trends Analysis Report By Product (PET, PE, PP, PVC, PS), By Source (Bottles, Films, Foams), By Application (Packaging, Building & Construction, Electrical & Electronics, Automotive), By Region, And Segment Forecasts, 2023–2030. 2023. Available at: <https://www.grandviewresearch.com/industry-analysis/recycled-plastics-market>. Accessed on: May 23rd 2025.

MARKETSANDMARKETS. Recycled Plastics Market by Source (Bottles, Fibers, Films, Foams), Process, Plastic Type (PET, PE, PP, PVC, PS), Type, End-Use (Packaging, Textiles, Building & Construction, Automotive, Electrical & Electronics), and Region - Global Forecast to 2030. 2023. Available at: <https://www.marketsandmarkets.com/Market-Reports/recycled-plastic-market-115486722.html>. Accessed on: May 23rd 2025.



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MATERIALS

SUBSECTOR

Engineered wood

PREMISE FOR CALCULATING REVENUE PROJECTION FOR 2032

A current market of US\$0.26 billion was considered in the engineered wood market and the projected market value between US\$1 billion and US\$3 billion in 2032.

SOURCES Interview with an expert

ALLIED MARKET RESEARCH. Engineered Wood Market Size, Share, Competitive Landscape and Trend Analysis Report, by Type, by Application, by End User Industry: Global Opportunity Analysis and Industry Forecast, 2024–2033. Published in December 2024. Available at: <https://www.alliedmarketresearch.com/engineered-wood-market>. Accessed on: May 22, 2025.

MATERIALS

SUBSECTOR

Bio-based foams, biolubricants and biosurfactants

PREMISE FOR CALCULATING REVENUE PROJECTION FOR 2032

Assumption that the bio market will capture 5 to 15% of the conventional market for these products by 2032

SOURCES

GRAND VIEW RESEARCH. Surfactants Market Size, Share & Trends Analysis Report By Source (Synthetic, Biobased), By Application (Home-care, Personal Care), By Product (Non-Ionic, Amphoteric), By Region, And Segment Forecasts, 2024–2030. Published in 2024. Available at: <https://www.grandviewresearch.com/industry-analysis/surfactants-market>. Accessed on: May 22, 2025.

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HEALTH

SUBSECTOR

Genomics

PREMISE FOR CALCULATING REVENUE PROJECTION FOR 2032

Brazil’s current MS in genomics was used to design the 2032 Fair Share

SOURCES

FORTUNE BUSINESS INSIGHTS. Genomics Market Size, Share & Industry Analysis, By Type (Products [Instruments & Software and Consumables] and Services), By Technology (Polymerase Chain Reaction [PCR], Next Generation Sequencing [NGS], Microarray, Sanger Sequencing, and Others), By Application (Diagnostics, Research, and Others), By End User (Research Institutes, Healthcare Facilities & Diagnostic Centers, Pharmaceutical & Biotechnological Companies, Contract Research Organization [CROs]), and Regional Forecast, 2024–2032. Published in May 5th 2025. Available at: <https://www.fortunebusinessinsights.com/industry-reports/genomics-market-100941>. Accessed on: May 22, 2025.

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**HEALTH**

SUBSECTOR
Enzymes

PREMISE FOR CALCULATING REVENUE PROJECTION FOR 2032

Based on Brazil’s current MS in the pharmaceutical sector

SOURCES

FORTUNE BUSINESS INSIGHTS. Enzymes Market Size, Share & COVID-19 Impact Analysis, By Type (Industrial Enzymes and Specialty Enzymes), By Source (Plants, Animals, and Microorganisms), By Product Type (Protease, Lipase, Carbohydrates, Nuclease & Polymerase, and Others), and Regional Forecast, 2020–2027. Published in 2021. Available at: <https://www.fortunebusinessinsights.com/industry-reports/enzymes-market-100595>. Accessed on: May 22, 2025.

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**HEALTH**

SUBSECTOR
Small molecules produced via radical innovation

PREMISE FOR CALCULATING REVENUE PROJECTION FOR 2032

Based on Brazil’s current MS in the pharmaceutical sector, the segment was included considering that 65% of small molecules are bioinspired.

The entry of three to five new drugs into the market was considered, projecting Brazilian participation in the preclinical phase.

SOURCES

NATIONAL HEALTH SURVEILLANCE AGENCY (ANVISA). Statistical Yearbook of the Pharmaceutical Market – 2023. Brasília: Anvisa, 2024. Available at: <https://www.gov.br/anvisa/pt-br/centraisdeconteudo/publicacoes/medicamentos/cmed/anuario-estatistico-do-mercado-farmaceutico-2023.pdf>. Accessed on: May 22, 2025.

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HEALTH

SUBSECTOR

Small molecules produced via biotechnological route

PREMISE FOR CALCULATING REVENUE PROJECTION FOR 2032

Based on Brazil’s current MS in the pharmaceutical sector, projections took into account that 13.5% of small molecules are produced via biotechnology.

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HEALTH

SUBSECTOR

Phytotherapeutics

PREMISE FOR CALCULATING REVENUE PROJECTION FOR 2032

A Fair Share of 1% was projected for the herbal medicinal market in 2032

SOURCES

Interview with an expert

FORTUNE BUSINESS INSIGHTS. Herbal Medicine Market Size, Share & Industry Analysis, By Form (Powder, Liquid & Gel, and Tablets & Capsules), By Application (Pharmaceutical & Nutraceutical, Food & Beverages, and Personal Care & Beauty Products), and Regional Forecast, 2025–2032. Published in May 5th2025. Available at: <https://www.fortunebusinessinsights.com/herbal-medicine-market-106320>. Accessed on: May 22, 2025.

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COSMETICS

SUBSECTOR

Dermocosmetics

PREMISE FOR
CALCULATING REVENUE
PROJECTION FOR 2032

Based on the current Brazilian MS of the beauty and personal care products market, 65% of molecules in the healthcare sector are assumed to be bioinspired.

SOURCES

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COSMETICS

SUBSECTOR

Clean beauty, Organic personal care, AI in beauty and cosmetics, Natural ingredients and Essential oils

PREMISE FOR
CALCULATING REVENUE
PROJECTION FOR 2032

Based on Brazil’s current MS of the beauty and personal care products market.

SOURCES

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COSMETICS

SUBSECTOR
Palm oil

PREMISE FOR
CALCULATING REVENUE
PROJECTION FOR 2032

It was assumed that 16% of global palm oil production is directed to the cosmetics sector. Brazil’s market share was projected to double by 2032, based on the trajectory observed over the last decade, in which the country had already doubled its share.

SOURCES GRAND VIEW RESEARCH. Palm Oil Market Size, Share & Trends Analysis Report By Nature (Organic, Conventional), By Product Type (CPO, RBD Palm Oil, Palm Kernel Oil, Fractionated Palm Oil), By End-use (Food & Beverage, Personal Care & Cosmetics, Biofuel & Energy, Pharmaceuticals, Others), By Region, And Segment Forecasts, 2024–2030. 2024. Available at: <https://www.grandviewresearch.com/industry-analysis/palm-oil-market>. Accessed on: May 22, 2025.



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FOOD

SUBSECTOR

**Fruit Concentrates,
Superfoods and Revalued
Foods**

**PREMISE FOR
CALCULATING REVENUE
PROJECTION FOR 2032**

Based on Brazil’s current MS in food and beverages, considering the exchange rate in December 31, 2024.

SOURCES GRAND VIEW RESEARCH. Fruit Concentrate Market Size, Share & Trends Analysis Report By Source (Apple, Grape, Pineapple, Mango), By Application (Beverages, Bakery, Confectionery, Dairy), By Region, And Segment Forecasts, 2023–2030. 2023. Available at: <https://www.grandviewresearch.com/industry-analysis/fruit-concentrate-market-report>. Accessed on: May 22, 2025.

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FOOD

SUBSECTOR
Functional foods

PREMISE FOR
CALCULATING REVENUE
PROJECTION FOR 2032

The Brazilian CAGR until 2032 was assumed to be double the global CAGR

SOURCES FORTUNE BUSINESS INSIGHTS. Food Intolerance Products Market Size, Share & Industry Analysis, By Product Type (Dairy Alternatives and Lactose-free Products, Bakery Products, Chocolates and Confectionary, Meat Alternatives, Specialized Nutrition, Snacks and Processed Food, and Condiments and Dressings), By Intolerance Type (Dairy and Lactose Intolerance, Sugar Intolerance, Gluten Intolerance, and Meat Intolerance), By Category (Organic and Conventional), and By Distribution Channel (Supermarkets/Hypermarkets, Convenience Stores, Online Retail, and Others), and Regional Forecast, 2025–2032. 2025. Available at: <https://www.fortunebusinessinsights.com/food-intolerance-products-market-110038>. Accessed on: May 22, 2025.

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FOOD

SUBSECTOR
Functional foods

PREMISE FOR
CALCULATING REVENUE
PROJECTION FOR 2032

Brazil was assumed to have the same CAGR as the global market in functional foods

SOURCES GRAND VIEW RESEARCH. Functional Foods Market Size, Share & Trends Analysis Report By Ingredient (Carotenoids, Prebiotics & Probiotics, Fatty Acids, Dietary Fibers), By Product, By Application, By Region, And Segment Forecasts, 2022–2030. 2022. Available at: <https://www.grandviewresearch.com/industry-analysis/functional-food-market>. Accessed on: May 22, 2025.

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FOOD

SUBSECTOR

Food technology

**PREMISE FOR
CALCULATING REVENUE
PROJECTION FOR 2032**

Brazil's current MS in food technology was used to project the 2032 Fair Share

SOURCES GRAND VIEW RESEARCH. Food Technology Market Size, Share & Trends Analysis Report By Component (Hardware, Software, Services), By Application (Delivery, Food Science, Supply Chain, Kitchen & Restaurant Tech), By Industry (Dairy Products, Fish, Meat, and Seafood, Beverages, Bakery and Confectionary, Others), By Region, And Segment Forecasts, 2023–2030. 2023. Available at: <https://www.grandviewresearch.com/industry-analysis/food-technology-market-report>. Accessed on: May 22, 2025.

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