OBSERVATÓRIO DE BIOECONOMIA

THE GREEN TRANSITION: THE BIOECONOMY AND CONVERSION OF GREEN INTO VALUE

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SUMMARY


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EXECUTIVE SUMMARY

The bioeconomy is a multifaceted concept open to different interpretations. The underlying idea of bioeconomy is the need to transform the economy's relationship with nature, no longer treating them as separate entities, and reintegrating them into the same harmonious habitat.

The construction of a global environmental governance regime and the new global status of the climate agenda make the bioeconomy a global priority and raise its importance as an economic variable. In this context, understanding, defining and measuring the bioeconomy is increasingly crucial for countries and sectors. "Bioeconomic" activities tend to be encouraged. The others, underprivileged.

But what does bioeconomy mean?

Over the last 50 years, three influential "visions" of bioeconomy, highlighted by the scientific literature, have taken predominant shape in the world: *bioecology*, *biotechnology* and *bioresources*.

The *bioecological vision* accentuates deep tension between the modern economy and the environment. According to this vision, technological and economic progress tends to degrade the planet's natural resources, resulting in the exhaustion of human living conditions in the future. To solve this problem, bioecology proposes the interruption of unsustainable economic growth and the pursuit of values and quality of life, as opposed to disorderly production and consumption. This solution requires a social transformation that alters productive structures, consumption habits and modern culture itself, and prioritizes the conservation of natural resources, biodiversity and harmony with the Earth.

The *biotechnological vision* believes in the creation of a new economic cycle driven by advances in areas such as information technology, biological science, biochemistry, biophysics, genetics and nanotechnology. From this perspective, nature is no longer a mere resource to be consumed and becomes a "factory" of new goods and services. This vision seeks advanced knowledge about how nature works to promote the development of new ways of producing food, medicines, energy and computing. In the new biotechnological production cycle, economic value would be increasingly associated with intelligence and mastery of nature's living energy, resulting in sustainable growth based on cutting-edge technology and reconciliation with nature.

Finally, the *bioresources* vision is based on the gradual substitution of products of fossil and chemical origin with new ones, of biological origin. This vision proposes the reconstruction of spaces of production and exchange in the contemporary economy, promoting the "de-fossilization" of society and the "re-naturalization" of the economy. Through technological and scientific progress, especially through biorefineries, the bioeconomy of bioresources aims to expand the use of biological inputs, replacing non-renewable ones, and promote sustainable industrialization in the countryside. This vision has implications both for climate agreements, such as the Paris Agreement, and for the private market, inspiring socio-environmental commitments and sustainable projects. By redirecting economic growth towards a sustainable future, the bioeconomy of bioresources enables the marriage between the economy and nature, with technological innovations and new production practices.

Each of these bioeconomy visions suggests a way to reconnect the economy and the environment. These visions, or their branches, have guided the path of dozens of countries towards a green transition and stimulated a wide range of analyses and comparisons.

The European, Chinese and North American projects are especially relevant. These projects aim to create production complexes or bioeconomic complexes, with abundant finance, business participation and the ambition to transform the global economy. Each country has a specific guideline. The analysis is based on official decisions and policies, such as plans, laws and legal commitments.

Europe focuses its efforts on the bioeconomy of *bioresources*. The main foundations of the European project are in the Bioeconomy Plan, in the Green New Deal—European Ecological Pact—and in its resulting strategies, such as the Farm to Fork Strategy and the Biodiversity Strategy for 2030. The Green Deal Industrial Policy, recently launched by the bloc, will also have relevance in the future of Europe's bioeconomy.

China is investing in the bioeconomy of *biotechnology*. The country periodically publishes its national strategy—the Five-Year Plan of the People's Republic of China—which guides state priorities, goals, and public investment expectations. In the last Plan, the Bioeconomy chapter clearly points out the Chinese ambition for the coming decades, with emphasis on the advancement of genetic engineering in the sectors of health, energy and food production.

The United States, in turn, oscillates between the European and Chinese projects, bioresources and biotechnology. The USA have recently announced the Executive Order "Advancing Biotechnology and Biomanufacturing Innovation for a Sustainable, Safe, and Secure American Bioeconomy." This Order establishes national coordination for the advancement of the bioeconomy. The Inflation Reduction Act, passed in 2022, will also influence the directions of the bioeconomy in the country.

The green transition and global competition introduce a new factor of production to the global economy: *the green factor*. This factor, which adds "bio" to the economy, differs from the traditional ones—capital, labor, and land—in its form and remuneration. In the absence of a better name, we consider that the green factor is offset by the "payment for environmental services."

The green factor is made up of 3 stocks. *Natural stock*, which represents environmental services. *Technical stock (with social technologies)*, which consists of sustainable technologies and techniques. *Advanced technological stock*, which involves cutting-edge knowledge to produce goods and services from natural resources. These stocks represent the value generated by the bioecological bioeconomy, with the natural stock; bioeconomy of bioresources, with the technical stock; and biotechnological bioeconomy, with the technological stock.

The global technological race is geared towards increasingly adjusting to the arrival of the *green factor*. The tendency is to internalize climate and environmental costs into businesses, administration of nations, trade and geopolitics. Countries with economies based on environmental degradation tend to face constraints to growth, while financial investments and demanding consumers tend to pursue sustainable activities and products.

Countries with larger stocks of preserved natural resources, such as Brazil, may have an advantage in the bioeconomy, as a new form of comparative advantage.

Brazil has more than 60% of its territory preserved. Each rural property in the country must, by law, maintain a legal reserve area ranging from 20% to 80% of the total area of the property, serving as a private factory of environmental services. *Here, the country adjusts to the bioecological vision*.

The country has technical capacity for sustainable production resulting in successive increases in agricultural productivity observed in the last three decades. This capacity offers opportunities for the development of new foods, energy sources and textile products, in addition to generating innovation resources. *Here, the country adjusts to the vision of bioresources*.

Brazilian productive progress is increasingly based on advanced technologies, with the use of genetic innovations and the development of species adapted to the specific characteristics of the country's soil and climate. These varieties are more resistant to pests and climate variations, allowing for more stable and resilient farming. *Here, the country adjusts to the biotechnological vision.*

The “installed potential” of a large share of the Brazilian economy, starting with the countryside, is sustainable. Halting deforestation in the Amazon and strictly complying with the Forest Code are critical for the sustainability of the Brazilian economy. If we do so, the potential for productive intensification, green factor remuneration and increased yield of national production will grow.

The spotlight on the *green factor* puts the bioeconomy in evidence. The presence of abundant and sustainable natural resources in a territory attracts companies. This advantage is incorporated into the economy in different ways, such as green premiums, carbon credits and future opportunities to capture credit, work and technology for more sustainable businesses.

On the other hand, the competition between production factors is dynamic and the levels of balance change over time. At different times, labor or capital may have greater importance in the formation of costs and opportunities. This scenario is evident in the "premature de-industrialization" of developing countries, where work loses relevance due to the advance of automation and technology. This phenomenon also affects developed countries.

The *green factor* advantage is not permanent. The predominance of production factors can be inverted, and those who are disadvantaged today can recover and succeed in the future. Several countries are now struggling to re-establish the role of national capital in key sectors of the economy, such as energy and transport. The success of these undertakings could undermine the advantages of countries that now enjoy e a greater supply of environmental services and cheap energy.

Additionally, international obligations can set down stricter requirements to access green benefits. When countries make international commitments, they set themselves certain limits, turning advantages into obligations. For Brazil, the deadline is 2030, when the country has committed to ending deforestation. After that date, it is not clear whether the environmental services provided by the green stock will be remunerated. This new dynamic of competition between production factors creates a challenging scenario for Brazilian development and progress.

The green transition offers opportunities, but also warnings. In the short term, the country may gain or lose the advantage of technical and technological stocks and environmental services. In the medium term, it may gain or lose the advantage of renewable energy with installed production capacity. Underlying both challenges is the same condition: the country's ability to convert green into value.

This is the *central task of the Brazilian bioeconomy*, defined in this study as:

“Stock, use and transformation of Brazilian natural and biological resources.”

Bioagriculture, bioenergy and bioresources are the shortcuts that would allow Brazil to take advantage of its “tropical” advantage and convert it into effective levels of growth, with cumulative gains in productivity. Finding out the size of this potential available in Brazil is a necessary criterion for economic valuation and, consequently, appreciation of green.

Fulfilling this task will require the country to be able to answer a few questions:

i) What is the value of a country's environmental assets

ii) How much income is generated from natural resources and who does it go to?

iii) How has the stock of environmental assets changed over time?
iv) o what extent are environmental assets being depleted?

The answer to these questions will require the construction of appropriate measurement instruments capable of valuing, in an *integrated fashion*, economic and environmental attributes of an economy.

The valuation of economic attributes is well established in the *System of National Accounts* (SNA). The SNA follows internationally shared standards, which allow Brazil to measure economic flows, such as the Gross Domestic Product (GDP), and compare performance with other countries. The "*green*" component of the GDP is one of its weaknesses.

The valuation of "*green*," in turn, is still a task under construction.

A promising strategy for incorporating the green factor into the national accounts is the development of the *National Bioeconomy Account – CNBio* based on the use of satellite accounts. Also known as thematic accounts, satellite accounts are extensions of the SNA, which allow expanding the analytical capability to areas other than the economy, including biodiversity, ecosystems and the environment.

Brazil has taken the first steps in this direction.

Firstly, we have made progress in measuring part of the "green" of the economic activities included in the country's GDP. The GDP of Bioeconomy (GDP-Bio), developed by the Bioeconomy Observatory of FGV, portrays the value chain of each of the activities that make up the Brazilian bioeconomy, as well as parts of the segments of inputs, bioindustry and services that add to the value added from bioeconomy activities. In other words, the project allows us to highlight the "bio" amount in the midst of the total wealth generated by the country.

The GDP-Bio, as well as other international strategies for measuring the bioeconomy through the traditional system of national accounts, carries the same characteristics of the GDP, that is, there is a synthesis of the flows between activities, not of stocks. GDP-Bio, in its current stage of development, does not "calculate" stocks of natural resources or environmental services—such as the amount of water, oxygen, biodiversity, and other natural resources and environmental services, either used or expanded in the economy. The recognition of these new environmental values requires additional analytical and methodological efforts.

The Brazilian Institute of Geography and Statistics (IBGE), in recent years, has taken important steps in this direction. The Institute has produced environmental satellite accounts in three core fields: (i) water (CEAA), (ii) energy (which includes biomass products—CEAE), and (iii) land. The three accounts are based on standardized concepts and methodologies developed by the United Nations Environment Program (UNEP) and the System of Environmental-Economic Accounting Central Framework (SEEA, 2012).

UNEP's economic-environmental accounting system offers global guidelines and frameworks for the preparation of environmental accounts in countries. The system includes criteria on how to integrate monetary and physical variables into a single national accounting system. Then, it is possible to develop indicators that incorporate the valuation of the ecosystem in the national accounts.

Expanding the satellite accounts, to cover other environmental services, is a challenge for the country to expand and implement an integrated vision of its green accounts. To this end, the country should also expand the collection of georeferenced data, build capabilities to compile and evaluate data, as well as other environmental accounting frameworks.

The new information bases should connect to existing ones—energy, water, and land bills—as well as the current system of national accounts. Once organized, national green accounts will allow Brazil to open a new horizon of understanding about the functioning, limits and potential of its economy, starting with the dependency relationship between economy and environment and valuation of ecosystem services. Specifically, it will also allow for the accounting and valuation of specific environmental assets involved in the production of goods and services, the measurement of income generated by natural and environmental resources in an activity, and the survey of the balance of environmental stocks over time.

As a result, it will be possible to analyze the efficiency of these activities with respect to the use of environmental resources. This analysis will allow, for example, to measure the volume of *natural resources* needed to generate BRL 1.00 of income in a given *economic activity*. As the demand for natural resources decreases in order to generate BRL 1.00 in income, there will be an indication that the economic activity is gaining efficiency. In turn, if the generation of an additional BRL 1.00 implies the use of more natural resources, the activity will lose efficiency.

The national green accounts would also allow comparison between sectors and their respective economic-environmental earnings. For example, it would be possible to compare Brazil's energy or agricultural sustainability with other regions of the world—or compare the progress of these sectors with other sectors of the national economy, to assess how each one advances in "sustainability" gains or losses.

New standards for assessing sustainable growth, which account for ecosystem services and biodiversity, may become the new "gold standard" for national accounts in the coming years on the planet. Leading the development of *Brazilian green accounts* could give Brazil the advantage of valuing its biodiversity, its economic-environmental contribution to the world and the perspective of guiding initiatives and advances that should also advance in other countries.

INTRODUCTION

The meaning of the word "bioeconomy" is not given by its letters or syllables, but by the context in which it is found. This context, in turn, is a horizon of understanding, which tends to prevail at a given moment, and which indicates a way of reconciling the *economy* and *the environment*.

Over the last few decades, different *visions of bioeconomy*—or proposals for reconciling the economy and the environment—have gained ascension in the literature and in the public debate on government decisions (EU, 2007; Von Braun, 2014; Bugge; Hansen; Klitkou, 2016; Rodríguez; Mondaini; Hitschfeld, 2017; Birner, 2018; OECD, 2018; Abramovay et al., 2021; Costa et al., 2022; Lang, 2022; Lopes; Chiavari, 2022).

Currently, more than 50 countries have put forward their national bioeconomy projects (Dieckhoff; El-Cicha, 2015; Fund et al., 2015; Rodríguez; Mondaini; Hitschfeld, 2017; Fund; El-Chichakli; Patermann, 2018; OECD, 2018). Among them, three "bioeconomic complexes" deserve special attention in the contemporary debate: the European complex, the Chinese complex and the North American complex.

Today, these bioeconomic complexes live in direct tension with each other. On the one hand, they present a national path of integration between production and the environment. On the other hand, they take a global shape: their development is the projection of the country's particular interests and values onto the rest of the world.

The conception of the bioeconomy in Brazil must be part of this context. Between the global complexes in distress and the Brazilian reality, there is a "middle land" of opportunities.

The definition of the Brazilian bioeconomy can and must take advantage of this space. The path is to indicate the most promising foundations for a production complex capable of qualifying and expanding national capabilities and projecting Brazil as a reference for development and preservation.

The Brazilian bioeconomic project must be directed to the combination between different visions of bioeconomy as an anchor of territorial development. The fields of action: food, energy and the environment—three growing global demands. The strategy: creating advanced production sites in each region of Brazil—the bioeconomic development zones. The regime: collaboration between the state and the private sector to support the construction of Brazil's national production sites.

This study is divided into four sections. The first section describes in detail, according to the best literature, the prevailing visions of bioeconomy. The second section examines, from legislation and official positions, the most influential bioeconomic complexes of our time. The third section suggests directions and foundations for the Brazilian bioeconomic complex and indicates guidelines for the reorganization of national accounts. The fourth section details the frameworks for measuring green in Brazil: constructing a national bioeconomy account.

1. BIOECONOMY VISIONS

Bioeconomy, for some, defines forest extractivism projects. For others, agricultural activities. Some countries include mining in their bioeconomy. And others include the latest technology of genetic manipulation, including computer sciences.

The intuition behind this idea is relatively simple. The economy, over the past 200 years, has evolved in tension with nature. For the economy, nature was just an externality that needed to be fixed or remedied.

A deeper understanding of environmental damage changes the perception of the problem. To solve it, it would be necessary to change, at birth, the economy's relationship with nature. Stop treating them as worlds apart and reintegrate them into the same harmonious and constant habitat.

At an international level, the construction of a global regime of environmental governance, starting in the 1990s, made solving the problem a global priority. Eco-1992, held in Rio de Janeiro, laid the foundations for a governance regime in which countries would collaborate to implement economic and environmental change. Until 2015, this was a priority project for rich countries, listed in Annex I of the Kyoto Protocol. From then on, it becomes an obligation of every nation on the planet.

The new global status of the climate agenda enhances the importance of the bioeconomy. What seemed like a conceptual or scientific challenge, becomes an economic variable: some can win, others can lose. The pursuit of a definition in which the relationship between economy and the environment can be evaluated and classified takes a decisive meaning for countries and companies.

“Bioeconomic” activities deserve to prosper.

The others do not.

But what does bioeconomy mean?

Despite global disagreements about its emergence (Enriquez, 1998; Gottwald, 2016; Von Braun, 2014) , the literature points out that the term was used for the first time in 1960, by economist Jirì Zeman, from the Czechoslovak Academy, to represent an “economic order” that would recognize the biological foundations of virtually all economic activities (Barañano et al., 2021; Bonaiuti, 2014; Lewandowski, 2018; Voicila ș, 2021)[4].

Since then, the concept has matured and become more sophisticated, giving rise to three *visions* of bioeconomy —bioecology, biotechnology and bioresources— that are leading discussions around the world (Bugge; Hansen; Klitkou, 2016; Vivien et al., 2019; Aguirre, 2022 ; Costa et al., 2022b; Lopes; Chiavari, 2022).

In social thought, the term *vision* is used to refer to concepts that become a horizon of meaning in public debate and government policy. The *visions* shape up the dialogue and proposals about a country’s directions. In the bioeconomy literature, the term became popular as a method and framework for reflection on the green transition (EU, 2007; Bugge; Hansen; Klitkou, 2016; Vivien et al., 2019; Aguirre, 2022; Lopes; Chiavari, 2022).

[4] For another perspective, see Beluhova-Uzunova et al, 2022, suggesting an original use of the concept by British biologist Hermann Reinheimer (Reinheimer, 1913).

Next, we reconstitute the foundations of the three dominant visions (Bugge; Hansen; Klitkou, 2016), qualifying and renewing their foundations from two angles. On the one hand are the primary intellectual foundations of each vision. On the other hand, the differences between the foundations and the directions subscribed by each perspective, to accentuate their particularities.

Each of the visions shares its own diagnosis of the challenge the planet is going through and the "dispute" between economy and nature. Each vision also tends to point out a prognosis for solving the problem—how to "merge" production and nature. And each vision, finally, influences projects, initiatives and policies in a particular context.

1.1 BIOECOLOGY

The first vision of bioeconomy is "ecological." Originally, it is believed that there is a radical tension between the modern economy and the environment. Technological and economic advances tend to degrade the "stocks" of natural resources on the planet (Georgescu-Roegen, 1971, 1979; Daly, 1980, 1991, 2007; Georgescu-Roegen, 2011).

The Earth, for Georgescu-Roegen (1971), is a closed system, in which matter and energy are a constant. When we produce an economic good, we are at the same time producing wealth, but also intervening in the disposal of matter and energy allocated in nature. What was previously stored in a denser form, such as coal and forests, is now transformed into goods and services, but also, partly, disposed of in nature as waste or pollution.

Technological breakthroughs, starting with the industrial revolution, have magnified the human capacity for production and generation of economic wealth, and exponentially increased the exploitation of stocks and the "degradation" of energy. Economic growth was accompanied by the "dissipation" of resources through the atmosphere, rivers, seas and landfills. What nature took millennia to "gather," the economy "destroys" very rapidly.

The effect of modern economy, according to Georgescu-Roegen (1960, 1966, 1971, 1975), cannot be construed as a mere externality. In a short time, the accumulated effect of this process would be the depletion of human living conditions on the planet, revealing that the economy does not fit in nature.

Inverting the traditional direction of economic thought, bioecology supports "stopping growth"—or, even better, degrowth—as the ultimate solution to society's crisis (Georgescu-Roegen, 1979; Cobb; Daly, 1989; Daly, 1980 , 1991, 2007; Georgescu-Roegen, 2011).

Implementing this change in society would require transforming production and commercial structures—as well as consumer habits and the culture of modern life. By "limiting" growth, the economy would reorient itself inwards, in pursuit of values rather than quantity. The main objective of society, ultimately, would be the equality between people and the restoration of harmony with the Earth.

Georgescu-Roegen recognized that the world was not organized to change. For this very reason, the tendency of companies and countries was always to seek an expansion path—in pursuit of particular advantages. If nothing were done, however, the competitive game of the modern economy would tend to lead humanity towards catastrophe.

What should be done?

The way out, for the author, would be the "bioeconomic project," with an orientation and three predominant goals.

The orientation is the pursuit of the *conservation* of the Earth's preserved stocks, particularly forests and mineral reserves, while they have not yet been "consumed" by unlimited economic growth. The idea was qualified from different principles.

- The first one: the fight against *technology*, particularly in land use, as in modern agriculture. Technology, by enhancing the impact of human action on natural resources, also accentuates the risks for the planet. The economy must *de-intensify*.
- The second one: *anti-consumerism*. Changing consumer culture is important to alleviate production pressure. Human fulfillment must be pursued outside the material goods and services available on the market. The economy must pursue values, quality of life for people.
- The third one: *anti-waste*. The economy must change the dynamics of production and exchange to stop waste and promote the circularity of goods. Waste from a production process can and should be converted into input for the next production process.

Each of these principles inspires relevant social movements and public initiatives.

In the 1960s/1970s, a wave of environmental organizations was formed, especially in Europe, for the purposes of conserving the planet.

Against *technology*, movements emerge to eliminate nuclear energy and against industrial food production—and in favor of agroecology. Against *consumerism*, movements to create new indices of human progress are put forward, accompanied by solidarity economy movements. Against *waste*, social and public initiatives to promote the circular economy—converting waste from economic activities into inputs for the new economy.

In 1968, a group of economists, industrialists, scientists and leaders gave rise to the so-called "Club of Rome." The purpose of the group was to discuss the "crisis of civilization" and the "deterioration of natural resources." One of the results of the work was the development of a computational model, carried out with the participation of MIT scientists, and later published by Dennis Meadows (Meadows; Randers; Meadows, 2004), with the title "Limits to Growth." The work, as the name suggests, "confirmed" the catastrophe alert (Levallois, 2010).

In academia, "bioeconomic resistance" finds its own form of expression. A new field of economics, *ecological economics*, is dedicated, among other topics, to understanding the interdependence between economy and nature. Focus is placed on examining the conditions of the steady state, while pointing out the limits of modern economics—the method, assumptions, neoclassical economic modeling and, above all, the growth project itself. What once seemed rational is actually environmentally degrading and potentially destructive.

In recent years, the bioeconomy of bioecological inspiration has cemented itself strongly in the public debate. Technological and regulatory moves to achieve the green transition in recent decades are perceived as insufficient or unsustainable (Ayres, 2007; Jérôme Pelenc et al., 2015; Pezzey; Toman, 2002; WWF, 2009; Birch, 2006, 2010; Gottwald and Budde, 2015; Vivien et al., 2019). The particular concern with forests and biodiversity reactivates the strength of bioecology and repositions concerns with ethics and conservation at the center of political and social agendas (Abramovay et al., 2021; Aguirre, 2022; Costa et. al, 2022).

In a nutshell: the ecological bioeconomy is about transforming the modern economy, to give up growth and change the path of human development. The ultimate solution to the problem would require the complete transformation of society, to reorient production, trade and consumption. Meanwhile, we are left with resistance—building intellectual and practical walls to extend the protection of fragile and generous nature against technology and human action. If possible, resistance should be aligned with marginal income distribution to alleviate the pain and suffering of the neediest ones.

In the eighteenth century, Rousseau said that the moment the first man who had fenced in a piece of land and said: "this is mine"; there, all the problems of humanity began. *"Oh, if only someone had raised their hand and shouted: stop this man."* Georgescu-Roegen, two centuries later, renews and updates the Genevan philosopher's concern: at the moment when science became a machine and the first coal-fired engine was started, there were born the dramas of the planet. It is not possible to remake the past, but with the bioeconomy we can still resist the future.

1.2 BIOTECHNOLOGY

The second vision of the bioeconomy is "biotechnological" (EC, 2005; OECD, 2009). This vision supports the creation of a new level of value. Its origin dates back to the 1990s, although its foundations have been around for much longer (Enriquez, 1998; Glick, 1982). The core idea is the commitment to a new economic cycle, inaugurated by radical advances in information technology and biological science.

The biotechnological bioeconomy would promote new opportunities for generating income and wealth, based on advanced knowledge about the functioning and mastery of nature. Genetic engineering, among other innovations, would give rise to advanced forms of food production, drug production, energy generation and computer sciences (OECD 2009, 2018; ECLAC, 2017; Lange, 2022).

The effect is that nature would cease to be "consumption," to become a "factory" of new goods and services useful to human well-being. Nature becomes an asset. The advancement of the "biotechnological" bioeconomy would replace the old economy based on the degrading and indiscriminate use of natural resources.

The advance of the economy does not follow a linear flow of progress throughout history. It takes leaps, in productive cycles that can be divided into three stages: growth, stabilization and crisis (Schumpeter, 1939) . Growth is the phase of innovation and euphoria, with new technologies, new goods and services, bold (and sometimes irrational) investments, with the opening and expansion of markets. It is also the phase of fast growth in demand and consumption which, in turn, reactivates production.

Today, we are witnessing the birth of a new *biological* economy, resulting of two simultaneous technological revolutions. On the one hand: the information technology revolution, with advanced computer science and a new ability to mobilize and utilize data and information. On the other hand: the *biology* revolution, with the growing mastery of human cells and the generative capacity of nature, to produce new materials and services.

The meeting of these two revolutions—bioinformatics—is the gateway to a new production cycle and new hope for sustainable growth (EU, 2005; Potocnik, 2005). What ecologism saw as a prelude to a catastrophe, in fact, would be the symptom of a fossil cycle that ends. Environmental damage, in other words, would be the "fever" of a sick economy, which, however, little by little, is also beginning to change.

The generation of wealth, in the new cycle, changes in two central ways.

On the one hand, economic value now disembodies the "physical world" and becomes increasingly "immaterial" (EU, 2000; EU, 2005). The price of a good is no longer the sum of its parts made of fossils and natural resources; it becomes the amount of built-in intelligence (a large portion of the value of a tractor, for example, is its embedded software). The physical medium is just the vehicle through which knowledge navigates through society.

At the same time, in the biotechnological bioeconomy, value is reincarnated in "organic" nature. Advanced science and technology allow for the mastery of nature's sources of life—beginning with control of the human genome and its constituent molecules. Through genetic engineering, nature becomes a source of goods and services at the service of human life. Value ultimately lies in the marriage of intelligence with the living energy of nature.

The promises of the biotechnological bioeconomy are exemplified in three major areas.[5]

In *health*: new drugs, such as the messenger RNA of one of the vaccines against Covid-19. In the interaction between mind and machine, new prostheses connected directly to neurological waves.

In *computer science:* storage of data in genetic sequences open the way for preservation of knowledge in new scale databases. DNA sequences become hardware for storing information.

In *agriculture*, adapted microorganisms open the doors to improved ability of plants to absorb nutrients or resist pests. Innovations should soon make it possible to convert crops into factories of new materials.

In each of these cases, economy and nature are reconciled on the high side—of advanced knowledge, state-of-the-art technology and continuous productivity. The generation of value based on the abundant use of fossil resources or on nature degradation, with relatively low aggregation of knowledge, is out of the picture. High-tech economy based on the creation and expanded mastery of nature's secrets comes into play (Aguilar et al., 2009; Levidow et al., 2012).

Biotechnology, in the 1990s, is seen as a new horizon for the development of nations. The OECD promotes biotechnology as the foundation of a new *industrial revolution* in the 21st century (OECD, 2009). The new industry, in the new green production cycle, tends to merge with nature itself, and absorb capabilities from agriculture, computer sciences and health.

The old metalworking factory is replaced by the cell. Its prime setup sites are *underground* and *water*.

Biotechnological development shifts to the core of new promotion policies and disputes for technological hegemony in several countries around the world. Some of the main projects are based in the three great powers—United States, Europe and China. Other countries, however, develop their sectoral policies. Brazil, for example, has an important record of contributions to genetic engineering in the food industry.

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[5] See the bioeconomy strategies of the United States and China, outlined in the next section of this study.

In a nutshell: biotechnological bioeconomy replaces the pessimism of ecological economics with high hopes for the potential of biotechnology as a route to the future. Against the degradation of nature—resulting from its conversion into a cheap input—the path to growth is the reincarnation of the source of economic value in nature itself, through state-of-the-art technology and ever-increasing biological mastery.

The intensification of biotechnological knowledge shifts the economy's degrading use of natural resources to the domestication of nature's intelligence. By doing this, the stock of natural resources, such as biodiversity, also tends to be valued as a source of latent knowledge, whose revelation and utilization will demand, precisely, the best of human capabilities. Human beings cease to be a destructive threat to the Earth and become a promise of a solution for a new *green* prosperity.

The optimism of modernity finds a new home in biotechnological bioeconomy. For John Locke, when intelligence and human effort touched nature, through the work of industrious and rational people, a new world of possibilities and wealth was born there. Man approached the divine, and made the Earth a little more sacred. In the 21st century, the promise of growth, through the leading role of humans, is renewed by the biotechnological bioeconomy. The Midas touch, however, is the deep integration of intelligence with nature, for the renewal of life.

1.3 BIORESOURCES

The third vision is the bioeconomy of bioresources (or the substitution, or the biomaterial bioeconomy) (EU, 2007; Bugge et. al, 2016; Birner, 2018) . This vision supports the reconciliation between economy and nature "from within," gradually promoting the substitution of fossil products, disseminated by the economy, with new bio-based materials.

The substitution bioeconomy started in the 2000s,[6] but gained strength in 2009, with the advancement of national policies in Germany and the European Union (Patermann; Aguilar, 2018). It deserves to be read as a "middle ground" between ecological economics and biotechnological economics. The key to reconciling economic growth with nature is *reconstructing*, from within, the spaces of production and exchange in the contemporary economy.

The central guideline for the growing achievement of sustainability is the substitution of fossil resources and their derivatives, at the base of the economy, with natural and biological resources (EU, 2007). Ultimately, the goal is to achieve a sustainable balance with nature—"net zero." The central path is the alteration of market mechanisms, modifying its incentives and opportunities.

As in the vision of ecological bioeconomy, society's fundamental problem is the indiscriminate use of fossils and chemicals, resulting in the degradation of natural resources. At the core of the problem, however, is not a radical or inevitable fight between the economy and the environment, but the product of a particular way of organizing knowledge and society, which has been imposed over the last few centuries.

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[6] Regina Birner (2018) argues that, in the 2000s, in Europe, there is a greater urge to increase food production investments, back then in decline, in order to increase agricultural productivity and, thus, "meet future goals of food production and biomass" for applications other than food. The scenario created an incentive for European leaders to coin new concepts that would direct this commitment.

Exploration of fossils is made possible by a range of technologies and rules that guide their operation. Science teaches the conversion of ore and forests into energy. Property rules ensure exploitation rights. Contract rules guarantee exchange rights. Liability rules exempt from blame or indemnity. Each of these rules is human creation.

The same society that created the problem can now devise the solution. The priority is to mobilize politics to change the technological and institutional working conditions of the economy.

The aim of economic reconstruction must be the "de-fossilization" of society—or, in the *opposite sense*, the "re-naturalization" of the economy.

At one end, rapidly reducing the use of fossil inputs and their products. At the other, expanding the use of biological inputs—with investments in innovations that expand the *quantum* of "nature" in society. Between one and the other, expanding preserved natural resources, so that, in the final accounting, nature and economy may come into balance.

The bioeconomy of biomaterials believes that the *elasticity of substitution* between fossil and biological products is much greater than one imagines. To promote it, however, it would be necessary to promote faster technological and technical progress. New science and technology must continually enable new ways of producing goods and services *from nature*. *Bioresources* would enter the market to substitute non-renewable products.

Investing in the future of the bioeconomy of bioresources involves further developing biorefineries. Just as oil refineries "fractionate" oil into by-products (e.g.: plastic), biorefineries would be factories for fractioning biomass, extracted from sugarcane or corn, for example, to produce energy from their by-products (e.g.: ethanol) or new materials (e.g.: bioplastics).

The technology of fragmentation and use of biomass has been maturing quickly, over the recent years, to utilize different sources of biomass—wood, cereals such as rice and wheat, in addition to sugarcane, corn, and other products. Biorefineries operate on a pilot scale in the United States, Europe and Asia.

Biofactories could renew space for sustainable growth. Firstly, by expanding the use of biomass—today, no less than one quarter of the biomass produced in agriculture is economically used. Secondly, by accelerating the substitution of fossil products with natural products while promoting industrialization in farming activities. Thirdly, in the medium term, by irrigating society with new materials, from the conversion of complex nature-abundant sugars, such as lignin and paper pulp, into new forms of matter and energy.

Ambitious projects to advance bioresources are under development in Europe, in the United States—where hundreds of biorefineries are operating—and, increasingly, in Asia. India has recently launched a plan to develop 12 experimental biorefineries, hoping to use wheat and rice waste as an input, to produce the so-called "second-generation ethanol" (India, 2022). Brazil has successful experiences in ethanol production.

At the international level, the bioeconomy of bioresources underlies climate agreements. The Paris Agreement is a governance model for "substituting" a carbon-based economy with an economy that is neutral in emissions and, therefore, more sustainable. At the basis of the regime lies a common objective: to prevent global temperature from rising above 2° Celsius (reduced to 1.5° in Glasgow, 2021). And each country's commitment to pursuing emission reductions.

The patterns of the substitution economy have also inspired the debate on other agendas, such as biodiversity. And they increasingly become a reference, in the private market, for the development of voluntary commitments and projects to comply with socio-environmental objectives—such as voluntary "net zero" pacts, new green financing regimes and sustainable investment commitments.

In short, the bioeconomy of bioresources is about an *inner* marriage between the economy and nature. The path forward is the internal renewal of the economy to, over time, replace stock-squandering resource-depleting activities with new sustainable materials that may, subsequently, open the doors to new industries and services.

Instead of vetoing growth (as the ecological bioeconomy proclaims), the bioeconomy redirects it towards a new future. Entrepreneurs and scientific and technological progress are put back into the economy. Trailblazers, adventurers, explorers, so to speak, are no longer considered destroyers *by definition*. Instead, they must now direct their energy to priority areas, under strict rules and regulations dictated by the state.

Between a pessimism that preaches apartheid between technology and nature, and unrestrained optimism in salvation through biological innovations, a new path of progress emerges. The bioeconomy, driven by new technologies and regulated creativity, can rebuild the future through the route of biomaterials.

The three visions of bioeconomy constitute the comprehensive horizon of paths, which were formed over the last half century, to reconnect economy and environment. Each one of the views proposes how to "reconcile" green and economy. The ecological bioeconomy preaches *unity*, enhancing and protecting nature from the economic field. It is a containment project. The biotechnological bioeconomy attests to the ability of new markets, generated by disruptive technologies in bioinformatics, to overcome degrading markets and rebuild, on another level, the relationship with nature. The bioeconomy of bioresources, finally, pursues a "middle way," seeking to direct market forces towards the generation of biological materials capable of replacing the fossil sources of the economy.

2. PRODUCTION COMPLEXES

The commitment to the green transition has driven dozens of countries, over the past two decades, to develop their respective bioeconomy projects (Dieckhoff; El-Cicha, 2015; Fund et al., 2015; Fund; El-Chichakli; Patermann, 2018). Several efforts, over the years, have sought to contrast national policies and strategies (Rodríguez et al., 2017; Azevedo, 2018; OECD, 2018; Birner, 2018; Costa et. al., 2022; Lopes and Chiavari, 2022).

In Latin America, ECLAC undertook a paradigmatic effort to contrast political orientations from different countries in the world, with special attention to the South American scenario (Rodríguez et al., 2017). In Brazil, WRI and CPI have made a relevant contribution to assessing the specific needs of the Amazon (Costa et al., 2022) and comparing institutional arrangements in different countries, with emphasis on the Brazilian regulatory scenario (Lopes; Chiavari, 2022).

Among the different national policies, three bioeconomy projects have become especially important in recent years, due to their economic strength and global projection: the European, Chinese and North American projects.

The three projects are on their way to forming new *production complexes*—or bioeconomic complexes—in their respective territories, irrigated by abundant funding, broad participation by companies and large market sectors, and the ambition to transform the economy and the reality of the country and the world.

From a distance, these bioeconomic complexes look similar—or nearly the same. All of them combine state and enterprise, energy and transport, agriculture and conservation. All of them offer subsidies and protections, divide the world between friends and the rest, and want to bend global trade according to their interests.

Up close, however, each of the bioeconomic complexes has a particular orientation. Therefore, instead of offering an overview of the bioeconomy policies of institutions and countries, as it is common in the literature, below are the criteria, positions and perspectives assumed by each of the three great global powers: Europe, United States and China.

The European project breaks down, as a priority, the ideas of the bioeconomy of substitution—or the bioeconomy of biomaterials. Europe publishes its strategy in official plans and regulations. The most systematic references are the European Bioeconomy Plan, the Green New Deal and their branched out strategies such as the Farm to Fork Strategy and the Biodiversity Strategy for 2030. The Green Deal Industrial Policy, recently launched by the bloc, will also have decisive relevance in the near future.

The Chinese project, in turn, is betting on the bioeconomy of biotechnology. China periodically publishes its national strategy—its Five-Year Plan of the People's Republic of China, which sets out state priorities, goals, and public investment expectations. In the last Plan, the Bioeconomy chapter clearly points out the Chinese ambition for the coming decades.

The North American project, finally, oscillates between extremes: Europe and China. The United States does not have an official "national strategy." However, they have official documents that guide public administration, a "robust budget," and national laws that set priorities and guide the actions of the State. The Inflation Reduction Act, approved in 2022, is the base document of the country's new Green Industrial Policy, and a watershed in the country's stance.

We have examined each of the projects in detail

2.1 THE EUROPEAN COMPLEX

The first bioeconomic complex is the European project.

The official proposal of the project is "to grow without degrading natural resources."

Content-wise, the European project embraces, above all, the bioeconomy of bioresources. The strategy is to promote the substitution of fossils by biological matter. The key word in the European discourse is "net zero"—finding a balance between economic progress and environmental protection across different sectors of the economy. By doing so, the continent also intends to redefine and strengthen the competitiveness of the Bloc's economy.

Shape-wise, Europe sets up an ambitious political project that coordinates changes in market infrastructure. The market, in the European view, is an "engine" made up of several gears that authorize and guide the action of economic agents. None of these gears "have fallen from the sky," so to speak. All of them originate in politics; they are legislative and institutional creations that, over time, constituted and disciplined the functioning of the economy as we know it.

While, today, the economy "pollutes" and "degrades," the way forward is not to condemn the "rationality" of the choices made by economic agents; it is to change the assessment framework based on which they make their rational decision, to reorient incentives in a new direction. The market, so to speak, can and should "shape" itself to a new environment of rules and institutions that draws up their borders. How should this market change process be conducted? Europe advances in stages.

The first steps came by adopting the global climate agenda. In response to the 1997 Kyoto Protocol, which made rich countries commit to cutting their emissions, Europe developed its decarbonization project. A decisive step towards this was the regulation of the energy sector, with the creation of the compliance carbon market, which includes 40% of Europe's emissions. Since 2005, emissions have dropped by 34.6% (US, 2022).

The first comprehensive vision of reorganizing the European economy came with the Bloc's Bioeconomy Plan. Inspired by the German strategy, later adapted by numerous European countries, the project pointed the way to regional sustainable development. The general message, presented at the introduction of the Bioeconomy Plan, highlighted the commitment to the environment, but also to European economic competitiveness.

The Plan also outlines the particularities of the European vision of the Bioeconomy. The "European Way," as the Plan suggests, combines two central guidelines. The first one: "the European bioeconomy needs to have sustainability and circularity at its core." Europe "is already a global leader in the sustainable use of natural resources in an efficient bioeconomy."

The second one: "this will promote the renewal of our industries, the modernization of our primary production systems, the protection of the environment and the strengthening of biodiversity."[7] According to the plan, the bioeconomy has the potential to generate one million new jobs in bio-based industries,[8] in addition to boosting the ecosystem of entrepreneurship and innovation.

[7] Bioeconomy Plan. P. 4.
[8] Bioeconomy Plan. P. 5.

The Bioeconomy Plan's list of particular objectives also combines commitment to nature and to growth. These objectives include: (1) ensure food and nutrition security, (2) manage natural resources sustainably, (3) reduce dependence on non-renewable resources produced within or outside Europe, (4) limit and adapt to climate change, and, (5) strengthen European competitiveness and create jobs.

The guidelines of the Bioeconomy Plan become the *norm* in the new European Ecological Deal—the Green Deal. Under the Pact, Europe commits, on the one hand, to cutting greenhouse gas emissions by 55% by 2030, compared to 1990 levels. On the other hand, the plan also intends to boost the European economy, with investments of one third of the total of 1.8 trillion euros provided in the NextGenerationEU Recovery Plan, in a 7-year budget (EU, 2023).

At the heart of the European Green Deal is the Farm to Fork Strategy. The document details goals and guides actions for the transition in the food sector. Among the priority goals are a 50% reduction in the use and risk of chemical pesticides by 2030, a 20% reduction in the use of fertilizers, expanding organic farming practices by 25%, improving animal welfare and recovering loss of biodiversity.

According to the Farm to Fork Strategy, the green transition must reduce environmental impacts and promote the competitiveness of European products and producers: "European food must also become a global standard for sustainability."

The second pillar of the European Green Deal is the Biodiversity Strategy for 2030, which prioritizes the restoration of degraded areas—on at least 20% of the continent's lands and seas. Europe is expected to plant 3 billion trees by 2030—in "afforestation," "reforestation" and tree-planting activities in urban and agroforestry areas (EC, 2023b).

The Green Deal draws relatively little attention to actions in the energy sector, which corresponds to more than 75% of the continent's emissions (the sector, however, had been regulated since the beginning of the century). To cut emissions by 55% by 2030, the Bloc countries must replace dirty energy with clean energy. Austria, for example, is planning on installing 100,000 solar panels on buildings and houses. Denmark expects to produce 4 GW of offshore wind power. France expects to implement six bids for offshore wind facilities. Greece and Portugal will be investing in solar farms and hydrogen infrastructure (EC, 2020).

Biofuels, on the one hand, have their local production encouraged to reduce dependence on fossil fuels. On the other hand, the sector also sustains highly demanding regulation, mediated by economic models that estimate the potential expansion of biofuels over food areas or forests. What goes for Europe can soon be converted into a standard to regulate biofuel trade with other countries.[9]

In the transport sector, the European Union is committed to electrification. Europe set the deadline of 2035 for the retirement of combustion engines.[10] Some countries in the bloc set an earlier deadline. Ireland, the Netherlands and Sweden have set the deadline at 2030. Norway, 2025. At the same time, the block grants a subsidy of 8,000 euros for each electric car, up to seven seats.[11] A threshold at the top and an incentive at the bottom aim to promote the technological conversion of European manufacturers, who have quickly started to adjust. In a relatively concentrated market, the course taken by Europe should impact other markets.

[9] Available at: www.energy.ec.europa.eu/topics/renewable-energy/bioenergy/biofuels_en
[10] Available at: www.ec.europa.eu/commission/presscorner/detail/en/ip_22_6462
[11] Available at: www.alternative-fuels-observatory.ec.europa.eu/transport-mode/road/luxembourg/incentives-legislations

On all fields, the European approach will tend to follow the same profile: re-engineering the market from within, creating constraints and new opportunities. It does so by setting targets, changing obligations and sectoral regulations, and creating new lines of subsidized production financing and/or placing constraints on foreign trade to attest to the strength of national legislation.

Finally, the European project is accompanied by a project to influence the new frontiers of the international economy. It seeks to do this in two ways. Firstly, via trade regulations that force European companies to "bring" European requirements to other countries in which they operate—particularly via human rights regulations and other regulations establishing the fight against deforestation.

The Deforestation Regulation,[12] *recently published by Europe, restricts the import of goods from areas deforested after 2020, and any other goods that coexist with violations of human rights and illegalities. On paper, Europe wants to shock the planet with "legality" and "sustainability." In doing so, it also wants, in its view, to "even out" the competitive setting and prevent companies from being unfairly harmed by companies that grow with illegal or immoral exploitation of resources.*

Along the same lines, the Carbon Border Adjustment Mechanism (CBAM) (EC, 2023a) intends to guarantee the environmental "isonomy" of European companies. By imposing carbon reduction requirements on companies within the Bloc, it hopes that goods produced outside will comply with the same standard. The strictness of the requirements is set by Europe, according to the capacity of companies. The measurement criteria, along the same lines, are created and defined by Europe, according to the production particularities of its climate, soil and production techniques.

Europe's global project also includes projects of reconstruction of the standards, which constitute the extralegal body of the market. They traditionally serve to facilitate interoperability and ensure common safety and quality criteria between different companies and sectors. However, these European standards eventually become guidelines that rank products and services as more or less "sustainable." In doing so, they help to guide public policy and private investment. And to globalize, through the market, European values.

Over the past years, Europe has promoted the integration of national standardization bodies. In February 2022, the European Union released its new "Standardization Strategy." Now, the national standardization bodies are submitted to the centralized coordination of a Chief Standardization Officer (CSO),[13] *who must follow the strategic priorities defined annually by a High-Level Committee. The focus of the European strategy consists in "ensuring European leadership according to global standards" and "ensuring" that standards "support investments in the green and digital transition" (EC, 2022).*

At the launch of the European standardization strategy, the central objective of the new standard was that "European technological sovereignty", that is, the ability to "reduce dependencies and protect European values" will depend on the continent's ability to be a "global standard-settler." The strategy underscores the "priorities of standardization" and the development of "conditions for European standards to become global benchmarks" (EC, 2022).

[12] Available at: www.environment.ec.europa.eu/topics/forests/deforestation/regulation-deforestation-free-products_en
[13] Available at: www.eur-lex.europa.eu/EN/legal-content/summary/integration-of-environmental-aspects-into-european-standardisation.html

European "productive nationalism" must be reinforced with the arrival of the Green Deal Industrial Policy, which reinforces the competitiveness of European industry on the frontier of clean energy. To this end, the continent hopes to create a special regime to support and protect companies (Net-Zero Industry Act), combined with policies to influence international trade to guarantee strategic supplies (Critical Raw Materials Act) and guide markets to their ends (EU's Network of Free Trade Agreements).

In summary, the European project plans on "cleaning" with bioresources and through substitution: closing the doors, on the one hand, to polluting productions, and opening the doors, on the other, to new sustainable goods. All managed according to general goals, distributed by sector, monitored and updated periodically, with the ultimate aim of reaching net zero.

The project also expects to influence the world to make its economy evolve. The substitution strategy, after all, is highly dependent on the strict control of market "borders," of what can or cannot be done, to promote the replacement of the old pollutant with new sustainable. Without changing the planet, the dirty economy will find operating spaces elsewhere, neutralizing European policy and undermining companies' competitiveness in the green transition.

The European project, finally, aims not only to advance towards a reconciliation between green and the environment in its territory, but "to protect its jobs," to reinforce the "competitiveness of European companies," to create "new markets" for itself and, via laws and standards in an economy that negotiates criteria in the economy of the future, to strive for its sustainability criteria to be the global standard.

2.2 THE CHINESE COMPLEX

China also embraces the green agenda as a strategy of development. The Chinese strategy, however, is different from the European one. The Asian country is betting, above all, on biotechnological bioeconomy as the pathway of the future.

There is a difference between "bioresources" and "biotechnology." The first proposal, as examined, wants, above all, to clean the present "from within" —penetrates reality, closes one door, opens another, redirects resources. Forces marginal adjustments in demand and supply. And expects to shape up a different culture. The second, biotechnology, wants to create the future "*ab ovo*"—directly, creating new demand and supply.

The logic of substitution was "relativized"—or belittled—by China. Starting with the nature of the climate commitments taken on by the country. Unlike Europe, which set an absolute and objective emission-cutting target, China, which accounts for 27% of global emissions in 2019, set a relative and proportional target.

See the contrast. European Union's Nationally Determined Contribution (NDC) mandates that the continent cut its emissions by 55% by 2030, compared to 1990. In other words, Europe is committed to cutting emissions "come rain or shine"—even if an unexpected war or food inflation erupts. China, in turn, committed to reducing its emissions only if the country's economy progresses. If the country grows, the environmental commitment also grows; if it does not grow, there is no climate effort. The Chinese target, submitted in October 2021, indicates that the country will increase its absolute emissions until around 2030, when the emissions curve should flip down (CAT, 2023) .

Brazil has embraced the European script. India, has embraced the Chinese one.

An apparent exception in the Chinese project is the carbon market, recently created for a part of the energy sector (coal and gas plants). The purpose of the Chinese regulation, however, is to combine the reduction of emissions, in the country's most polluting sector, with investments by large conglomerates in cutting-edge technologies. Coal substitution efforts are expected to promote advanced innovation in sustainable energy sources.

The core of the Chinese bioeconomy vision is announced in China's 14th Strategic Plan ("Plan"), in 2021. According to the document, the country will invest in the bioeconomy (NDRC, 2022)[14] as the driving force of the Chinese industrial development in the coming years (Zhang et al., 2022). At the heart of the Chinese strategy is advanced biotechnology.

The Chinese strategy is divided into two stages.

From 2021 to 2025, the aim is to expand China's biotechnology capacity—"in science and technology, combined with industrial integration, and of strengthening biosecurity." Biological resources must be more widely integrated into other sectors of the economy, particularly agriculture, medicine, forestry, energy and materials. To achieve this goal, the Plan outlines some particular goals:

- Encouraging the bioeconomy to reach an estimated scale of CNY 22 trillion (USD 3.3 billion USD).
- Increasing the bioeconomy share in the GDP.
- Increasing the number of companies in the bioeconomic sector with annual revenues above CNY 10 billion.
- Increasing investments in life sciences and biotechnology to promote breakthroughs in strategic technologies.

From 2026 to 2035, China hopes to become a world leader in the bioeconomy. The country must establish a new development model, increasingly based on bioindustries, with a mature research, innovation and development chain, and diverse applications.

The State plays a leading role in the development of the Chinese bioeconomy. To "get there," the Plan suggests a two-dimensional government coordination regime (NDRC, 2022). Firstly, *vertical coordination*: various initiatives should be coordinated by a "national biotechnology governance" structure, which will allow the country to plan, evaluate and guide efforts.

According to the *horizontal coordination*: with the development of Bioeconomy Pilot Zones, which will serve as "incubation areas" for the development of new technologies and as a hub for cooperation and international contact. Innovative companies will receive subsidy to be set up in these regions, which will include Tianjin-Hebei, Yangtze River Delta, Guangdong-Hong Kong-Macao Port Area, and the Chengdu-Chongqing Economic Region (NDRC, 2022).

Together, the regime intends to encourage varied experiments in the provinces. Local experiments are brought together in a kind of "federalism with Chinese characteristics." While accelerating the dynamics of innovation at the cutting edge, it also guarantees the conditions to disseminate results among other parts of the country's economy. Assessment regimes integrate and guide the regional dissemination of successful experiences.

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[14] China's 14th Five-Year Plan defines bioeconomy as "based on the protection, development and utilization of bioresources, to drive the development of life science and biotechnology for promoting a blueprint for the sustainable development of human society."

A highlight in the plan is "bio-agriculture." China is placing its bets in biotechnological development to ensure food supply in the country—including, according to the Plan, grains, oils, eggs, meat, milk and dairy products. At the heart of the strategy is the new seed industry, based on the development of new genetic sequencing technologies. The country expects that the local production of genetically modified seeds, such as soybeans and corn, will help reduce the country's dependence on grain imports and, consequently, will support its food sovereignty (Rouzi, 2023).

The Chinese strategy has three particular objectives. *Genetic improvement*: with new genomic manipulation and synthetic biology technologies and the use of artificial intelligence to develop highly productive climate-resilient crops. *Bioinputs*: development of biological and natural pesticides and fertilizers to strengthen crop resistance and improve soil fertility. *Biofuels*: in particular, with improved use of biomass as an alternative energy source, through highly productive and resistant crops. The plan sets out advances in ethanol, biodiesel and biogas.

Bio-industrialization is also in the backbone of the Chinese bioeconomy project. On the one hand, the country hopes that the advance in the use of biomass will serve as a route for building a low-carbon ecological system in rural areas, while promoting employment and generating income in the countryside. The reuse of agricultural waste, such as wood and forest remains, in addition to urban organic waste, straw and cereal husks, should be done via biomass energy industries. On the other hand, the bioindustry should also prosper with advances in biomedicine, development of treatments and alternative drugs, whose demand grows with the aging of the Chinese population.

China is committed to developing new sustainability *standards* in the future. The country's main concern seems to be the market for new technologies—such as green hydrogen, artificial intelligence, new batteries, and electric cars. But it also addresses the production of food, medical products and other industrial goods.

The country is explicit about its vision. For the Chinese, *standards* are the key to the advanced market. According to Beijing, "third-tier companies make products, first-tier companies create *standards*." By mastering them, the country would also be promoting the Chinese industry.

In 2018, the country launched the Standards 2035 Strategy. The objective, says the document, is to make China the world leader in defining production and trade *standards*. By doing so, the country would allow Chinese companies to benefit from royalties, and enjoy competitive advantages in the global market. In other cases, it would be a strategy to maintain Chinese leadership in highly competitive markets, such as electric car batteries.

In 2021, the country launched the National Standardization Development Outline. Among other issues, it addresses the importance of establishing standards for "green development." Three major fields are noteworthy in the standard. The first one: *carbon neutrality* targets and standards. The second one: standards of environmental conservation and intensive use of natural resources. It also lays down the development of national statistics on green inventories and asset accounting. The third one: sustainable consumption standards, including standardization of sustainability labels and sustainable patterns of water and energy consumption (CN, 2021).

The country's project must advance on two levels. Internally, China plans on creating more than 50 *standardization* centers across the country, in addition to research institutes and certification companies and awards for companies to develop their own standards. Externally, it intends to expand its participation in global structures for negotiation and definition of standards, such as the International Organization for Standardization (ISO), as well as the growing involvement of representatives of the country in other sectoral organizations—which has sparked off reactions from other countries (CN, 2021).

Most importantly, the country expects to expand "dialogue" with other countries on defining standards. The Chinese project says a lot more when it is "silent." Firstly, the plan lists the intention to talk to virtually everyone in the world—BRICS and APEC members, Northeast Asia, Asia-Pacific, Pan-America, Europe, Africa, and other regions—except the United States and its closest allies. Secondly, the country intends to "support developing countries to improve their ability to use standardization for sustainable development" (CN, 2021).

The Belt and Road Initiative has served as China's avenue for exporting its standards. International criticism point out that Chinese investments are often contingent upon the adoption of Chinese standards. By doing so, the country gradually expands the "interoperability network" among Belt and Road Initiative countries. The effect of this type of requirement is to "lock up" the supply market for Chinese companies that adopt the authorized technical profile.

In conclusion, the Chinese bioeconomy project follows a different route from the European one—just as "biotechnology" bets on a different path to "sustainability." On the surface, the structure of action may seem similar: a climate target for reducing emissions, sectoral regulation, state guidance, financial support, substituting fossil fuels. But the way to achieve it is different: China's focus is not on "braking" or "cleaning up" the existing market, via regulation and law enforcement, but on reopening new markets, via incentive and opportunity.

To make the project worthwhile, the Chinese state adapts the mold that has guided the country's industrial development in recent decades, by combining national coordination, local autonomy, robust economic stimulus to the creation of companies, with partnerships and exchange of information and experiences between companies, in the "pilot zones of bioeconomy," all combined with evaluation and ongoing publishing of results. An accelerated learning dynamo to create the future it wants to dominate.

Doing so, in biotechnology, also requires the country to ensure the conditions for its inventions to have a "market," to be able to expand and grow. "Having a market", in the competitive world, depends on "integration patterns" capable of making the production model of a company and a country the global "rule." Future innovations tend to "reaffirm" the originality of the country, which becomes the "headquarters" of technological advance in vanguard sectors—such as new foods, pharmaceuticals and biomaterials. In short, bioeconomy in China is advanced *biotechnology*.

2.3 THE US COMPLEX

The United States has historically remained "divided" on environmental issues. The country sometimes resists taking on international commitments, sometimes advances and retreats unexpectedly. National politics oscillates between moments of skepticism and euphoria about the environmental agenda. States and parties are divided, some in favor of environmental ambition and others against it.

The North American bioeconomy complex must be interpreted as the combination of "two halves." The first half is the "biological" bioeconomy, guided by the substitution of fossils and chemicals by biological ones.

The second half is the "climate" bioeconomy. Especially after 2021, with the approval of the Inflation Reduction Act—IRA, also known as the country's new project to reindustrialize and combat climate change. The IRA reorients the "bioeconomic game": the way toward reintegrating the economy and nature, now, is pushing back the technological frontier of the economy in the clean energy sector, far beyond the biological origin.

PART I. "BIO" BIOECONOMY

The North American project, at first, combined differences. It prioritizes, on the one hand, and more and more, the substitution of fossils and chemicals by biological ones, like Europe. Private and state experiences, step by step, and slowly, tend to follow this profile—promoting technical innovations, substituting polluting activities and businesses with "cleaner" ones. On the other hand, the main way to fulfill this purpose in the country is through the "biotechnological" route. "Substitution *via* biotechnology" seems to be the main—and increasingly influential—brand in the country's bioeconomic policy.

This position advanced in stages. It starts with private sector and state experiences. The country's private sector has set up, in recent years, more than 600 biorefineries that operate mainly in the generation of renewable energy from biomass, particularly corn. It is the world leader in this sector. Technological advances anticipate, in the country, the emergence of industries, on a small scale, producing alternative energy from biomass—especially wood. It is the bioeconomy of substitution, advancing from the bottom up under private leadership.

At the state level, valuable experiences such as California's also drive the substitution bioeconomy. In the last decade, it set strict targets for energy transition, particularly in the country's energy sector, primarily from fossil sources. The carbon market created by the state is one of the largest in the world. The project is accompanied by scientific advances in the measurement of emissions and regulations, in the monitoring of companies. The Californian agenda also includes curbing emissions from transportation and agriculture—with a particular focus on the importance of methane gas.

At the base of the pyramid, so to speak, the country takes a step in the substitution bioeconomy, proving its concept as an economic opportunity—while prevailing, or despite, the country's ambivalences at the federal level.

The first national bioeconomy vision was announced by the Obama administration in 2012—National Bioeconomy Blueprint. The bioeconomy is defined in the first line of the document: "economic activity that is fueled by research and innovation in the *biological sciences*." The document exemplifies and illustrates what is expected from innovations. There is a clear focus on developing and economically harnessing disruptive innovations that modify research methods and production processes to substitute dependence on fossils and chemicals.

In health, production of drugs from biological and non-chemical syntheses. An example are biologically derived molecules to pursue the cause of a disease. The process tends to specialize, creating increasingly personalized medicine, based on the analysis and understanding of genetic identity (USA, 2012).

In energy, the recreation of energy sources from advanced biological processes, such as via re-engineering microorganisms that use light and CO_2 to create products. Alternatively, the development of biomanufactures driven by microorganisms fed on natural products, which "manufacture" new materials for human use (USA, 2012).

In agriculture, advances in soil management and microorganism control capacity to increase productivity and allow plants to adapt to different—and increasingly customized—climate and land conditions. Biotechnological engineering would have the potential to generate two new types of "biorefineries" (USA, 2012).

In the environment, "basic and applied biological research has the potential to produce a whole generation of the new knowledge and technologies needed to understand how the living world functions, to monitor and mitigate human impact, and to develop informed approaches to use and restore environments" (USA, 2012). Adapted microorganisms can be used to detoxify industrial waste and clean polluted ecosystems (USA, 2012).

In common: the advance of the bioeconomy is based on innovations in "genetic engineering, DNA sequencing and 'automated high-throughput manipulations of biomolecules'. The future, says the document, must be based on "synthetic biology, proteomics (the large-scale study and manipulation of proteins in an organism), and bioinformatics (computational tools for expanding the use of biological and related data)."

The US Bioeconomy Plan guides the budgeting practices by government ministries and agencies, with special emphasis on science and technology projects in the country. The document's objectives show the paths that resources should prioritize:

1. Basic and applied research in biotechnology.
2. Facilitating transition of bioinventions from research to market.
3. Developing and reforming regulations to reduce barriers and gain predictability-regulatory speed, with cost reduction
4. Training programs, with incentive adjustments for academic training
5. Public-private partnerships and precompetitive collaborations (where competitors pool experiences and resources).

The country's emphasis on the bioeconomy prioritized the autonomy of the private sector, without any central coordination. The regime, in this aspect, is different from the European and the Chinese ones. Europe, from the beginning, was interested in "engineering the market"—with rigid regulations and changes in rights and powers. China, in turn, focuses on territorial complexes with flexible and adaptable characteristics, with strong public intervention. Both penetrate, so to speak, the core of the market and its organization in the territory in order to take a shortcut. The United States, on the contrary, has little intervention in the core of the market so far. The private sector takes the main role. Emphasis is placed on its dynamism to create, produce and grow, as long as it is stimulated by guidelines and resources.

The US regime's explanation has historical sources. Unlike Europe—or China—the United States tends to see the market as the home of freedom. Its ultimate and untouchable foundation: ownership rights. The first of this perception, rooted in the country's constitutionalism, is to restrict the state's ability to interfere with producers' autonomy.[15] At the same time, the US regime is characterized by federal decentralization, with broad normative autonomy conferred on the federal states. Legislative competence to set taxes, contracts, companies, crimes—or even environmental law (restriction to property)—belongs, as a rule, to the states, with important but residual attributions of the central government.

The combined effect is the following: centralized policies for economic change in the country tend to be harder, questionable and rarer. For this very reason, "bioeconomic" initiatives in the country advanced, almost always, from scattered leaders and initiatives.

In the past 12 months, the bioeconomic-biotech agenda has seen a major boost—and a decisive reorientation. The main change was the central government's decision to take on the task of coordinating advances in the bioeconomy.

The first element of change came in July 2022. Approval of the Chips and Science Act by the US Congress encourages the bioeconomic project. This Act allocates ample resources to advanced computing-intensive biomanufactures (biotechnology accounts for 5% of the country's economy, semiconductors, 1%). The plan was to boost the industry and trade of bioproducts. National coordination begins with the creation of an Office in the Presidency, tasked with managing investment efforts and dialogue between public and private agents.

A new decisive step is taken in September 2022, when President Biden edits the Executive Order "Advancing Biotechnology and Biomanufacturing Innovation for a Sustainable, Safe, and Secure American Bioeconomy." This Order formalizes the national coordination of the country's efforts to advance the bioeconomy. The bioeconomy ceases to be a guideline, almost a set of principles and good intentions that the market may or may not adopt, to become the country's true priority and strategy.

Its central objective is "to coordinate a whole-of-government approach to advance biotechnology and biomanufacturing towards innovative solutions in health, climate change, energy, food security, agriculture, supply chain resilience, and national and economic security" (USA, 2022a).The expectation, therefore, is "to provide opportunities to grow the United States economy and workforce and improve the quality of our lives and the environment" (USA, 2022a).

The new order takes a set of decisive steps (USA, 2022a). Firstly, it stipulates 180 days for each of the agencies—Health, Energy, Agriculture, Commerce, National Science Foundation, to submit comprehensive reports on potential advances and applications of biotechnology and biomanufacturing for economic advancement and climate benefits. Each report must also

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[15] See the Supreme Court's decision in West Virginia v. EPA, which limits the authority of the American environmental agency to institute climate programs, such as the Clean Power Plant (Obama Government), which sought to regulate greenhouse gas emissions in the country.

"identify high priorities for basic and technological research development" and "opportunities for public-private collaboration."

Secondly, it creates a national database on bioeconomic initiatives—Data for Bioeconomy Initiative."[16] *On the one hand, the government determines the adaptation of the national statistics system to reclassify bio-based products (USA, 2022a)*.[17] On the other hand, it commits the country to developing techniques and setting deadlines to "measure the bioeconomy."

Thirdly, it creates a policy to promote and expand the "Vibrant Domestic Biomanufacturing Ecosystem." Government agencies are urged to expand purchases of bio-based products. For this, they must adapt the public procurement bidding system to support biomanufactures. At the same time, the country will identify actions to "mitigate risks posed by foreign adversary involvement in the biomanufacturing supply chain" (USA, 2022a).

Lastly, the order also reorients the performance of diplomacy, focusing on developing countries, international organizations and non-governmental entities. The goal is to align international classifications to allow for the valuation of biomanufactured products for both the US and the global bioeconomy. The concept of bioeconomy is explained in the order:

> Sec. 13. Definitions. For purposes of this order:
>
> (d) The term "bioeconomy" means economic activity derived from the life sciences, particularly in the areas of biotechnology and biomanufacturing, and includes industries, products, services, and the workforce (USA, 2022b).[18]

In December 2022, the Council of Advisors on Science and Technology of the US Presidency, with 30 members, among the greatest national leaders, released a report on Biomanufacturing to Advance the Bioeconomy, to promote savings of "trillions of dollars." The relevance of the document justifies this emphasis (USA, 2022a).

The Council states that "the world is on the eve of a new industrial revolution—that emerges from advances in biotechnology". Some of the critical innovations in the field, like gene editing, were born in the US, partly with public support. Staying at the forefront of the sector is an opportunity to "generate qualified jobs" and "expand the country's industrial base." "Inaction", in turn, would accelerate climate and economic problems that the country is experiencing.

At almost the same moment, the government published a new Executive Order from the President to create the National Biotechnology and Biomanufacturing Initiative (USA, 2022c). The government's message: "strengthen supply chains" and "address climate change" and "train a qualified workforce" to drive innovation in the country. The biotechnology-based bioeconomy takes the center of the North American development agenda.

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[16] "Within 2 years of the date of this order, agencies at which recommendations are directed in the implementation plan required under subsection (c) of this section shall report to the Director of OMB, the APNSA, the APEP, the APDP, and the Director of OSTP on measures taken and resources allocated to enhance biotechnology and biomanufacturing."

[17] Sec. 9, (A) Within 1 year of the date of this order, the ITWG shall recommend bioeconomy-related revisions to the North American Industry Classification System (NAICS) and the North American Product Classification System (NAPCS) to the Economic Classification Policy Committee.

[18] It formalizes other key definitions for the national bioeconomy: Sec. 13. Definitions. For purposes of this order: (b) The term "biotechnology" means technology that applies to or is enabled by life sciences innovation or product development. (c) The term "biomanufacturing" means the use of biological systems to develop products, tools, and processes at commercial scale. (d) The term "bioeconomy" means economic activity derived from the life sciences, particularly in the areas of biotechnology and biomanufacturing, and includes industries, products, services, and the workforce. (e) The term "biological data" means the information, including associated descriptors, derived from the structure, function, or process of a biological system(s) that is measured, collected, or aggregated for analysis. (f) The term "biomass" means any material of biological origin that is available on a renewable or recurring basis. Examples of biomass include plants, trees, algae, and waste material such as crop residue, wood waste, animal waste and byproducts, food waste, and yard waste. (h) The term "bioenergy" means energy derived in whole or in significant partfrom biomass.

PART II: "CLIMATE" BIOECONOMY

The North American bioeconomy must also be understood from its green transition project, through the change in the country's energy mix—regardless of its "biological" source. It's high tech, but not biotech. The basis of the new vision is the country's new industrial policy—the Inflation Reduction Act (IRA) (USA, 2022d).

This act is a milestone in the US climate agenda. One of its multiple motivations is allowing the country to meet its climate target of cutting 50% of emissions by 2030, counting from 2005. It is expected, therefore, that, in a short time, it will "reorient" the energy, transport and agricultural sectors of the country.

The IRA establishes investments of around US$ 390 billion in climate transition actions. Of this amount, US$ 270 billion in the country (and at least the double of this amount, indirectly, by the private sector), in "green reindustrialization." The focus: "energy security and climate change." The allocation of resources includes US$ 220 billion in energy, US$ 67 billion in manufacturing, US$ 48 billion in energy efficiency, US$ 33 billion in transportation, US$ 26 billion in environmental justice, land use and resilience, and US$ 21 billion in agriculture.

The scale of investments "weighs" on the operation of the private sector. Its implementation indicates the privileged sectors. In the energy sector, the first highlight are renewable energies—hydrogen, in particular. Another topic of priority attention is the production of batteries. The green transition—and the advancement of the clean transport mix, in the country's view, depends on the development of high-capacity batteries. The dispute with China is at the base of the country's orientation.

The food sector enters the new agenda strongly. The country highlights the importance of plant adaptation projects, in order to prepare the sector for the impacts of climate change. It also emphasizes the importance of new bioindustrial projects, based on biomass, starting with the production of biofuels from diversified sources.

The most striking geopolitical trait of the IRA is the "renationalization" of the global supply chain. In the "strategic" sectors for the US economy, the country's expectation is that the volume of resources poured into the market will attract the entrepreneurial and technological elite to the country's wings. In doing so, it also hopes to take back cutting-edge dominance in critical technologies. In addition to weakening the ability of the Chinese economy to lead the "energy" of the future.

The American project, like the European and the Chinese ones, also takes a "globalizing" stance. The country believes that the focus of the advance is reestablishing its industrial capacity, lost over the last decades to China. What was once seen as an efficient reallocation of resources between countries is increasingly seen as a threat to sovereignty and national security.

The IRA institutes a new "division" of the world between friendly countries and the rest. Allocation of subsidized resources is conditioned to the location of the company and its inputs. Companies located in "friendly" countries, and which use resources from these countries, are authorized to raise funds subsidized by the US policy. The economic advantage intends—and has stimulated—market movements. The signs of migration of European companies to the US triggered reaction on the other side of the Atlantic, with the approval of the Green Deal Industrial Policy.

In this context, the concern with technical “standards” of the new economy also becomes more and more decisive. In recent years, the country has restructured and strengthened the national standardization system. The aim is to strengthen integration between the technical parameters—typically negotiated autonomously and spontaneously by companies in the country—through a private-diplomatic partnership that allows the country to face the state-centered models that tend to predominate in Europe and China. In particular, the country has been critical of alleged efforts by Chinese companies to “shape up” standards, in new technologies, to its situation.

In short, the North American bioeconomy project is concerned with the reunion of environment and economy through the route of advanced technologies. The American route is made up of two parts. The first one: the advance of biotechnology—as a way of “biological” substitution and as a source of biomaterials. The second one: green reindustrialization in the “clean energy” sector—largely non-bio-based.

If bioeconomy is the project of reconciling the economy and the environment, the North American bio is the fusion between (i) a new economy based on biological sciences and biomanufactures—in a governmental coordination arrangement that organizes, classifies, measures, promotes and supports production advances; and (ii) a new economy based on clean energy technologies—such as hydrogen, new batteries, and relevant adaptations—at the global competitive forefront.

What unites the two projects is a national vision: the affirmation of the country's technological and economic sovereignty with a controlled supply chain (and marginalization of China).

3. THE BRAZILIAN COMPLEX

3.1 GATEWAY

The green transition and the increasing competition between countries have altered economic dynamics in a particular way. At the base of this change is the emergence of a *new production factor*. Alongside the traditional production factors—capital, labor, and land—the *green factor* now appears.

On the one hand, “green” works in the economy like other factors: it is a *relative cost*, that is, its price is variable according to market availability (demand and supply). Just as the price of capital is variable (capital can be more expensive or cheaper), or just as land has a *variable cost* (according to fertility or location), and just as labor has different prices (according to qualification and availability)—the price of “green” should also fluctuate according to availability.

As environmental concern mounts around the world, the demand for “green” increases, and so does its weight for the competitiveness of companies and countries. Economic competition increasingly demands the adoption of smart strategies, which mobilize a wide range of production factors, including environmental factors. Schumpeter named this set of strategies "entrepreneurship."

Entrepreneurship, in this context, is not limited to technological innovations and business models; it also includes the ability to incorporate sustainable practices into all stages of the production process. The advantage is to attract conscientious consumers and investors, in addition to complying with increasingly stringent environmental regulations. Moreover, concern for the environment is intrinsically related to energy efficiency, the rational use of natural resources and the reduction of operating costs.

Likewise, countries that promote public policies for sustainable development and environmental preservation have the opportunity to stand out on the global stage, attracting investments and strengthening their image in the international context.

Therefore, companies and countries that recognize and adapt to the integration of "green" as a factor of economic competitiveness have more chances of achieving success and prosperity, while supporting the preservation of the planet and the construction of a sustainable future.

On the other hand, the "green" has a unique form of *remuneration* in the market. While work is remunerated by wages, capital by interest and property by rent, "green" is compensated by what we can call "payment for environmental services."

Remuneration of the *green factor* differs in the following sense: while the other factors are remunerated for their direct contribution to production and income generation, the *green factor* is remunerated for its ability to provide essential public services.

The *green factor* consists of natural stocks, such as forests, ecosystems, water resources, and others. These stocks play a fundamental role, such as climate regulation, air and water purification, biodiversity preservation, and other environmental benefits.

The first is the *natural stock:* a natural fabric of environmental services, which tend to be recognized and valued by the world (starting with carbon sequestration, but advancing onto water services and biodiversity). For example: payment for carbon sequestration by planting trees, or providing water or other relevant services to the rest of the economy. It is the value created by a generous interpretation of *ecological* bioeconomics.

The second one is the *technical stock (with social technologies):* a set of knowledge, technologies and techniques that create “sustainability gains” in environmental accounting, replacing polluting activities via, for example, new sustainable materials. For example: the development of “land”-saving production techniques or techniques that combine environmental services with production dynamics, such as the integrated crop-livestock-forestry system. The development of biofuel also comes into play here. Biofuel replaces fossil energies—such as gasoline and diesel—and the generation of new materials, such as degradable bioplastics, which ultimately “add a green hue” to society. It is the value created by the bioeconomy of *bioresources* (or bioeconomy of *substitution*).

The third one is the *advanced technological stock*: a set of state-of-the-art of knowledge on how to mobilize nature's living capacity to produce goods and services useful to human life. For example: the creation of new drugs, genetically modified seeds (as in soy or corn, for example), or the production of materials from adapted microorganisms. It is the value created by the *biotechnological* bioeconomy.

In summary: the *green factor* can take sources of value from the three visions of bioeconomy: ecological, as natural stock; bioresources, with “positive flow” towards *net zero*—technical stock; and biotechnology, with “innovations” (future market)—technological stock.

OPPORTUNITY AND THREAT

The global expectation is that the advancement of the planet's climate transition will consolidate the influence of "green" in the arrangement of the global economy. It will be the moment of fully assimilating climate-environmental costs into the countries' business model and management of countries, in trade relations and in global geopolitics. Care for the environment will be included in the price of each transaction. The integration between economy and environment will be close.

In this process, those who still have an economy anchored in environmental degradation may have to face new restrictions to growth. Financial investments will tend to pursue "sustainable" activities or regions. Companies will assess the "green cost" of doing business—and any difficulties in sourcing sustainable supplies. More demanding consumers, at the same time, also tend to opt for sustainably sourced goods.

This new approach to green competition will touch the ground of national realities. In this encounter, particular advantages tend to emerge. More preserved countries, such as Brazil, have the potential to enter the "green" economy with a head start—a new kind of original comparative advantage.

Ecological bioeconomy: the country has more than 60% of its territory preserved. Each Brazilian rural property has, by law, a private factory of environmental services, a legal reserve, on 20% to 80% of the property's area.

Substitution bioeconomy (or bioeconomy of bioresources): the country also has a high technical capacity for sustainable production, with integrated systems, no-till farming, and benchmark projects, such as biofuel projects. Farming productivity has increased by 400% in the last three decades. This capability opens the door to new food production systems, new sources of energy and textiles—in addition to the generation of new materials.

Biotechnological bioeconomy: Brazil's production progress is increasingly based on cutting-edge technology, with genetic adaptations and development of species "adjusted" to the particularities of the country's soil and climate, more resistant to pests and climatic volatilities.

GREEN COMPETITION

The "installed potential" of a significant portion of the Brazilian economy, starting with agriculture, is mostly sustainable. If we manage to stop deforestation in the Amazon—a critical condition for the sustainability of the Brazilian economy—the potential for increased production and green gains could also increase. And the profitability of national production should also increase. This is good news for the country.

There is, at the same time, a warning—or a threat. Competition between the factors is dynamic. The terms of "balance" change over time. Each production factor competes for a leading role. At times, "labor" can have a privileged importance—and prevail over the others in the formation of costs and in the opportunity for earnings. At other times, "capital," for example, can take the lead and make labor overweigh prices.

This is, incidentally, what is happening now with the so-called "premature deindustrialization" of developing countries. The labor factor, at the base of national development projects throughout the 20th century—particularly in Asian countries such as Korea, Malaysia, China and, more recently, Vietnam and Thailand—lose its preponderance with the advance of automated and digital machines. Factories become warehouses, full of machines, but empty of people.

The availability of cheap labor loses "price"—whereas the availability of capital and technology gains value. The effect is what we perceive around the world: the inverted movement of factories (Rodrik, 2013a, b, 2014, 2016). If in the past they left advanced centers towards the East (outsourcing), now they are starting to go back home (insourcing) (Tyler, 2016). Developing countries begin to de-industrialize before they develop. Followed by the rich countries themselves, which also start to deal with the same problem (Emmenegger et al., 2012).

What the example indicates is that the terms of dispute between production factors change over time. Whoever is losing today can strike back and win tomorrow.

What does this have to do with the green transition?

Today, the relative weight of "green" tends to increase vis-à-vis other factors. The presence of abundant green, in a given territory, tends to be a significant attraction for companies to settle, in terms of money, people and land. If we imagine two factories, with the same pool of capital, labor and land, the first integrated into a "greener" chain; the second, to a less "green" chain, it seems right to infer that the "greener" factory has an advantage.

This advantage is incorporated in the economy in different ways. Firstly, *green premium*—paid by buyers who appreciate the "green" side of the goods. Secondly, *environmental credits*—starting with carbon, which remunerates the negative contribution of the goods. Thirdly and most importantly, for the *opportunity* to attract credit, work and technology in the future, which, ultimately, "commits" to more sustainable businesses. New ways of benefit are to come.

The advantage of the "green factor," however, is not eternal. Just as labor has lost weight in the organization of the economy—and just as there is an enormous effort to reactivate it—it is also true that countries today are moving with great impetus to rebuild the stature of "capital" in the economic dynamics of key sectors of the economy, starting with energy and transport.

The creation of alternative sources of clean energy should mean an accelerated reduction in the cost of energy. Innovation and the incorporation of new clean energy systems—produced from the sun, wind and water, as well as from hydrogen—into the economy tend to undermine Brazil's energy edge.

Today, Brazil has a highly sustainable energy mix, made up of renewable energy or bioenergy. Industrialized goods produced here cost "less" nature than the good that is produced based on thermoelectric energy in Europe, the United States or China. As countries complete the transition to new energy sources, the Brazilian advantage tends to disappear.

Furthermore, international obligations tend to raise the cost of accessing the *green benefit.* When countries enter into international commitments, they set a minimum threshold for themselves—that is, an "obligation." What was a distinctive feature becomes a debt to the world. For Brazil, the turning point is 2028—the deadline in which the country committed to zero deforestation. From then on, it remains to be seen whether the environmental services provided by the green stock will be remunerated.

Finally, the technological race, in the great powers of the planet, is also an effort and a preparation of countries around the world to avoid the *green* risk on their economies, fueled by fossil fuel. As the climate transition advances, the green cost should drop—and economies become "net zero." There will be, so to speak, a full assimilation of climate-environmental costs in the business model and in the management of countries, as well as in trade relations and geopolitics. Care for the environment must become a prerequisite and will be "charged" in the transaction.

In this environment, those who still have an economy anchored in environmental degradation may have to face new restrictions to growth. Financial investments will tend to pursue "sustainable" activities or regions. Companies will assess the "green cost" of doing business—and any difficulties in sourcing sustainable supplies. More demanding consumers, at the same time, also tend to opt for sustainably sourced goods.

The green transition, therefore, must be read as a double-edged sword: an opportunity, but also a warning.

In the short term (in the next decade): natural conditions of forest, sun, wind and water still allow the country to expand the availability of clean and cheap energy and, thus, to attract investments in energy-intensive sectors. From then on, the Brazilian advantage tends to disappear, as new sources of clean (and cheap) energy are formed in the world. The country may *lose* the green advantage of technical and technological stocks, as well as environmental services linked to the productive economy. An obvious question, in this case, is: how could the country capitalize on them?

In the medium term (from 2030): new production technologies and techniques tend to reduce the relative weight of the green factor—capital and labor, so to speak, should "recover" some of the lost advantage in defining the price of businesses, starting with the advantage of cheap energy. The question, therefore, is how can the country prepare for the future?

In this context, knowing how to play with "time" is key to the country's progress.

The two challenges are based on the same condition: the country's ability to convert *green* into *value*.

This is the central task of the Brazilian bioeconomy, *defined here* as:

> *"The stock, use and transformation of Brazilian natural and biological resources."*

Progress in the country will require two courses of action.

i. Organizing the shape of the Brazilian bioeconomy — the green standards.

ii. Developing the substance of the Brazilian bioeconomy — bio-agriculture, bio-energy and bio-manufactures.

3.2 THE SHAPE OF THE BIOECONOMY: GREEN STANDARDS

The first step in this conversion is to “build” the foundations for enhancing the national green.

Converting green into value is not automatic; it requires a combination of advances. Firstly, scientific advance, starting with the development of metrics, methodologies and parameters for measuring the environmental footprint that are increasingly adjusted to each product in the country. Secondly, economic advance, starting with the development of economic parameters for converting green into an asset and its flows and stock. Thirdly, legal advance, starting with the regulation of new markets for environmental services in the country.

Scientific advances will require the country to “define” green among its activities. This definition begins with the main environmental service in the world: carbon. Over the last few years, the country has advanced in the “tropicalization” of international measurement parameters based on “averages” of aggregated experiences, especially in temperate countries. This process, however, is dynamic, and needs to be continuously improved and detailed, to incorporate advanced production techniques and recognize the peculiarities of each part of the country's territory.

Ultimately, comprehensive knowledge of the Brazilian green must supply a national database, metrics, methodologies and parameters that are valid in the country. Doing so, on the one hand, is a way of building “public infrastructure” that can be absorbed by producers. It is this available technology that will make it possible to show the accurate “carbon footprint” of each product, service and value chain, and reveal the “green cost” implicit in the goods and services produced in Brazil. Doing so, ultimately, is the way to reveal the merits and defects of each Brazilian economic activity.

Economic advances will help the country convert green into an asset. Not everything that is “sustainable” is “economical.” This bridge needs to be built. And this will depend on Brazil’s capacity to "quantify" the green economy. At a micro level, the advance will come as the market advances and demands sustainable goods. At a macro level, it should be influenced by advances in trade and global requirements. In both cases, it will require the country to provide comprehensive data on the interaction between the economy and the environment, on the ways of organizing this “interaction” at a micro level—in each sector or business—and at a macro level—in aggregated sectors and in the country. This topic will be further discussed in the next chapter.

Finally, *legal advances* are necessary for the expansion of markets. In sectors where the good exchanged is immaterial—such as carbon credit—and “transparency” and “quality” control is complex, regulation is a decisive instrument to ensure trust and security to the market. By doing so, regulation helps to expand the horizon of investments and exchanges.

The carbon market is the regulatory mechanism and ensures trading conditions for the "carbon" *commodity*. The instrument—which is already in place in Europe, California, and China, and in other places—is highly sensitive and demanding. Its implementation is usually cautious, its object well established by law, and with relatively long maturities (between, for example, 3 and 5 years). The focus of the mechanism is the energy sector (in particular, thermoelectric plants).

Advances in science, economics and law should contribute to creating, in the country, a *bridge* between the current economy—in which "green" has no relevant price or market—to a new economy capable of rewarding relatively more sustainable production activities.

3.3 THE SUBSTANCE OF BIOECONOMIC DEVELOPMENT: GUIDELINES

The bioeconomy can be a central step towards the "green industrialization" of Brazil. At the heart of production progress is the marriage between intelligence and nature. Developing this idea requires, first of all, avoiding past mistakes.

The development of a production policy in the 21st century must have a different profile from the policies adopted in the past. The space for generating qualified employment, in the old industrial format of the 20th century, is increasingly less competitive and relevant in the world.

At the same time, however, the economy's progress reopens new frontiers of production development and the creation of qualified jobs. Some of these frontiers are known and sought-after, starting with the shoulder-to-shoulder dispute between China and the United States over energy storage technology (batteries), and over control of rare sources of lithium in the world. The chance of Brazil winning disputes in which global leaders are placing all their bets is small.

Many frontiers, however, are open and available to Brazil, without the country facing, in the short and medium term, a clear entry restriction. These are frontiers where traditional economic competition "does not reach" due to market particularities (different preferences), locational advantages or unique natural capital.

BIO-AGRICULTURE

Integration between "bio" and "advanced technology" is already taking place in Brazil—in agriculture. Recognizing this opportunity requires considering the sector an "open-air industry," in which increasingly sophisticated technologies and techniques, created in applied research and development centers, are continuously incorporated and partially disseminated to expand production capacity in the territory. And around which a significant portion of the Brazilian economy (one quarter of the GDP) is structured around a continuous cycle of lessons learned and developments.

This technology is mostly "tropical"—and linked to the Brazilian reality. In this field, the country has an open space for innovation and, at the same time, for meeting the growing international demand for food, with expectations of an increase in the world population and nutritional quality. At the same time, there is a mass of Brazilian farmers that could still benefit from the dissemination of the latest production techniques and technologies, supporting productivity gains and, therefore, income from farming activities.

One of the most promising fields for the advancement of bio-agriculture are the bio-inputs. Brazil is where farmers most incorporate bioinputs in the world (McKinsey, 2023). The sector is growing at high rates, with continuous availability of new "organic" alternatives that save costs and increase productivity. Some of the main developments today are in the biological control of pests and the promotion of plant development (e.g.: biological nitrogen fixation). Advanced research promises important agricultural innovations in the coming years.

BIO-ENERGY

Progress in energy transition also earns Brazil particular advantages. Over the past few decades, Brazil has developed a unique ability to convert sugar into energy. This advance, combined with proper land use, opened up a market integrated with technological advances in the transport sector—with innovations in the flex-fuel engine and regulated fuel mixtures. Today, the institutional arrangement allows the country to produce fuel at a competitive price with the fossil competitor. Safe demand for cheap energy—in Brazil and abroad—may stimulate the development of the sector in new frontiers.

Two pathways can open to the country.

The first: taking advantage of continuous wind flows on the coast to create a new energy complex for the production of clean energy, particularly in the Northeast. Ceará has recently launched a "green hydrogen hub" and entered into a partnership with the Netherlands for production and export.

The second: the development of new technologies for generating biofuel, especially ethanol, with new products—such as corn—but increasingly with advanced biorefineries. The so-called "second-generation ethanol" can allow the use of complex sugars—such as paper pulp and lignin—present in abundance in biomass (including straw, tree trunks and branches, wheat and rice husks, and others).

The technology could be integrated into existing production systems, multiplying their capacity to use biomass for production and, therefore, with continuous gains in sustainability and productivity (as a rule, one quarter of the biomass of a crop is effectively used in production) (Windisch, 2021). This is the project in India, which has recently released the "Innovation Roadmap of the Mission Integrated Biorefineries," which should support the setup of experimental biorefineries in several states of the country. Biorefineries should absorb, as an input, waste from rice and wheat production (India is one of the world's largest producers of rice and wheat), increasing the sustainability of the production system and bringing development inland.

The advance of bio-energies in the country would also contribute to the sustainability of other chains. Brazilian flex-fuel cars are more "sustainable" than European electric cars not because they release less greenhouse gases—in the tailpipe, CO_2 emissions are similar. The difference lies in the production system, that is, in the role played by the farms: it is the photosynthesis of the sugarcane that is responsible for "neutralizing" emissions; the ethanol production system converts CO2 and water into alcohol. The same happens with products from the agro-industrial chain—one quarter of the Brazilian GDP—based on "farm" goods.

The industrial sector, in other words, is "low-carbon" because it consumes goods manufactured, at one end, from farmer-managed photosynthesis (and because it consumes clean energy). The advantage of the national "industry" and "trade", in other words, is also the consequence of what happens "past the farm gate." It is this "productive sequestration," on the farm, that can contribute to financing production activities in the city. The city, in turn, can also contribute, over time, with improvements in our ability to "interact with nature"—more knowledge, more technology, more techniques that allow more "photosynthesis," more soil carbon and biomass carbon, with less emissions.

BIO-MANUFACTURES

"Agriculture produces raw material, and the industry transforms it"—the traditional distinction between sectors is diluted by biotechnology. Bio-manufactures are nature's factories: it is nature, prepared and managed, that becomes the source of production of new resources useful to society. Bio-manufactures can advance based on Brazilian production systems. Today, agriculture "plants" food, energy and "textiles." Tomorrow, it can plant new materials. It is nature manufacturing, with human guidance.

With more advanced technologies, knowledge also makes it possible to convert agriculture into "planting" of genetically adapted microorganisms to "work for us." Those microorganisms that can, for example, consume waste and convert it into clean energy sources (new fuel, for example), or even provide natural services, such as cleaning polluted environments.

The world of bio-manufactures is beginning. Brazil has growing experience in working with nature and its tropical organisms. National capacity can advance and, over time, make room for new fields of production.

BIOFACTORIES

The Amazon and the Brazilian Cerrado are home to a diversity of production arrangements for the extraction of natural products. These arrangements include the initial stages of adding value, involving stricter collection techniques, leading to farming, and preparation for sales. International demand plays a crucial role in boosting the qualification of these products and the first advances in the production system (Coslovsky, 2021) (CPI, 2021). To facilitate access and export, cooperatives or associations play an important role in mitigating the costs involved.

The importance of products extracted from the Amazon is reflected in the 2021 statistics. The extraction of fruits and hearts of palm from açaí, Brazil nuts, copaiba oil, tonka bean and rubber (Hevea) in the Amazonian States represented most of the national production. For example, the açaí fruit accounted for 95% of the total production value, while the Brazil nut represented 91% of this value. In financial terms, production of the 10 main extractive products reached BRL 901.6 million in states with the Amazon biome, up 35% compared to 2017 and 15% compared to 2020 (IBGE, 2023).

Among the extractive production chains, açaí and Brazil nuts draw special attention. The acaí production chain involves extractivists, small and medium-sized producers, intermediaries, processing industries and artisanal açaí beaters. This production system involves multiple practices, such as extractivism, management in riparian areas, farming with irrigation and farming without irrigation in dryland areas. The main farming areas are in the states of Rondônia, Acre, Amazonas, Roraima, Pará, Maranhão, Tocantins and Mato Grosso. Pará is the largest producer, accounting for 94.41% of the national production of açaí (IBGE, 2023).

Regarding Brazil nuts, production is also predominantly extractive, with great socioeconomic importance for the Amazonian populations. The State of Amazonas is the largest producer, with 11,737 tons extracted in 2021, outweighing the production of Pará and Acre.

These production forest arrangements can serve as a gateway to the setup of *bio-factories*. However, the challenge in these locations is to create tools to speed up the transition from an economy predominantly based on the collection of natural products to more advanced forms of bioeconomy. This transition involves the continuous incorporation of techniques and technologies that add value and reduce dependence on raw extraction as the main expression of economic value (Homma, 2022; Botelho et al., 2022; Freitas et al., 2022, 2023).

BIOECONOMIC DEVELOPMENT ZONES

The development of the Brazilian bioeconomy must be connected with the characteristics of each territory. The advance of new production centers does not usually occur in an equal and disseminated way in the soil. Rather, it follows areas of concentration—that can be called clusters or production arrangements. Productive arrangements facilitate and streamline access to resources and the exchange of experiences and knowledge. In doing so, they also speed up the learning process and convert productivity gains into local development.

Bioeconomic Development Zones based in locations that already have growing production and productivity, would house a pool of bio-agriculture, bio-energy, bio-manufacture and bio-factory projects across Brazil. They would inaugurate, "on the traditional economy", an advanced frontier of localized experimentation, which would also contribute to the promotion of diversified production vanguards. Monitoring and assessing these projects, considering their market capacity, would help to guide development and disseminate good practices.

Economic Development Zones should be set up throughout Brazil, recognizing its potential and particularities. Special attention, however, should be paid to the new frontiers of Brazilian territorial development: the Amazon, the Northeast and the Midwest. Each of these areas can and should host a new chapter in the construction of knowledge, local and advanced industrial production practice on how to dilute the traditional division of sectors and develop in loco an example and a reference of new frontiers of knowledge and the economy.

3.4 NATIONAL ACCOUNTS

At the base of a national production policy is the intelligence of an accurate understanding of reality—and the value of production factors in the country. To define this value, there is the System of National Accounts (SNA), a robust accounting structure, officially adopted by regions and countries in the world. It is the "common language" of economic comparability between countries.

To expand or supplement the GDP, some alternatives were developed from a welfare economics perspective, such as green accounting. This type of accounting is based on the GDP, but subtracts negative impacts on well-being, such as the degradation of natural resources, and adds the positive ones, such as the service generated by ecosystems.

The SNA, therefore, is the starting point for the development of green accounting. It is the basis for valuing the "bio" amount among the total wealth generated by the Brazilian economy. The Bioeconomy Observatory of Fundação Getulio Vargas took this step forward by developing the Bioeconomy GDP (Bio-GDP), which maps out "bioeconomic" activities within national accounts.

The next step is the development of the country's environmental accounts, which make it possible to measure and integrate the value of environmental stocks and services into the national accounts. The first steps of this task are underway in Brazil, under the leadership of the Brazilian Institute of Geography and Statistics (IBGE), based on the statistics proposed by the System of Environmental-Economic Accounting (SEEA) and its extensions, as discussed below.

4. NATIONAL BIOECONOMY ACCOUNT — CNBIO

Valuing green will require Brazil to develop appropriate measurement instruments that are capable of valuing, *in an integrated manner*, economic and environmental attributes of an economy.

The valuation of economic attributes, well established in the *System of National Accounts* (SNA), follows internationally shared standards, with universal classifications and rules, which allow Brazil to measure economic flows, such as the Gross Domestic Product (GDP), and compare performance with other countries.

The GDP of an economy is defined by the wealth it generates. Wealth, in turn, is the resulting sum of the added value of all activities in that same economy, for example, the value that an industry adds to the raw material it acquired.

Although it is a widespread accounting system, the GDP does not consider stocks and has limitations, as it does not account for the value that *green activity* adds, such as ecosystem services that increase agricultural productivity or help improve air quality.

In Brazil, some studies present the economic value of the bioeconomy and its potential (De Lima; Pinto, 2022; Silva; Pereira; Martins, 2018); however, these studies have the same limitations, as they consider only monetary values in their composition. Without proper metrics, it is not possible to measure the value that green adds to an economy.

This “green valuation” is still a task under construction in the world.

A promising strategy for incorporating the *green factor* into national accounts is the development of the *National Bioeconomy Account – CNBio*, based on satellite accounts. These accounts are extensions of the SCN and allow the measurement to be extended to fields beyond the economy, including biodiversity, ecosystems and the environment.

By incorporating satellite accounts with an environmental focus into the SNA, an important step is taken towards valuing the bioeconomy. A decisive step to be taken, which will allow optimizing the development of these accounts from a statistical point of view, is to explore the environmental accounting of the System of Environmental Economic Accounting (SEEA), recognized as an international standard (Banerjee et al., 2016).

4.1 CHART OF ACCOUNTS FOR THE BIOECONOMY IN BRAZIL: THE WAY FORWARD

The latest metrics of economic performance are based on the SNA, developed in 1947 at the newly formed United Nations as a set of recommendations taken from the committee led by Richard Stone in the United Kingdom (STONE et al., 1947). These recommendations, in 1953, appear in the technical report “A System of National Accounts and Supporting Tables” (UNITED NATIONS, 1953), which consists of a standard set of accounts and tables that present and classify in detail the flows in an economy. The innovative double-entry format where each payment made corresponds to a payment received by another economic agent reflects the macroeconomic concept of the circular flow of income that has its roots in the 1700s with Richard Cantillon and François Quesnay (Miller; Blair, 2009a). More than that, the SNA provided nations with a "common economic language," as these concepts and definitions were widely applied in several developed and developing countries (European Commission et al., 2009).

The SNA made it possible, among other metrics, to calculate added value — which is nothing more than the balance of the value of goods and services sold by an industry minus the cost of inputs (except labor). What is left is the newly-generated income that will be distributed among the owners of the capital of this industry, payments to employees and compensation for the risk incurred during a given period. The combination of values added from various industries (adjusted for capital formation and taxes) is equivalent to the Gross Domestic Product (GDP). The GDP summarizes the economic efforts of all residents in a country and is easy to interpret. For this reason, it has become the economic performance metric most used worldwide (Hoekstra, 2019). Intuitively, a GDP that is higher than the previous year generates additional income to be distributed to growing populations and has a positive connotation.

The GDP calculation has many limitations and must be carefully interpreted. This is not a failure of GDP, but a consequence of its own mathematical definition. The GDP considers income from activities as flows that contribute to its growth. However, it does not specify whether these earnings come, for example, from income from capital investment or from the settlement of capital stocks. Furthermore, the GDP considers various forms of capital settlement including fixed produced, natural or human capital as positive contributions to economic growth. Consider selling wood from a managed forest that is later reforested; and the sale of wood from illegally cleared rainforests that are later on converted to pasture. Both activities contribute positively to GDP growth. However, there is a difference in how each one impacts social well-being and the environment through the settlement of natural capital, biodiversity and ecosystem services that generate inter-generational benefits. Additionally, when placed in perspective with the population, the GDP does not consider income distribution and inequality.

To get around these GDP issues, many alternatives have been proposed from neoclassical theories of well-being and theory of capital under the term Beyond-GDP. This includes green accounting, which starts with the GDP but subtracts welfare-reducing impacts, such as degradation of natural capital, and adds monetary value to other dimensions of well-being, such as leisure time (Hoekstra, 2019).

In 1994, the UN Statistical Commission established the London Group on Environmental Accounting as a forum for sharing experiences in developing frameworks for environmental accounting. This group participated in the review of the first SEEA version (1993) and the subsequent production, in 2003, as a set of best practices for environmental accounting (United Nations et al., 2003). An important aspect of the 2003 document is that it was endorsed by the same institutions that standardized the SNA; namely, the United Nations, the European Commission, the International Monetary Fund, the Organization for Economic Co-operation and Development, and the World Bank. A precedent was then set for its further development, as a statistical standard.

At the 43rd Session of the Statistical Commission, in March 2012, the SEEA Central Framework was adopted as the International Environmental-Economic Accounting Standard (Banerjee et al., 2016). The SEEA tracks changes in natural capital stocks and their contribution to the economy. It connects with the SNA and complements the GDP.

According to the Global Assessment Report (SEEA, 2023), 92 countries have implemented the SEEA, as shown in FIGURE 1.

Note: The 2022 Global Assessment Report provides information on the implementation stage of each participating region. The implementation is divided into three stages: Stage I: compilation, Stage II: dissemination; and Stage III: regular compilation and dissemination. According to the results, 72% of countries fall into Stage I of implementation, 17% of countries fall into Stage II and 11% of countries fall into Stage III. Source: SEEA Global Assessment Report 2022, 2023.

The SEEA[19] allows capturing and integrating data on natural resources, environmental degradation, greenhouse gas emissions, environmental stocks and flows, economic impacts, and other relevant aspects. This system provides a conceptual and methodological structure for statistics and environmental indicators, allowing a more comprehensive analysis of the relationship between the economy and the environment.

4.2 PHYSICAL FLOW MEASUREMENT STRATEGY

Flows from the environment to the economy are entered as natural inputs. Flows that occur within the economy are entered as product flows, while flows from the economy to the environment are entered as waste, as shown in FIGURE 2. The economy's use of natural inputs is intrinsically related to changes in the stocks of environmental assets that provide those inputs.

[19] Available at: https://seea.un.org/content/about-seea

Figure 1: SEEA Implementation Around the World

Source: Prepared by the authors.

Ecosystem accounting (EA) covers the assessment of flows known as ecosystem services, which represent the contribution of ecosystems to economic activity and other human activities. These services can be classified into three main groups: (i) provisioning services, such as the supply of natural resources from forests; (ii) regulatory services, for example, when forests serve as carbon sinks; (iii) cultural services, such as national parks open to visitors.

By focusing on ecosystems and on the tangible and intangible benefits generated by environmental assets, a basis is formed for assessing the impacts of economic activities on ecosystems and for integrating the resulting data into national accounts. This includes spending on environmental protection and resource management, and the production of environmental goods and services, such as clean energy devices.

Ecosystem accounting (SEEA EA) has been used to inform policy-making in at least 34 countries (United Nations, 2021).

The SEEA EA is built on five main accounts.

These accounts are compiled using spatially explicit data and information about the functions of ecosystem assets and the ecosystem services they produce. They are the following:

i. SEEA ECOSYSTEM EXTENT (SEEA-EEx): it maps out and characterizes different types of ecosystems that are present in a given area, such as forests, wetlands, mangroves, coral reefs, and others. It allows the identification and spatial delimitation of these ecosystems, providing information about their geographic distribution and physical extension. This extension makes it possible to assess the economic and environmental impacts of human activities on ecosystems, and to analyze the contribution of ecosystem services to human well-being and environmental sustainability.

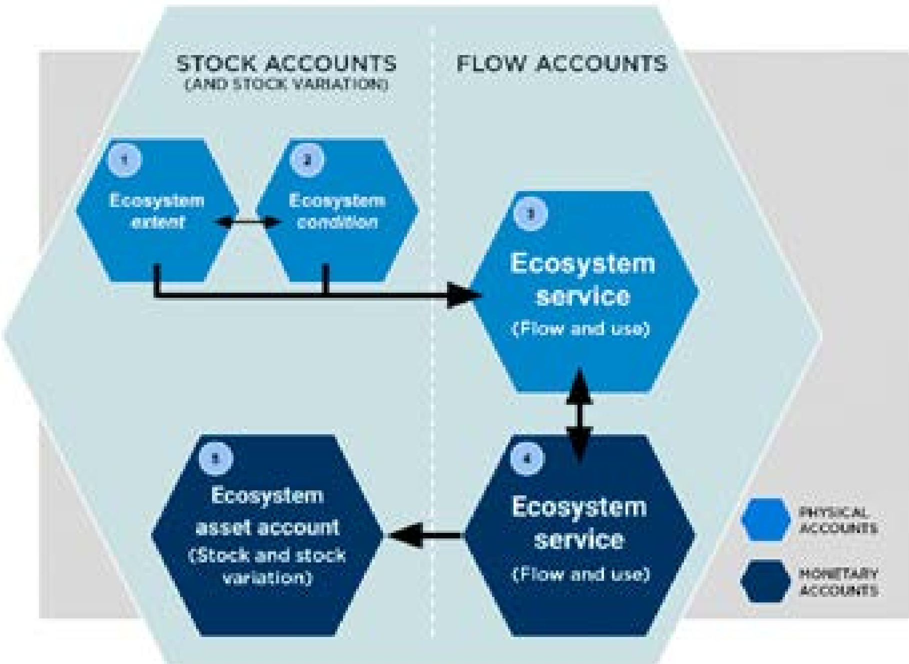
Figure 2: Physical Flows of Natural Inputs, Outputs and residuals

ii. SEEA ECOSYSTEM CONDITION (SEEA-EC): it provides indicators and information on the status of ecosystems, including biodiversity, water quality, air quality, soil health, habitat health, and others. It allows assessing the health and functioning of ecosystems, as well as identifying changes and trends over time. It is applicable at different geographic scales, from local to national and regional levels.

iii & iv. SEEA ECOSYSTEM SERVICES flow accounts (SEEA-ESFA): it allows to identify, measure and monitor flows of ecosystem services over time and their impact on the economy. These accounts help quantify the contribution of ecosystems to human well-being and provide important information for decision-making and policy-making related to the conservation, management and sustainable use of ecosystems. These accounts record the flows of ecosystem services in physical and monetary terms, relating them to economic agents such as companies, households and government.

v. SEEA MONETARY and ECOSYSTEM accounting for ASSETS (SEEA MEAA)[20]: it provides a conceptual and methodological framework for accounting and valuing environmental assets, which include both physical and monetary assets related to ecosystems. It addresses the accounting of environmental assets through the attribution of monetary values, considering their contribution to the economy and society. It involves valuing natural resources such as forests, land, water and biodiversity, as well as valuing the ecosystem services these assets provide, such as climate regulation, pollination, protection against natural disasters, and others.

The five accounts connect to provide a complete picture of ecosystems, as shown in FIGURE 3.



Source: *SEEA Ecosystem Accounting, 2017.2017.*

[20] For further information on the Physical Supply and Use tables, see Appendix.

Figure 3: Ecosystem Accounts and how they relate to each other

SEEA accounting makes it possible to quantify in monetary units the value of ecosystem services, such as water protection, climate regulation or pollination. This approach provides a more complete view of the value of ecosystems.

Although the translation of ecosystem accounting into monetary values is a challenging task, it makes it possible to create indicators that compare the contribution generated by ecosystems to society's well-being with other goods and services. *Indicators of Environmental Assets, Wealth, Income and Depletion of Resources* cover physical measures of the levels and changes in stocks of different environmental assets. They also include indicators of resource lifetimes, patterns of land-use and land-cover change, resource use intensity, and measures of income and changes in wealth associated with natural resources.

The questions that can be answered with the development of these accounts include:

- How has the stock of environmental assets changed over time?
- What is the value of a country's environmental assets?
- How much income is generated from natural resources and who does it go to?
- To what extent are environmental assets being depleted?

In general, the development of the accounting structure is guided by a pyramid of information, based on a range of basic statistics and data from various sources, such as surveys, censuses, scientific measurements and administrative sources, as shown in FIGURE 4. This data is collected using various measurement approaches, frequencies, definitions and classifications. Each data source is relevant to analyzing or monitoring specific themes.

The role of accounting structures, located at the intermediate levels of the pyramid, is to integrate this data, taking into account differences in scope, frequency, definition and classification. The final step consists in deriving indicators of interest that can be used consistently with standard economic indicators such as GDP, national savings, national wealth, terms of trade and multifactor productivity.

Figure 4: Pyramid of information guiding the proposed accounting structure

Indicators such as the Gross Domestic Product (GDP), national savings, national wealth, terms of trade and multifactor productivity emerge from a unique structure of national accounts. Derived indicators can be consistently used in combination with standard economic indicators. Finally, the proposed accounting offers a structure that allows the integration of economic and environmental information, offering a more comprehensive view of the links between economic activity and the environment, allowing the evaluation of the resulting environmental impacts. Additionally, the standardization of methodology promotes greater international collaboration and expands the possibility of cooperation between countries, which is key to promoting consistency and quality of data and environmental-economic analyses.

4.3 MEASUREMENT CHALLENGES: ECOSYSTEM SERVICES AND BIODIVERSITY

The consolidation of a system of satellite accounts for the bioeconomy involves valuing Ecosystem Services and Biodiversity (SEB), measuring the economic value of environmental assets. This valuation is especially important for regions abundant in natural and environmental resources, such as Brazil, as it allows the development of metrics aimed at local populations, in particular for carbon sequestration (e.g., through the cessation of deforestation), water cycle and consumption, cultural ecosystem services such as recreation and ecotourism, and natural habitat for native species. As the *green factor* comes into play, these metrics become essential, as they allow estimating the opportunity costs of forest preservation (Brouwer et al., 2022) based on the market value of alternative land uses (Richards, Walker, Arima, 2014; Rodrigues et al., 2013).

Here, the big challenge is to answer the following key question: what is, in fact, this cost?

Based on a meta-analysis of 53 studies published in Portuguese in Brazil and in English internationally (Brouwer et al., 2022), US$ 411.2/ha/year is estimated for all ecosystem services analyzed.[21] *In a previous study, the estimated value at 2020 prices was US$ 524/ha/year (Carrasco et al., 2014).*

Although they do offer some direction, studies of this nature do not often consider that the provision of ecosystem services occurs simultaneously. Separately quantifying, for example, the economic value of pollination services provided by bees and the economic value of plant biodiversity in a given region may lead to double counting. This is because bees depend on plant diversity for food, and plants depend on bees for pollination and reproduction. By not considering this interdependence, the real value of the pollination service and biodiversity is not properly reflected.

Sustainable development has been discussed in terms of the use of different forms of capital, including environmental assets. By providing useful indicators for assessing sustainable growth patterns and the long-term feasibility of industries that depend on natural resources, the SEEA asset accounts are an important part of the information required to consider these issues.

[21] Carbon regulation: US$ 333.3/ha/year; water cycle: US$ 150.8/ha/year; recreation and ecotourism: US$ 410.3/ha/year; habitat for species and biodiversity: US$ 454.6/ha/year.

5. CLOSING REMARKS

The purpose of this study is to support an understanding of the main visions of bioeconomy in the world, and how the great economies have advanced in the construction of their green production complexes. The bioeconomy is a broad concept that is open to different interpretations, but its underlying idea is the transformation of the relationship between economy and nature, reintegrating them into the same harmonious habitat. With the construction of a global environmental governance regime and the increasing importance of the climate agenda, the bioeconomy becomes a global priority and a decisive economic variable.

There are three dominant visions of the bioeconomy in contemporary literature and public debate: bioecology, biotechnology and bioresources. The bioecological vision emphasizes the need to stop unsustainable economic growth and pursue quality of life and conservation of natural resources. The biotechnological vision sees nature as a "factory" of new goods and services, using advanced knowledge to develop sustainable forms of production. The vision of bioresources is concerned with a gradual substitution of products of fossil origin with others of biological and natural origin, promoting the "de-fossilization" of society and sustainable industrialization.

These different visions are at the base of national bioeconomy projects. These projects include those of Europe, China and the United States, each with its own strategic guidelines. Europe has focused on the bioeconomy of bioresources, with a particular emphasis on replacing fossils with biologicals—although, in recent years, its orientation has changed; China is committed to the biotechnology bioeconomy, oriented towards the creation of new goods and services at the border, based on cutting-edge technology; the United States oscillates between the European and—increasingly more—Chinese approaches.

Where does Brazil stand on this?

Brazil must incorporate aspects of the three visions of bioeconomy, not limiting itself to just one of them. The Bioeconomy Observatory defines it as *stock, use and transformation of biological and natural resources*. The development of the Brazilian bioeconomy must prioritize the advancement of bioresources and biotechnology—with the aggregation of gradually advanced techniques and technologies. Without neglecting the value of environmental assets and the services they provide.

The first foundation of this advance is the creation of an “infrastructure” for converting green into value. This infrastructure begins with the ability to measure the products and services of the Brazilian economy. It advances with pricing parameters for environmental services. And it continues with the eventual regulation of the exchange relations, to guarantee the integrity and transparency of the services.

In a world that is increasingly oriented to the dispute for markets on the border, the advance of the bioeconomy tends to demand the collaboration of the State. Activities such as bioagriculture, bioenergy, bioresources and biofactories suggest pathways that would allow Brazil to capitalize on its "tropical" advantage and transform it into an effective frontier of growth, with cumulative gains in productivity.

Finally, this study was an effort to size and value the "aggregated" Brazilian bioeconomy. It points out the foundations of an accounting structure that integrates physical and monetary data and provides a full view of the relationship between economic activity and the environment. Adopting appropriate accounting frameworks allows for a comprehensive understanding of the bioeconomy, which can support public and private planning, investment and collaboration decisions.

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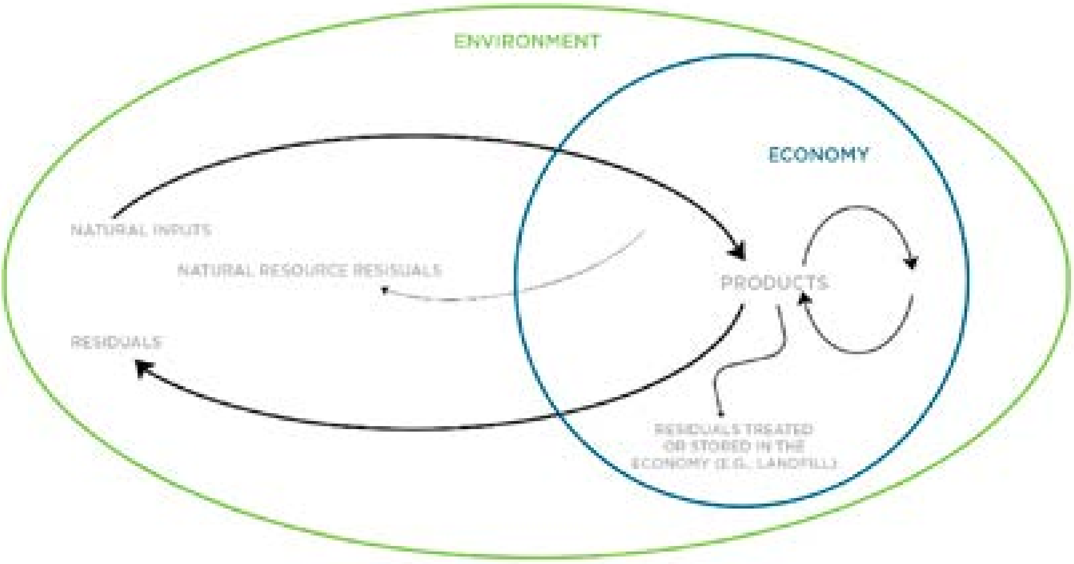
APPENDIX

I. PHYSICAL SUPPLY AND USE TABLES

Physical flows are recorded by compiling supply and use tables using physical units of measurement. These tables are extended to incorporate the environment, natural inputs and waste.

Flows from the environment to the economy are recorded as natural inputs; flows within the economy consist of products or waste; and flows from the economy to the environment are recorded as waste, as shown in FIGURE A1.



Source: SEEA, 2012.

Physical supply and use tables play a critical role in measuring how an economy uses and supplies energy, water, and materials. They make it possible to analyze production and consumption patterns over time, identifying relevant changes and trends. By combining this data with information from the monetary supply-use tables, it is possible to assess productivity, the intensity of use of natural inputs and waste generation.

Although the basic structure of the tables is the same, different rows and columns can be used for each of the subsystems of physical flows, such as energy or water. This allows for a more detailed and specific analysis of the different aspects related to the use of these resources and their contribution to the economy.

Figure A1: Physical flows in relation to the economy's production frontier
Table A1: Basic form of a physical supply and use table

	Industries	Households	Accumulation	Rest of the world	Environment	Total
Supply Table						
Natural inputs					Flows from the environment	Total supply of natural inputs
Products	Output			Imports		Total supply of products
Residuals	Residuals generated by industry	Residuals generated by final household consumption	Residuals from scrapping and demolition of produced assets			Total supply of residuals
Table of uses						
Natural inputs	Extraction of natural inputs					Total use of natural inputs
Products	Intermediate consumption	Final household consumption	Gross capital formation	Exports		Total use of products
Residuals	Collection and treatment of waste and other residuals		Accumulation of waste in controlled landfill sites		Residual flows direct to environment	Total use of residuals

Note: Dark grey cells are null by definition. Blank cells may contain relevant flows, depending on the structure of the table. Source: SEEA, 2012.

The physical supply and use table presents a fundamental consistency, which is guaranteed by the equality between the total amount of outputs and imports, and the total amount of intermediate consumption, final household consumption, gross capital formation and exports. This equivalence ensures that all flows can be properly accounted for. The same equivalence applies to natural inputs, ensuring that the total amount of supply and use of these resources is also equal.

The Table incorporates a second equality, known as input-output equivalence, related to flows between the environment and the economy. This equality requires that all flows into the economy, into a business or a household during an accounting period, can be either returned to the environment or be accumulated in the economy. For example, a company's energy inflows, such as electricity, must be released into the environment, for example, in the form of residual heat losses, or else they can be stored as stock for future use, or even incorporated into non-energy products.

ASSET ACCOUNTS

The objective of an asset account is to report the opening and closing stock of environmental assets, as well as the variations occurring over an accounting period. One of its purposes is to assess whether current economic activities are causing depletion and degradation of environmental resources. This information is useful to guide the management of environmental assets and combine assessments of natural resources and land with assessments of produced and financial assets, providing more comprehensive estimates of national wealth (SEEA, 2012).

Using the opening and closing stock of environmental assets it is possible to determine variations between periods. Variations are recorded as increases or decreases in stock. Wherever possible, the nature of the variation is also recorded. In monetary terms, entries are made in the same way, but an additional entry is included to record the revaluation of the stock of environmental assets. This entry reflects changes in the value of assets over the accounting period due to changes in prices.

The asset accounts and the supply and use tables have different purposes, but they allow the creation of an integrated system, according to TABLE A2, offering a comprehensive analysis of the interactions between environmental assets, economic flows and natural resources. Different modules make up this accounting, including Ecosystem Accounts,[22] Natural Resource Accounts, Economic-Environmental Accounts, and Accounts of Air Emissions and Resource Use. Using these modules, it is possible to obtain detailed information about the interactions between environment and economy.

						Asset accounts (In physical and monetary terms)	
		Industries	Households	Government	Rest of the world	Produced assets	Environmental assets
						Opening stock	
Monetary supply and use table	Product-supply	Output			Imports		
	Product-use	Intermediate consumption	Household final consumption expenditures	Government final consumption expenditures	Exports	Gross capital	
Physical supply and use table	Natural inputs-supply						Extracted natural resources
	Natural inputs-use	Inputs of natural resources					
	Product-supply	Output			Imports		
	Product-use	Intermediate consumption	Final household consumption		Exports	Gross capital formation	
	Residuals-supply	Residuals generated by industry	Residuals generated by household final consumption		Residuals received from the rest of the world	Residuals from scrapping and demolition of produced assets; emissions from controlled landfills	
	Residuals-use	Collection and treatment of waste and other residuals			Residuals sent to the rest of the world	Accumulation of waste in controlled landfills	Residuals flowing to the environment**
						Other changes in volume of assets	
						Revaluations	
						Closing stock	

Note: Dark grey cells are null by definition. Blank cells contain relevant flows. *While residual flows, such as air emissions, are not environmental asset flows, they can affect the ability of environmental assets to deliver benefits. The changing capacity of environmental assets can also be reflected in other changes in asset volume.

[22] Available at: www.seea.un.org/ecosystem-accounting

Table A2: Connections between supply and use tables and asset accounts

II. INPUT-OUTPUT MATRIX FOR ECOSYSTEM ACCOUNTING (IOM-EA)

IOM-EA includes additional data on natural resource use, greenhouse gas emissions, waste generation and other environmental impacts associated with economic activities. The Matrix helps to understand the interactions between the economy and the environment, allowing a more comprehensive analysis of environmental impacts and the identification of opportunities to promote sustainability.

Through the IOM-EA, it is possible to assess the direct and indirect effects of economic activities on the environment, as well as identify the sectors that have the greatest environmental impact and their interconnections in the economy. This information is useful for developing environmental policies, sustainable planning, efficiency analysis, and making informed decisions on environmental and economic issues.

Models based on IOM-EA have been used to study the impact of changes in carbon emissions on economic activity, the connections between water use and industry performance, and the connections between economic activity and the location of environmental pressures (SEEA, 2017). While there are discussions about what is an appropriate choice of analytical or modeling technique, it must be recognized that establishing an accounting-based input-output dataset is an important channel towards understanding environmental and economic issues.

To develop an IOM-EA, it is necessary to attribute environmental flows to final demand. Firstly, it is necessary to identify which environmental flows will be considered in accounting. This may include greenhouse gas emissions, use of natural resources, and others, depending on the proposed definition of the bioeconomy. To assign environmental flows to final demand, it is necessary to develop a matrix that relates the economic sectors of the input-output matrix to the relevant environmental flows. This matrix, known as the Environmental Intensity Matrix, provides information on the amount of environmental flow generated per unit of output in each sector. Using the Environmental Intensity Matrix, it is possible to assign the environmental flows to the final demand components. This is done by multiplying the Environmental Intensity coefficients by the corresponding values in final demand. Finally, the environmental flows attributed to each component of final demand can be aggregated to obtain an estimate of the total environmental impacts associated with the economy.

OBSERVATÓRIO DE BIOECONOMIA

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