2nd EDITION

Brazil's Climate and Nature Solutions

instituto arapyaú

INSTITUTO ITAÚSA

22 Página

Implementations in progress

This document results from a call: to answer what it means having Brazil as a provider of climate and nature solutions based on initiatives of the private sector. More than an aspiration, this is about recognizing and shaping what Brazil already does – and how this contributes, at the same time, to national decarbonisation, combined with the creation of jobs and generation of income, and the world's effort to limit global warming to 1.5ºC.

The text offers a broad overview of the economic sectors that are crucial for mitigating climate change in Brazil, revealing a web of concrete actions that are already in progress. These actions are the result of sound scientific guidance, political leadership and an intersectoral cooperation that reflects the complexity and power of Brazil.

In this extended second edition, six themes are highlighted, not as the only ones, but as emblematic expressions of a broader movement: agriculture and livestock, circular economy, energy, forests, carbon and mining. The actions brought together here directly converse with the major emitters in the national inventory of greenhouse gases – and show that Brazil is already in motion. This is not a plan for the distant future, but a portrait of the present being transformed.

Preparing this document was a challenge in itself: reflecting the diversity and scale of the opportunities that Brazil offers in this field required sensitivity and rigor. This is not an exhaustive document, nor does it intend to be final. It is alive. It is a contribution to the climate agenda that Brazil seeks to carry forward during its presidency of COP 30 – and beyond.

Finally, more than a record, this material is also an invitation: for Brazil to move forward with even more audacity as a leading player in climate solutions. Because in Brazil, these solutions are like a collage – a rich composition of superimposed, parallel and supplementary strategies. A mosaic of paths and disruptions that reveal a common motive: the Brazilian ambition of being a country, in the future, in which climate, nature, development and economy walk along together, inseparably.

Lívia Pagotto
Institutional director of the Arapyaú Institute

[presentation]

by **Renata Piazzon*** and **Marcelo Furtado****

This publication arises from the recognition that Brazil has all the conditions to be among the leading players in a new regenerative, inclusive, low-carbon and future-oriented economy. At a time when the world urgently seeks references to face the climate crisis, Brazil needs to show to the international community that it can be a great provider of actual and scalable solutions. We must identify and share these good stories.

With a primarily renewable energy matrix, rich biodiversity, innovative agricultural practices, sustainable fuels, capacity to restore millions of forest hectares and make progress in bio-economy, mining, clean energies and carbon, Brazil is more than a country with potential.

Many of the case studies surveyed in this publication show that the private sector is prepared to respond to the climate challenges, with products, investments and services that have already been implemented. The publication also brings examples that are gaining scale and others that have not yet reached this stage, but are highly promising.

COP 30, which, in a few months will place Brazil in evidence, is an opportunity for Brazil to take a stand, which will require ambition, cooperation and financing. Philanthropy has a significant role to play in this economic transition by testing alternative models, assuming risks and facilitating innovations. But, to gain scale, we need financial capacity and action of the private sector, in line with the efforts and commitments that have already been declared by the public sector. Only then it will be possible to build new positive paradigms for climate, nature and people.

The opportunity is not limited to, nor does it end, in November this year, when COP 30 will be held in Belém, State of Pará. Brazil is still at the forefront of the global climate negotiations until 2026, when it hands over the baton to the next host of COP 31.This is a fundamental time window to inspire the world in the agenda of action and implementation of climate solutions.

Brazil has unique natural assets, knowledge – the result of public and private research and innovation – and successful sustainable solutions stories. More than participating in the global transition, Brazil wants to help shape it. And by doing that, point out new paths of prosperity, in harmony with people and the planet.

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* *General director of the Arapyaú Institute*
** *Head of sustainability at Itaúsa and Executive Director at Instituto Itaúsa*

by **Pedro Wongtschowski***

In addition to the great relevance to the world's climate agenda, COP 30 is expected to contribute to explain the economic opportunities arising from the need to reduce emissions and improve the use of natural resources, in addition to shedding light in particular on the initiatives that Brazil, the meeting's host, already leads.

The examples are many. The environmental restoration field, which 10 years ago was considered a "tree hugger" matter, currently attracts funds and large investors that are attentive to business opportunities. Low-carbon projects have also emerged in energy – such as SAF, sustainable aviation fuel – agriculture and livestock, industry and waste management, through the adoption of circular production processes oriented by efficiency gains. Many other projects already reveal to be consolidated and operating on a large scale, as exemplified in this report.

With strategic advantages due to the tropical climate, mega-biodiversity and abundance of sunlight, rain and wind in its vast territory – in addition to its thriving civil society, gifted with much knowledge – Brazil has a lot to contribute to the generation and distribution of wealth in line with the protection of natural capital, climate and people.

The industry, as an agent of transformation, plays a decisive role in these processes. Even if Brazil faces challenges in the macroeconomic field, such as tax imbalance, high interest rates and bottlenecks in infrastructure, there is room to aspire a national industrialization project that is more compatible with Brazil's potentialities.

In this respect, the financing lines approved by the National Bank for Economic and Social Development (BNDES) in 2023 and 2024 of R$ 181 billion, of which R$ 14 billion is for innovation, are encouraging. In this period, the Financing Agency for Studies and Projects (Finep) also doubled its budget in relation to the previous years, reaching R$ 22 billion. This is a virtuous movement in the industrial sector because it evidences three essential elements in the search for global solutions: technology, innovation and sustainability.

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by **Roberto S. Waack***

This document presents, in a blunt and unequivocal way, that the Brazilian corporate initiatives in the energy, food, mining, carbon and consumer goods markets have large-scale solutions for the climate and nature challenges. More than that, it confirms Brazil's recognition as a global leading player capable of offering products and services to mature markets, both domestic and foreign, meeting the climate urgency and the understanding that the natural capital in general will be worth, in the future, more than it is today. In this field, many solutions point out the valuation of nature as an economic asset.

On the other hand, the challenges in controlling deforestation, social inclusion and recognition of the importance of indigenous peoples obliterate the great achievements of the Brazilian private sector and place obstacles for investment opportunities. In the current context of vulnerability of multilateralism, hyper complex geopolitical environment, polarizations and national political frailty, the Brazilian private sector does not have any alternative other than presenting itself as the global leading player of this agenda.

The leverage of this process also goes through a deep reflection on the role of environmental movements. Their importance is unquestionable regarding the contribution of technical-scientific content and the visibility they gave to the climate emergency and the deterioration of natural resources. However, a more concrete impact agenda seems necessary. This is not about turning a blind eye to the negative externalities of these business models but about cooperating to eliminate, mitigate and offset their damage and, above all, help them prosper as alternatives with lower environmental and social impact in favor of the construction of natural capital.

A large part of the solutions presented as being on the rise demands leverages that involve specific public policies, support from civil society and academia, and innovative financial instruments. These are alternatives that mostly coexist with tax situations and grants that unbalance the game in favor of technologies that are more dependent on fossil fuels or the non-sustainable exploration of natural resources.

The volume and the actual impact of mature solutions endorse the potential of the rising cases, indicating how much Brazil has to gain by introducing itself to the world as the country of solutions in climate and nature. It depends on a good dosage of coordinated effort by government, society and companies, which is something that has already been done in many of the cases presented.

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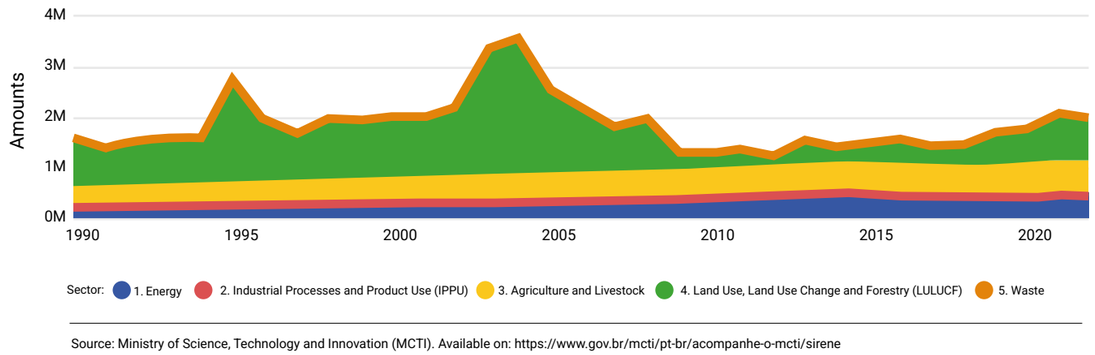
Brazil’s contributions to climate and nature

If Brazil is often seen as the country that is capable of pointing out solutions to the crises generated by climate change and nature loss, what are these solutions and how are the productive sectors engaged in concrete actions?

This document was created on the eve of the Climate COP 30 based on this guiding question, mapping the main economic topics in Brazil, such as agriculture and livestock, forests, energy, mining, carbon, and industry and waste management (addressed from the circular economy standpoint) – which are the sectors measured by the National Inventory of Greenhouse Gases *(chart below)* – and which are interrelated. The answers seek to meet the need for an implementation agenda.

GREENHOUSE GAS EMISSIONS PER SECTOR

2024 NATIONAL INVENTORY (1990 - 2022)
(IN GWP-AR6 KT CO_2 EQUIVALENT)



Source: Ministry of Science, Technology and Innovation (MCTI). Available on: https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/sirene

In addition to pointing out and describing solutions, this document presents each topic, showing why Brazil is a leading player in the matter, and contextualizes them, exposing the opportunities and challenges involved.

Tropical conditions allow Brazil to be a breeding ground of solutions. Exuberant biodiversity, extensive protected areas, immense arable land, voluminous rivers, abundance of sunlight and wind – all of this, combined with public and private investments in research and innovation, means that Brazil has a set of attributes that are practically unique on the planet, and proves to be one of the most capable of positively contributing to the challenges that the world faces in terms of climate and nature. Many of the solutions are based on nature itself and on the response that it is capable of giving to problems.

Under Brazil's presidency of the G20 – the group of the 20 largest economies and emitters – bioeconomy was included as a central axis of development and economic transformation through the G20 Bioeconomy Initiative (GIB). More than strengthening environmental governance, this inclusion influenced national public policies, promoting greater integration between sector plans and financial strategies for Nature-based Solutions (NbS)[1].

Based on the sustainable use of renewable biological resources, such as plants, animals, and microorganisms, bioeconomy promotes economic growth, environmental protection, and social inclusion. In biodiverse countries such as Brazil, it also contributes to conserving ecosystems, valuing traditional cultures, and creating economic opportunities such as those described in this document.

As regards food production, Brazil has developed, over decades, a new model of tropical agriculture, through investments in research, public policies and the action of cooperatives. The techniques originally created to increase productivity – called land-sparing – ended up by having positive effects on environmental conservation and the climate.

Now, another revolution is under way, with new regenerative practices that seek to restore the soil, conserve biodiversity and produce foods with low or neutral carbon emissions, or even remove more carbon than they emit – an action that must be concurrent with the elimination of deforestation. Using biodiversity as a lever is what has driven, for example, the bioinputs segment, in which Brazil is consolidating itself as a world leader – a clear example of a Nature-Based Solution (NbS).

The conservation of the greatest biodiversity on the planet is combined with the restoration and planting of native and exotic forests, with large-scale contributions to both carbon reduction and removal and the protection of the living conditions on Earth.

Opportunities include innovations in economic instruments, strengthening of bioeconomy and development of the carbon and biodiversity credit market, supported by fundamental regulations, such as the Forest Code and public policies such as the Arpa Program (Amazon Protected Areas) – the world's largest tropical forest conservation initiative that protects 62.5 million hectares, and has already been replicated in Colombia and Ecuador.

Brazil's prominence in the use of renewable sources is largely due to its natural resources, but the positive results already obtained stem mainly from the adoption of long-term strategies, public policies linked across different governments, and a regulatory framework that have encouraged the creation and expansion of an energy matrix that is less polluting than the global average.

In biofuels, for example, the virtuous cycle of sound public policies, positive response from companies, and consumer acceptance have added to the current scenario a robust industry, which includes at least 68 biodiesel plants and 436 ethanol plants, employs more than 2.2 million people and accounts for about 4.5% of GDP. Meanwhile, wind and photovoltaic solar sources are rapidly growing in the national electrical matrix. Both together account for 91% of the power that was installed in Brazil (photovoltaic solar for 52% and wind for 39%) and for 268 of the 301 plants that started to operate in 2024.

The global energy transition to a low-carbon economy, in turn, requires a significant increase in the production of critical minerals. For the world to join the net zero route (with net emissions equal to zero) by 2050, the demand for critical minerals would have to triple by 2030. Accordingly, the mining activity will have to expand itself, without having an environmental and social impact that corresponds to this expansion.

Brazil is an essential player in this field. It already stands as a relevant player in the mining industry – the world's second largest exporter of iron ore and largest exporter of niobium. In 2023, it exported around US$4.2 billion in strategic minerals, with more than 50 projects in progress aimed at the production of lithium, nickel, copper, graphite, rare-earth elements, cobalt, niobium and vanadium.

But this is only the current portrait of the situation. For the future, Brazil is in a unique position to take a leading role: it holds from 10% to 20% of the global critical mineral reserves and the second largest reserve of rare-earth elements (23%). The world's largest niobium

reserve is in Brazil (94% of the total global reserve), as well as the third largest nickel reserve (12%), the fourth largest manganese reserve (14%) and the fourth largest bauxite reserve (9%).

In the best-case scenario, the production of these minerals in Brazil will absorb the good practices developed over the past few years in segments such as iron ore mining, in which the efforts to reduce emissions have been showing positive results. Additionally, conservation, restoration and environmental management techniques in explored areas have been improving.

Cross cutting these sectors are the Carbon and the Circular Economy. Brazil has been proving to be a fertile ground for the implementation of projects aimed at generating carbon credits, due both to its extensive tropical forests area and its potential to generate energy from renewable sources and to the development of an arsenal of agricultural techniques that capture and store carbon. The legal framework sanctioned in 2024 is yet to be regulated but is already a climate policy instrument that is expected to engage the private sector, funds and governments.

Brazil, by the way, was the first signatory country to the Kyoto Protocol to internally regulate the treaty and also the first to have a Clean Development Mechanism (CDM) project registered at the UN – of energy recovery from biogas in the sanitary landfill of Nova Iguaçu, state of Rio de Janeiro, in 2024. The experience with the CDM was a major milestone for both Brazilian diplomacy, which led the negotiations over the topic, and Brazilian society as a whole, which started to see this carbon pricing process as an opportunity to also attract investments and generate wealth linked to environmental protection.

The Circular Economy in Brazil is still in its initial stage except for more one-off initiatives.

Cross-cutting these sectors is the circular economy, which in Brazil is still in its initial stage except for more one-off initiatives. But this picture can change, as Brazil expects to complete, still in 2025, its set of essential policies to leverage the model: the National Circular Economy Policy. The text addresses circular economy as a systemic solution for the linear economic model and defines the bases for all institutional developments on the topic. Meanwhile, the National Circular Economy Plan was launched on May 8, representing a significant step forward in this agenda.

Most Brazilian manufacturers – 85% of them – is already developing at least one circular economy practice. In the biological cycle, there is a world to explore, bringing together two public policies that are under construction – that of circular economy and that of bioeconomy – at the same time as they develop solutions in the fields of agribusiness and planted forests.

The following tables summarize the main solutions, mapped based on 66 experts interviewed, in addition to institutions surveyed and studies consulted for this Report. The solutions are organized as "mature", that is, those that have already demonstrated broad and positive results; on the rise (in the process of maturing); and promising, with high growth potential.

The solutions are detailed in the yellow pages throughout this document.

Examples of solutions in **Agriculture and Livestock**

MATURE

NO-TILLAGE SYSTEM AND PLANT COVER
Brazil is the undisputed leading player in no-tillage farming, a technique that has been developed in Brazil since the 1970's that replaces plowing, protects the soil and avoids greenhouse gas (GHG) emissions. Today, the system accounts for 95% of the Brazilian agricultural production, leading its application in the world, followed by the United States and Argentina. This technology is combined with plant cover or green fertilization, which is the planting of species aimed at increasing soil fertility.

BIOINPUTS
Brazilian mega-biodiversity contributes for it to be the world's most competitive country in the use of bioinputs. Brazil leads the use of both biofertilizers and biological pesticides worldwide. The size of the market is R$ 5 billion in sales in one year, and the average growth is four times higher than the world's average.

PRECISION AGRICULTURE
Brazil is also a world leader in the precision agriculture practice, which directs the application of fertilizers and pesticides to only where it is necessary, reducing costs and environmental impacts.

ON THE RISE

INTEGRATED SYSTEMS
Combining and rotating different crops in one area is an ancestral practice, but it was in Brazil where it reached an unprecedented production scale in integrated systems between crop and livestock (ICL) and between crop, livestock and forestry (ICLF). According to the ICLF Network, made up of Embrapa and cooperatives, private banks and companies form the agribusiness, the area of these systems currently covers between 15 million and 17.4 million hectares.

REGENERATIVE LIVESTOCK FARMING
The diversification of forage and the use of integrated systems, and mixed crops of grasses and legumes with high content of soil fertility recovery are examples of regenerative management that increase animal productivity. These are combined with the management of the breeding periods, improvement and diversification of breeds and cattle feed that reduces methane emissions. A significant reduction has already been obtained from the reduction of the time to slaughter the cattle.

Legend:
- **Mature:** that have already proven positive results on a large scale
- **On the rise:** in the process of maturing, moving towards gains of scale
- **Promising**: with high growth potential and positive impacts

PROMISING

RECOVERY OF DEGRADED PASTURES
There are at least 28 million hectares of degraded pasture areas with potential for conversion into agriculture, reforestation, increased livestock production, or even for the production of energy. The number of hectares is equivalent to the size of the state of Rio Grande do Sul. If this area were used for the cultivation of grains, there would be an increase of 35% in the total planted area in Brazil.

MEASURING AND ACCOUNTING FOR SOIL-BASED CARBON SEQUESTRATION
Soil-based carbon sequestration carried out by no-tillage and integrated systems, such as ICL and ICLF, adds up to 30 million metric tons of carbon a year, according to CCarbon, the world's first center of research on carbon in a tropical climate.

These figures have not yet been fully accounted for in the National Inventory of GHG Emissions and Removals. The measurements of carbon removal from the soil by the agricultural activity are important for the productive sector to better account for its balance of emissions and monetize the activities with environmental attributes.

CIRCULAR ECONOMY IN AGRIBUSINESS
Cutting-edge Brazilian farms are seeking to close the production cycle using waste and manure and own generation of renewable energy.

BIODIVERSITY CREDITS
Rural producers are beginning to generate biodiversity credits from activities that have a positive impact on nature protection.

Examples of solutions in **Forests**

MATURE

CONSERVATION: ARPA PROGRAM
With an innovative financing model, the world's largest rainforest conservation initiative protects 62.5 million hectares and has already been replicated in Colombia and Ecuador.

PLANTED FORESTS: FORESTRY OF EXOTIC SPECIES
Plantations of eucalyptus and other exotic species for industrial purposes represent a highly developed activity in Brazil. Pulp and paper companies are a global benchmark, with a positive climate impact, while preparing for transactions in the carbon market.

ON THE RISE

CONSERVATION: FOREST CODE
The implementation of a Brazilian public policy provides for the recovery of 18.8 million hectares of degraded native vegetation areas on rural properties, in addition to areas already preserved.

RESTORATION: CARBON FARMS
Forestry companies attract investments from global corporations in carbon credits to restore degraded areas on a large scale in the Amazon and Atlantic Forest.

PROMISING

PLANTED FORESTS: FORESTRY OF NATIVE SPECIES
With innovative forestry technologies, companies expand Brazilian tree plantations to change the pattern of the timber and carbon credit market, with the recovery of degraded areas in the Atlantic Forest.

Examples of solutions in **Energy**

MATURE

ETHANOL
The most widely used biofuel in Brazil shows versatility and less dependence on sugarcane as it is also produced from maize. Now, it is starting to be tested on tractors, trucks and even thermoelectric plants.

BIODIESEL
The second most widespread biofuel in Brazil can still gain a lot of room in Brazil and in the world, with the global need for decarbonization, new usages, new raw materials and the project for the largest plant on the planet.

WIND
Secure regulatory environment, relevant local industrial base, robust growth: wind power is expected move from a good phase to an even better phase with offshore generation and the incorporation of batteries into generating farms.

SOLAR
Solar generation capacity is growing at a rapid pace throughout the world – and even faster in Brazil. The sector is ready for greater domestic content and projects that are integrated with the agribusiness and hydroelectric plants.

ON THE RISE

BIOGAS AND BIOMETHANE
The versatility of biogas and biomethane has been proven, and they can be easily produced throughout Brazil. The next step is to expand the analysis and certification network.

BIOMASS
Ethanol producers invest in this source with a double benefit: the generation of energy with low carbon emissions and the best environmental disposal of waste.

2G ETHANOL
Business projects provide for the creation of a network of biofuel plants by 2030, in a race for the most efficient technological route.

SAF
New rules in Brazil and on international flights create guaranteed demand, both inside and outside Brazil, for sustainable aviation fuel from 2027 onwards.

PROMISING

BIOFUELS
For thermal power plants, ships, and large engines – A growing range of biofuels, from ammonia to methanol, is gaining the attention of manufacturers and operators of ships and large power systems.

RENEWABLE HYDROGEN FROM BIOFUELS
The potential of hydrogen is drawing the attention of investors – and its renewable version opens up new possibilities for the energy transition.

Examples of solutions in **Mining**

EMISSION REDUCTION

MATURE

ENERGY EFFICIENCY GAIN
Mine operations have been reducing energy consumption and the resulting greenhouse gas (GHG) emissions through the use of equipment such as frequency inverters, automation systems and new motors, with attention paid to the most demanding stages of the process.

TRANSPORTATION ALTERNATIVES
Using conveyors for local ore transport, instead of trucks, provides an additional reduction in energy consumption.

ELECTRIFICATION AND BIOFUELS
The adoption of biofuels and electric motors for mining trucks, excavators and machinery in general provides another way to reduce emissions from operations.

LESS HEAT IN THE IRON AND STEEL INDUSTRY
The high concentration of iron ore in Brazil and innovative products such as green briquettes reduce energy consumption at another point in the chain, in the iron and steel industry.

100% CLEAN ENERGY
The spread of solar and wind power plants on different scales has ensured that more mines can operate exclusively with renewable electricity.

CLEANER ELECTRIC AND ENERGY MATRIX
Any operations in Brazil, from mineral prospecting to steelmaking, metallurgy or ore transportation by ship, become less carbon-intensive (compared to the global average) due to the electric matrix with more than 88% renewable sources (mainly hydroelectric, wind and solar) and the fuel mix with more than 25% renewable origin (mainly biodiesel and ethanol).

ON THE RISE

AI, IOT AND BIG DATA IN INTEGRATED CONTROL

Increasing the use of digital technology in mine management, with more sensors and automatic equipment distributed throughout the field, provides more options for real-time analysis and decision-making. This results in efficiency gains and reduced energy consumption across the operation, from excavation points to tailings transportation.

AUTONOMOUS VEHICLES

AI and GPS make mining trucks drive as efficiently as possible, reducing energy, parts, and tire consumption – all leading to lower GHG emissions at the mine and in different points of the value chain.

SHIPS WITH LOWER BUNKER CONSUMPTION

Cargo ships equipped with "air lubrication" (a layer of bubbles that facilitates the hull's sliding on the water) and wind propulsion (with rotary sails) show gains of around 10% in the consumption of their fuel, the bunker fuel.

LONG-DISTANCE ORE PIPELINES

Ore pipelines stretching hundreds of kilometers provide a transportation solution with lower GHG emissions than trains and trucks.

PROMISING

EMISSION-REDUCING FUELS FOR SHIPS

Experiments are underway with cargo ships powered by different fuel mixes, including renewable-content bunker fuel (with a portion made from various plant-based raw materials, such as used cooking oil), hydrotreated vegetable oil (HVO or "green diesel"), ethanol, synthetic fuels (such as ammonia), and liquid natural gas (LNG, a fossil fuel that emits less GHGs than traditional bunker fuel).

THE ROLE OF CRITICAL MINERALS

MATURE

ASSERTIVE DECISIONS

Brazil's sectoral prospecting experience, combined with the presence of deposits with high mineral concentrations, allows for more assertive and efficient operations, with lower energy consumption and emissions, in the mine and in the subsequent stages of the chain.

LITHIUM PRODUCTION WITH REDUCED ENVIRONMENTAL IMPACT

Segment-specific mine management techniques and the occurrence of high-concentration ore deposits allow operations using 100% renewable energy, recirculation of almost all water, absence of tailings dams and dry processing.

ELECTRIC EFFICIENCY IN ALUMINUM PRODUCTION

Aluminum production is an electro-intensive process and overall efficiency has increased little in the past decade, according to the IEA. Operations in Brazil reduce their carbon intensity thanks to a combination of factors such as a predominantly renewable electric matrix (hydroelectric, solar, wind, and a portion of biodiesel in thermal plants), the use of electric trucks in the mines, and an ore pipeline to transport bauxite over distances.

ON THE RISE

AI IN PROSPECTING AND EXCAVATION DECISIONS

Artificial intelligence applied to geological analysis, combined with Brazilian sectoral prospecting experience and the occurrence of high-concentration ore deposits, provides a new leap in efficiency in decisions prior to the opening of a mine and during its operation.

AI, IOT, AND BIG DATA IN ENVIRONMENTAL MONITORING

The combination of digital technologies such as artificial intelligence, automation, and field sensors enables continuous monitoring and better decisions regarding air and water quality maintenance.

PROMISING

REMINING

Improved mine management, advanced mineralogical and metallurgical models, the use of artificial intelligence, and the occurrence of high-concentration ore deposits create opportunities for waste recovery in several operations in Brazil. This provides a double benefit: greater efficiency in mine production (with lower GHG emissions) and a reduction in the volume of waste (with less local impact).

COGENERATION

Producing electricity from heat generated in the mine can provide new energy efficiency gains to operations.

CONSERVATION, RESTORATION AND ENVIRONMENTAL MANAGEMENT

MATURE

STRIP MINING
The strip mining technique, combined with Brazil's extensive experience in reforestation, allows for the progressive rehabilitation of the area throughout the mine's lifespan. The technique provides maximum preservation of soil, vegetation and landscape.

WATER MANAGEMENT
Techniques initially adopted in larger operations and in regions of water scarcity are spreading across the sector. Innovative practices, which lead to water savings of over 90% in relation to traditional practices, include dry stacking of tailings, precise spraying, and various reuse and treatment systems, with recirculation in dams and processing facilities.

ON THE RISE

AI, IOT AND BIG DATA IN WATER MANAGEMENT
Integrated digital systems to control mine operations, including monitoring water capture, treatment, and reuse, allow for additional gains in preserving water resources.

PROMISING

WATER MANAGEMENT IN ORE PIPELINES
Water is added to the ore to form a slurry and allow transportation via an ore pipeline, a system that emits less GHGs than railways and highways. Ongoing projects may enable the treatment and reuse of water, reducing the impact of this mode of transport on water resources.

Examples of solutions in **Market**

MATURE

REDD AND REDD+ PROJECTS
Reducing Emissions from Deforestation and Forest Degradation, provides for payments for results in reducing carbon emissions associated with deforestation and forest degradation. It involves forest conservation and forest management projects. On the other hand, REDD+ adds the positive impact factor for local communities, such as indigenous peoples and quilombola communities.

ENERGY PROJECTS
Propose replacing more polluting fossil fuels with less polluting and/or renewable ones; renewable energy generation projects (wind farms, solar plants, biomass); methane recovery from sanitary landfills; energy efficiency projects.

DECARBONIZATION CREDITS (CBIOS)
Established by Renovabio, a public policy aimed at expanding Brazilian biofuel production, CBIOs were designed as financial assets issued by ethanol or biodiesel producing companies that demonstrate greenhouse gas emission reductions. They are purchased by fossil fuel distributors as a way of mitigating emissions.

ON THE RISE

ECOSYSTEM RESTORATION AND RECOVERY PROJECTS
Known by the acronym ARR (Afforestation, Reforestation and Revegetation), they are aimed at recovering degraded areas and ecosystems, such as forests, pastures and agroforestry systems (SAF).

AGRICULTURE AND LIVESTOCK PROJECTS
Rural producers can generate credits by adopting low-carbon and regenerative agricultural practices, such as the use of bioinputs, no-tillage farming, crop rotation, and Integrated Crop-Livestock-Forestry (ICLF) systems.

PROMISING

JURISDICTIONAL REED+:
Similar to REDD+, the new approach works by accounting for emission reductions within the boundaries of a specific region, which can be a municipality, a state or a country. Brazilian states such as Tocantins, Pará, Acre, and Piauí are structuring their policies.

CREDITS LINKED TO BIODIVERSITY GAINS:
projects with methodologies that combine carbon removal with benefits for fauna and flora and generates tradable financial assets. Examples include EcoAustralia in Australia and PSA Carbonflor in Brazil.

BIOCHAR
Obtained from the pyrolysis of biomass, it can generate credits by quantifying the removal of CO_2 from the conversion of biomass into biochar and its subsequent application as soil amendments or in construction materials, such as concrete.

CCUS
Carbon capture, utilization and storage, provides for the reduction of emissions by capturing and locking in carbon in geological formations that are deep underground. The methodology for generating carbon credits from this technology is being reviewed and should be launched soon.

Examples of solutions in **Circular Economy**

TECHNICAL CYCLE (FINITE MATERIALS)

ON THE RISE

DESIGN
Circular design in Brazil is still in the development stage but has been making important progress driven by sustainability demands, public policies and changes in consumer behavior.

PRODUCTION/ MANUFACTURING –
Production and manufacturing lines are guided by linear models (take-make-dispose), but show increasing signs of adaptation to circular models, mainly in reducing loss in the production process, reusing waste, using recycled material, and designing for disassembly.

The automotive industry, for example, has programs to remanufacture parts and increase durability; the food and beverage industry has examples of reuse of organic waste and recyclable packaging; the textile and fashion industry works with regenerative or recycled fabrics and the reuse of waste.

CONSUMPTION
Environmental and social awareness drives more responsible choices, but advertising encourages consumerism, whereas sustainable products can have higher prices than the conventional ones (which do not price the externalities they cause).

REPAIR
Is currently at a more limited stage. In Brazil, repairs often cost more than buying a new product. There is also the challenge of planned obsolescence.

REUSE
Shows significant progress in some areas and persistent challenges in others. For example, platforms for selling second-hand products (online thrift stores and refurbished electronic products) popularize reuse. However, there is a lack of a culture of conscious consumption and a resistance to second-hand products by consumers.

COLLECTION
According to the Brazilian Institute of Geography and Statistics (IBGE), 60.5% of the Brazilian municipalities provide a selective garbage collection service, but it is not always comprehensive. The collectors, whether in cooperatives or informally, are responsible for a large part of the collection of recyclable material, but they lack technical and financial support. In reverse logistics, the National Solid Waste Policy (PRNS) requires manufacturers and distributors to assume responsibility for the lifecycle of electronic products, tires, medicines, light bulbs, among others, but there is a lack of efficient logistics networks outside large urban centers.

RECYCLING
Shows meaningful results in some materials, in particular aluminum and cardboard, but structural and cultural challenges limit the recycling potential.

PROMISING

DISTRIBUTION
Despite its strategic importance, the sector that connects production, consumption and reverse logistics is at an early stage from a circular chain standpoint. There are efforts to optimize routes, reduce disposable packaging and reverse logistics.

BIOLOGICAL CYCLE (BIOMATERIALS)

ON THE RISE

DISTRIBUTION
Reusable packaging is present, but not widely used. Logistics focused on low carbon emissions is still at an early stage, with exceptions in niche companies.

CONSCIOUS CONSUMPTION
Interest in organic, natural and sustainable products is growing, in particular in Brazilian state capitals, but there is still a strong appeal for the consumption of conventional processed and ultra-processed foods.

COMPOSTING/DIGESTION
Public and private initiatives are emerging to convert biological waste into fertilizer, energy or other inputs, but the infrastructure is limited. Home composting is growing in small projects and schools, but with no significant scale.

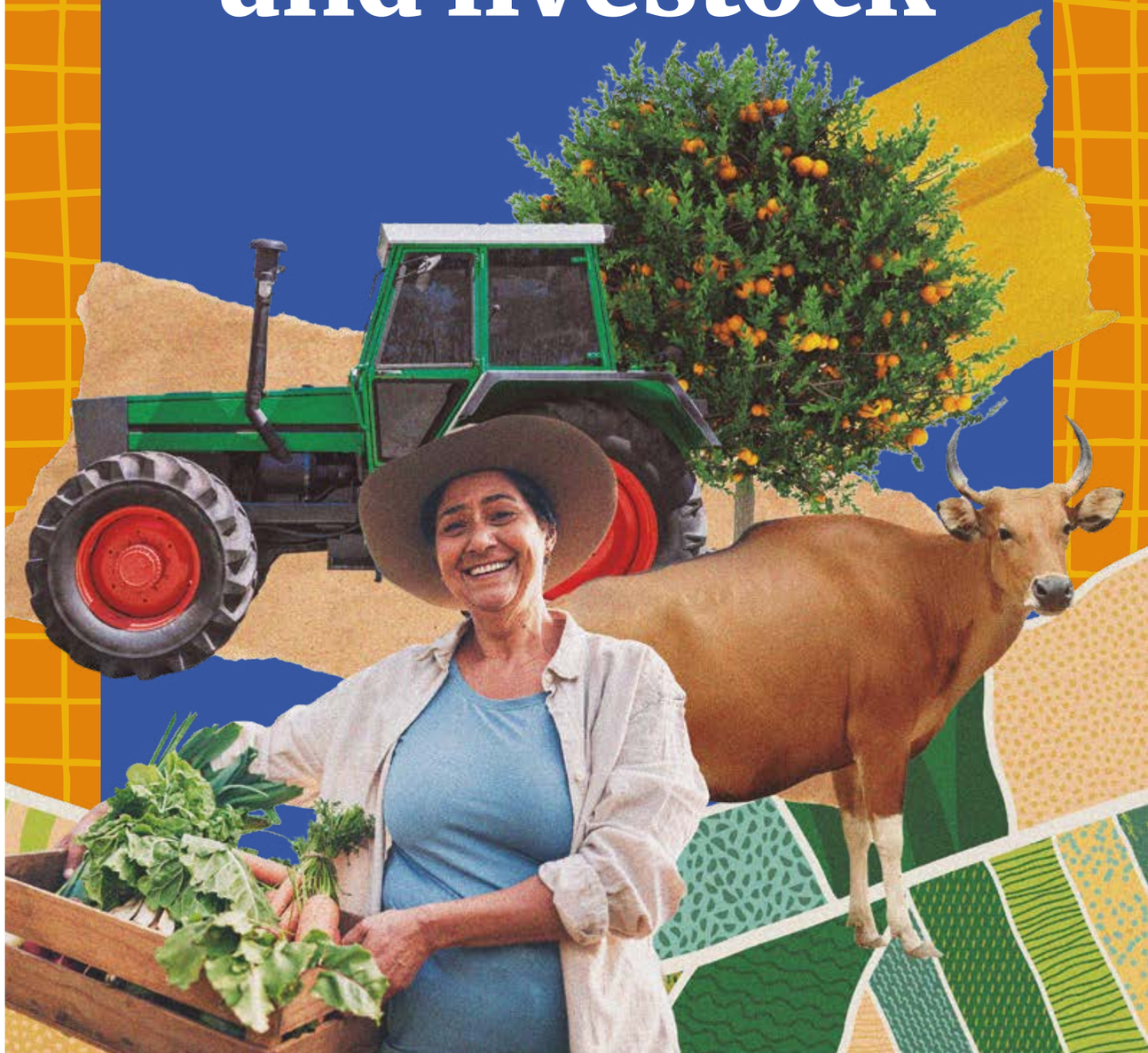
SOIL REGENERATION
Soil regeneration practices are still rarely applied on a systematic basis. There are reforestation, agroforestry, and regenerative agriculture movements in the consolidation stage.

PROMISING

BIOLOGICAL PRODUCT DESIGN
The use of biodegradable and renewable natural materials (cassava root packaging, organic fabrics, makeup) is growing, but it is still restricted to niches and sustainable brands.

PRODUCTION AND PROCESSING
Organic agriculture and agroecology are growing, but they represent a small share of domestic production. Large producers are beginning to adopt sustainable practices, and there is plenty of room for expansion.

agriculture and livestock



Transformations in the field

Through investments in research, public policies and the action of cooperatives, Brazil has developed, over decades, a new model of tropical agriculture. The techniques originally created to increase productivity ended up by having positive effects on environmental conservation and the climate. Now, another revolution is under way, with new regenerative practices that seek to restore the soil, conserve biodiversity and produce foods with low or neutral carbon emissions, or even remove more carbon than they emit

“the land itself is of very good air, fresh and temperate…Waters are many; endless. And in such a way it is gracious that, if one wants to take advantage of it, everything will grow in it”, wrote Pero Vaz de Caminha in a letter to King Dom Manuel I during the expedition of Pedro Álvares Cabral in 1500.

The first impressions of the letter writer only corresponded to part of the reality. The tropical soil has a challenging characteristic for agriculture. It is naturally acid and, as a result, of low fertility, implying corrections and constant replacements of nutrients to ensure high levels in agricultural production, being also susceptible to erosion processes due to the torrential rainfalls of the tropics. Neither did the waters reveal to be as endless as those described in the letter, which requires proper management of water resources, in particular in view of the climate crisis of nowadays.

It was thanks to a nationally developed technological progress that Brazil dribbled its natural difficulties. Brazil, which 50 years ago imported, for example, watermelon, tractors, rice and beans, became the world's fourth largest producer of foods, behind China, United States and India in volume of grains. In commodities, such as orange juice, coffee and soybeans, Brazil is the first and, in livestock, second.

Today, Brazilian agribusiness accounts for 25% of GDP, 20% of jobs and 48% of exports, according to the Brazilian Agriculture and Livestock Company (Embrapa). One out of four agribusiness products in circulation in the world is Brazilian. This relevance in economy is the consequence of a constant growth over the course of the past few decades, of 2.1% a year between 1994 and 2020[1].

This leap was not only due to the Green Revolution, a global innovation movement in the field that Brazil started to implement in the 1970's, supported by high mechanization, hybrid seeds and intense use of chemical fertilizers and pesticides. The great transformation in Brazilian agriculture was specially favored by adaptations to tropical conditions, which are very different from those in the Northern Hemisphere in terms of climate, soil, rainfall and biodiversity – starting by the lack of rigorous winters, which, in the North, naturally help fight pests.

Brazil, through investments in research, public policies and the action of cooperatives, has practically developed a new model of tropical agriculture, adapting cultivars, animals, production systems and soil management. This construction process took around 50 years.

Many of these adaptations made by Brazil towards tropicalizing the Green Revolution have already been consolidated for decades, such as the no-tillage farming, plant cover, nitrogen fixation in the soil and crop rotation, which will be described in this document. Originally created to increase productivity, they ended up by causing positive effects in environmental conservation, such as the protection of the soil and bodies of water, and in the mitigation of greenhouse gas emissions.

AGRIBUSINESS IS RESPONSIBLE FOR:

25%
OF GDP

20%
OF JOBS

48%
OF EXPORTS

ONE IN FOUR AGRIBUSINESS PRODUCTS IN CIRCULATION IN THE WORLD IS BRAZILIAN.

Source: Embrapa

New leap

The time now is for a new leap to adapt to climate change and extreme events, such as severe droughts and excess of rainfalls. Another revolution is under way, with regenerative agricultural and livestock practices that seek to restore the soil, conserve biodiversity and produce foods with low or neutral carbon emission, or even remove more carbon than they emit.

In this respect, techniques such as integrated crop-livestock-forestry, bioinputs – which are considered one of the current great fronts of transformation of Brazilian agriculture – recovery of degraded areas and soil-based carbon sequestration are taking shape.

The interaction between agriculture and livestock production and conservation of native vegetation is another Brazilian advantage. Defined by the Forest Code, a law that sets the production and conservation limits of a property, the maintenance of Permanent Preservation Areas and Legal Reserve assures to the producer the provision of water, climate gains and biodiversity. It also provides microorganisms such as fungi and bacteria that can serve as biological inputs for production – it is biodiversity being used as an asset of the agricultural production.

In addition to producing food, fiber and bioenergy, the Brazilian agribusiness is responsible for meeting a fourth purpose, as a provider of environmental services, which include carbon removal, protection of the soil, fauna and flora, pollination, and regulation of rainfalls.

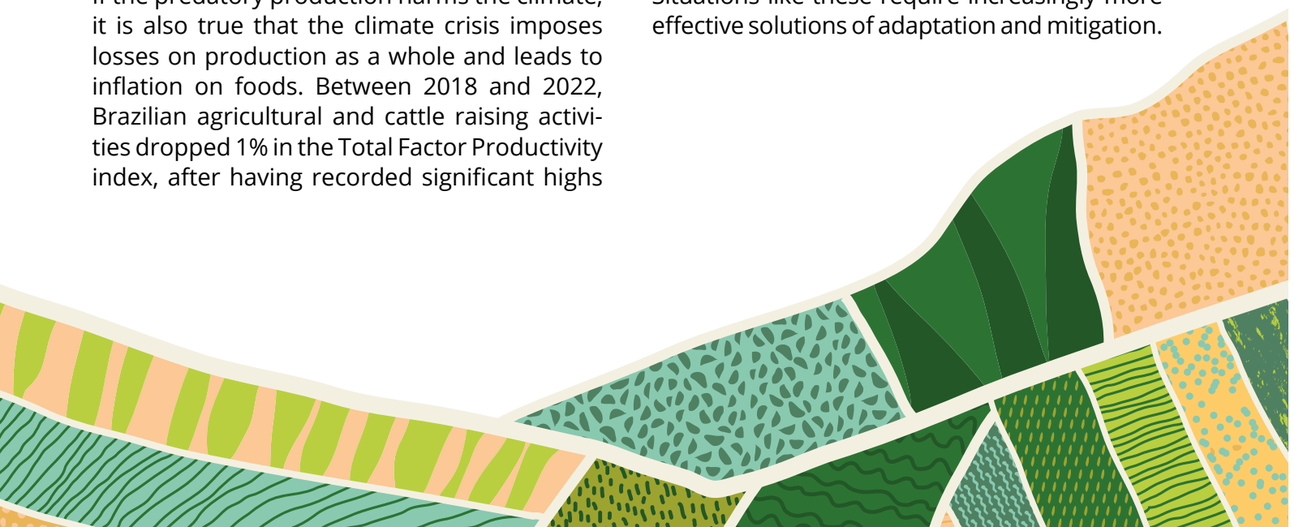
Brazil has, therefore, the possibility of leveraging an agricultural economy based on renewable and biological products, which basically depend on the photosynthesis. This is its great advantage in relation to the developed world, which requires fossil and mineral products due to the low availability of natural resources and, which, for this reason, will face growing difficulties in a context of aggravation of the climate crisis and its effects, with restrictions to GHG emissions, depletion of soil and less access to clean water.

The world depends on solutions that Brazil is developing in the planet's tropical belt, which combine agricultural and livestock production with conservation and the provision of environmental services. But these solutions must be combined with the control in the expansion of the agricultural and livestock frontier.

Deforestation alone accounts for half of the Brazilian emissions *(see chart on page 11)*. Other 27% comes from the agricultural and cattle raising activities itself, in particular cattle raising. Brazil, for example, is the world's fifth largest methane emitter, according to data of the System of Estimates of Greenhouse Emissions – SEEG (Alencar *et al.*, 2022)[2].

If the predatory production harms the climate, it is also true that the climate crisis imposes losses on production as a whole and leads to inflation on foods. Between 2018 and 2022, Brazilian agricultural and cattle raising activities dropped 1% in the Total Factor Productivity index, after having recorded significant highs of 3% for decades, according to the United States Department of Agriculture (USDA)[3]. In accordance with the Inter-Union Department of Statistics and Social and Economic Studies (Dieese), in 2024, the price of the staple basket increased in 16 of the 17 Brazilian capital cities analyzed due to climate issues, which particularly affects the lower-income population.

Situations like these require increasingly more effective solutions of adaptation and mitigation.



Although Brazil presents a high production quality and strong environmental attributes, the degradation of the Amazon, the illegal deforestation, the wildfires, and the land grabbing – which are not necessarily related to the production structure – feed the negative image that is explored in commercial disputes.

The reputation of the Brazilian agricultural and cattle raising activities was always in the agenda in foreign trade negotiations. Sustainability inconsistencies and production health are usually used in the defense of protectionist interests of the competing countries. Although Brazil presents a high production quality and strong environmental attributes, the degradation of the Amazon, the illegal deforestation, the wildfires and the land grabbing – which are not necessarily related to the production structure – feed the negative image that is explored in commercial disputes.

Additionally, competitors such as the United States affirm that they produce soybeans with the lowest carbon impact in the world, which is not exactly due to the agricultural practice per se, on farm, but to what happens off farm. Since the transportation of inputs and grains is predominantly carried out by trains and river barges, the complex of the U.S. agribusiness system is able to reduce its carbon emissions.

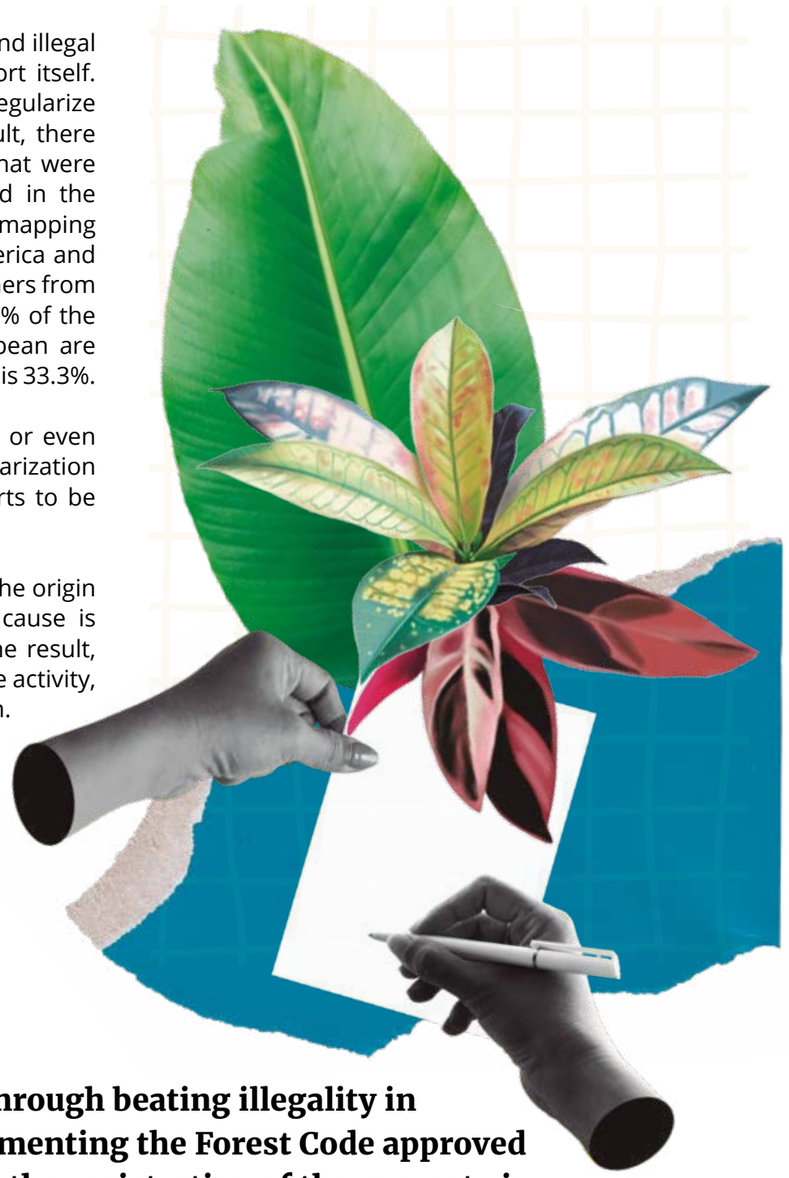
This shows the importance of Brazil investing in the decarbonization of transports and logistics *(further information on low-carbon energy on page 93)*, which, combined with the capacity of decarbonization of the agricultural and cattle raising activity themselves, can make Brazil the world's most competitive country in terms of emissions – provided, of course, that deforestation is also overcome *(further information on forestry solutions on page 57)*.

The cutting down of forests and the wildfires, which in the dry period are used to open areas, are intrinsically connected with land illegality. The process starts with land grabbing, that is, the undue appropriation of usually public land. In order to give the area an economic destination for the purpose of registering or regularizing the land in the future, the simpler and cheaper action consists of removing the native vegetation, sowing seeds of grass and placing a few head of cattle to pasture, thus stopping the forest to sprout again. Whereas productive cattle raising in the Southeast and Mid-West has seven to eight head of cattle per hectare, in the Amazon, there is 0.8 head per hectare.

In the long run, this non-productive and illegal cattle raising activity does not support itself. If the land grabber is not able to regularize the area, they abandon it. As a result, there are more than 20 million hectares that were grabbed, deforested and abandoned in the Amazon. In accordance with a recent mapping on the health of the soil in Latin America and the Caribbean, conducted by researchers from the University of São Paulo (USP), 38% of the soil in Latin America and the Caribbean are degraded, whereas the world average is 33.3%.

When the State takes the land back, or even when the invader obtains the regularization and sells the property, this area starts to be used by agriculture.

In these cases, the agriculture is not the origin of the deforestation process – the cause is property related – but it becomes the result, which poses reputational losses to the activity, and it is associated with deforestation.



The path, therefore, goes through beating illegality in Brazil and definitely implementing the Forest Code approved in 2012, which provides for the registration of the property in the Rural Environmental Registration File (CAR), and, should there be a need to regularize environmental liabilities, in the Environmental Regularization Program (PRA).

In 2024, only 3.3% of the analyses of the Rural Environmental Registration File (CAR) had been completed, according to a report of the Climate Policy Initiative (CPI) of the Pontifical Catholic University of the State of Rio de Janeiro (PUC-Rio)[4]. But, according to the Forest Dialogue initiative, there was an increase of 12% in the analyses that started last year. More than one million CARs were analyzed, representing around 15% of all registration files in Brazil.

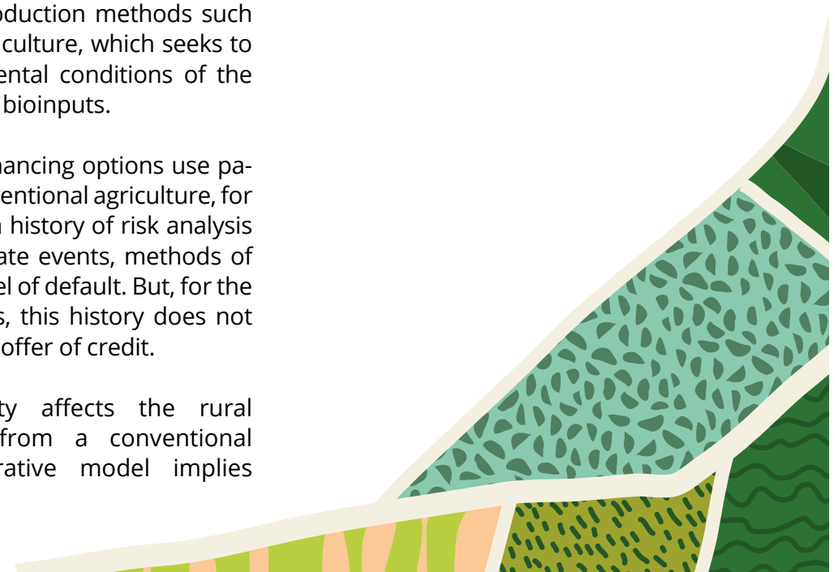
Low CAR validation prevents owners from enjoying several financial instruments of the new green economy, such as carbon credits, biodiversity credits and Payment for Environmental Services, in addition to not having access to bank financing. This is a situation of legal insecurity that moves potential investors away from programs such as the Integrated Crop-Livestock-Forestry (ICLF) or forest restoration, for example.

The financing restrictions do not abide to cases of non-compliance with environmental legislation – which is essential to restrain illegality. At the other end, producers that are more in line with sustainability practices face challenges to invest in innovative production methods such as the regenerative agriculture, which seeks to improve the environmental conditions of the soil, using, for example, bioinputs.

This is because rural financing options use parameters based on conventional agriculture, for which there is already a history of risk analysis on the cultivation, climate events, methods of pest control and the level of default. But, for the most recent techniques, this history does not exist, thus reducing the offer of credit.

The same uncertainty affects the rural producer. Migrating from a conventional model to a regenerative model implies assuming new risks. Even though the climate crisis imposes the need for changes, the rural producer needs to feel safe with respect to the variables of a new production system. To this end, innovative financing instruments that are capable of cushioning risks need to be designed until the regenerative activity proves to be more competitive and resilient than the conventional model.

To deal with this, the Brazilian Federal Government reformulated the ABC+ Program[5], which is now called RenovAgro, aimed at investments in climate adaptation and mitigation practices, such as recovery of degraded pastures, organic production systems, no-tillage with straw mulching, integrated systems, regularization of environmental liability, waste management, soil management and use of bioinputs. Financing is available at institutions that distribute funds from the National Bank for Economic and Social Development (BNDES). The initial amount provided for in the RenovAgro in the 2023/24 Harvest Plan was R$ 6.9 billion[6].



Mature, on the rise, and promising paths in the field

Among the most mature solutions adopted in Brazil, that is, that have already proven comprehensive and positive results, is the No-Tillage System. Brazil is the undisputed leading player in this technique that replaces plowing, protects the soil and avoids emissions. Today, the system accounts for 95% of the Brazilian agricultural production, leading its application in the world, followed by the United States and Argentina. This technology is combined with plant cover or green fertilization, which is the planting of species aimed at increasing soil fertility.

Additionally, Brazilian mega-biodiversity contributes for it to be the world's most competitive country in the use of bioinputs – another example of mature solution. Brazil leads the use of both biofertilizers and biological pesticides worldwide. The size of the market is R$ 5 billion in sales in one year, and the average growth is four times higher than the world's average. Brazil is also a world leader in the precision agriculture practice, which directs the application of fertilizers and pesticides to only where it is necessary, reducing costs and environmental impacts.

Those that are in the process of maturing or growing include integrated systems, such as those between crop and livestock (ICL) and between crop, livestock, and forestry (ICLF). According to the ICLF Network, the area of these systems reached between 15 million and 17.4 million hectares.

Another solution in vogue is regenerative cattle raising, which uses the diversification of forage, integrated systems and mixed crops of grasses and legumes with high content of soil fertility recovery, management of the breeding periods, improvement and diversification of breeds and cattle feed that reduces methane emissions. A significant reduction has already been obtained from the reduction of the time to slaughter the cattle.

A promising solution, that is, with high potential of growth and results for the climate and nature, is the recovery of degraded pasture. There are at least 28 million hectares of degraded pasture areas with potential for conversion into agriculture, reforestation, increased livestock production or even for the production of energy. If this area were used for the cultivation of grains, there would be an increase of 35% in the total planted area in Brazil.

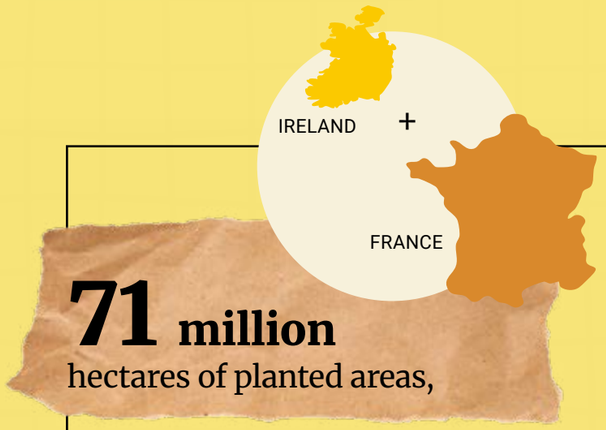
Another solution with great potential is the measurement of soil-based carbon sequestration, which, with the adoption of no-tillage farming and integrated systems, adds up to 30 million metric tons of carbon a year, according to CCarbon - the world's first center of research on carbon in a tropical climate. Measurements of soil-based carbon removal by agricultural activity are important for the production sector to better account for its balance of emissions and monetize the activities with environmental attributes. The circular-economy initiatives in the agribusiness, in which farms seek to close the production cycle using waste and manure and own generation of renewable energy, are also promising.

The environmental attributes of these solutions also have social benefits, such as better living conditions for farmers and cattle raisers, reducing the use of toxic products, promoting a healthier environment and ensuring food security in a climate change scenario. In cattle raising, for example, the adoption of practices that meet sustainability criteria by small producers allow for their inclusion in the supply chain of large industries, with greater generation of income, health and safety, in addition to combating informal and illegal activities.

Details on these and other mapped solutions are presented below.

"Land sparing" technologies

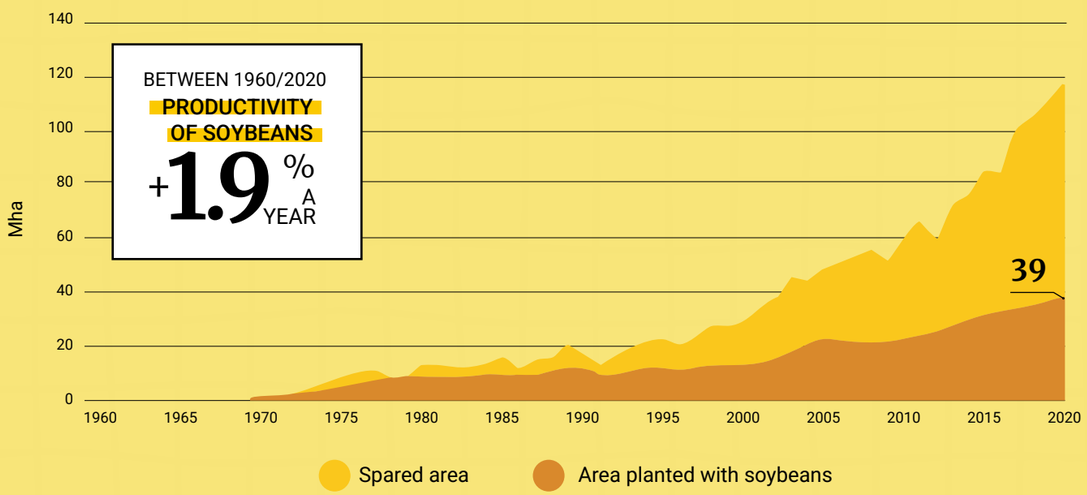
Several techniques adopted by Brazil for the purpose of increasing productivity is added to a new boundary of technological innovation



which corresponds to the sum of the territories of Ireland and France, was the spared area between 1960 and 2020 in Brazil – only in the case of soybeans – by the employment of the so-called "land sparing" technologies, which, consequently, avoid GHG emissions by reducing the need to expand the agricultural boundary.

EFFECT OF "LAND SPARING" TECHNOLOGIES

SPARED AREA IN THE PRODUCTION OF SOYBEANS (IN MILLIONS OF HECTARES)



Source: Brazilian Agriculture and Livestock Company (Embrapa) with data from the National Supply Company (Conab) 2020

Land sparing technologies include systems such as no-tillage, use of bioinputs, including nitrogen fixation in the soil, crop rotation and the integrated crop-livestock-forestry (ICLF) systems. An example of the increase of productivity is the fact that Brazil is capable of harvesting at least two large crops a year in the same area: 80% of the maize production is carried out in the land where the soybeans were harvested.

This utilization makes Brazil have a good score in the statistics of the Food and Agriculture Organization (FAO): in the cropping frequency indicator, that is, when the harvest is by unit of area, Brazil presents a rate that is 30% higher than the global average.

NO-TILLAGE SYSTEM

In order to air the land frozen by Winter in the Northern Hemisphere, farmers need plows. But this technique, when it was imported by Brazil, led to erosive processes that significantly reduced the productivity of the national agriculture. This is when the farmer Herbert Arnold Bartz from Rolândia, state of Paraná, conducted some research and brought to Brazil, in the 1970's, a technique created in the United States that provided for planting directly on the straw from the newly-harvested crop, without changing the structure of the soil and using specific machinery.

The No-Tillage System, a technology that was developed by Embrapa and was broadly consolidated all over Brazil, was then born. The technique protects the surface of the soil from erosion, silting and compaction, reduces the evaporation rate, increases the storage of water in the soil and controls temperature in the superficial layer. This favors the growth of organisms in the soil and the increase of the organic matter, resulting in greater productivity of the crops (Heckler; Salton, 2002)[7].

Therefore, the system uses biodiversity in favor of the production system and contributes to the adaptation to extreme climate events, such as droughts. Since it does not revolve the land, it also avoids the emission of carbon from the soil that would go into the air.

Today, the no-tillage system accounts for 95% of the Brazilian agricultural production, which leads the application in the world, followed by the United States and Argentina.

Plant cover or green fertilization, which is the planting of species aimed at increasing soil fertility, is added to this technique.

BIOINPUTS

The replacement of nitrogen fertilizers with bioinputs (product, process or technology of a biological origin, such as vegetal, animal or microbial, used in agriculture)[8] is an important solution for climate mitigation since it avoids the generation of nitrous oxide (N_2O) in the soil, which has a potential for global warming that is almost 300 times higher than carbon dioxide (CO_2).

As it is based on biological variety, the use of bioinputs opens up an array of possibilities of application that is greater than those of chemical products. Another advantage is to increase national independence, particularly in uncertain macroeconomic and geopolitical scenarios, such as the war in Ukraine, an important supplier of inputs to Brazil – which also imports 87% of the fertilizers that it uses, in accordance with the Ministry of Development, Industry, Commerce and Services.

Increasing the production of bioinputs based on tropical biodiversity is, therefore, a strategy that strengthens Brazilian sovereignty. The legal framework[9] of bioinputs was approved in 2024 and is currently in the process of regulation.

Brazilian mega-biodiversity contributes for Brazil to be the world's most competitive country in the use of bioinputs. Brazil leads the use of both biofertilizers and biological pesticides worldwide, as shown in McKinsey's Global Farmer Insights 2024 report. In accordance with Embrapa, more than 600 products are registered in the Brazilian market of bioinputs with different usages.

According to CropLife, the size of this market in Brazil is R$5 billion in sales in one year, and the average growth is four times higher than the world's average. According to information of CCarbon, Center of Studies of Carbon in Tropical Agriculture, which dedicates one of its projects to research on bioinputs, there was an increase of 148% in the past year in the application in Brazilian agricultural areas – nowhere in the world the use has increased so much.

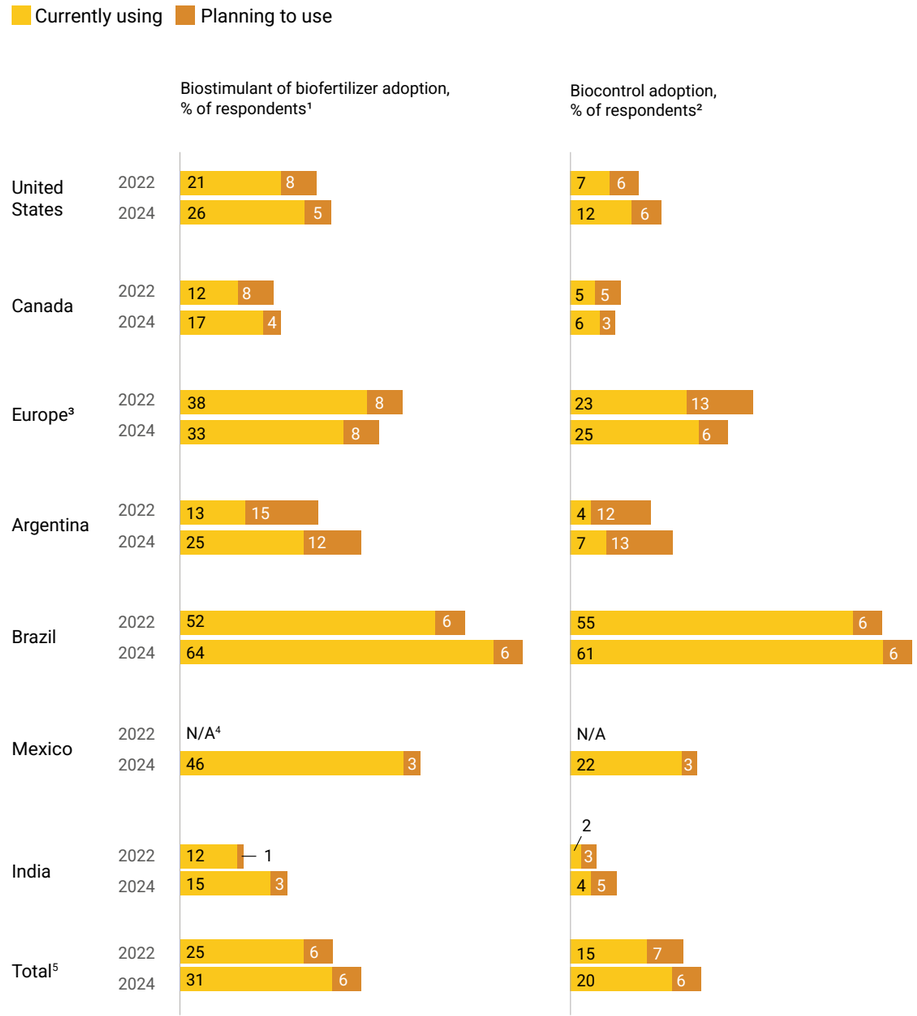
BRAZIL IS A GLOBAL LEADER IN THE USE OF BOTH BIOFERTILIZERS AND BIOLOGICAL PESTICIDES

R$5 billion
IN SALES IN ONE YEAR

4x higher
THAN THE WORLD'S AVERAGE GROWTH.

+148%
IN APPLICATION IN BRAZILIAN AGRICULTURAL AREAS

USING AND PLANNING THE USE OF BIOFERTILIZERS AND BIOLOGICAL CONTROL



[1] Question: Are you using biostimulants or biofertilizers in your fertilizer protocol? (2022, n = 4,474; 2024, n = 4,382).
[2] Question: Are you using alternative forms of crop protection into your pest management protocol? (2022, n = 4,474; 2024, n = 4,382).
[3] France, Germany, and Netherlands.
[4] Mexico was not part of this survey in 2022.
[5] 2024 total average excludes Mexico, so samples are comparable.

Source: McKinsey Global Farmer Insights 2024

ADOPTION OF MORE SUSTAINABLE AGRICULTURAL PRACTICES

BRAZIL LEADS THE USE OF NO-TILLAGE FARMING, PRECISION AGRICULTURE, BIOINPUTS AND PLANT COVER, ACCORDING TO A SURVEY

In % of respondents that currently adopt the technology[1]

	0	<10%	10-39%	40-59%	60-80%	>80%

	Total global	United States	Canada	Europe	Brazil	Argentina	Mexico	India
Crop rotation	68	87	93	71	65	77	23	48
Reduced or no tillage farming	56	78	84	56	97	78	42	6
Precision agriculture	40	56	56	53	68	38	7	3
Use of bioinputs	38	23	14	41	67	21	35	11
Plant cover	33	49	24	58	58	37	16	7

[1] Question asked in the survey: "What's your level of adoption on the following practices?"(The adoption entails use of a given sustainable practice on any part of a farmer's operations and does not necessarily indicate use on 100% of the area).

Source: McKinsey Global Farmer Insights 2024

Although there are several innovations in progress in this field, some techniques that use biological processes in production have already been consolidated in Brazil for decades, such as the Biological Nitrogen Fixation (BNF) and the use of agents such as insects, fungi, viruses and bacteria for pest control.

The BNF is carried out by bacteria that are present in or added to the soil, reducing the need for chemical nitrogen fertilization. This reduces not only the cost of the agricultural production but also the contamination of springs (rivers, lakes and water tables) and also improves the health of the soil by rebalancing the microorganisms. This technique has been commercially used in legumes, such as soybeans and beans since the 1980's, accounting for more than 30 million hectares with no addition of nitrogen from fossil sources. Today, practically 100% of the Brazilian soybeans are already produced with biological nitrogen fixation.

According to Embrapa, there is a trend to intensify the use of FBN in other crops, such as maize and grasses, and to recover the degraded areas. Solutions have also been researched to solubilize the phosphorus in the soil through bacteria and, therefore, reduce the dependence of the Brazilian agriculture on the import of the input.

REGENERATIVE AGRICULTURE: WHAT IS IT, AFTER ALL?

The expression "regenerative agriculture" was coined in the 1980's by Robert Rodale, an U.S. editor who supported organic agriculture. For Rodale, the regenerative agriculture prioritizes the health of the soil and, at the same time, covers high standards of animal welfare and justice for workers.[10]

Currently, it is known that regenerative agriculture should not be regarded by its practices, but for the results of these practices. And the result of regenerative agriculture is, above all, an assessment of the quality of the soil. If, from the chemical, physical and biological analysis standpoint that soil is better, it is being regenerated. This improvement can happen through several practices, such as no-tillage, bioinputs, crop rotation and integration (ICL and ICLF) – provided for in plans such as the ABC+, which was succeeded by RenovAgro.

CROP ROTATION AND INTEGRATED SYSTEMS

Brazil has been making progress in integrated systems, which combine no-tillage farming with crop rotation within the same production system. One of them is the Integrated Crop-Livestock (ICL) system, which usually combines an annual crop with pasture. By including the planting of trees in this system – such as eucalyptus and pine for wood production – the Integrated Crop-Livestock-Forestry system is implemented. Embrapa Agro Silvo Pastoril in Sinop, state of Mato Grosso, has experiments with fruit trees as well.

Combining different crops in one area in integrated systems is an ancestral practice, but it was in Brazil where it reached an unprecedented productive scale. According to the ICLF Network, made up of Embrapa and cooperatives, private banks and companies from the agribusiness, the area of these systems reached between 15 million and 17.4 million hectares in Brazil in 2020 (Polidoro *et al.*, 2020).

According to the article *Regenerative cattle farming in Latin America and the Caribbean, far beyond the oxymoron*[11], the ICLF system produces food at the same time as it

provides ecosystemic services and contributes to the creation of jobs. Whereas in conventional cattle raising a new workstation is created at every one thousand cattle units, in the ICLF system, more than one direct job is created for every 100 hectares of pasture (Oliveira *et al.*, 2013).

Also according to the article, the integrated system increases by 20% the productivity of the soybeans planted in these areas by at least five times the stocking rate of the pasture and eight times the production of beef and reduces by one year the age at slaughter, leading to the reduction of, at least, one fourth of methane per kilo of beef produced (Oliveira *et al*., 2013; Garrett *et al*., 2020). Additionally, under a moderate grazing intensity, the system results in better levels of carbon inventory, higher forage production, gain of live weight and increased resistance to moderate and extreme climate events (Delandmeter *et al.*, 2024).

According to the article, this happens because the presence of domestic herbivores plays a positive role in the carbon cycle (Fundación para la Conservación del Bosque Chiquitano, 2020) and helps increase the production of biomass through manure and urine during the grazing period or as a final waste of the season (Delandmeter *et al*., 2024). This accumulation of organic matter in the soil also tends to increase the resilience of the systems to climate disturbances (Franzluebbers, 2010).

INTEGRATED SYSTEM IN NUMBERS

20%
MORE SOYBEAN PRODUCTIVITY

5x
HIGHER STOCKING PASTURE RATES

8x
MORE MEAT PRODUCTIVITY

-1 year
TO SLAUGHTER

-25%
METHANE PER KILO OF MEAT

Regenerative practices in the Cerrado (Brazilian scrubland)

The Cerrado, a Brazilian biome with the highest number of degraded areas, is the target of a program called Landscape Accelerator - Brazil (LAB), a joint initiative of the World Business Council for Sustainable Development (WBCSD), the Brazilian Business Council for Sustainable Development (CEBDS) and the Boston Consulting Group (BCG). According to this group, Brazil can lead the transition of large agricultural landscapes to regenerative practices by 2030, combining productivity and environmental conservation.

The Resilience for the Future[12] report, developed by BCG, shows that investments of US$55 billion can generate an opportunity of up to US$100 billion (in net present value) in an area that is equivalent to Norway in size, contributing to an increase of US$20 billion a year of Brazilian GDP by 2050, and a reduction of carbon emissions of 140 $MtCO_2eq$ (millions of metric tons of carbon equivalent).

In the investments in the conversion of 23.7 Mha (million hectares) of degraded pasture, it is estimated that producers can obtain an internal rate of return (IRR) from 15% to 22%, between seven and nine years. And, in the case of investments in generative agricultural practices in 8.6 Mha, the expected return is from 16% to 29%, between three and five years, with the integration of crop rotation, plant cover and bioinputs.

OPPORTUNITIES IN THE BIOME

US$55 billion
IN INVESTMENTS TO TRANSFORM THE CERRADO BIOME WOULD GENERATE:

US$100 billion
OF POTENTIAL RETURN IN THE REGION

US$20 billion
A YEAR OF IMPACT ON GDP BY 2050

140 $MtCO_2eq$
OF EMISSIONS AVOIDED

GENETIC IMPROVEMENT AND BIOTECHNOLOGY

For the 2025/26 harvest, the Centro de Tecnologia Canavieira (CTC), which provides varieties of sugar cane for planting, launched a technological package that, according to the company, has the potential to move R$ 60 billion in the next 15 years, contributing to its target of doubling the productivity of Brazilian sugarcane plantations by 2040.

The package includes genetic improvement; development of more functional transgenic cultivars (for example, resistant to sugarcane borers); and research for the planting of sugarcane with seeds instead of billets. The synthetic seeds are being developed by CTC in the town of Piracicaba, State of São Paulo, and there is already a highly successful experimental plantation. The new varieties will be submitted to the regulatory bodies for approval.

TECHNOLOGIES FOR THE REGENERATIVE AND ORGANIC CULTIVATION OF GRAINS

The use of bioinputs and practices such as composting and crop rotation, which increase soil health and contribute to carbon sequestration, are the core activities developed by the Folio Institute, a non-profit initiative. What started as a project of the organic egg producer Raiar for the production of organic maize has recently become an institute. The purpose is to contribute to a regenerative and organic model for the cultivation of grains, banning the intensive application of pesticides and fungicides. Additionally, new farming implements have been tested for the removal of plants without the application of herbicides.

Folio operates on three fronts: development of technologies for the transition to regenerative agriculture, data generation and management and knowledge exchange.[13] To this end, it established a partnership with the Federal University of São Carlos (UFScar), which dedicated to these experimentations 40% of its planted area of Lagoa do Sino School Farm (Fels) in Buri, in the southeast of the state of São Paulo.

A partnership with the Avaré Federal Institute also seeks to provide knowledge to producers of on-farm bioinputs, that is, directly produced in rural properties in accordance with their specific needs. There is also a project of Folio with Embrapa Soja, for the recovery of degraded areas.[14]

REGENERATIVE LIVESTOCK FARMING

Practices can be regenerative in cattle raising as well. Diversification of forage, use of integrated systems and mixed crops of grasses and legumes with high content of soil fertility recovery are examples of regenerative management that increases animal productivity. These are combined with the management of the breeding periods, improvement and diversification of breeds and cattle feed that reduces methane emissions. These changes are accessible to producers from all economic dimensions, contributing to the regeneration of biodiversity in a fast, cheap, profitable and technically accessible manner.[15]

However, these are measures that must be accompanied by public anti-deforestation policies and that require the traceability of the cattle productivity chain to prevent the meat from originating from illegally deforested areas. In December 2024, the National Plan for the Individual Identification of Cattle and Buffaloes (Pnib) was launched. The program establishes an individual identification system to qualify traceability, providing producers with time to adapt by 2027, when participation will be mandatory for all cattle farmers.

Another proposal that was presented by the Brazilian Association of Meat Exporting Industries (Abiec), MBR Global Foods Company and the consulting firm Agroicone at the end of 2023, during the New York Climate Week, is to combine the data that is already available on the Rural Environmental Registration File (CAR) of the producing property with the Animal Transit Form (GTA), a document that is already regularly required upon trading cattle so as to meet sanitary standards.[16]

While a national traceability policy has been developed in Brazil, the largest beef industries in the country, such as MBR Global Foods Company, have been creating, over the past few years, techniques that allow to identify with more precision the origin of the cattle across the supply links, such as the small breeding and rearing farms and, based on this mapping, they avoid purchases from places related to illegal deforestation, invasion of Conservation Units and Indigenous Land, as well as the use of forced labor.

SOCIAL INCLUSION OF SMALL PRODUCERS

In order to stimulate the best environmental and social practices, MBR Global Foods Company conditions the inclusion of small producers in its supply chain upon compliance with rules. As a result, the small land owners obtain benefits such as higher income, supply regularity and access to technical assistance and financing.

The company already monitors 100% of the direct suppliers and 88.8% of the indirect suppliers in the Amazon, and 79.6% in the Cerrado. Its target is to reach 100% by the end of 2025. In 2024, it reintegrated more than 630 farms through the *Verde Mais* (Greener) Program, totaling 4,194 farms since 2021, and registered 151 new producers in the *Bezerro Sustentável* (Sustainable Calf) Program. In partnership with IDH, a Netherlands foundation that finances projects for the sustainable production of commodities, the program supports producers, in particular in the state of Mato Grosso, for the purpose of increasing the productivity of the herd, adjusting practices to the environment and promoting the conservation and recovery of forests.

First company of animal protein in the Americas to have its emissions reduction targets approved by the Science Based Targets initiative (SBTi), MBR Global Foods Company's targets are to reduce by 68% scopes 1 and 2 emissions (related to industrial operations and use of electricity) and by 33% scope 3 emissions (related to the supply chain) by 2035.

REGENERATIVE AGRICULTURE AND LIVESTOCK ON A LARGE SCALE: A PRACTICAL CASE STUDY

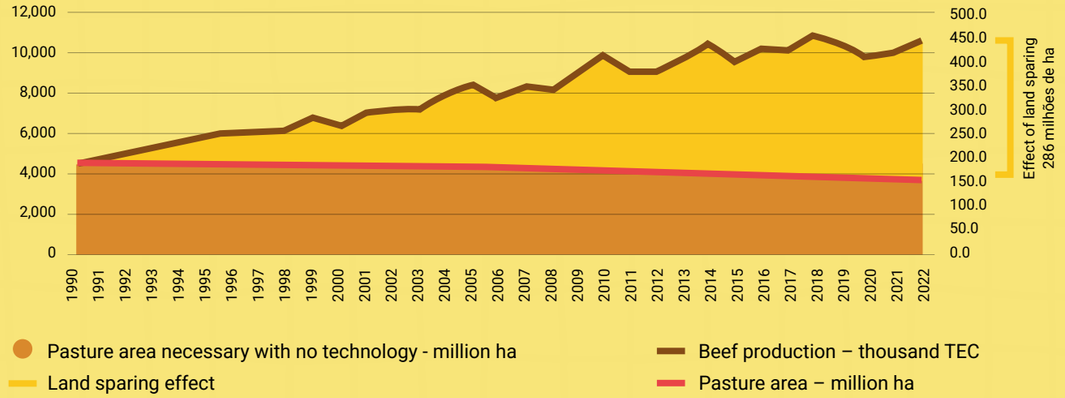
Among the properties that adopt regenerative practices on a large scale is Fazendas Reunidas Baumgart in Rio Verde, state of Goiás, focused on the creation of Nelore cattle breed and the cultivation of rice, soybeans, maize and sorghum in an area of 25,000 hectares, according to information disclosed by the Baumgart Group. In an interaction with the academic environment, the farm participates in studies to improve and enhance techniques to be applied in agricultural and cattle raising activities, such as the no-tillage farming, bioinputs and high technology in precision agriculture. The combat of pests is carried out by a robotic system, guided by a drone and GPS that applies the product only on the necessary places, allowing for cost savings, reduction of environmental impact, better health and safety conditions for workers and increase of productivity.

Alongside these corporate strategies, a market action became emblematic for increasing productivity in cattle raising and, consequently, significantly reducing emissions. China, which absorbs 60% of the exports of meat from Brazil, asked for a juicier meat with a lower sanitation risk, willing to pay 10% to 15% more to those that reduced the age to slaughter to 30 months. Brazilian producers, which slaughtered the cattle at around five years of age, had to invest to improve the pasture to fatten the cattle in less time.

As a result, there was a recovery of the pastures and less methane emission per slaughtered cattle unit due to the reduction of their lifetime. The case became known as "China Cattle".

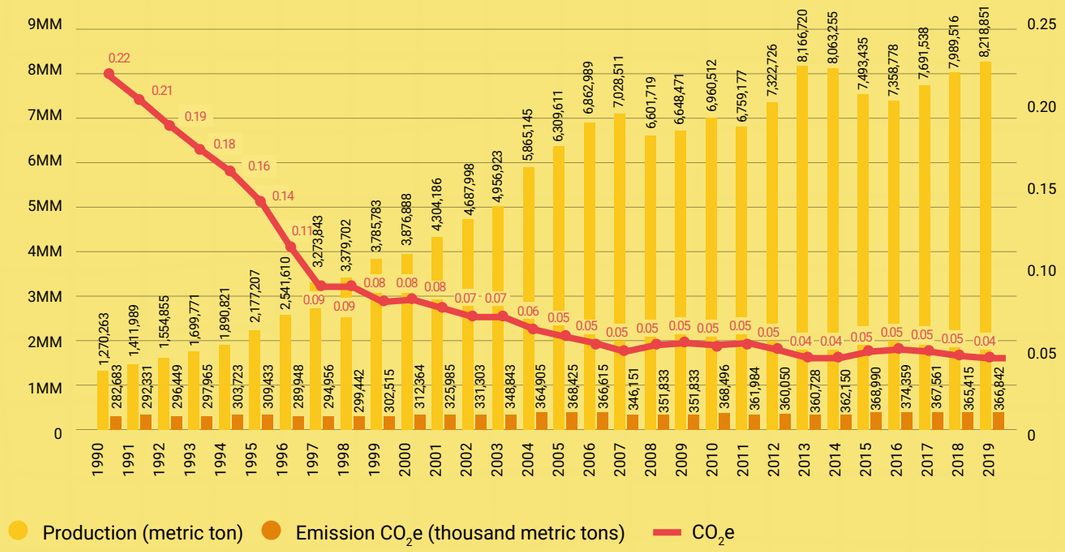
EFFECT OF LAND SPARING ON LIVESTOCK

PASTURE AREA THAT WOULD BE NECESSARY TO PRODUCE THE SAME AMOUNT OF BEEF TAKING INTO ACCOUNT THE TECHNOLOGY OF 30 YEARS AGO



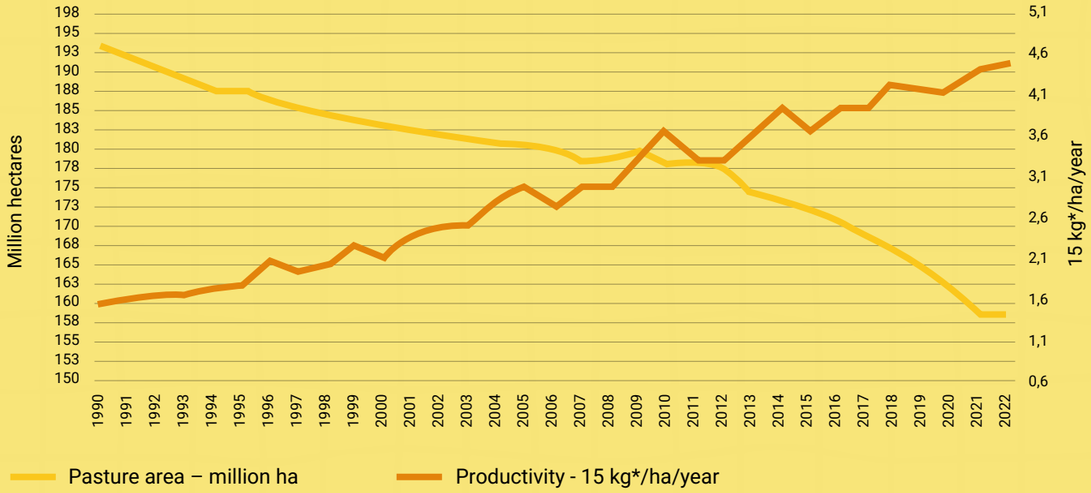
Sources: Athenagro, IBGE data (PPM, PPT, PAM, Censo), Inpe (Terraclass/Prodes), Lapig, Rally da Pecuária, Embrapa

EMISSIONS PER METRIC TON OF BEEF PRODUCED



Source: System of Estimates of Greenhouse Gas Emissions and Removals (SEEG)

EVOLUTION OF THE PASTURE AREA AND LIVESTOCK PRODUCTIVITY IN BRAZIL



* Approximately.

Source: Athenagro, IBGE data (PPM, PPT, PAM, Censo), INPE (Terraclass/Prodes), Lapig, Rally da Pecuária, Embrapa

RECOVERY OF DEGRADED PASTURES

Pastures in Brazil cover 177 million hectares, of which 109.7 million hectares (60%) present some level of degradation: 40% present average vegetative vigor (intermediary degradation) and 20%, low vigor (severe degradation), according to Embrapa.[17] Of this total, there are at least 28 million hectares of pasture areas in degradation with potential for conversion into agriculture, reforestation, increased livestock production or even for the production of energy. The number of hectares is equivalent to the size of the state of Rio Grande do Sul, according to Agência Brasil. If this area were used for the cultivation of grains, there would be an increase of 35% in the total planted area in Brazil.[18]

A study conducted by the Image Processing and Geoprocessing Laboratory of the Federal University of Goiás (Lapig – UFG) verified an expressive reduction in the number of properties with pasture areas with severe and moderate degradation between 2010 and 2018. The study shows that, in the same period, 26.8 million hectares of degraded pastures were recovered, a number that is a lot higher than the target set by the ABC+ Plan of 15 million hectares. The area recovered was larger than the territory of the United Kingdom, which has approximately 24.2 million hectares.[19]

SOIL-BASED CARBON SEQUESTRATION

In addition to reducing GHG emissions into the atmosphere, the adoption of regenerative management practices can increase soil-based carbon sequestration. The soil represents Earth's largest terrestrial carbon reservoir and is an important carbon sinkhole of the atmosphere.

Part of the carbon withdrawn from the atmosphere by plants via photosynthesis is transformed into plant tissue, such as leaves, branches and trunks. And part of this carbon in the plant tissue is inserted into the soil. Those responsible for this sequestration are the organisms whose body size is smaller than 0.1 millimeter, such as bacteria, protozoan, fungi, algae and yeast. A soil that is reach in microorganisms is apt, therefore, to sequester more carbon, thus contributing to fight climate change.

However, it is necessary to increase the level of knowledge about the carbon sequestration potential on a large scale in tropical agriculture. To this end, a year and a half ago, the University of São Paulo (USP) created at the Higher School of Agriculture Luiz de Queiroz (Esalq) CCarbon, the first center in the world aimed at studies on carbon in a tropical climate. The center, with 30 projects, is financed with funds from the Research Support Foundation of the State of São Paulo (Fapesp).[20]

CCarbon is responsible for developing technology and methods from the tropicalization of protocols used in countries with temperate climate, taking into consideration the characteristics of the six Brazilian biomes.

Researchers have already made some findings. In the No-Tillage System, adopted in approximately 30 million hectares, carbon sequestration is of 15 million metric tons every year, taking into consideration a weighted average of the Brazilian regions of 0.5 metric tons of sequestrated carbon per hectare.

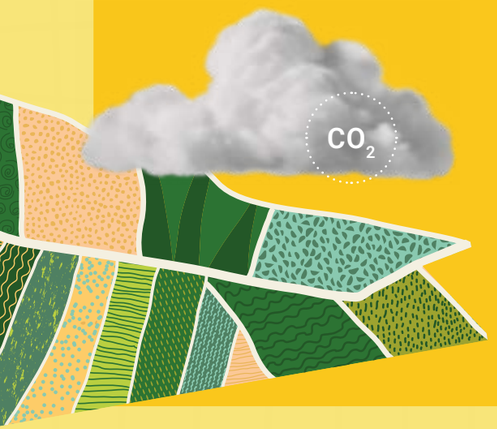
POLICIES FOR DEGRADED AREAS

Degraded areas emit carbon and are unproductive. Their recovery represents, therefore, a large-scale solution for both Brazilian companies and economic productivity and creation of jobs and generation of income.

In view of this, the National Program for the Conversion of Degraded Pastures in Agricultural and Livestock Production and Sustainable Forest Systems was created (Executive Order No. 11,815/2023. Also, a credit line that is expected to offer US$ 10 billion to the producers interested in recovering areas was launched. The funds will come from a blended finance line of the China Fund.
In order to put the program into practice, Embrapa published in a book more than 30 suggestions of public policies in which Brazil brings together experience and technology for its implementation.[21]

AI and regenerative agriculture in Xingu

From a partnership between SLC Agrícola, Agro Penido, Agrorobótica and Embrapa Instrumentação, the Carbono Xingu (Xingu Carbon) program, an initiative that combines IA, regenerative agriculture and large farms from the Xingu region, in the state of Mato Grosso, was created. Their purpose is to transform rural properties into carbon sequestration plants through regenerative agricultural practices, such as no-tillage farming, ICLF and bioinputs. The project will monitor an area of 18,960 hectares in the Darro, Água Viva and Pioneira farms, using the AGLIBS system, developed by Agrorobótica together with Embrapa Instrumentação.



The system uses laser spectrometry and artificial intelligence to collect information on carbon and soil fertility – the same technology employed by NASA in the missions in Mars, with the Curiosity rover, patented, certified by ISO 17025 and adapted for large agricultural scales. The information is stored in the cloud and transformed into reports that guide management. Based on that, carbon credits will be generated to be traded in the voluntary market, with the certification of the Verra VM0042 methodology.[22] [23]

The capacity of sequestration of the integrated systems, such as ICL and ICLF, is at least twice as that of the no-tillage system. Considering a conservative figure of one metric ton of carbon sequestrated per hectare per year and 15 million hectares in integrated systems, this amounts to more than 15 million metric tons of carbon.

The center estimates that 90 million hectares of pastures are at some level of degradation, which leads to carbon emissions. But, when recovering these areas, the soil starts to sequestrate carbon. CCarbon calculated the amount of 0.3 to 0.4 metric tons of carbon sequestrated per hectare per year when recovery techniques of degraded pastures are applied. This amount, if multiplied by the 90 million degraded hectares, results in up to 36 million metric tons of carbon sequestrated – more than the sequestration in the no-tillage system and integrated systems together. The sum of all these systems would reach nothing less than 66 million metric tons a year.

This shows that agriculture, livestock and forestry activities, when they are well performed, become an essential part of the climate solution and also increase productivity. This is because the carbon in the soil is in the form of organic fractions that improve the health of the land and make this environment better for plant development.

These figures, however, have not yet been fully accounted for in Brazil's National Inventory of GHG Emissions, which calculates carbon removals only in the case of land use, land use change and forestry (LULUCF).

The measurements of carbon removal from the soil by the agricultural activity are important for the productive sector to better account for its balance of emissions and monetize the activities from the point of view of payment for environmental services, carbon credit market, green bonds and premium price of products, where there is value added due to the environmental and social attributes.

The weight of land use change, forestry and agriculture and livestock

WHAT ARE THE MOST RELEVANT CATEGORIES AND ASSOCIATED GASES FROM BRAZIL'S STANDPOINT?

CATEGORIES	MOST RELEVANT GASES		MATERIAL FACTS ON RESULTS FOR 2022
Area converted into Field and Pasture 	Carbon dioxide	CO_2	Main source of emissions in Brazil and the sector, accounting for47% of total CO_2eq emissions in Brazil. Most emissions arise from the conversion of native forests into pasture.
Area converted into Agriculture 	Carbon dioxide	CO_2	Second main source of emission of the sector, accounting for 9% of total CO_2eq emissions in Brazil.
Forest remaining as Forest 	Carbon dioxide	CO_2	Main source of removal in Brazil, accounting for 77% of total CO_2eq removals.
Wood-based forest products 	Carbon dioxide	CO_2	Second main source of removal in Brazil, accounting for 15% of total CO_2eq removals.

Source: Booklet Understand the National Inventory of Greenhouse Gas Emissions and Removals – The most frequent questions explained in an accessible manner

LARGE SCALE ORGANIC AGRICULTURE

A pioneering company in regenerative agriculture, through large scale organic production, is Usina São Francisco (UFRA), of the Balbo Economic Group, which owns the Native brand. Located in the town of Sertãozinho, state of São Paulo, it is one of the world's largest organic sugar producers and exporters.

As early as 1982, UFRA installed a bioplant to produce natural enemies of sugarcane borers, thus inaugurating a successful biological control system.

At the same time, the first nurseries for the production of seedlings of Brazilian native trees were set up, specifically for the purpose of reforesting the Permanent Preservation Areas in their properties.

In the restored forest massif, 340 species of vertebrate animals have been registered to date, of which 49 are at some risk of extinction, by the current list of the Environment Department of the State of São Paulo. According to UFRA, this biodiversity is 23 times higher than that usually found in conventional sugarcane plantations in the region.

Since 2006, Native has been regularly carrying out the inventory of GHG emissions of the regenerative organic production of sugarcane, sugar and ethanol of UFRA, based on the GHG Protocol, an international emission quantification model. The assessment covered from the agricultural production of sugarcane and the consumption of inputs and the industrial phase of sugarcane and ethanol production at the mill, to transportation, sale and consumption of products, in both domestic and foreign markets. This is an approach called Lifecycle Analysis, which is popularly known for accounting for the emissions of the "from the cradle to the grave" process.

The amounts verified for UFRA are lower than the average amounts of emissions for the sector due to the organic production methods. When compared to the production carried out in Europe or Japan, from beetroot, or in the United States, from maize or beetroot, the advantages are event greater. This is because they are productive methods that use energy arising from the burning of fossil fuels, whereas at UFRA, the energy comes from the burning of sugarcane bagasse.

Therefore, taking into consideration the lifecycle of the group of products of UFRA, on average, the emission of equivalent to four metric tons of carbon dioxide per hectare per year is avoided. For comparison purposes, a tropical forest under development sequestrates 2.59 metric tons of CO_2 equivalent per hectare per year.

Credits for nature

A promising solution, yet to be scaled, is the sale of biodiversity credits generated from certificates of corporate activities with a positive balance regarding actions for the protection of nature such as conservation and regeneration of natural areas, recognizing the value of nature services for business with lower impact on the use of water and energy, soil protection and waste management – going beyond the offset of emissions and mere compliance with environmental legislation.

In the emerging biodiversity credit market, one of the most well recognized certifying companies in the world is Brazilian: the Life Institute (or Lasting Initiative for Earth) founded in 2009.

The application of Life's methodology, which is audited by third parties, uses two main metrics: the rate of pressure on biodiversity, that is, the impact caused by economic activity, and the positive performance in biodiversity. Through the Life Key software, organizations of any size and from any sector can enter data and, consequently, continuously monitor their environmental performance, supporting the engagement, commitment and disclosure related to Target 15 of the Global Biodiversity Framework (GBF).[24]

There are two relevant aspects in Life methodology. One of them is the division of the Brazilian territory into 45 ecoregions, which enables the assessment of the environmental conditions in a more specific manner. The other one is the measurement of the environmental impact of companies taking into consideration not only the amount of the expenditures with energy, water, GHG emissions and direct impact on biodiversity, but also the level of severity of these impacts.

That is, conserving or regenerating native vegetation in a devastated ecoregion has a greater positive impact than in an area that is not threatened. Accordingly, the negative impact of a company's expenditure with water in an ecoregion with water scarcity is greater than in an area with abundant water. This enables the prioritization of actions for nature protection. The conservation actions scoring system also prioritizes initiatives with greater potential to maintain the ecosystemic and biodiversity conservation services in a shorter timeframe.

Life's operation, which started in Brazil from an initiative of the Boticário Group, the Avina Foundation and the Wildlife Research Society (SPVS), was subsequently adapted for Paraguay, with a focus on the primary sector, where an agriculture, livestock and forest committee was created. Later, it was launched in Europe and Mexico and soon it will be all over Latin America, according to information of the institute.

Caiman Agropecuária, in the Pantanal (Brazilian wetland) area, is one of the certified organizations, with 473,446.16 Biodiversity Life credits – but the list also includes companies from the pulp and paper, and packaging (C-Pack) sector and other sectors, in addition to SPVS itself, which maintains 19,000 hectares of private natural reserves. Certified in 2024, Caiman protects natural areas through a Private Natural Heritage Reserve (RPPN)[25], at the same time as it maintains productivity cattle raising activities, raising Nelore cattle breed, and ecotourism.

Additionally, the Regional Development Bank of the Far South (BRDE), with the support of the Sustainable development Department of the State of Paraná, will certify 20 RPPNs of rural producers, generating biodiversity credits that will be acquired by the bank.

Climate heritage of a naturally beautiful country

Conservation, restoration and tree planting for industrial purposes drive large-scale Brazilian solutions in biodiversity and climate change agendas

When flying over the Brazilian territory, one can see a vast landscape with different shades of green from North to South. These remind us of mosaics integrated like a large patchwork quilt. The portrayal of different land uses highlights the presence of forests, in their most diverse features, functions and utilities, sharing spaces where human activities are carried out. Under the concept of "forest continuum"[1], which outlines the multilayered scenario of this relationship, there is room for all forms of conserving, planting, managing and valuing trees for the ecosystem services they provide to planet Earth.

Along the forest continuum, different economic, environmental and social contributions can be observed – from the permanent preservation of forest masses and riverbanks to human interventions through sustainable management, restoration of deforested areas, forestry of native trees and monocultures of fast-growing exotic species, such as eucalyptus. Since the beginning of time, forests have been essential to life on Earth. Today they play an even greater role in the global climate emergency scenario.

For its territorial dimension, climate conditions, occupation dynamics and biodiversity, Brazil – which owns 40% of the planet's tropical biomass, in the Amazon - has a key role to play in the face of this challenge. Forests play a key role in the mitigation of global warming as they store carbon, regulate the water cycle and protect biodiversity. According to the UN[2], 30% of Earth's land area is covered by forests. However, the cutting down of trees in tropical areas releases over 5.6 billion metric tons of greenhouse gases (GHG) every year – more than four times the total volume emitted by global aviation and shipping activities.

According to the Intergovernmental Panel on Climate Change (IPCC)[3], natural climate solutions – via forest conservation and restoration, for example – could account for 20% to 50% of opportunities to reduce emissions by 2030, about 5 to 12 gigatons (billion metric

tons) of CO_2 equivalent ($GtCO_2eq$). Brazil alone accounts for 15% of this potential – the second largest, after Indonesia.

This scenario showcases socioeconomic risks and opportunities in connection with the demand for a deeper reconnection with nature. According to a report from the World Economic Forum[4], about US$44 trillion – in excess of half of the world's GDP – is moderately or highly dependent on nature and its services, such as pollination, water resources and carbon mitigation, as the world seeks to avoid the worst-case global warming scenario.

Under the Paris Agreement, countries have committed to reducing emissions and capturing carbon from the atmosphere to keep global temperatures from rising above 1.5°C compared to pre-industrial times. With about 90 million degraded pastures, Brazil is one of the world's most suited locations to removing carbon from the atmosphere via forests. Amid this scenario, Brazil has a climate commitment to reducing illegal deforestation to zero and reforesting 12 million hectares by 2030.

Changes in forest and land use currently account for 46% of gross Brazilian carbon emissions, according to the System of Estimates of Greenhouse Emissions – SEGG[5]. Between 2004 and 2012, deforestation decreased by 80% in the Amazon, to 4,500 square kilometers from about 25,000 square kilometers. However, figures have risen again, partly due to the lack of economic policies that could generate income from standing forest activities.

As from 2022, with new policies and related crackdown and inspection actions, deforestation rates resumed its downward trend. According to data[6] from the National Institute of Space Research (Inpe), from August 2023 to July 2024 the deforestation rate in Amazon was down by 30.63% compared to the previous year.

According to the Amazon Environmental Research Institute (Ipam), the carbon stock in the region is equivalent to 10 years of global emissions. Ways are being sought to increase the value of climate and biodiversity assets as a reward for the importance of the Amazon in regulating the rainfall cycle, as it acts as a major watering station for crops in South America.

Accordingly, Brazil has the cutting edge, as it is able to harvest in up to three crops per cycle *(learn more about agriculture on page 27)*, contributing to the production of agricultural commodities that feed 800 million people in the world, according to a study of Brazilian Agriculture and Livestock Company (Embrapa). Concurrently, the Amazon rainforest in the water cycle has a key role, as it provides energy safety for hydroelectric plants, with a knock-on effect on other economic segments in Brazil.

NATURAL CLIMATE SOLUTIONS

20% to 50%
OF GLOBAL POTENTIAL FOR EMISSION REDUCTION CAN COME FROM NATURE BY 2030.

5 to 12 $GtCO_2eq$
VOLUME OF CO_2 THAT CAN BE AVOIDED WITH FOREST CONSERVATION AND RESTORATION.

15%
OF GLOBAL POTENTIAL IS IN BRAZIL – THE 2ND LARGEST IN THE WORLD, BEHIND INDONESIA.

Source: Intergovernmental Panel on Climate Change

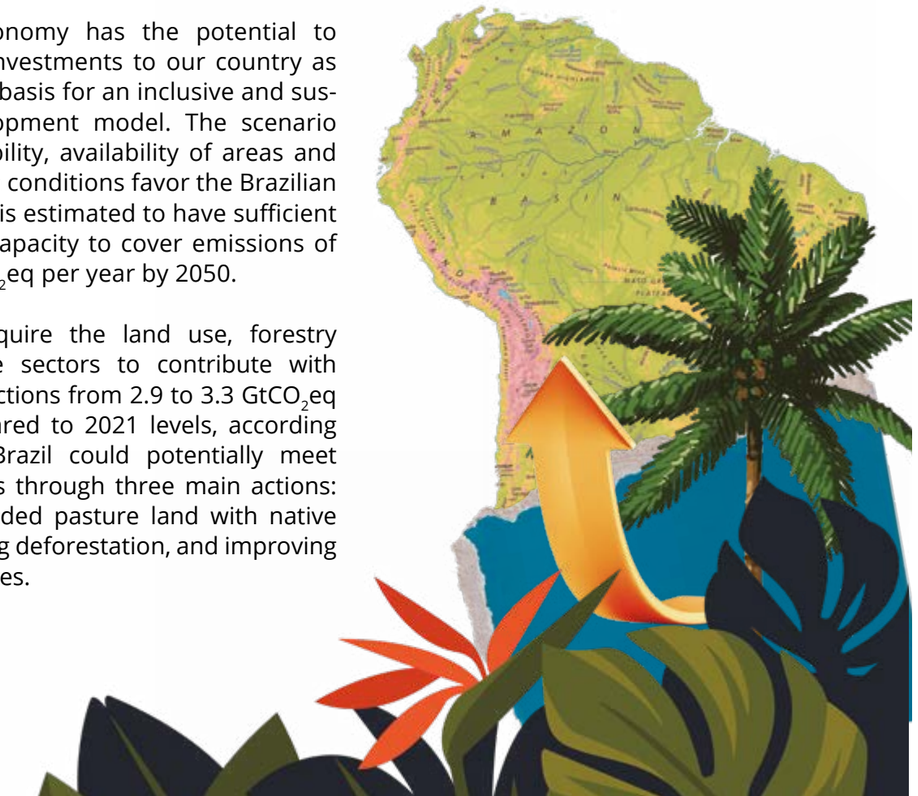
Opportunities generated by nature

Carbon credits linked to forest and land use solutions account for a global market that could reach US$15 billion in 2030 and US$35 billion in 2040, according to McKinsey projections[7].This consultancy estimates that the transition to low carbon will require from US$3 trillion to US$5 trillion in investments per year until 2030 – the largest allocation of capital ever – across all climate mitigation fronts. Through its forests, Brazil is a strong candidate to take on these opportunities, contributing to the process of decarbonizing the global economy.

The green economy has the potential to attract major investments to our country as it constitutes a basis for an inclusive and sustainable development model. The scenario of political stability, availability of areas and positive climate conditions favor the Brazilian position. Brazil is estimated to have sufficient carbon credit capacity to cover emissions of about 1.7 $GtCO_2eq$ per year by 2050.

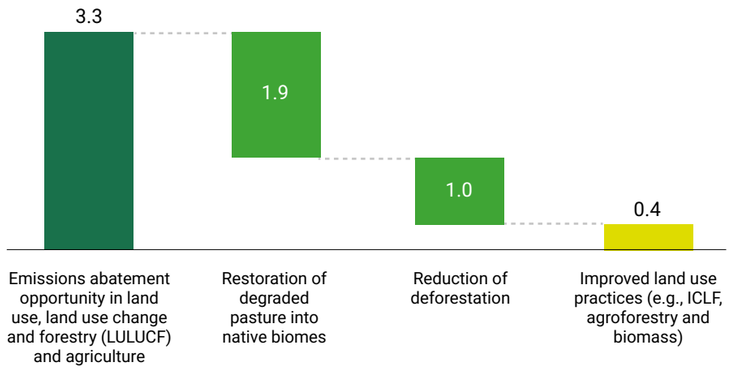
This would require the land use, forestry and agriculture sectors to contribute with emissions reductions from 2.9 to 3.3 $GtCO_2eq$ in 2050, compared to 2021 levels, according to McKinsey. Brazil could potentially meet these indicators through three main actions: restoring degraded pasture land with native forests, reducing deforestation, and improving land use practices.

A greater financial inflow is estimated for tropical countries to reduce deforestation and increase the retention of carbon gases released globally into the atmosphere. In addition to bilateral donations, philanthropy and capital raised from international development banks, the US$300 billion per year agreed at COP 29 in Baku for financing the climate transition of developing countries should come into play, with recommended efforts to reach at least US$1.3 trillion per year.



MASSIVE DECARBONIZATION OPPORTUNITIES

POTENTIAL REDUCTION OF EMISSIONS BY 2050 IN LAND USE, LAND USE CHANGE AND FORESTRY, AND AGRICULTURE SECTORS (IN $GtCO_2e$)



Source: Beyond Net Zero: Brazil's massive opportunity to decarbonize the world, September, 2023

There is anticipation surrounding the Brazil-led Tropical Forest Forever Facility (TFFF), expected to be launched at COP 30, to reward tropical countries for forest conservation. Based on funds from national sovereign funds, this mechanism provides for financial incentives per hectare of forest kept preserved, with appreciation of environmental assets and capital gains for investors.

The estimated potential is US$125 billion, of which US$25 billion coming from countries to leverage US$100 billion from companies, with 20% passed on to traditional peoples. If it commits to seeking zero deforestation, Brazil has the potential to raise about US$1.5 billion per year from the TFFF, according to WWF-Brazil.

A study[8] indicates that protecting the Amazon rainforest, where most of the deforestation takes place and which makes Brazil one of the world's 10 largest carbon emitters, would cost between US$1.9 billion and US$2.3 billion annually. By way of comparison, preserving the Amazon is worth US$317 billion per year in natural capital, according to the World Bank.

This section on Forest solutions is broken down into three parts: Conservation, Restoration and Forestry, as detailed below. Each part is composed of a background and a solution mapping.

Among developed solutions, we find the Arpa Program – the world's largest tropical rainforest conservation initiative, protecting 62.5 million hectares and already replicated in Colombia and Ecuador; and the forestry of exotic species, such as eucalyptus, for industrial purposes such as paper and pulp production, which have a positive climate impact.

A solution on the rise is the implementation of the Forest Code, which provides for the recovery of 18.8 million hectares of degraded native vegetation areas on rural properties, in addition to areas already preserved in accordance with environmental law. Furthermore, restoration initiatives to attract investments are in place to restore degraded areas on a large scale in the Amazon and Atlantic Forest. The forestry of native species is deemed a promising solution, notably in degraded areas in the Atlantic Forest.

Conservation

Targeting zero deforestation

Creating and consolidating protected forest areas, by promoting sustainable use, is a key strategy for reducing forest degradation and multiplying climate solutions

The protection and sustainable use of biodiversity in Conservation Units (CU), Indigenous Land (IL) and mandatory native vegetation areas on rural properties, according to the Forest Code, are key for carbon capture and storage and climate mitigation in connection with socioeconomic opportunities for Brazil.

PROTECTING NATURE ON A LARGE-SCALE

Established in 2000, the National System of Conservation Units (Snuc) brings together criteria and standards for the creation, implementation and management of these areas according to different management categories. There are 3,119 federal, state and municipal conservation units, totaling 260,000 hectares in the six biomes and marine environment of Brazil.

Classified into different categories according to their purposes and uses, they protect 19.16% of the continental and 26.58% of the maritime area. The full protection status category, such as national parks and biological reserves, covers 32% of the CUs. The category related to sustainable use, with the presence of populations earning their livelihood from biodiversity, account for 68.1%.

Indigenous Land total 805 areas – 14% of the national territory. Overall, protected areas, such as UC and IL, overall account for 33.1% of the Brazilian continental area, where the Legal Amazon stands out. In these territories, despite challenges posed by the invasion of illegal loggers and gold miners, deforestation indicators are considerably lower compared to those in non-protected areas.

BREAKTHROUGHS IN ECONOMIC TOOLS

Due to the characteristics of its territory, rich biodiversity and conservation challenges, Brazil is a fertile ground for the development of innovative financial mechanisms for solutions that gain visibility in the climate scenario. Caring for those who take care of the forest as a strategy to keep it standing has inspired pioneering initiatives in Brazil, such as the *Guardiões da Floresta* (Forest Stewards) Program[9] (formerly *Bolsa Floresta* – Forest Grant) – a public policy in Amazonas implemented by the Sustainable Amazon Foundation (FAS) to support communities and reward residents of environmental reserves who protect and use the forest in a sustainable manner.

Under the Payment for Environmental Services (PSA) model, this program currently benefits 12,000 people in 28 CUs.

In addition to being a benchmark for current federal government support *Bolsa Verde* (Green Grant) program, the initiative in Amazonas, created in 2007 within the scope of the State Climate Change Policy, has given rise to initial debates in Brazil on tools for economic incentives for carbon conservation and mitigation. The voluntary mechanism for Reducing Emissions from Deforestation and Forest Degradation (REDD+) stands out among them, and is aimed to offset carbon through the conservation of natural forests, which avoid deforestation emissions.

Businesses are now looking at the concept of biodiversity credits to prevent global species losses, inspired by the carbon market. This tool is currently under development about the world, with the challenge to ensure credibility and security to transactions by conforming with ecological mechanisms and environmental and social safeguards.

Analysts believe that this equation needs to be further explored, and Brazil is seen as one of the best places for such experiments, with an environment favorable for research and dialogue. WWF-Brazil analysis underscores the stance that Brazil has played a leading role at global biodiversity conferences and has a robust, modern legal framework, although some aspects of its implementation need to be improved.

CLIMATE DEMAND BOOSTS BIOECONOMY

The expansion of bioeconomy, in its different concepts, is one of the priority axes in the climate agenda – both through the production of bioresources to replace fossil sources in the energy transition and the innovation and valuing of the various sociobiodiversity productivity chains as a driver for income, quality of life and maintenance of the standing forest.

Brazil has made headway in public policies linked to the bioeconomy agenda as a national development strategy. This topic is included in the new Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm)[10] as an economic axis for forest conservation. Launched in 2024, the National Bioeconomy Strategy brings together a set of policies aimed to develop the sector, providing for a National Plan – currently under progress – with effective financial instruments and actions.

Brazil has led the inclusion of the bioeconomy concept in the final document of the G20 meeting held in 2024 in our country. In 2025, in addition to the opportunity being brought to the fore once again at the BRICS (world's five largest emerging countries) meeting, this agenda should stand out at the COP 30 climate conference in the city of Belém. Bioeconomy may benefit from the global inflow of funds amid the climate change and biodiversity scenario.

A WRI[11] study shows that bioeconomy generates a GDP of R$ 12 billion in the Amazon. With additional investments, it will be possible to reach at least R$ 38.6 billion in 2050, generating 833,000 new jobs that would replace occupations currently linked to forest destruction.

BIOECONOMY IN THE AMAZON

R$ 12 billion
CURRENT GDP OF BIOECONOMY IN THE AMAZON.

R$ 38.6 billion
GDP POTENTIAL OF BIOECONOMY BY 2050.

833 thousand
NEW SUSTAINABLE JOBS CAN BE CREATED UNTIL 2050.

Source: WRI

In Pará, the Amazon state of the largest economy and greatest population, a WRI survey published in 2025 identified climate action-related investments from R$ 1.7 billion to R$ 1.8 billion already negotiated or with the potential to be raised in the coming five years. Of this total, about R$ 400 million can potentially finance bioeconomy production activities, together with R$ 320 million in incentives via the National School Food Program (PNAE). These investments have the potential to bring R$ 816 million into the state's GDP through the bioeconomy, with 6,500 jobs created in five years.

The potential for expanding Brazilian climate solutions through the bioeconomy is also measured by the current booming of startups in positive impact business in the Amazon. Since 2021, accelerator Amaz, held by NGO Idesam, has evaluated more than 500 potential businesses, accelerated 17 initiatives and invested directly in 14 of them who showcased environmental and social impact. These undertakings have helped the conservation or restoration of over 447,000 hectares of native forest, benefiting nearly 2,000 households in 56 Brazilian Amazon municipalities.

The role of impact businesses is recognized as key to conservation. Until eight years ago, this topic was led by the Third Sector, academia or governments. Today it is difficult to talk about systemic transformation in the Amazon without the strength of undertakers who demand investments and development capital to keep the wheel turning. The prevailing view is that to increase conservation it is necessary to boost the forest economy.

According to Certi Foundation, the number of startups in the business model and technologies, with a focus on the Amazon, has increased sevenfold since 2018, totaling at least 700 today. By 2027, the mark of 1,000 startups is set to be surpassed in the various segments of the Amazon bioeconomy – from applying artificial intelligence (AI) to monitor the sustainable management of açaí berry to innovative solutions to trade nuts and various oils for local and global markets.

Arpa Program:

the world's top tropical rainforest conservation initiative

Created in 2002, the Amazon Protected Areas Program (Arpa) is a benchmark as the world's top tropical rainforest conservation initiative. Coordinated by the Ministry of the Environment with funds from international and national donors worth US$267 million to date, actions are aimed at supporting the conservation and sustainable use of at least 60 million hectares by 2039, equivalent to 15% of the Brazilian Amazon.

At a protection cost of US$1 per hectare per year, no global climate change solution is more cost-effective, according to an analysis by the Brazilian Biodiversity Fund (Funbio), the program's manager and financial supporter. The initiative is funded by the German Development Bank (KfW), the Global Environment Facility (GEF) through the World Bank, the Gordon and Betty Moore Foundation, Anglo American and WWF.

Based on scientific studies and mapping of priority areas, the program supports the basic implementation of CUs, with a framework comprised of management plans, operation of the management council, signaling, equipment research and infrastructure, among other key demands for the protection of the area. Once consolidated, the areas become a benchmark for territorial management and local development, strengthening communities who look for access to government social programs and financial mechanisms to reward forest stewardship.

BEYOND EXPECTATIONS

With a total of 120 CUs supported in two decades, the Arpa program has reached the mark of 62.5 million hectares of preserved forest, surpassing the initial target. About 43% of the areas acted on are already consolidated, benefitting biodiversity and climate mitigation. It is estimated that, from 2008 to 2020, territories covered by this initiative reduced deforestation by 264,000 hectares, the equivalent of 104 million metric tons of carbon in avoided emissions.

The next step is scheduled for 2025, with the launch of a new action front in the program – Arpa Communities, with an investment of R$ 150 million to strengthen forest productivity chains in connection with the Amazon bioeconomy.

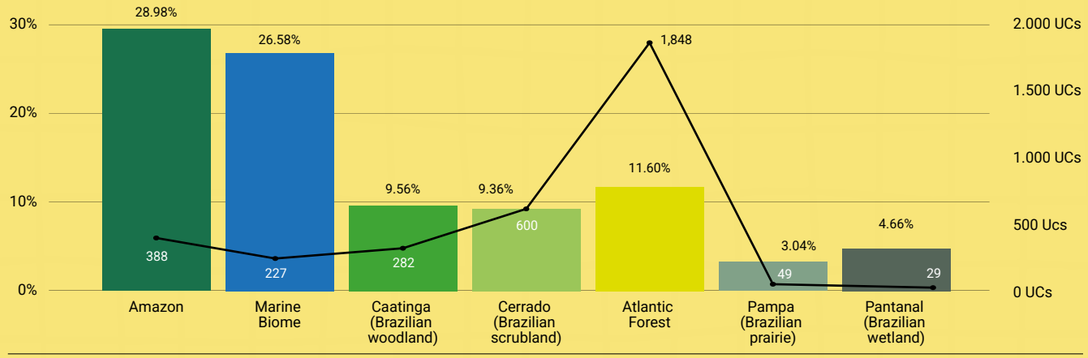
It has the ambition to scale up sustainable production as a way to generate income with no deforestation or degradation, permanence in the forest and visibility for achieving partnerships that pay producers for environmental services. The estimated annual potential for generating income through sociobioeconomy activities is US$50 million to US$60 million in Arpa's sustainable use CUs.

This Brazilian biodiversity conservation program experience was replicated in Colombia and Peru. The innovative financing mechanism, under the Project Finance for Permanence (PFP) model, first adopted in Canada and Costa Rica, allows for a long-term vision more suited to the demands for public conservation policies. This tool ensures sustainability in the transfer of resources to management and maintenance of protected areas, with a better effective cost ratio, without depending on political scenarios or other uncertainties in the future.

In Brazil, this successful initiative in the Amazon has inspired a similar model in the caatinga region. The Caatinga Protected Areas (Arca) program will receive US$10 million from the Global Environment Fund (GEF) to tackle degradation in this unique exclusive Brazilian biome. With 80% of native vegetation modified by human activities already, the territory is home to 27 million people and a symbol of resilience in dealing with drought. It can also inspire other regions in Brazil and abroad in solutions for adapting to the current and future impacts of climate change.

NATURE UNDER PROTECTION

NUMBER OF CONSERVATION UNITS AND PROTECTED PERCENTAGE IN THE BIOME



Source: Brazilian Conservation Units Panel

Forest Code:
when the solution comes from a public policy

Approved in 2012, the Forest Code[12] is one of the most important environmental public policies in Brazil, with repercussions on large-scale climate solutions. There are about 115 million hectares of conservation and planted forests on rural properties that make up one of the world's largest food production systems. Overall, rural establishments comprise 167 million hectares. However, only 3.3% of the analyses of the Rural Environmental Registration File (CAR) had been completed in 2024, according to a Climate Policy Initiative (CPI) report of the Pontifical Catholic University of Rio de Janeiro (PUC-Rio)[13].

Despite the political, economic, environmental and social challenges for its effective implementation, the Forest Code brings about growing opportunities for the maintenance of native vegetation and restoration of environmental liabilities as business fronts and socioeconomic development in Brazil.

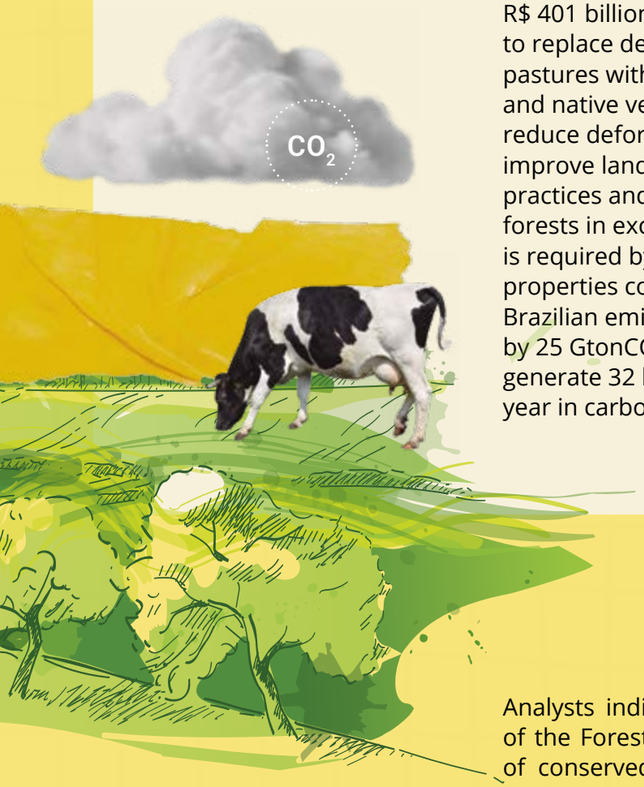
With law enforcement, the prospect is for greater integration of these forests into the mosaic of land use. Today Brazil has a deficit of 18.8 million hectares of native vegetation on rural properties – 8.1 million hectares in Permanent Preservation Areas (APPs) and 10.7 million hectares in Legal Reserves. Concurrently, it has over 110 million hectares of native vegetation exceeding the minimum area required by law.

The Strategic Plan for the Implementation of the Forest Code (PlanaFlor) has mapped priority areas for the restoration of this environmental liability, based on cost-benefit ratio, notably degraded pastures with low agricultural suitability and areas with high potential for natural regeneration, in addition to strategic river basins for water supply and hydroelectric power generation. Recovering this deficit is pivotal for Brazil to meet the climate targets set in the Paris Agreement.

PUBLIC POLICY AS A DRIVER OF SOLUTIONS

A study prepared by PlanaFlor has found that compliance with the Forest Code can be a driver of more comprehensive transformations in rural Brazil. Investments of R$ 401 billion by 2030 to replace degraded pastures with agriculture and native vegetation, reduce deforestation, improve land use practices and maintain forests in excess of what is required by law on properties could reduce Brazilian emissions by 25 GtonCO_2eq and generate 32 billion per year in carbon credits.

In addition to boosting sustainable agriculture, conservation and environmental restoration, these measures would also benefit 2.6 million family farmers and open up spaces to conserve native vegetation areas subject to deforestation, according to legislation. It is estimated that conserved areas more than triple in comparison to degraded areas in rural properties, which makes room for tools such as the Legal Reserve quota system to offset these liabilities.



Analysts indicate the need to regulate Articles 41 and 48 of the Forest Code, which provides for the economic uses of conserved areas. Approved in 2021, the Payment for Environmental Services law is also pending regulation by the federal government so it can be consolidated as an economic tool to encourage forest conservation by making climate contributions.

PROJECTIONS OF THE BENEFITS FROM THE IMPLEMENTATION OF THE FOREST CODE

		BENEFITS			
	Impacted area (Mha)	Climate impact Emissions reduction (Gt CO_2eq)	Creation of jobs and generation of income[1]	Workers benefitted from FF[2]	Revenue (billions of R$/year)[3]
Conversion of degraded pasture into agriculture	11,3	to be assessed	39.397		
Conversion of degraded pasture into ICLF, CLI, SAF	20,4	to be assessed	698.353		
Family Farming (557 priority municipalities)	11,4	to be assessed		2.577.880	
Conservation of native vegetation (Legal Reserve surplus)	110	>20,4 Gt CO_2eq			25,0
Reforestation (restoration of Legal Reserve and Permanent Preservation Area (APP) deficit)	12	>4,6 Gt CO_2eq	1.670.107		7,5
TOTAL	**165,1**	**25 Gt CO_2eq**	**2.407.857**	**2.557.880**	**32,5**

[1] in number of workers.
[2] FF = Family Farming
[3] By 2030 (projection based on the investments necessary between 2023 and 2030)

Source: PlanaFlor

Business-community relationships keep forests thriving

In bioeconomy, the engagement of large companies in regenerative productivity chains is key, with the replacement of production inputs with innovative alternatives from the forest and partnerships in new business models. When it comes to examples from the corporate world integrated into the bioeconomy, Brazil stands out with cosmetics company Natura and its relationship with community suppliers of raw materials. The strategy leads to climate benefits through the forest conservation, sustainable use and regeneration.

The company's relationship with traditional communities began to be structured in the late 1990s, driven by the strategic decision to incorporate inputs from Brazilian biodiversity into the formulation of its products. Today there are over 10,000 households in 51 supplier communities – 87% in the Amazon region, with conservation practices in about 2.2 million hectares of forest. This model also resulted in the development of 44 Amazonian bioingredients, with local production in 19 mini oil extraction factories, adding value to the communities' production.

In Natura's experience, agroforestry plays a central role in its relationship with communities: it strengthens community-based value chains, regenerates degraded ecosystems, diversifies farmers' incomes and contributes to carbon sequestration.

PRODUCTION PROTECTED BY THE FOREST AND ITS PEOPLES

Certified by organizations such as the Union for Ethical BioTrade (UEBT), Natura's supply system is recognized for its commitment to biodiversity conservation, fair benefit sharing and respect for the cultural practices and way of life of forest peoples. In addition to offsetting, with nature solutions, 100% of the remaining carbon emissions it cannot avoid, the company has expansion targets by 2030 that include protecting three million hectares of forests. It expects to expand the number of partner communities, the purchase of sociobioeconomy inputs, and fully adopt regenerative practices in critical chains.

Monitoring systems

Brazil is also recognized for its satellite monitoring of forests, which provide key data for public policies and actions to control deforestation in the Legal Amazon. Inpe's Prodes system monitors clear cutting in the Amazon region with a historical series of annual deforestation rates since 1988. The TerraClass Project aims to qualify Prodes data, indicating vegetation cover and uses of deforested areas.

The purpose of the Degrad system is mapping forests under a degradation process not yet completed. This work supplements the Deter system, which provides alerts on deforestation and changes in vegetation cover in near real time to support environmental monitoring. Finally, the *Queimadas* (Wildfires) Program, also from Inpe, monitors fire outbreaks via satellite, generating statistics, graphs and maps to support control decision making in rural areas.

Based on digital technologies, in addition to official data platforms, MapBiomas is a recognized local and international benchmark in land cover monitoring. It was created in 2015 by remote sensing and vegetation mapping experts who were viewing to produce annual land use and land cover maps for the entirety of Brazil in a cheaper, faster and more up-to-date way than existing methods and practices. The project was also aimed to recover historical data over the decades. To this end, this initiative had unprecedented high processing capacity, automation and collaboration of communities of experts in each area – in addition to technical cooperation with Google by using the Google Earth Engine platform as a foundation.

MapBiomas carries out the annual mapping of land cover and use and monitors water surface and burn scars monthly based on data gathered as from 1985. It also validates and prepares reports for each deforestation event detected in Brazil since January 2019 through MapBiomas Alerta. All data and methods are made available to the public in an open and non-onerous manner. Overall, the platform brings together 20 thematic initiatives in Brazil and other countries such as Indonesia, Colombia, Peru, Uruguay and Ecuador.

Restoration

Carbon sinks

Restoring degraded areas is at the heart of Brazilian climate mitigation, in connection with economic, social and environmental opportunities

With large plots of degraded areas *(learn more on page 50)*, Brazil makes headway in the restoration of forests and other ecosystems with a large-scale climate solution that is a role model for the world. In areas undergoing nature reconstruction, carbon capture and storage through tree growth are associated with a mix of agendas. In addition to conserving biodiversity, the challenge provides water and energy security, food cultivation and sustainable production, with supply of renewable raw materials aimed at decarbonizing the economy. Added to this the positive environmental and social impact, through the creation of jobs and generation of income and improvement in quality of life.

The high degree of biological diversity favorable to the formation of new forests, the framework of public policies and the tradition of scientific knowledge on this topic are Brazil's differentials when it comes to native vegetation recovery. With these attributes, Brazil represents one of the main frontiers of ecosystem restoration in the world, attracting increasing interest from capital funds, development banks and other key financial players, who are interested in carbon mitigation opportunities.

Under the Paris Agreement, a large part of Brazil's commitment to reducing GHG emissions is based on forests, with its target of restoring 12 million hectares by 2030. Since the required mitigation is not possible to be achieved solely by reducing deforestation, a strategic goal lies in the replacement of trees in degraded areas. Therefore, nature is mobilized to enhance the capturing of carbon dioxide from the atmosphere in plant growth, through photosynthesis. Stored in forest biomass and soil, carbon no longer contributes to the worsening of the GHG effect.

Brazil is a member of international forest recovery movements. In addition to the Paris Agreement, it has joined the Bonn Challenge, a global effort to restore 350 million hectares by 2030, and the 20X20 Initiative, aimed to protect and restore 50 million hectares of landscapes and forests by 2030 in Latin America and the Caribbean to make the region carbon neutral by 2050. The UN Decade on Ecosystem Restoration[14] mobilizes 70 countries to reverse land degradation by 2030 and provide a major boost to restoring 40% of all land on our planet. Brazil is at the center of these challenges.

The UN states that every dollar invested in restoration generates up to US$30 in economic benefits, in addition to the potential to increase food security for 1.3 billion people worldwide and provide one-third of the carbon mitigation needed by 2030. Restoring 15% of converted areas could prevent 60% of species extinctions by 2050.

According to analysts, one of the challenges of large-scale forest restoration is the lack of an integrated vision in public policies that can assist this process, so as to avoid costs and provide income for rural producers – a barrier still to be overcome despite recent initiatives by the federal government in the search for solutions. A consensus exists on the need for a better structuring of the restoration production chain, with seedling nurseries, technical assistance and access to credit facilities and insurance policies to protect these preserved or restored areas.

Researchers caution that signing up to the Rural Environmental Registry (CAR) and corresponding Environmental Regularization Program (PRA) is like writing a blank check, due to the lack of the structural conditions required for the success of the initiative. Producers would be giving up revenue in areas that cease to produce and incurring costs. But some experts draw attention to the fact that reduced revenue due to the PRA is the consequence of producing in an irregular area that needs to be restored, since regularization is a legal obligation of the producer.

BRAZIL ADOPTS A NEW NATIONAL TREE REPLACEMENT PLAN

Approved in 2024 with broad engagement of society, the new National Plan for the Recovery of Native Vegetation (Planaveg)[15] reinforces Brazil's target of restoring at least 12 million hectares by 2030. It also updates the pathways to achieve this target, with governance, financial mechanisms and monitoring, highlighting the economic uses of restoration.

According to a study conducted by Escolhas Institute, the target of restoring 12 million hectares will require investments of R$ 228 billion and could generate a return of R$ 776.5 billion in net revenue alongside 2.5 million new jobs. As a climate potential, it is estimated that meeting the target will result in the removal of 4.3 billion metric tons of carbon from the atmosphere.

RESTORATION TARGET

R$ 228 billion
INVESTMENT NEEDED TO RESTORE 12 MILLION HECTARES.

R$ 776.5 billion
ESTIMATED RETURN IN NET REVENUE.

2.5 million
NEW JOBS CREATED WITH RESTORATION.

4.3 billion
METRIC TONS OF CARBON REMOVED FROM THE ATMOSPHERE.

Source: Escolhas Institute

INVESTMENTS AT SCALE

Among the larger-scale investment initiatives announced, the *Arco da Restauração* (Restoration Arc) program stands out, as it is a partnership between the National Bank for Economic and Social Development (BNDES) and MMA aimed to recover six million hectares by 2030 with R$ 1 billion from the Climate Fund and the Amazon Fund.

In partnership with Petrobras, a statement of intent was announced for the acquisition of carbon credits generated from forest restoration in the Amazon, under the Pró-Floresta+ initiative. This initiative will cover a total of up to 50,000 hectares of degraded areas, capturing about 15 million metric tons of carbon (equivalent to the volume emitted annually by 8.94 million gas-powered cars).

New investments are planned to expand forest-based climate solutions through the concessions of degraded public areas for restoration by companies. In 2025, the first Pará government project under this model was launched in the Triunfo do Xingu Environmental Protection Area, in Altamira, state of Pará, in partnership with the Inter-American Development Bank (IDB).

It is aimed to make 10,000 hectares available to the private sector for reforestation, for 40 years, with expected investments of R$ 258 million, total revenue of R$ 869 million and the creation of about 2,000 jobs. It is also aimed to capture 3.7 million metric tons of carbon – the equivalent of 330,000 plane trips about the world.

Along the same lines, in the state of Rondônia, the Brazilian Forest Service (SFB) kicked off the process of granting 14,300 degraded hectares of the Bom Retiro National Forest to be recovered by the private sector. The concessionaire in charge will be entitled to trade carbon credits and wood and non-wood forest products originated from the forestry of native species.

6 million hectares

RESTORATION ARCH TARGET BY 2030.

R$ 1 billion in investments

VIA CLIMATE FUND AND AMAZON FUND.

With the promise of reducing pressure from land grabbing and deforestation, the model follows the federal government's experience already underway with the concession of public forests for timber production by forest management companies. To date, at the federal level 1.3 million hectares have been granted in 23 contracts, covering eight National Forests, with the target of reaching five million hectares by 2027 according to the Multi-Year Forest Grant Plan.

Data from the Forest and Agricultural Stewardship and Certification Institute (Imaflora) indicate that the potential for public forest management concessions is 25 million hectares in 30 years, enough to provide legally certified timber to meet domestic demand and Brazilian exports. Analysis conducted by the Amazon's Institute of Man and the Environment (Imazon) indicates that 40% of current timber production in the Amazon is of illegal origin.

AMAZON EXPANDS MULTIFUNCTIONAL AGROFORESTRY AMID CLIMATE IMPACT CHALLENGES

The territorial extension, availability of areas degraded by deforestation and high biological diversity capable of enhancing natural forest regeneration mechanisms make Amazon the top frontier for large-scale restoration in Brazil.

The region has about 14 million hectares of environmental liabilities that, to a large extent, need to have forests restored – equivalent to three times the area of the State of Rio de Janeiro. Of this total, 10 million hectares are located within private properties, 1.4 million hectares in settlements and the remaining portion is on Indigenous Land and conservation units.

To do so we have a number of paths. In addition to large tree plantations associated with the carbon market, the Amazon region is the background for expanding productive restoration in agroforestry, with the engagement of small producers. According to a survey by the Alliance for the Restoration of the Amazon, of the 2,700 restoration initiatives carried out in 2021 in the region, 60% referred to agroforestry system production models that combine food cultivation and extractive products – one of the main bases for bioeconomy growth.

The movement is one of continuous expansion, but the impacts of climate change on restoration areas must be addressed. The drought in 2024 has highlighted the need for irrigation of plantations and record heat waves have increased wildfires, with ecological and economic losses for new growing forests.

Greater species diversity is needed in the restoration process. In the Amazon, despite its biological richness, with the presence of 300 to 400 species of plants per hectare, science

A BENCHMARK IN SCIENTIFIC KNOWLEDGE

Brazil is at the forefront of scientific knowledge on large-scale forest restoration. With over three decades of experience in the field, the Higher School of Agriculture Luiz de Queiroz of the University of São Paulo (Esalq-USP) has developed protocols that are now benchmark. The key ones address the use of different functional groups of species in the restoration process: the recover group, with fast-growing plants and good canopy formation to provide shade, and the diversity group, featuring slow growth, attracting fauna and setting major ecological relationships aimed at the longevity of the restored forest.

As an academic milestone, scientific work has recommended the use of at least 60 native species for a successful ecological restoration. Furthering knowledge to increase plant yield and reduce costs is the basis for increasing the scale of the activity, with quality forests to store carbon.

The current demand for climate mitigation is driving new lines of research with genetic engineering to improve plant performance, in addition to the growing use of AI and drones to monitor plantations, especially in the replacement of degraded pastures with forests. This scenario includes the challenge of developing forest species resilient to impacts from climate change.

knows the propagation method for 20 or 30 of them – that is, about 10% of the total diversity in natural areas, on average, according to Alliance data.

CARBON, THE NEXT BIG THING IN TREE PLANTING

The carbon market is today the main driver of large-scale forest restoration in Brazil. Initially developed in specific projects to make rural properties compliant with the Forest Code, environmental compensation for undertakings and to guarantee water security in river basins with greater stress, this activity takes on new contours and expands with opportunities for economic uses, under the model of agroforestry with multiple functions. In addition to being a climate solution, forest restoration structures a new forest base with its products and services for bioeconomy development.

Young or newly planted forests are more active when it comes to carbon sequestration. The Brazilian Institute of Forests (Ibef) believes that every seven trees planted correspond, on average, to the capture of one metric ton of carbon in the first 20 years after planting.

The Symbiosis Coalition brings together the joint commitment of companies globally to invest in removing up to 20 million metric tons of carbon by 2030, via restoration and agroforestry. The strategy aims to achieve greater security and lower cost of climate outcomes in light of the global demand for emissions reduction.

A McKinsey's analysis estimates Brazil's potential for gross added value from US$16 billion to US$26 billion per year in forest carbon credits. With availability of areas, privileged conditions of climate and soil, legal certainty and a favorable political environment, Brazil can achieve a leadership position, attracting major international partners for climate mitigation activities.

Carbon capture through tree planting in the restoration process, with an advantage in the additionality criterion given the retention capacity of growing plants, has proven attractive to investors. The development of the activity as a business can boost the expansion of planted areas: today about 3.3 million hectares are announced by companies that identify themselves as a "new restoration industry" for carbon, established in the last three to five years in Brazil.

Business models are characterized by innovative partnerships with multinational big techs required to offset emissions, via forest carbon credits, given the sector's high energy demand. By purchasing farms or establishing rural partnerships with producers under more advantageous conditions than in livestock activities, tree planting employs cutting-edge technology in connection with suppliers in the forest restoration productivity chain. One point of focus for projects is the adoption of good practices to reconcile economic interest and ecological balance.

ATLANTIC FOREST MAKES HEADWAY IN RESTORATION SCALE WITH NETWORK ACTION

In the most populous and developed biome in Brazil, key economic cycles in Brazilian history have combined territorial expansion and deforestation. Since the exploration of brazilwood by colonizers, Atlantic Forest native vegetation has been gradually depleted until it has reached just 24% of its original cover to date.

Created in 2009, the Pact for the Restoration of the Atlantic Forest[16], today composed of 347 members including companies, government and civil society, was recognized in 2024 by the UN as one of the ten global initiatives with the greatest potential on restoration scale. A benchmark under the governance model, this Pact has the target of restoring 15 million hectares by 2050, which accounts for 15% of the biome. A total of 114,000 hectares has been recovered to date.

The plan is to accelerate actions by transforming the Pact into a facilitator for forest restoration, through the creation of a pipeline of projects in already mapped priority areas, aiming to attract public and private investment funds. The goal is to strengthen productivity chains and reduce red-tape and costs for economies of scale.

This increase in fund raising is meant to contribute to restore four million hectares by 2030. About one million hectares is undergoing natural regeneration and need improvements, and three million hectares are being restored through seedling and seed planting, among other techniques, in addition to enriching degraded remaining areas. This total would represent the capture of 30 million tons of carbon per year.

The Conservador da Mantiqueira initiative, coordinated by TNC alongside 604 municipalities in the states of São Paulo, Rio de Janeiro and Minas Gerais, supports the creation of laws and the strengthening of local governance to promote the Atlantic Forest restoration. The territory is home to the first macro-region project certified by international organization Verra for carbon credit transactions, totaling 1.5 million hectares.

Located in the Serra da Mantiqueira region, the municipality of Extrema, state of Minas Gerais, is recognized for its pioneering role in the creation of a public policy on forest restoration 20 years ago, with a PES mechanism and seedlings planted to protect and recover springs on rural properties. The project is maintained funded by funds linked to the offset of carbon emissions by industries operating in the municipality and general society, with a percentage of taxes (urban real estate tax - IPVA and tax on vehicles - IPTU) allocated to the agenda.

The reference to the Pact has inspired the introduction of multiple groups focused on ecosystem restoration in the last decade. In the transition between the Amazon and Cerrado (Brazilian scrubland) biomes, in the state of Pará, the Xingu Seeds Network, coordinated by the Environmental and Social Institute (ISA), currently brings together 647 groups of collectors, including six Indigenous ethnic groups. To date, 353 metric tons of seeds have been sold, with a total of 220 species, based on the rationale that Brazil will not be successful in restoration only with projects involving millions of hectares, but with the involvement of local stakeholders knowledgeable in seed management.

This move led to the creation of Redário[17]– a network of native seed collectors working at the base of the restoration chain in Brazil. These are 27 groups, with a total of 1,500 collectors in the various biomes (67% of them women). In 2024, Redário members provided almost 100 metric tons of seed.

The model allows the sharing of technical protocols, indicators, action methods and logistics, enabling the restoration chain to operate in an integrated manner, with better outcomes. In addition to tackling the climate crisis, the collective strategy brings about the dimensions of dignity, quality of life and the right to a voice to communities and traditional peoples.

PACT FOR THE RESTORATION OF THE ATLANTIC FOREST

347 members
ARE PART OF THE PACT FOR THE RESTORATION OF THE ATLANTIC FOREST.

15 million
HECTARES RECOVERED IS THE RESTORATION. TARGET.

114 thousand
HECTARES HAVE ALREADY BEEN RECOVERED.

1 out of the 10
MAIN GLOBAL INITIATIVES, ACCORDING TO THE UN IN 2024.

RESTORATION PRODUCTIVITY CHAIN PREPARES FOR CLIMATE DEMAND

Developing the ecosystem restoration productivity chain, especially based on seeds and seedlings in nurseries, is a pivotal factor for Brazil's leadership in climate and nature solutions coming from forests. Taking into consideration that 30% of Brazil's climate target of restoring 12 million hectares by 2030 will be met by planting seedlings (the remainder by seeds or natural regeneration), demand would reach over 1.2 billion plants per year in the period, as estimated by association Nativas Brasil, which brings together 73 nurseries in Brazil. This would account for the capture of one GtonCO_2 as climate contribution in the next five years.

The current capacity of Brazilian nurseries is 250 to 300 million seedlings per year, four times below projected requirement. Analysts estimate that the sector is being held back by issues of access to credit and taxation, alongside a lack of information and recognition, which creates a gap between financial mechanisms and those at the base of the restoration chain. Greater demand predictability is required for nurseries to plan seedling deliveries.

Business initiatives towards large scale

With the target of planting two million hectares of native trees in 20 years, company Biomas is the outcome of combining expertise in the forestry and financial sectors in the business with the restoration process that mainly targets the carbon market. The goal is to neutralize third-party emissions by capturing one GtonCO_2 in the period – nearly half of total Brazilian emissions in 2023. The company sees this expansion in scale as a response from private investments to sectoral public policies.

The goal for company re.green is to restore one million hectares of native vegetation in the Amazon and Atlantic Forest for carbon credits, from a portfolio currently with 30,000 hectares of areas assessed and already acquired, with low agricultural productivity but with high economic, environmental and social potential when it receives the forest back.

The first transaction in the climate market was carried out with Microsoft involving the capture of 6.5 million metric tons of carbon over 25 years, via 34,000 hectares restored. re.green plans to accelerate the purchase of land and the planting of seedlings, with the challenge of raising catalytic capital to promote expansion. A R$ 180 million fundraising is being negotiated in connection with the pledge of surety guarantees with BNDES. This is a recurring obstacle to the access to financing for restoration, characterized by long-term risks and results.

In 2025, BNDES has released R$ 80 million from the Climate Fund to the Brazilian company so the latter could restore degraded areas in the Amazon and Atlantic Forest. Specialized in large-scale forest restoration, re.green was the first company to enter into a financing contract with BNDES for reforestation via the Climate Fund, including the restoration of a portion of the Arco da Restauração territory, which runs from eastern Maranhão to Acre, passing through southern Pará, Mato Grosso and Rondônia.

Funds from the Climate Fund – one of the main tools of the Environment and Climate Change Policy (MMA) – will be allocated to restoration activities involved in the performance of the re.green contract with Microsoft in the Atlantic Forest, in addition to the Amazon biome. These are nearly 15,000 hectares in priority areas for climate mitigation, biodiversity and socioeconomic development. This transaction marks the first biodiversity labeling applied to a restoration project in Brazil, with a "Dark Green" rating from S&P Global.

In 2025, as a milestone in the forest restoration industry towards large-scale climate solutions, company Mombak also managed to raise funds from the Climate Fund, managed by BNDES, for reforestation in the Amazon with a focus on the carbon market. For the first time ever, it was possible to release the financing via a bank guaranty of Banco Santander. It amounts to over R$ 100 million worth of investments available to the company for the restoration of degraded areas. Mombak has carbon credit contracts with Microsoft, McLaren Racing and Google, and had already raised US$36 million from the World Bank and US$120 million from a fund with a number of foreign investors to make headway in planting activity.

Belterra, a company leading agroforestry projects in the states of Pará, Rondônia, Mato Grosso and Bahia, has tested different financing models and, in the last two years, has accelerated the transition to large scale through innovative arrangements for accessing capital, including through carbon capture. As revenue from restoration periods are long-term, around the third to fifth year after planting, one needs to make new investment models viable so that climate market transactions involving traditional crops, such as soybeans, become competitive.

The cocoa productivity chain is the flagship in the company's areas, alongside açaí berry, *cupuaçu*, peach palm and other native species in agroforestry. Expansion production is notable in the state of Pará, where the supply of areas is greater. The target is to increase the current 4,000 hectares under contract to at least 50,000 hectares by 2030, with plantations implemented by 2035. Revenue from carbon credits funded in advance by investors accounts for 20% of capital required alongside public financing. Private investment raised to date totaled R$ 20 million of blended finance at a lower cost, including venture capital, development and philanthropy.

Forests Planted by Forestry

Mosaics that capture carbon

Brazil is recognized worldwide for its large forest plantations that supply paper production, civil construction, steel and iron and other markets, helping tackling climate change

Industrial forests cultivated in large-scale monocultures for the production of pulp and paper, timber for furniture and construction, energy power and other uses are part of the menu of Brazilian climate solutions based on carbon retained by trees. There are extensive forest mosaics – mainly eucalyptus trees – associated with native forests in conservation areas on rural properties.

These large forest plantations meet the demand for materials of renewable origin in the background of economy decarbonization, even though they require permanent care of good practices amid environmental and social risks and natural resources as an intensive land use activity.

The current scenario is the result of a long record of research and investment by Brazil in eucalyptus productivity. Originally from Australia, Indonesia and other Oceania islands, this species arrived in Brazil in the 19th century and seedlings were planted in Rio Grande do Sul. The first commercial-scale plantations, characterized by rapid tree growth, were carried out early in the 20th century to provide firewood for locomotives and railway sleepers in São Paulo. Then they spread across the country for various uses as an alternative to native wood extracted from the Atlantic Forest.

The species found ideal climate and soil conditions to thrive in Brazil in the 1960s, eucalyptus forestry was encouraged by federal government incentive programs as a driver for economic development. Over time production increased from 20 to the current 33 cubic meters of wood per hectare per year – ratios that have placed Brazilian paper and pulp production in the global spotlight.

Business organization Brazilian Tree Industry (Ibá)[18], which represents forests cultivated for industrial and restoration purposes with high scalability potential, currently covers 10.2 million hectares planted in Brazil – much of it on land degraded by the livestock activity. Associated with this production area, other 6.9 million hectares of native vegetation are preserved in compliance with the Forest Code or in excess of what is required by law. These natural patches promote the ecological interactions required for the production of commercial eucalyptus tree plantations.

Companies that own industrial forests plant 1.8 million trees per day in different cutting cycles for later replanting, which means an accumulated annual stock of 4.92 billion metric tons of carbon – equivalent to over two years of total emissions from Brazilian forests (two billion metric tons/year), according to Ibá indicators. The largest planting areas of eucalyptus trees, pine trees and other species are in connection with the pulp and paper sector (36% of total area), ahead of the steel and iron and vegetal charcoal sectors (12%).

With its native forests, restored or cultivated for industrial purposes, Brazil is set to play a major role in the regulated system for reducing carbon emissions between countries, to be regulated by Article 6 of the Paris Agreement, with potential advantages for forest-based companies.

Opportunities arise in the voluntary carbon market, from native forest plantations in degraded areas on rural properties that supply timber to industries. An increase in the potential for CO_2 capture is expected in the current process of expansion of the forestry sector in Brazil: Between 2024 and 2028, about R$ 105.6 billion in new investments are estimated to be allocated for industrial cellulose and other plants, with demand for expanding forestry to advance Brazilian climate contributions.

A producer of eucalyptus trees for charcoal used in the steel and iron industry, the Plantar Group is recognized for the first Brazilian carbon project under the former Clean Development Mechanism (CDM), created by the Kyoto Protocol, which came into force in 2005. It was aimed to reduce methane emissions and increase the use of renewable charcoal in the production of pig iron, replacing coal coke. Over thirty years, the company's forests are expected to reduce the concentration of carbon in the atmosphere by about 12.8 million tons, via financial transactions involving carbon credit funds.

ENVIRONMENTAL SERVICES SEEK RECOGNITION

Over three decades, the adoption of environmental and social certification seals for access to foreign markets has led to good forest management and conservation practices – with repercussions on the scale of climate solutions. Brazil has been actively involved in this scenario since the creation of the Forest Stewardship Council (FSC), the largest certification system for forests and forest-based products in the world, which today also seeks to value the ecosystem services made possible by the seal. This tool enables organizations managing certified forests to measure, verify and report their positive impacts on carbon storage, biodiversity protection, water and soil conservation and recreational services.

Overall, 18 million hectares of forests (natural under management and cultivated) in Brazil are FSC certified, and this figure is expected to rise in the face of the climate change emergency. Although this is a topic increasingly present in people's daily lives due to climate impacts and damage already underway, we still face the challenge of having climate solutions embedded in products to be recognized and appreciated by the consumer market.

Native species: Brazilian species enter the game

Plantations of native trees for commercial purposes contribute to tackling the challenge of zeroing deforestation, capturing carbon and concurrently ensuring the supply of legal timber to meet market demands

Plantations of native trees for commercial purposes contribute to tackling the challenge of zeroing deforestation, capturing carbon and concurrently ensuring the supply of legal timber to meet market demands. With native species forestry, the expectation is to change the pattern of timber production by offering alternatives with less dependence on products extracted from natural forests often made deforestation and degradation.

In forestry, large-scale plantations of native species employ genetic improvement and management methods aimed at economic purposes and the recovery of ecosystem services. In addition to offering quality wood to the civil construction industry and other segments for more noble uses not adequate for eucalyptus trees, the activity helps supply markets that seek renewable alternatives rather than products based on carbon-emitting fossil-based raw materials.

Started in 2015 under WRI coordination, the Verena[19] (Economic Valuation of Reforestation with Native Species) project has been a milestone for the development of the sector in Brazil. This initiate has driven players to bridge gaps in research, support risk analyses and measure business potential, the agroforestry systems model included. Over 30 projects have been carried out and modeled through the Verena Investment Tool.

This movement has gained momentum with the creation of a specific task force in the Brazil Climate, Forests and Agriculture Coalition to design a new pre-competitive Research & Development program. Launched in 2021 to raise funds, this initiative, which is focused on the Amazon and Atlantic Forest, has raised US$2.5 million from the Bezos Earth Fund to commence its studies.

In partnership with the Scientific Technological Park of the South of Bahia, this project has created an experimental center for genetic improvement, aimed at the quality and performance of wood in the long term until trees mature. Its purpose is to showcase in the field the role of native forestry in forest conservation and the economy, with positive impacts on climate mitigation.

The concept was introduced by the Brazilian government in the Planaveg as one of the models to implement national targets for the restoration of degraded areas. Forestry of native vegetation is also an integral part of the National Program for Conversion of Degraded Pastures, aimed at attracting investments and business partnerships amid a backdrop of climate opportunities.

STRATEGIC OPPORTUNITY

1.7 million
HECTARES CAN SUPPLY THE DEMAND FOR TROPICAL TIMBER.

20 million
METRIC TONS OF CO_2/YEAR CAN BE CAPTURED.

The Coalition states that about 1.7 million hectares of native species plantations would be enough for Brazil to initially meet the growing demand from international markets for tropical timber. This would have the potential to capture about 20 million metric tons of CO from the atmosphere per year.

Due to its importance in the current climate and biodiversity scenario, native species were incorporated into the forestry sector represented by Ibá, alongside eucalyptus forests for cellulose and other industrial uses. Commercial plantations of Brazilian trees contribute to national ecosystem restoration goals, including in Integrated Crop-Livestock-Forest Systems (ICLF) projects, in the context of low-carbon agriculture.

From brazilwood to *jequitibá*

In the Trancoso region, in the south of Bahia, Brazilian company Symbiosis is a becoming a benchmark in native forestry associated with timber production, biodiversity restoration and the carbon market. Since 2017, Research & Development has undergone an intensive journey to build up an unprecedented database on costs, forest inventories and growth potential of wood species, tested on different scales aimed at "domesticating" native trees, enabling its commercial use.

From brazilwood to *jequitibá*, the list of options is varied. Of the 56 plant species initially studied, 20 were selected as promising and 12 advanced in a cloning and genetic improvement program aimed to maximize the yield and quality of wood in plantations. Studies cited by the company show that a 60% gain in forest productivity represents an equal increase in carbon capture. Alongside the climate factor, the challenge faced is to reconcile the search for long-term productive results with effective gains in restoring biodiversity in previously deforested areas for livestock activities.

After pilot work on 1,500 hectares, the planting area was expanded to 5,000 hectares on five farms occupied by degraded pastures in the Atlantic Forest. The goal is to make the forestry of native species as relevant to Brazil's economy as eucalyptus trees by expanding the country's capacity to supply wood and climate solutions. Esalq-USP researchers believe that the business can be eight to ten times more profitable than livestock activities.

In addition to offering native sawn timber without deforestation of natural areas, the strategy includes trading carbon credits in the voluntary market to offset GHG emissions from companies through new forests.

In 2023, we signed a partnership with Restore Fund, held by multinational company Apple, which became a partner of this undertaking. The core business s revolves around native wood aimed at noble uses in civil construction and other segments, and has carbon as a strategy to accelerate investments in initial plantings. There is expectation to capture one million metric tons of carbon in 30 years in 5,000 hectares provided for in this partnership (2,000 ha this year).

A sawmill will be installed by the company this year to begin processing wood, in different color patterns and textures imprinted by nature, with an eye on premium markets. In addition to selling seedlings of high genetic quality wood species to third parties, there are plans for expansion by purchasing and leasing land, bringing opportunities in other restoration models with economic purposes, such as cocoa agroforestry.

Pulp and paper companies: keeping an eye on the climate market

Klabin has engaged in the development of the Brazilian forestry industry since the exploration of araucaria to produce newsprint. After operations commenced in Telêmaco Borba, state of Paraná, in 1934, the pine and eucalyptus forests that supply the company have expanded and today comprise properties totaling 911,000 hectares – 43% of native forests, home to 841 species of fauna.

Its 24 industrial units emit 10.5 million metric tons of carbon per year, while forests capture 15.8 million metric tons, a positive balance of 5.5 million metric tons as a climate contribution. Moreover, to align with the 1.5-degree global temperature rise limit set by the Paris Agreement, the company intends to reduce 42% of emissions by 2030, according to reduction targets approved by the Science Based Targets initiative (SBTi).

Klabin is currently carrying out a pilot project on farms of eucalyptus suppliers to validate methodologies to target future opportunities in the climate market. The greatest expectation is in the regulated carbon market traded by countries, with new advancements expected to be made at the COP 30 climate summit to be held this year in the city of Belém. As it prepares for potential benefits from forest-based climate solutions, the company stands out in the access to sustainability financial tools. Today, 34% of the company's funding is from green bonds, with falls in interest rates linked to the achievement of targets in environmental services – such as biodiversity, with the company's efforts to reintroduce animals into nature.

One of the largest paper manufacturers in Brazil, with 2.9 million hectares of land, of which 1.7 million are allocated to production and 1.1 million to conservation, Suzano has committed to removing 40 million metric tons of carbon from the atmosphere by 2025. By 2024, it had achieved 73.4% of the target set. In 2025, it will continue to expand the forest base, proceeding with its conservation and ecological restoration programs, set to lead to increased carbon removals over the years.

On another front, the company plans to reduce the intensity (emissions per ton of product) of scope 1 and 2 emissions (not including supply chain) by 15% by 2030, considering the base year of 2015. By 2024, 58.15% of the target has been achieved.

The strategy is aimed to expand the forest base in anthropized or degraded areas, expanding vegetation cover. Carbon removals occur when forest biomass grow– for example, when even a single tree is planted in pastureland or an area already planted is expanded. Therefore, when there is an increase in the volume of biomass in a given area of company Suzano, its equivalent increase in carbon is considered as "direct removal due to land use change". The company's carbon

KLABIN

911 thousand
HECTARES OF FORESTS – 43% OF NATIVE FORESTS, WHICH ARE HOME TO 841 FAUNA SPECIES.

5.5 million
METRIC TONS OF CO_2 – ANNUAL POSITIVE BALANCE BETWEEN EMISSIONS AND REMOVALS.

SUZANO

2.9 million hectares
OF LAND – WITH 1.1 MILLION DEDICATED TO ENVIRONMENTAL CONSERVATION.

40 million
METRIC TONS OF CO_2 – TARGET OF REMOVAL FROM THE ATMOSPHERE BY 2025, WITH 73.4% ALREADY COMPLETED.

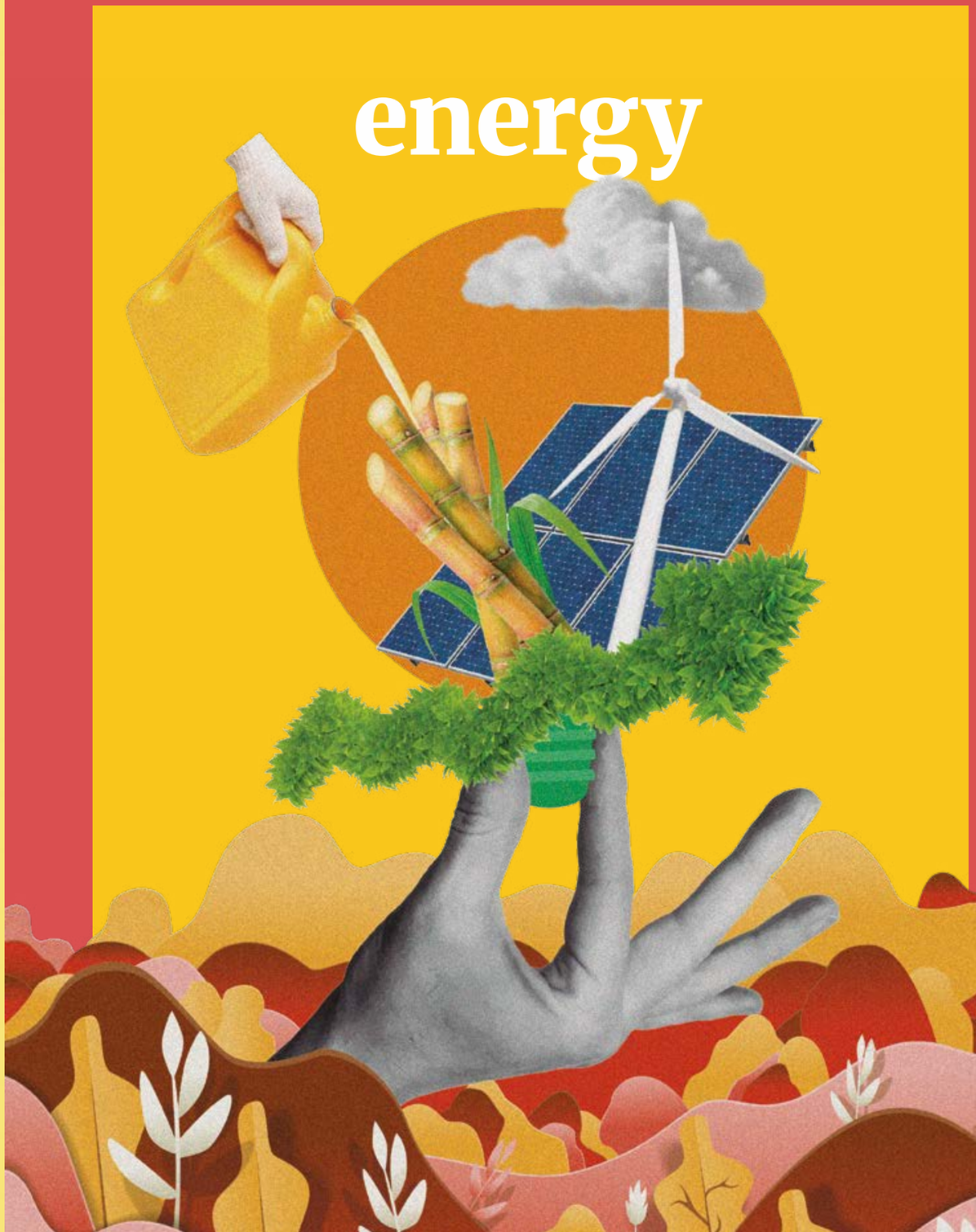
stock is then the balance between all direct emissions and removals from land use in forested areas occurred in a given year (or an annual "snapshot" of all the carbon stored in its natural reservoirs).

With responsible forest management, Suzano has eucalyptus cultivation areas where the process of planting, harvesting and conservation of native forests is in the form of a mosaic. Accordingly, the company maintains a constant carbon stock, with areas designated for conservation stabilized or growing and removing carbon from the atmosphere, and eucalyptus cultivation areas, for the most part, with seedlings growing. The CO_2 removal value linked to the environmental restoration process and High Conservation Value Areas (HCVAs) is included in the removal values for native vegetation areas. In its planted forest areas, Suzano has a cultivation cycle of about seven years, although only one seventh of the planted forest areas are under constant harvesting. The other six-sevenths of planted forest areas are, to varying degrees, storing carbon over time and ensuring the permanence of this stock in the field.

Native forests in the company's areas account for 80% of net removals, while eucalyptus plantations account for 20%. Concurrently, the supply of renewable products on the market helps decarbonize the global economy. The target is to make available 10 million metric tons of products that can replace plastic and other oil byproducts by 2030.

When it comes to biodiversity, Suzano aims to connect half a million hectares of priority areas for wildlife conservation in the Cerrado, Atlantic Forest and Amazon regions. In 2024, stretches of ecological corridors were implemented to connect more than 102,000 hectares of patches of native forests.

2024 has marked the kick-off of implementation of ecological corridors outside Suzano's area, through a partnership with Inovaland. This partnership constitutes a match funding with Kirkib to carry out part of the planned implementations for the Atlantic Forest ecological corridor, the so-called Corredor da Mata (Forest Corridor) project. Actions in 2024 drove the implementation of the Maturembá ethnoecological corridor, which enabled the connection of two important CUs, namely the National Discovery Park (PND) and the Monte Pascoal National and Historical Park.



Renewable strength

Biofuels belong to a select group of economic segments with potential not only to eliminate, but to become negative in greenhouse gas emissions

Brazil stands out as a leading player in the use of renewable sources due, in part, to its natural resources – abundance of arable land, large rivers, winds and solar radiation, and large land and sea areas. But the good result was mainly due to the adoption of long-term strategies, public policies implemented across different governments and a regulatory framework that encouraged the creation and expansion of an energy matrix that was less polluting than the global average.

Bioenergy – energy created from biomass that can be used not only to produce electricity, but also to generate, heat and biofuels – plays a crucial role in the mitigation of climate change and the transition to a low-carbon economy. Biofuels belong to the select group of economic segments with potential to not only eliminate, but to become negative in greenhouse gas (GHG) emissions.

The bioenergy sector already has a mitigating effect by nature, as it cultivates agricultural raw materials, usually in monoculture and on a large scale, and replaces fossil fuels with options that emit less carbon. But it can increase its impact by adopting practices and business fronts that are still underutilized, such as agroforestry cultivation, soil regeneration and carbon capture and storage – each with an additional contribution to mitigation.

Cargo and people transportation accounts for 20% of GHG[1] emissions in the world. In Brazil, this segment emitted 224 million metric tons of carbon equivalent in 2023, an increase of 3.2% in relation to the previous year and more than half of the total domestic energy use[2]. This highlights the importance of its decarbonization.

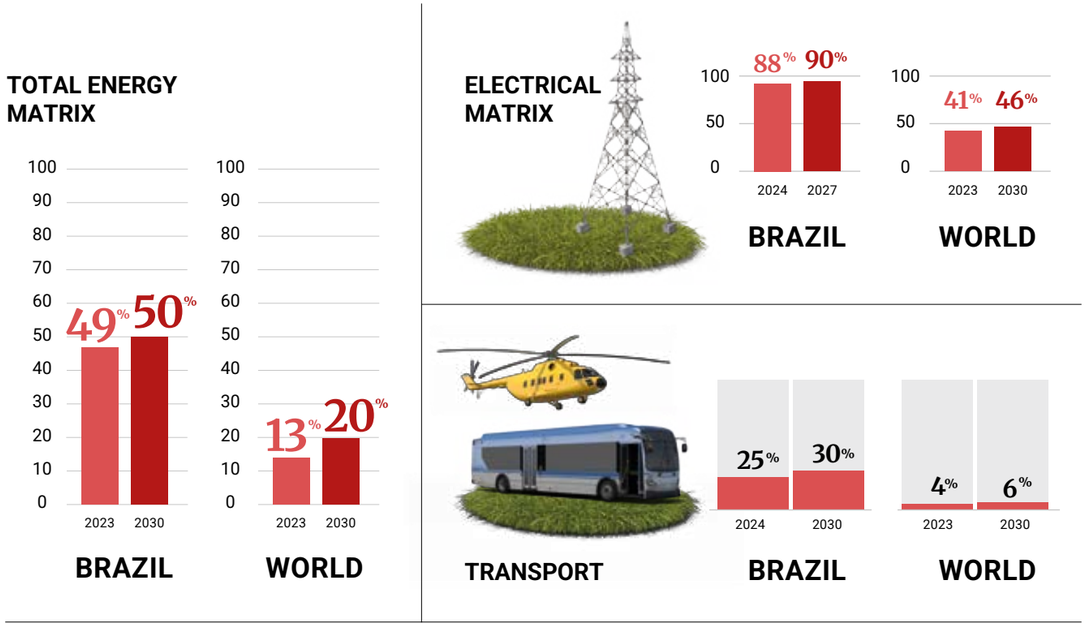
Biofuels, in which Brazil is a pioneer and global leader, are particularly important for this work – and their global production needs to increase for humanity to have a chance of reaching a net zero scenario (net zero emissions) by 2050[3].

These fuels are already successfully applied to the road transport mode, which contributes the most to emissions in the transport sector (72%)[4], and its use is expected to spread across air and sea modes as well.

The beneficial effects of the segment are not restricted to tackling the climate crisis. They can extend to sustainability in a broader sense, including the creation of jobs and generation of income in a diffuse manner adapted to different regions, professional qualification, local development and provision of various environmental services.

BRAZIL AS AN EXAMPLE AND CREATOR OF SOLUTIONS

SHARE OF RENEWABLE ENERGY SOURCES OF BRAZIL'S ENERGY MATRIX WILL CONTINUE TO GROW OVER THE COMING YEARS (IN % OF RENEWABLE ENERGY SOURCES)



Source: Electricity 2025 - IEA
Renewables 2024 - Global overview - IEA
Global Electricity Review 2025 - Ember
Studies of the 2032 Ten-Year Energy Expansion Plan – Energy and Environment - EPE
Studies of the 2034 Ten-Year Energy Expansion Plan – Energy and Environment - EPE
Ministry of Mines and Energy (MME) - https://agenciabrasil.ebc.com.br/politica/noticia/2021-08/brasil-quer-chegar-2030-com-30-de-combustiveis-renovaveis

CONTRIBUTIONS FROM THE SUN AND WIND

Electricity generation accounts for another 30% of global GHG emissions – hence the importance of decarbonizing this activity. In Brazil, 38 million metric tons of carbon equivalent were emitted in 2023. Brazil once again offers a good example by increasing the participation of wind and solar photovoltaic power sources in its electricity matrix (which was already predominantly renewable even before this movement). Both provide the system with greater diversity of sources, distribution in installed capacity and resilience, in the face of changes in rainfall patterns that may have an impact on hydroelectric generation.

As with bioenergy, the beneficial effects of wind and solar sources can extend beyond the construction of a low-carbon economy and result in job creation and income generation, and professional qualification that is also valuable for the export of goods and services, local development and stimulation of research and development in the Brazilian territory.

In the face of the climate crisis, it is up to Brazil – government and society – to step up the pace and show to the international community a workable path for the energy transition.

ENERGY AND EMISSIONS IN NUMBERS

30% of global emissions
COME FROM THE GENERATION OF ELECTRIC ENERGY.

38 million metric tons
OF CO_2E EMITTED IN BRAZIL IN 2023.

2 renewable sources
TRENDING: WIND AND PHOTOVOLTAIC SOLAR

Leading player in bioenergy

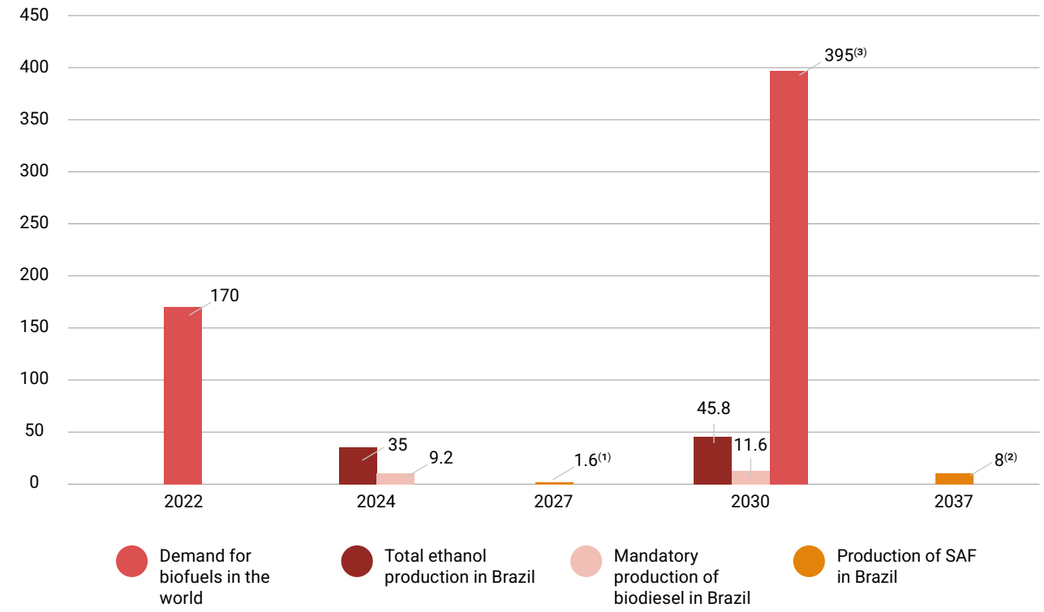
The virtuous cycle of public policies, positive response from companies and consumer acceptance has brought to the current scenario a robust sector, which includes at least 68 biodiesel plants and 436 ethanol plants, employs more than 2.2 million people and corresponds to around 4.5% of GDP

Brazil has become a global leader in bioenergy due to a number of decisions adopted over the past few decades, from the National Alcohol Program (Proálcool) in the 1970's, to the continued research and development efforts of the Brazilian Agriculture and Livestock Research Company (Embrapa) in tropical agriculture – which resulted in an increase of more than 180% in soybean crop productivity over the past 45 years – leading to the National Biofuels Policy (RenovaBio) of 2017.

The most recent advance was the approval and sanction of Law No. 14,993/2024, known as the Fuel of the Future Law, which strengthened Brazil's position by setting up incentives for biofuels (more specifically, ethanol, biodiesel, biomethane, Sustainable Aviation Fuel – SAF – and green diesel).

BIOFUELS: GROWING DEMAND

THE BEST GLOBAL ENERGY TRANSITION SCENARIO REQUIRES HIGHER PRODUCTION IN BRAZIL (IN BILLIONS OF LITERS)



[1] Initial projection
[2] Higher limit of the projection
[3] Assuming the same biofuel mix; IEA's Net Zero scenario in 2030

Source: Studies of the 2034 Ten-Year Energy Expansion Plan – Biofuel Supply - EPE
IEA - Biofuels - https://www.iea.org/energy-system/low-emission-fuels/biofuels

The virtuous cycle of successful public policies, positive response from companies and consumer acceptance has brought to the current scenario a robust sector, which includes at least 68 biodiesel plants and 436 ethanol plants, employs more than 2.2 million people and corresponds to around 4.5% of GDP. Maturity, in this case, does not mean stagnation: the federal government estimates that the sector will receive total investments of R$ 260 billion by 2037 (and neutralize 705 million metric tons of CO□ in the same period)[5].

The production of Brazil's two main biofuels, ethanol and biodiesel, is expected to grow 30% and 26%, respectively, by 2030. In its 2025-2029 Business Plan and its 2050 Strategic Plan, Petrobras, Brazil's largest company, highlights that it will seek to enter the ethanol segment.

Despite the promising scenario, the expansion of bioenergy in Brazil faces challenges. The biogas segment needs to make progress in the adoption of technologies and management models that are already available, capable of increasing its production and efficiency, as well as reducing its environmental impact.

The purification of biogas into biomethane, as well as second and third generation ethanol, renewable hydrogen and SAF[6] still require investments in research and development to reach the stage of large-scale and economically viable production (SAF can currently cost up to five times more than aviation fuel).

Infrastructure for storage, distribution and blending of SAF at airports also needs to be developed. The increase in ethanol production projected for the coming years demands expansion of the railways and pipelines in Brazil. The sector lacks investment in professional training specific to each region and each technological route.

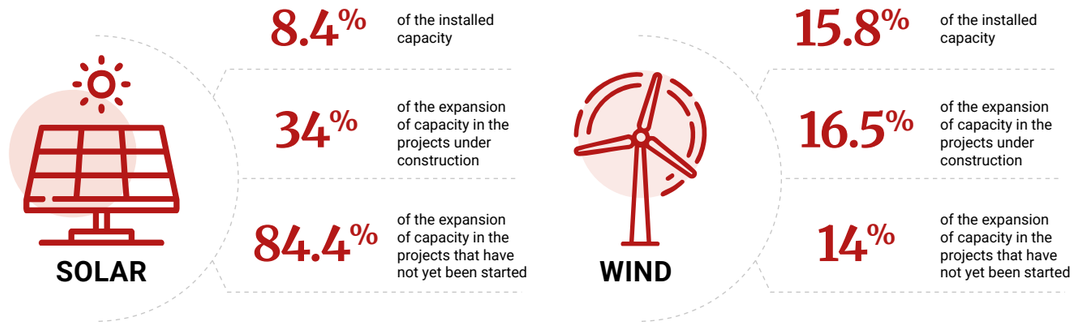
Furthermore, in order to maintain the environmental benefit and global appeal of the Brazilian case, it is necessary to ensure that the increase in biofuel production respects the sustainability of the production processes, the preservation of biodiversity, the rational use of water and the guarantee of food security.

There is still resistance to biofuels in some markets, due to the difficulty in measuring occupational environmental risks and risks of dispute for arable land with food. Brazil needs to fill this information gap, in the view of the Brazilian Association of Vegetable Oil Industries (Abiove), and certify best practices, according to the renewable energy company Be8.

Among the solutions to meet the global demand with low risk are the use of agricultural, pastoral and forestry waste (which eliminates the need to increase the planted area[7]), the preferential use of degraded areas (without the need to open new agricultural frontiers, a major advantage in favor of the sector in Brazilian territory), and the adoption of integrated biorefinery systems with regenerative agriculture and agroforestry systems.

SOLAR AND WIND POWER GENERATION INCREASES SHARE

SOLAR POWER IS EXPECTED TO TAKE THE LEAD IN THE EXPANSION OF INSTALLED POWER (IN JANUARY 2025)



91% of installed power in 2024 comes from wind and solar power sources

Source: National Electric Energy Agency (Aneel)

COMPLEMENTARY FORCES

Wind and photovoltaic solar sources are rapidly growing in the national electrical matrix. Both together account for 91% of the power that was installed in Brazil (photovoltaic solar for 52% and wind for 39%) and for 268 of the 301 plants that started to operate in 2024[8]. As a result, wind power accounts for 15.8% of the installed capacity of the integrated system and solar power accounts for 8.4% (if we also consider the autonomous solar power systems, this share leaps to 22.2% of all installed capacity in Brazil).

Due to this rapid progress, the Global Wind Energy Council (GWEC), in its 2024 report with data on 145 countries, highlights Brazil among the markets to be watched.

Both sources, solar and wind, benefit from Brazil's natural situation, which receives a lot of sunlight and constant and intense winds. They are also complementary to each other, as the months with stronger winds tend to be those with less sunlight, and vice versa.

As with biofuels, both sources have long value chains, that is, with potential to create jobs in the industry and associated services, as well as to export goods and services. Both segments also have a satisfactory level of legal security, offered by Law No. 15,097/2025 (offshore wind power) and by Bill PL5829/2019 (distributed solar generation). But both face challenges to maintain the pace of expansion.

The Brazilian Wind Power Association (ABEEólica) questions subsidies, tax incentives and market reserves in the Brazilian Electric System, as well as the expansion of thermoelectric plants that is in progress. The entity also calls for the inclusion of large-scale batteries in the Brazilian system – which would benefit wind and solar operations, considering the intermittency in generation.

Meanwhile, the Brazilian Association of Photovoltaic Solar Power (Absolar) is seeking stricter monitoring and punishments from the National Electric Energy Agency (Aneel) for distributors that, in its opinion, do not comply with the sector regulation by denying requests to connect distributed generation systems.

Renewable energy is one of the economic sectors in which Brazil has achieved unquestionable global prominence. It is a desirable development that, based on the production chains that have already been established and are under development in Brazil, the beneficial effects extend beyond national borders.

Any strategy – current and future – adopted for the sector can include different approaches for international insertion, including export of biofuels and bioenergy in different forms, export of industrialized goods with a lower carbon footprint (manufactured renewable energy), export of services associated with renewable energy chains, technology transfer to poorer countries and the presentation, to the world, of a cleaner and fairer energy security development model.

Brazil presents mature solutions in ethanol, biodiesel, wind and solar power

Ethanol

Brazil is the world's second largest producer of ethanol, behind only the United States. The use of this biofuel, pure or in addition to fossil fuels, is an efficient way to contain GHG emissions, as it emits approximately 73%[9] less carbon than gasoline in passenger vehicles. The ethanol content in gasoline in Brazil could increase from 27% to 30% still in2025 and the Fuel of the Future Law foresees a possible increase of up to 35%.

This maximum limit, however, does not have proven technical feasibility yet. If it proves to be impractical, the growth path for ethanol through increasing the content in gasoline could soon be closed. But there are many others to be explored, such as the expansion of the flex-fuel car fleet (preferably accompanied by educational campaigns for consumers who are still resistant to biofuel); the possible adoption of electric vehicles powered by hydrogen obtained by reforming ethanol[10]; and use in heavy machinery.

As the most established biofuel and with the largest production volume in Brazil (36.8 billion liters in 2024[11]), ethanol can lead the process of creating a more resilient production chain, capable of combining different activities – agriculture, livestock, forest management – resulting in a genuinely Brazilian proposal for the world: a regenerative agroindustry.

In a move that brings environmental, social and economic benefits, the sector has been diversifying its raw material base and reducing the predominance of sugarcane: maize crops already account for 22% of ethanol in Brazil and this share is expected to continue to grow. The National Agency of Petroleum, Natural Gas and Biofuels (ANP) has been evaluating and authorizing plants based on other options, such as sweet potatoes, soybeans, sorghum and wheat[12].

NEW HORIZONS FOR ETHANOL

One of the most comprehensive projects currently in this area is Brave, conducted at Unicamp and funded by Shell[13], in the ANP R&D clause. It is aimed at developing a complete biorefinery model, in degraded areas of the Northeast, based on agave biomass – a plant with high resistance to drought. The program covers the production of biochar (used to enrich the soil and capture carbon in agriculture) and a number of biofuels: first and second generation ethanol, biogas, bio-oil and synthesis gas.

Another work front involves the use of ethanol in thermoelectric plants and heavy vehicles such as tractors. In 2024, Vale announced[14] an initiative to develop off-road trucks (vehicles weighing over 70 metric tons, specifically for mining) powered by a mixture of ethanol and diesel. Meanwhile, Finland's energy equipment manufacturer Wärtsilä will conduct a pioneering experiment at Suape II[15] thermal power plant, in Recife, state of Pernambuco. The facility is expected to be the first in the world in its category to operate with ethanol. Initial testing took place in 2025 and the experiment is expected to last five and a half months starting April 2026[16].

Biodiesel

In biodiesel production, Brazil is also in second place globally, only behind the United States. The production of the national biofuel is diverse in terms of raw materials and geographical origin: it is relevant in the five Brazilian regions and uses mainly soybeans (69% of the total[17]), but also cotton, other oilseeds (such as castor oil, palm oil, canola, sunflower and peanuts) and animal fats.

The sector can become more resilient if it reduces its dependence on soybeans and uses more local raw materials. The minimum percentage of diesel blending, required by law, increased from 2% in 2005 to the current 14% (blend called B14), with the possibility of reaching 25% by 2030. Since 2024, the Indonesian[18] experience with a 40% content has yielded positive results, as have the tests carried out in Brazil with trucks from Scania and Volvo that use pure biodiesel (B100).

THE WORLD'S LARGEST BIODIESEL PLANT

The effect of biofuel as an investment multiplier is evident in one of the most ambitious projects underway in Brazil: the Potencial Group wants to build the world's largest biodiesel plant, with incentives from the Fuel of the Future Law. In October 2024, the company announced an investment of R$ 600 million to expand the production capacity of its plant in Lapa, in the Metropolitan Region of Curitiba[19] and the total planned investment exceeds R$ 2 billion.

The expansion is aimed at increasing soybean biodiesel production from 900 million liters per year to 1.62 billion liters (Brazil's total production is close to 9.2 billion liters per year).The project includes the construction of a railway terminal to connect the plant to the railway line to the Port of Paranaguá and a 55 km biodiesel pipeline, connecting Lapa to the Araucária Petrochemical Complex, in the state of Paraná, with an investment of R$ 150 million. The construction work began in 2025 and is scheduled to be completed in 2026.

Wind power

Installed wind power capacity grew to 34.3 GW in Brazil in 2024, an increase of 13%[20] (nearly 16% of the country's total capacity), exceeding the global expansion rate of 11%[21]. This form of generation contributes to make the Brazilian electrical matrix more renewable and safer, with less dependence on rainfall to feed hydroelectric reservoirs. The variable generation characteristic that is typical of this technology (given the variation and lower predictability of winds) is expected to be better managed in Brazil this year, with the inclusion of batteries in wind farm construction auctions[22] – a regulatory progress being made, in line with the progressive global reduction in the cost of energy storage systems.

The other major transformation underway in the sector occurs with the enactment of Law No. 15,097, in January 2025, which regulates offshore wind farms in Brazil.

In March, the Brazilian Institute of the Environment and Renewable Natural Resources (Ibama) had 104 offshore projects registered awaiting analysis, already well distributed along the coast: 50 in the Northeast, 32 in the South and 22 in the Southeast[23].

The definition of the regulations for this segment follows a schedule that allows the first auction to be held in 2025 and the start of operations of the turbines in 2031.

The gaps in standardization involve some crucial issues for the segment. It is necessary to define the procedures for those who are interested to propose prospects for prisms – as areas with potential for exploration are known – the technical, economic, and domestic purchasing requirements for those who are interested in competing for prisms; the penalties for non-compliance with the obligations of the concession; and the rules for the use of the space in cases where prisms match with oil and/or natural gas production blocks.

It is also necessary to complete the Marine Spatial Planning (MSP) in order to regulate the use of sea space and consider the various environmental and social impacts of the activity on coastal communities and marine fauna.

In addition to reducing carbon emissions by providing renewable electricity, the expansion of this energy frontier on land and at sea creates beneficial economic effects through other ways: it has a strong presence in the Northeast, the most deprived region of Brazil (there is a promising work front in professional training policies in wind power, as India and Poland have already done successfully); it generates income through land leasing in areas that would be unproductive with another activity; and it requires the contracting of specialized products and services in a long value, around 80% of a wind-farm content are manufactured in Brazil[24]. ABEEólica estimates that each 1 MW installed in the sector create11 jobs and each R$ 1 invested in the sector adds R$ 2.9 to GDP within 14 months.

Solar power

The installed capacity of photovoltaic solar power in the world increased almost 30%[25] in 2024, to 2,200 GW (this source is on track to become the most relevant renewable in the world by 2030[26]). This is an intense pace of capacity growth – and yet, the expansion of installed power in Brazil surpassed it, reaching 38% in 2024[27], to 55 GW (more than one fifth of total installed capacity).

Brazil was the world's sixth largest producer of solar power in 2023[28].

The solar source provides Brazil with several advantages: it makes the matrix less dependent on the rainfall regime, which tends to be affected by the climate crisis; it reduces the need to operate thermoelectric plants, which are polluting and more expensive; it gains efficiency in the absence of cloud cover (a characteristic of the drier weather conditions that tend to become more common in Brazil) and it generates more power during the period of the day with greater sunlight, which tends to concur with the time of highest average temperature and consequent increase in the demand for electricity by air conditioning and industrial refrigeration systems.

Furthermore, it shows versatility, fitting well into both the centralized generation model, from large plants, and the distributed generation model. The leading states in terms of number of consumer units[29] are Minas Gerais, with 900,000, São Paulo, with 756,000, and Rio Grande do Sul, with 468,000; in the first quarter of 2025, more than 147,000 systems were installed by consumers, supplying 228,700 properties and

adding 1.6 GW[30]. In the distributed generation model, it also fits into the different conditions and needs of households, isolated communities, commerce, industry and agribusiness.

Among the underutilized potentialities is the domestic manufacturing of components. Brazil has a significant production of some items, such as solar trackers and support structures, but there is room for production of modules and inverters that can compete with imported products. Another potentiality is the integrated use in agribusiness, since extensive areas of photovoltaic panels create shaded areas, suitable for specific livestock or crops, and with less evaporation (that is, better maintenance of soil moisture).

Brazil can also increase floating solar generation in hydroelectric reservoirs and other bodies of water, taking advantage of the greater efficiency of the panels through cooling and additional protection of springs against excessive evaporation. In addition to creating local networks with battery power storage systems – a promising solution for isolated areas, still very dependent on diesel generators, which are expensive and emit carbon and noise pollution. The federal program *Luz para Todos* (Light for All) has brought solar power to more than 150,000 consumers in the Legal Amazon over the past five years. By 2026, the goal is to reach around 2 million people[31].

The segment is expected to gain additional boost with improvements in management and standardization. Part of the progress depends on the implementation of the Energy Storage Regulatory Framework by ANEEL. The framework would cover both on-grid and off-grid systems and could result in cheaper equipment, such as batteries. Implementation might take place in 2025.

On another work front, since September 2024, the National System Operator (ONS) has been testing changes in the processes for suspending wind and photovoltaic power generation in the states of Ceará and Rio Grande do Norte. These restrictions resulted in a reduction of 400,000 hours of generation in 1,445 power plants in 2024, according to consulting firm Volt Robotics. ONS states that it imposes these restrictions mainly due to limitations in the transmission networks. The agency is evaluating the possibility of distributing the restrictions more geographically, which could lead to the same result (respecting the network limitation) without causing a financial burden that is excessively concentrated on power plants in some areas.

GROWTH OF SOLAR ENERGY

900 thousand
CONSUMER UNITS IN THE STATE OF MINAS GERAIS — THE LEADING STATE IN DISTRIBUTED GENERATION.

756 thousand
IN THE STATE OF SÃO PAULO AND 468 THOUSAND IN THE STATE OF RIO GRANDE DO SUL.

147 thousand
SYSTEMS INSTALLED ONLY IN THE 1ST QUARTER OF 2025.

228.7 thousand
PROPERTIES SUPPLIED AND 1.6 GW ADDED TO THE GRID.

Biogas and biomethane, biomass, 2G ethanol and SAF are on the rise

BIOGAS AND BIOMETHANE

Biogas, produced from the anaerobic digestion of organic matter (agroindustrial waste, wastewater, urban solid waste) and its derivative biomethane, are booming in Brazil. This is interchangeable with natural gas, that is, it can completely replace the fossil equivalent or be mixed with it in any proportion, without the need to adapt the engine.

Both biogas and biomethane can replace fossil fuels in industrial processes, in the generation of electrical power, in the generation of heat and as fuel in freight vehicles. Its controlled use, rather than simply releasing it into the atmosphere, contributes to mitigate the climate crisis. Additionally, it adds value to waste and encourages its careful management – a desirable development, considering that there are still around 3,000 open-air urban waste dumps in Brazil[32].

But there are obstacles to the dissemination of these fuels. The adoption of biomethane and biogas on a large scale requires resolving issues of infrastructure, supply assurance and quality, according to the Alberto Luiz Coimbra Institute of Postgraduate Studies and Research in Engineering of the Federal University of Rio de Janeiro (Coppe-UFRJ).

The product – manufactured in a decentralized manner in Brazil – needs to be analyzed in a laboratory, considered consistent with the ANP specification (in Brazil, gas with at least 90% methane is considered biomethane) and sent to a distribution network. None of these steps are properly organized.

The Brazilian Biogas and Biomethane Association (ABiogás) has been promoting projects

such as the Sustainable Biomethane Corridor, connecting strategic producers and consumers in the states of Paraná, Rio de Janeiro and São Paulo. The objective is to make biomethane available at gas stations along highways to meet the needs of heavy goods transportation. In the state of Paraná, the project covers more than 4,000 kilometers of roads in 147 municipalities. Fuel switching has been providing users with savings of up to 60%[33].

There are good examples of wastewater treatment with appropriate technology in Brazil, such as high-rate reactors (much smaller and more efficient). Among them are the Barão Geraldo Wastewater Treatment Plant (WWTP), in Campinas, state of São Paulo, and the Água Vermelha WWTP, in São Carlos, state of São Paulo. In these facilities, converting biogas into biomethane is the next step. There are several technologies available that are already industrially mature, such as chemical washing, adsorption in activated carbon and biodesulfurization. These processes are expensive when compared to the average cost of wastewater treatment, but economically viable in a biomethane production and sales model.

BIOMASS

The most relevant case of biomass use in Brazil is the generation of electric energy from sugarcane bagasse. The practice is already well established in the sugar-energy sector. Bagasse, a byproduct of ethanol production, is burned in thermoelectric plants, which helps diversify the energy matrix, reduce carbon intensity in the energy sector and dispose of the waste.

This circular-economy practice can be extended: several projects use the ashes resulting from bagasse combustion as an additive for ceramic material, bricks, asphalt and fertilizers[34]. The Brazilian Sugarcane Industry Association (Unica) estimates that 2025 will be the year of the greatest expansion in this segment in 20 years.

PROJECTS IN AGRIBUSINESS AND CHEMICAL INDUSTRY

Among the projects to boost the segment is the initiative of Louis Dreyfus Company, a French agribusiness multinational, to build the world's largest biogas plant, according to information from the company, using citrus effluents, in Bebedouro[35], state of São Paulo. The construction, announced in March 2025, is expected to be completed in 2026. The sludge generated in the process can be used as organic fertilizer in more than 30,000 hectares of orchards.

Another case of decarbonization occurs in the chemical sector, with the use of biomethane provided for in a contract between Gás Verde and Henkel. The aim is to reduce emissions from Henkel's fleet and plants. One of the plants, in Jundiaí, state of São Paulo, will be 100% supplied with biomethane. The operation is scheduled to start in 2025.

SECOND GENERATION ETHANOL (2G)

This biofuel is produced from remaining stocks of lignocellulosic materials (solid waste) from the production of sugarcane ethanol, like bagasse and straw. The technology makes it possible to increase ethanol production without the need to expand the area cultivated with sugarcane.

The Raízen group has two plants in operation (including the largest in the world, in the Bonfim Bioenergy Farm, in Guariba, state of São Paulo) and plans to have 20 of them in operation by 2030. In 2025, the company received financing of 1 billion from the National Bank for Economic and Social Development (BNDES) for the construction of the Andradina (state of São Paulo) unit.

But the expansion of the 2G ethanol still depends on technological advances to achieve greater productivity. These efforts involve third and fourth generation ethanol and the search for yeast strains that are more suitable for processing lignocellulosic biomass.

SUSTAINABLE AVIATION FUEL (SAF)

Two forces will drive the production of Sustainable Aviation Fuel (SAF) in the coming years. The mandatory phase of the Carbon Offset and Reduction Scheme for International Aviation (Corsia) will begin in 2027, for the purpose of achieving carbon neutrality by 2035 and net zero by 2050.

In domestic aviation, also in 2027, a gradual reduction in emissions will begin, initially of 1%, reaching 10% by 2037, as part of the National Sustainable Aviation Fuel Program (ProBioQAV). With these two programs, Brazil alone will demand 941 million liters of SAF in 2027 and 2.89 billion liters in 2037, in the most conservative estimate. The demand could reach three times that[36].

There are 11 technological routes for SAF production accepted by the International Air Transport Association (IATA). The HEFA (Hydroprocessed Esters and Fatty Acids) routes, which are the origin of 80% of the SAF produced in the world, and AtJ (Alcohol-to-Jet) are the most promising means of producing SAF from, respectively, soybeans and sugarcane, the most abundant raw materials in Brazil.

FINANCING FOR SAF

Vibra became the first company to offer SAF in Brazil, produced from used cooking oil (UCO). But among the most notable efforts to begin to explore this nascent market is that of Acelen, which received the first financing from BNDES for SAF production in the amount of R$ 257.9 million.

Acelen will implement, in Montes Claros, state of Minas Gerais, a research and development center to produce SAF from *macaúba*, a native Brazilian plant with high energy value. The initiative includes family farming and the recovery of degraded land. The complete project is aimed at expanding the *macaúba* producing region to Mataripe, state of Bahia, and create 90,000 jobs.

Promising progress: BECCS, CCS/CCUS applied to energy, new uses of biofuels in large equipment and renewable hydrogen

BECCS (BIOENERGY CARBON CAPTURE AND STORAGE)

Carbon capture and storage (CCS) technologies are rapidly gaining relevance in the quest for a global net zero scenario by 2050[37] and are being tested in various industrial sectors – the Global CCS Institute's 2024 balance sheet lists 47 operations underway worldwide and 22 to start operating in 2025, in a total of nearly 680 projects at different stages. In bioenergy, the inclusion of BECCS in the business model has the potential to make the sector carbon-negative.

The main route under analysis consists of filtering the carbon that would be emitted during the ethanol production and injecting it underground, in previously assessed areas, which ensure the retention of the gas in the long term (the system is in operation at Gevo's ethanol plant in Richardton, in the United States).

The activity received basic regulation through Law No. 14,993/2024, known as the Fuel of the Future Law, but there are still gaps in the regulation, such as access to pipelines and reservoirs used to transport and store carbon[38]. The largest BECSS project in Brazil is led by FS Bioenergia, which plans to inject carbon underground from its ethanol plant in Lucas do Rio Verde, state of Mato Grosso.

CCS/CCUS APPLIED TO ENERGY

Brazil is in a position to present exemplary case studies of CCS to the world and, going one step further, of carbon capture, utilization, and storage (CCUS). There are at least 25 technological routes on the global market today, according to the Global CCS Institute, with ample room for experimentation and cost reduction.

The most common use of captured carbon in the world today is the injection into oil and gas wells so as to facilitate the extraction of raw materials sought by oil companies. Petrobras is leading the world's largest effort in this category, with the goal of injecting 12 million metric tons of CO_2 into pre-salt reservoirs in 2025. The initiative reduces the intensity of carbon in the oil produced in Brazil without, however, contributing to the necessary energy transition. However, the progressive spread of experiences with CCS tends to multiply its beneficial effects. For example:

- **CCS in industrial activities that are difficult to mitigate, such as steel, glass, and transportation:** the result would be low-carbon inputs and services for desirable target activities in a green economy, including equipment for renewable energy generation and sustainable agriculture and construction;

- **CCS for the production of "blue" hydrogen as a transition:** at least 95% of global hydrogen production capacity currently depends on fossil raw materials. Carbon capture in the process results in "blue" hydrogen, which can contribute to the spread of the fuel and the gradual transition to the adoption of renewable hydrogen;

- **CCUS in different activities:** as the Brazilian Emissions Trading System (SBCE), approved in 2024, is implemented, carbon tends to gain a clearer price in Brazil and channel resources to mitigation efforts, including CCUS systems. They tend to allow the re-entry of captured carbon into a renewable and circular economy. Among the possible uses of this raw material is its combination with hydrogen (preferably green or renewable) for the production of synthetic fuels that are capable of replacing fossil fuels without the need to adapt infrastructure and engines.

The Fuel of the Future Law was an important first step for this activity. Other definitions are necessary, such as business models for carbon transport and storage infrastructure to be shared by companies; tax treatment that encourages the practice; and clear monitoring plans by the National Petroleum Agency (ANP) and other authorities in charge.

NEW USES OF BIOFUELS IN LARGE EQUIPMENT

A potential new factor to encourage biofuel production in the short term is its use in a wider range of large equipment, including tractors, locomotives, ships and thermal power plants. The sea shipment sector is currently evaluating a range of renewable fuels, including several that originate from bioinputs: ammonia, biodiesel, biogas, biomethanol, e-methanol and renewable hydrogen[39].

The International Maritime Organization (IMO) is expected to make progress in the discussion on Net Zero Emissions (IMO Net-Zero Framework) in an extraordinary session to be held in October 2025. The framework under analysis includes carbon pricing in marine fuels and mandatory measurement of emissions intensity.

RENEWABLE HYDROGEN FROM BIOFUELS

In the process of producing hydrogen and converting it back for use (in generating heat or electricity) there is a large loss of energy, of around 50%, which makes its use recommendable in specific circumstances. In its sustainable version (produced from renewable energy and raw materials), this gas can contribute to clean up the global energy matrix.

Among its potential energy applications is its use as fuel in trains and trucks, in cargo transportation in remote regions; in ships, in short-haul cargo and passenger transportation; in aircraft; and in isolated communities.

Another route under consideration would be its use as a component, together with carbon (captured in CCS or BECCS systems), for the production of synthetic fuels capable of replacing fossil fuels without requiring any adaptation of infrastructure or engines. Since the burning of synthetic fuels emit greenhouse gases, the net decarbonizing result of this route would need to be guaranteed throughout the production process.

The electricity matrix, which is already predominantly renewable, gives Brazil advantages on this technological front. Estimates indicate that Brazil could have an annual production of 200,000 to 800,000 metric tons of low-carbon hydrogen by 2030[40]. Studies on the segment include, in addition to the production routes, analysis of the physical risk in transportation and storage, which is higher than that posed by fuels.

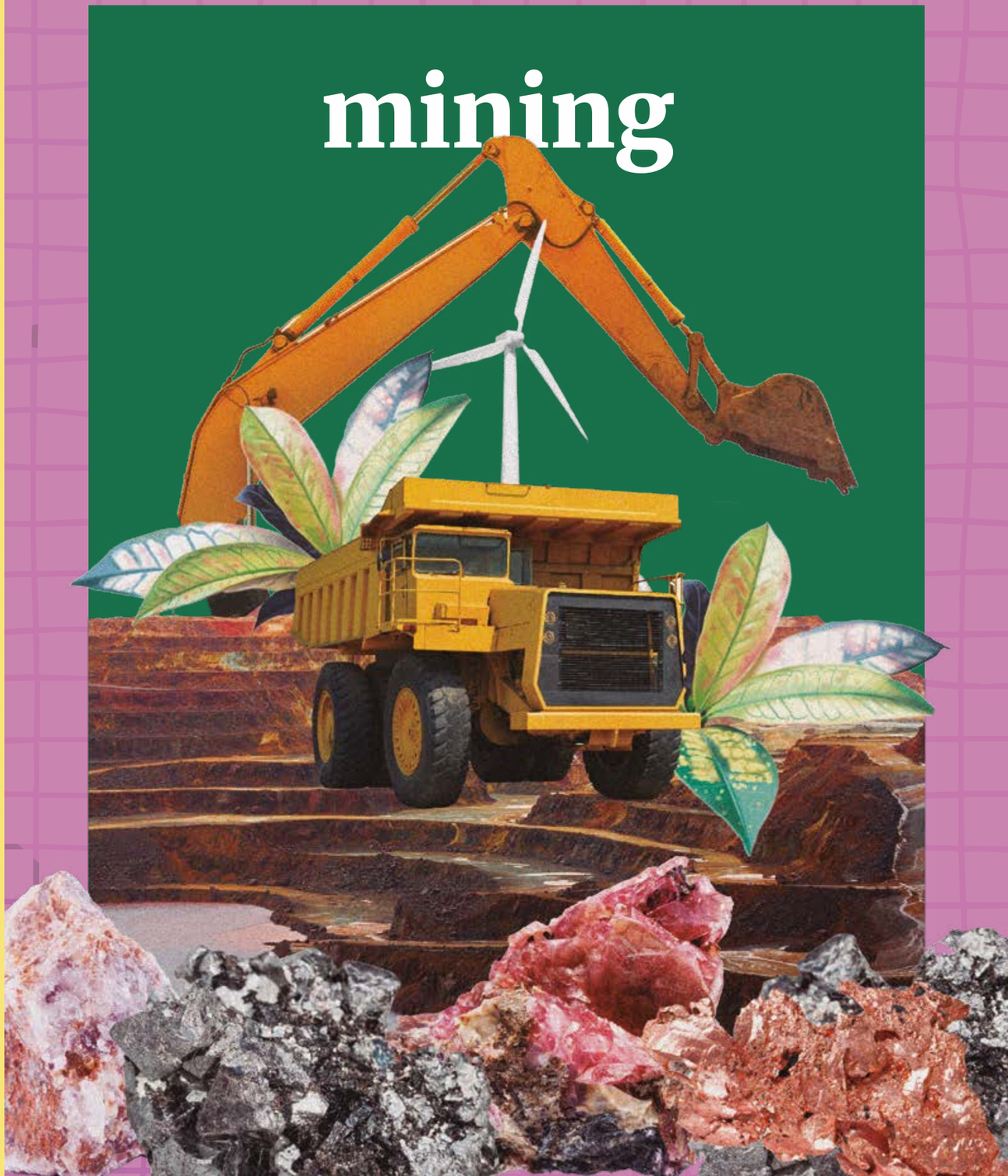
Between February 2021 and March 2025, 74 projects of renewable hydrogen and its by-products were announced in Brazil, with a total electrolysis capacity of 45 GW and more than US$ 68 billion in investments provided for the 2030-2032 period, according to a mapping carried out by consultant Monica Saraiva Panik, from SAE Brasil – Society of Mobility Engineers.

The expansion of the segment depends on the reduction of technological costs and on incentive policies. In recent years, there have been advances in regulations. In August 2024, Law No. 14,948-2024 of the Low Carbon Hydrogen Development Program (PHBC), was sanctioned, providing for R$ 18.2 billion in tax credits until 2032 to boost the sector, establishing the legal framework for green hydrogen and defining guidelines for its production, commercialization, and use in Brazil. Since 2021, the Electric Energy Trading Chamber (CCEE) has been studying and implementing hydrogen certification mechanisms, having issued Brazil's first Hydrogen Certificates for the voluntary market, attesting to the renewable origin of the energy used in production, following the European standard.

Despite greater regulatory security, challenges remain. Progress must be made on topics such as certification of origin, definition of purity standards, and clarity regarding the regulatory body for the field. Specific regulations are also essential for the infrastructure and logistics of hydrogen, which is more flammable and easier to escape than other fuels.

The expansion of the segment depends on the reduction of technological costs and incentive policies – such as the Low Carbon Hydrogen Development Program (PHBC), which provides for R$ 18.2 billion in tax credits by 2032 to boost the sector.

Carbon pricing will also play a fundamental role in this construction. In Brazil, the first business strategies include an initial focus on the domestic market, in particular industrial sectors such as fertilizers and renewable fuels, with future potential for export.



Caminho das pedras

The global energy transition requires a significant increase in the production of critical minerals. Accordingly, the mining activity will have to expand itself, without having an environmental and social impact that corresponds to this expansion. In the best-case scenario, the production of these minerals will absorb the good practices developed over the past few years in segments such as iron ore mining. It will also be supported by advances in monitoring and traceability systems

Mining, in much of the world, is undergoing profound transformations, driven by the growing demand for a more sustainable and decarbonized global economy. Although essential, the segment has been marked over the past few centuries by negative environmental and social impacts, such as large volumes of tailings, degraded excavation areas, excessive water use and other liabilities and negative externalities.

In Brazil, according to the Department of Mining Engineering of the Federal University of Minas Gerais (UFMG), part of the ore transport still depends on highways[1], the least efficient shipping mode. The new environmental and social demands created over the past few decades were increased by the disasters that occurred in Mariana and Brumadinho, resulting from the use of upstream tailings dams and their flawed management.

However, there is a relevant change underway. The sector has raised its standards in the analysis of environmental and social impacts, in the practices adopted, in the definition of goals and in transparency. Additionally, it invests in new models for generating benefits for territories and communities affected by its operations. Since the beginning of railway concessions in 1996, private investment in the segment has been growing 7.4% per year. In 2024, Brazil recorded the largest absolute investment in this mode (R$ 14.3 billion) and the largest share of private capital (98%), due mainly to modernization and increased safety and productivity[2].

Among the companies associated with the Brazilian Mining Institute (Ibram), 51 participate in the Brazil Mining ESG Agenda, with 12 pillars of action and respective Working Groups. The institute's Letter of Commitment to society represents the companies' decision to continually improve factors such as operational safety, dam control, risk management, impact mitigation, and development of affected communities. The commitment has been monitored by a corresponding increase in investment in this development.

This change is a vital issue for mankind, because the global energy transition requires a significant increase in the production of critical minerals in the coming years and decades. Accordingly, the mining activity has to expand itself, without having an environmental and social impact that corresponds to this expansion.

In the best-case scenario, the production of these critical minerals will absorb the good practices developed over the past few years in segments such as iron ore mining. It will also be supported by advances in monitoring and traceability systems. There will be greater pressure from business partners for environmentally correct conduct, since mining companies and their investors are or will be part of the supply chain of companies that present themselves to the market as developers of "clean" technologies.

These chains tend to show less tolerance with ore suppliers that engage in outdated, polluting, and environmentally harmful practices and prioritize those that seek cleaner extraction and production methods, for example, without tailing dams, with less water use, more attention to circularity, pollution control, minimal deforestation, and forest restoration. This evolution is part of what is called fair energy transition – fair to society, communities, companies, and nature.

Reducing emissions in mining

Efforts to reduce the footprint

Mining products become more carbon-intensive in the transportation and processing stages, such as steel and aluminum production. As a result, companies in the sector have been working to mitigate emissions in their networks of commercial partners

The mining industry directly accounts for 0.8%[3] to 4%[4] of global greenhouse gas (GHG) emissions, depending on the analysis criteria – but this share is continually falling as coal mines, the sector's main emitters, are closed. In Brazil, the mining activity directly represents 0.55%[5] to 1.9%[6] of total GHG emissions, also depending on the analysis criteria (more usually, mining emissions are aggregated with those from the metallurgical and steel and iron industries. This group accounts for approximately 7%[7] of global emissions and approximately 5%[8] of Brazilian emissions).

The share of emissions from mining in Brazil is well below the global share, mainly because of its predominantly renewable energy matrix and the relatively low share of coal production in the sector. From a global emission-management standpoint, these are favorable points for managers and investors in international mineral value chains and their applications to consider opening and expanding mining operations in Brazil.

MINING IMPACT MANAGEMENT

13.9 tons of CO_2e
are emitted, on average, per metric ton of lithium carbonate extracted from rocks. The process is energy-intensive and the most common situation globally is the use of energy from fossil sources.

28%
at least, is the possible cut in carbon emissions in copper mining operations, by replacing fossil fuels by renewable sources.

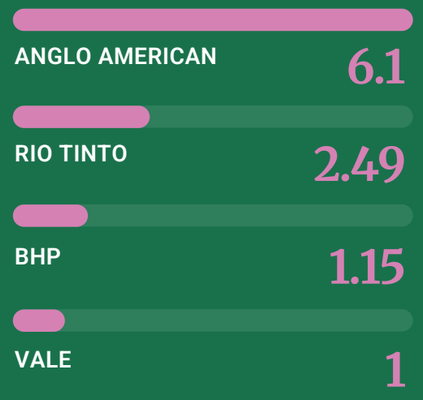
Part of the virtuous process that is underway stems from the adaptation and dissemination of practices initiated in larger, already well-established operations, such as iron or bauxite, to smaller or emerging operations in Brazil, such as projects related to nickel and rare-earth elements (a group of 17 chemical elements that are essential for new technologies, such as electronic products, renewable energy and defense). One example, according to UFMG, is water-management practices, initially adopted in larger operations and in regions with water scarcity, now spreading throughout the sector, even in areas with greater availability of this resource.

Additionally, the Brazilian Mining Institute (Ibram) encourages companies to work towards the zero-carbon target by 2040[9] – one example is CBMM. Another one is Vale, Brazil's largest mining company and one of the five largest in the world, which, in 2019, adopted the targets of reducing emissions by 33% in scopes 1 and 2 by 2030 and becoming carbon neutral by 2050 (scope 1 refers to direct emissions from the activity itself and 2 to emissions from the electricity used). Since 2024, Vale has been using 100% renewable energy in Brazil and meeting 16% of its needs with solar generation, a result achieved with its Sol do Cerrado Project, in Jaíba, state of Minas Gerais.

Mining products become more carbon-intensive in subsequent stages of transportation and processing (such as steel and aluminum production). Just as an example, at Vale, scope 3 emissions (out of the company's direct control, distributed throughout its value chain) correspond to 60 times the emissions of scopes 1 and 2[10]. This ratio is much lower for the rest of the economy, close to 10 times in sectors with the shortest supply chain and 26 times on average across sectors[11].

CARBON INTENSITY IN IRON MINING

IN THOUSANDS OF METRIC TONS OF CO_2 EMITTED (IN SCOPES 1 AND 2) PER MILLION METRIC TONS OF ORE EXTRACTED (2021/2022 DATA)



13%

FROM 2017 TO 2024 WAS THE REDUCTION in the carbon intensity of Vale's iron ore in scopes 1 and 2, to 18.3 kg CO2e / t Fe-eq (kilograms of carbon equivalent per ton of iron ore equivalent).

Fontes: Unearthed Solutions, Vale

In addition to the corporate efforts is the fact that the regulatory framework in Brazil is robust. Current regulations include sustainability principles, rational use of resources and environmental and social responsibility.

Due to this pronounced characteristic of mining, companies in the sector have been working to mitigate emissions in their networks of commercial partners. For example, Vale has signed more than 60 cooperation agreements with suppliers and customers so as to reduce emissions and expects that 40% of its investment in decarbonization in 2025 will go to projects linked to the value chain. Regarding scope 3, the company is committed to reducing net emissions by 15% by 2035 compared with 2018.

One example is the process of updating the Regulatory Mining Standards (NRMs), promoted by the National Mining Agency (ANM), which represents a significant advance in regulatory alignment with best international practices, incorporating modern concepts of operational safety, risk management and Mine Closure Plans (PFMs), according to the Research Center for Responsible Mining of the Polytechnic School of the University of São Paulo (Poli-USP).

The National Mining Plan 2050, which, in the second half of 2025 was in consolidation phase by the Ministry of Mines and Energy, highlights the need to incorporate ESG criteria into mining. Tools such as the Rural Environmental Registration File (CAR), the National Dam Control System, and the Environmental Impact Report (RIMA) requirements help improve the sector's work standards.

Another layer of supervision is being built through dialogue and specific actions of Ibram with the three branches of government. In 2023, the Federal Supreme Court (STF) ruled that Marketable Securities Distributors (DTVMs) could no longer claim a presumption of good faith (based on the miner's word) regarding the legal origin of the gold they purchase. The Central Bank confirmed the new guidance for DTVMs and the Federal Revenue Service established the mandatory issuance of an electronic invoice for transactions with gold as a financial asset or foreign exchange instrument. In 2025, the STF's ruling was confirmed by the Congress and became irreversible[12].

Illegal mining covered as much as 241,000 hectares in the Amazon at its peak in 2022, according to the Amazon Environmental Research Institute (Ipam)[13]. Since then, it has fallen by at least 45%, according to the Environmental and Social Institute (ISA)[14]. Although prospecting and mining are distinct activities in terms of scale, practices and regulations, the reputation of illegal prospecting compromises the value chain of ore originating in Brazil.

Concrete results

Among mature solutions are the transportation of materials by conveyors or pipelines, the adoption of biofuels and electrification for mining trucks, excavators and machinery in general

To achieve minimal use of fossil fuels, some of the work fronts that already offer concrete results in mining are the transportation of materials by conveyors or pipelines (instead of trucks), the adoption of biofuels and electrification for mining trucks, excavators and machinery in general. Although Brazil's electric matrix is predominantly renewable, there are mines that have been ensuring the use of 100% clean electricity by exclusively using solar or wind sources.

The energy efficiency gain, desirable regardless of the type of generation, is obtained from the use of frequency inverters, high-efficiency motors and automation systems, with special attention to specific stages, such as comminution (a mechanical process that reduces particle size) and flotation, which are highly energy-consuming, according to UFMG.

The reduction or elimination of water use has been achieved through a set of techniques that include dry stacking of tailings; precise spraying technologies; water reuse, with recirculation in dams and processing plants (when processing requires specific processes, such as flotation, the solutions involve more efficient separation technologies – coarse particle flotation, high-intensity magnetic separators – heat recovery and cogeneration in thermal processes, use of biodegradable reagents and closed water systems), according to Ibram and the Brazilian Center for International Relations (CEBRI).

THE BRAZILIAN ENERGY MATRIX MAKES A DIFFERENCE

MINING'S SHARE OF TOTAL CARBON EMISSIONS

4% IN THE WORLD

1.3% IN BRAZIL

Testing ground for new technologies

The mining industry works with equipment under boundary conditions and many isolated operations. Therefore, it serves as a testing ground for developing extremely robust technologies and systems. Among the most promising solutions are the autonomous mining trucks, vehicles whose circulation is restricted to the mine area and whose weight reaches hundreds of metric tons.

Optimal vehicle driving through artificial intelligence (AI) has already shown productivity gains of 18%[15] and above, which reduces fuel or electricity consumption.

Autonomous vehicles and other pieces of machinery are being connected to IoT (Internet of Things) networks. Sensors distributed throughout the mining area and integrated with an AI system can monitor environmental conditions and equipment performance, transmit real-time data to control centers, optimize routes, and move works within the mine to areas with higher ore concentrations.

Additionally, specific AI models can predict failures and optimize water-treatment circuits. The net result is lower consumption of electricity, fuel, water and maintenance inputs.

Another tool for increasing productivity consists of explosives with adaptable energy, to provide a new level of efficiency and precision in rock blasting, with less exposure for people and the surrounding area.

In the pre-mining operation phase, AI models can also perform more accurate geological modeling, helping identify deposits. This tool reduces exploratory risk and directs investments and work towards areas with higher ore concentration, which minimizes overall impacts.

EXAMPLES OF BUSINESS PERFORMANCE

Anglo American, Nexa Resources and Vale (several operations): implement autonomous systems and AI in mines and plants. The use of sensors and real-time monitoring systems allows for the optimization of ore utilization, reducing the volume of sterile material moved and the resulting environmental impact. Autonomous or semi-autonomous excavators and trucks, equipped with AI algorithms, can follow optimized routes, assess ore grades in real time, and avoid areas of low mineral quality. This reduces fuel consumption, equipment wear and tear and carbon emissions. Companies apply these solutions in iron, copper and zinc operations.

Anglo American (several operations): obtained the first independent IRMA (Initiative for Responsible Mining Assurance) assessment certificate for an operation in Brazil. The Barro Alto nickel mine (in Barro Alto, state of Goiás) and Minas-Rio iron mine (in Conceição do Mato Dentro, state of Minas Gerais) were awarded the IRMA 75 seal, which indicates 75% compliance with environmental, social, integrity and positive legacy criteria for the surrounding area. In the Minas-Rio Project, the company uses ore pipeline transportation (the largest in Brazil, 529 km long), which reduces emissions and fuel consumption. In asset management, it adopts a data-intensive approach to make operations more integrated and systematized; precision in mining minerals and metals to reduce water and energy consumption and reduce waste in the process; and achieve levels of nearly 100% recirculation in water use. Anglo-American is developing, with research partners, processes to further reduce water consumption, which is particularly important for copper and nickel mining.

CBMM (Araxá – state of Minas Gerais): is developing, in partnership with international institutions, technology for the use of niobium in lithium-ion batteries, with greater safety and shorter recharge time. It also invests in AI for predictive equipment monitoring, using sensors and real-time analysis, which enables optimized maintenance and reduced operational failures. Another important front is the use of AI for waste recovery, with models that integrate mineralogical and metallurgical data to identify viable reuse routes. These solutions increase the use of resources and contribute to reduce the volume of waste, with a focus on the circularity of industrial processes.

CBL Lítio (Araçuaí – state of Minas Gerais): has been expanding its production capacity with a focus on minimizing environmental impacts, in particular water use, carbon emissions and tailings disposal. The company uses digitized environmental control systems, water and tailings reuse systems and AI for production control. Specialized sensors and platforms continuously monitor the quality of water and air. The processing plant operates with a closed-loop water use system, minimizing water impact — a relevant point for the Jequitinhonha Valley. The operation is also a benchmark in territorial harmony with local communities, promoting social benefits and productive coexistence activities with the communities surrounding the mine.

CSN Mineração: has a recirculation system that reuses more than 95% of the water used in processing. In 2024, CSN Mineração recorded a 23% reduction in water withdrawal intensity per metric ton of iron ore in relation to 2023. In addition to the recirculation system, the company has more than 40 control systems for effluents and drainage, and more than 30 monitoring points. The aim is to ensure the proper management of water resources and minimize the environmental impacts of its activity[16].

Gerdau - Miguel Burnier Mine (Ouro Preto – state of Minas Gerais): achieved the IRMA 50[17] classification in 2025, from the Initiative for Responsible Mining Assurance, which indicates 50% compliance with environmental, social, integrity and positive legacy criteria for the surrounding area. Only 26 mines in the world have undergone independent assessment and only 8 have completed the process. In 2025, the National Bank for Economic and Social Development (BNDES) approved financing of R$ 566 million for works that include a 13-km long ore pipeline. The project received resources from the Climate Fund as it is a low-carbon emission alternative to other modes of transport.

Horizonte Minerals (two operations in the state of Pará): nickel projects adopting technologies for emission reduction and energy efficiency, including cogeneration. The method uses heat generated during the production process to generate electricity.

Hydro (state of Pará): mitigation measures along the chain include the use of electric and ethanol-powered vehicles in the light fleet, electric trucks, and transportation of ore via a 244 km pipeline from Paragominas (state of Pará) to the Alunorte refinery in Barcarena (state of Pará). At Mineração Paragominas, 90% of the electric energy used comes from renewable sources, such as the Mendubim solar and Ventos de São Zacarias wind complexes. As a result, primary aluminum that leaves the subsidiary Albras in Barcarena, Brazil's largest producer, emits around three metric tons of carbon equivalent per metric ton of aluminum, one-fifth of the reference accepted by the International Aluminum Institute. Operations in Brazil (Albras, Alunorte and Mineração Paragominas) achieved the Gold Seal in the Brazilian GHG Protocol Program in 2024 and are certified by the Aluminum Stewardship Initiative (ASI), which attests to compliance with international standards in environmental management.

Largo (state of Bahia): vanadium mine with optimized drying processes and thermal energy reuse.

Mineração Taboca (state of Amazonas): modernized the

tin and tantalum circuits with more selective flotation and full water recirculation.

Sigma Lithium (Jequitinhonha Valley – state of Minas Gerais): global reference in "green lithium", with 100% renewable energy, 90% water recirculation, no use of tailings dams, dry processing and gravity separation of lithium from spodumene (mineral composed of lithium and aluminum silicate) with a high concentration of the metal – a method summarized in the "Quintuple Zero" formula (that is, the effort to produce lithium without dams, chemicals, carbon emissions, fossil energy and water consumption). This is a case of adapting traditional iron and bauxite mining practices to a lithium mine, with international recognition for its ESG practices.

Vale - S11D Mine (Canaã dos Carajás – state of Pará): the system adopted at the mine eliminates the use of trucks on site, reducing diesel consumption and carbon emissions. Suspended conveyors transport the iron ore over 9 km, between the extraction site and the processing plant. It also includes dry processing plants, reducing water consumption, and integrated digital operational control systems. Results indicate that the truckless mining system, which is considered a global benchmark, reduced CO_2 emissions by 77% a year[18]. The vehicles used are controlled by software, GPS, radars and AI. Accordingly, it was possible to increase the useful life of truck tires and the wear and tear of parts in general by 25%. The processing uses the natural moisture of the ore, eliminating the need to add water and form tailing dams, which saved 93% of water and 18,000 MW of electricity per year[19]. The site also uses the strip-mining technique, which allows for the progressive rehabilitation of the soil, with less impact on the landscape and better control over drainage and revegetation.

Vale (several operations): other examples of Vale's mitigation initiatives in the value chain include green briquettes[20], a product that has been supplied to steel and iron mills since 2021 that reduces the need for heat in steel production; the supply of ore with a high concentration of iron, which reduces emissions in the steel and iron industry by up to 10%; and changes in the heavy-duty fleet to reduce its greenhouse gas emissions, including ships with "air lubrication" (a layer of bubbles that facilitates the hull's sliding on the water), wind propulsion (with rotary sails), and alternative fuels (such as LNG, already in use, and ethanol and ammonia, under development)[21].

Vale: the creation of an "Integrated Operations Center" (IOC) for real-time decisions based on AI data, a scalable technology for critical mineral projects, can be highlighted. The company also implemented drones at the Tubarão Yard, in the state of Espírito Santo, for the purpose of generating greater safety and efficiency in checking shipment in wagons.

The role of critical minerals

Energy transition

Mining is part of the solution to today's climate and environmental restoration challenges

A group of at least 37 minerals, such as copper, lithium, manganese, niobium and nickel (some of which occur in Brazil) have become strategic for being used in the manufacture of equipment for the energy transition, including solar panels, wind turbines, batteries and other components that make electric vehicles viable.

Some of these minerals are also used in cooling and air conditioning systems, which are necessary for adapting to the new climate reality in many parts of the world. Several of these minerals are also considered critical, as they face some material or potential restriction on production and sales.

For the world to join the net zero route (with net emissions equal to zero) by 2050, the demand for critical minerals would have to triple by 2030[22].

THE BUILDING BLOCKS OF ENERGY TRANSITION

37 minerals

at least, are necessary for renewable energy systems, according to the International Energy Agency (IEA).

The U.S. Department of Energy lists 50

THE LIST INCLUDES ALUMINUM, COBALT, COPPER, CHROMIUM, GRAPHITE (NON-METAL), LITHIUM, MANGANESE, MOLYBDENUM, NIOBIUM, NICKEL, SILVER, SILICON, TANTALUM, RARE-EARTH ELEMENTS (REE)* AND PLATINUM GROUP METALS (PGM)**

Sources: IEA, U.S. Department of Energy, World Economic Forum
*17 heavy metals, also called "rare-earth oxides": scandium, yttrium and the 15 lanthanides – lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium
**platinum, palladium, iridium, rhodium, ruthenium and osmium

The demand for lithium has already grown almost 30% in 2024, a much faster pace than the average of 10% per year recorded over the past decade. The demand for cobalt, graphite, nickel and rare-earth elements grew between 6% and 8%. The current trend is for a lithium supply deficit in the 2030's and, in a more severe situation, a 30% copper supply deficit by 2035[23].

Brazil is integrated into this scenario as a strength for global decarbonization. Brazil is already positioning itself as a relevant player in the mineral sector – the world's second largest exporter of iron ore and largest exporter of niobium. In 2023, it exported around US$4.2 billion in strategic minerals, with more than 50 projects in progress aimed at the production of lithium, nickel, copper, graphite, rare-earth elements, cobalt, niobium and vanadium. But this is only the current portrait of the situation.

For the future, Brazil is in a unique position to take a leading role: it holds from 10% to 20% of the global critical mineral reserves and the second largest reserve of rare-earth elements (23%). The world's largest niobium reserve is in Brazil (94% of the global total reserve), the third largest nickel reserve[24] (12%), the fourth largest manganese reserve (14%) and the fourth largest bauxite (9%) reserve.

The high potential has already been confirmed in terms of critical and strategic mineral reserves, and there is still 73% of Brazil to be mapped on a desirable scale, according to the Geological Service of Brazil (SGB).

Brazil is also the world's fifth largest producer of lithium, with 4,900 metric tons in 2023, and has the seventh largest reserve in the world. Brazilian reserves in rocks (spodumene) with high concentrations of the metal offer a competitive advantage in terms of exploration cost and feasibility, including lower water demand, when compared to brine reserves in South America.

The Jequitinhonha Valley, in the state of Minas Gerais, is establishing itself as a lithium hub ("Lithium Valley"), focusing on the chemical conversion to battery-grade lithium carbonate and hydroxide (with purity greater than 56.5% and greater value added than "technical grade" or "industrial grade" substances).

BRAZIL LEADS THE WAY IN CRITICAL MINERALS

ACCORDING TO PROVEN RESERVES IN BRAZILIAN TERRITORY (% OF GLOBAL RESERVES)

1º	IN NIOBIUM	89.9%
2º	IN RARE-EARTH ELEMENTS	23%
3º	IN NICKEL	12.3%
7º	IN LITHIUM	0.8%

Sources: Geological Service of Brazil, U.S. Geological Service

RARE-EARTH ELEMENTS AND CRITICAL MINERALS

Among the recent developments, a large deposit of rare-earth elements was confirmed in the Poços de Caldas region (state of Minas Gerais). Australia's Viridis and Meteoric have received authorization to operate in the area. Both projects contain many of the desirable features for the future of mining, such as the use of 100% renewable energy, the absence of tailings dams, water reuse, pit covering and plant cover[25]. In 2023 and 2024, more than 100 research requests were made to the ANM (National Mining Agency) in that region. The amount of US$1 billion in mining-related investments is estimated to flow to the region by 2028[26].

There is also a project under construction of Graphcoa, which intends to become Brazil's largest producer of graphite, a critical mineral for the energy transition, and to explore supply opportunities for battery anodes. The venture includes environmental and social variables since its conception.

Ibram estimates that, between 2025 and 2029, there will be US$15.8 billion in investments in energy transition minerals, including copper, nickel, bauxite, lithium and rare-earth elements, in addition to US$11.3 billion in meeting environmental and social requirements in the entire mining industry (these amounts are part of a total investment estimate of US$68 billion in the sector)[27]. This capital should boost the development of the internal value chain, according to researchers from the Department of Mining Engineering of UFMG.

Global battery and automotive companies (such as BYD, CATL, Volkswagen) are entering into partnerships in Brazil to secure mineral supply and develop local conversion processes. There is also support from international coalitions, such as the Minerals Security Partnership of the United States and the European Union, promoting rare-earth element projects in the state of Goiás with investments of around US$150 million. Some companies supply more elaborate products for export, such as carbonate hydroxide. There are still very promising experimental projects under development, such as the niobium battery from the partnership between Companhia Brasileira de Metalurgia e Mineração (CBMM) and Toyota, according to the Mineral Technology Center (CETEM), a research unit of the Ministry of Science, Technology and Innovation (MCTI).

Brazil also has several deposits with sufficient concentration of rare-earth elements for them to be extracted from tailings, as mining byproducts, through various remining processes. The procedure allows for additional production with lower environmental impact and is technically and economically viable in mines and mineral provinces in a stretch that crosses Brazil through the states of Amazonas, Rondônia, Pará, Goiás and Minas Gerais[28].

In addition to these natural occurrences there are Brazil's institutional constructions over decades: well-established diplomatic relations, a peaceful and conciliatory position in the geopolitical scenario, a mature regulatory framework for the industry, and sophisticated environmental regulation.

HOW MUCH MINERAL WE NEED[1]

INCREASE IN GLOBAL DEMAND

115% LITHIUM 2021TO 2024

6% NICKEL 2021 TO 2024

122% LITHIUM 2024 TO 2030

140% NICKEL 2024 TO 2030[2]

200% BY 2030 **300%** BY 2040

is the increase in demand necessary for the world to enter the net zero route by 2050

FOR EVERY 1 MW IN OFFSHORE WIND GENERATION, THE FOLLOWING ARE NECESSARY:

239 kg OF REE (RARE-EARTH ELEMENTS)

240 kg OF NICKEL

790 kg OF MANGANESE

8.000 kg OF COPPER

FOR EVERY 1 MW IN PHOTOVOLTAIC SOLAR GENERATION, THE FOLLOWING ARE NECESSARY:

1 kg OF NICKEL

30 kg OF ZINC

2,822 kg OF COPPER

3,948 kg OF SILICON

FOR EACH AVERAGE ELECTRIC CAR UNIT, THE FOLLOWING ARE NECESSARY:

8.9 kg OF LITHIUM*

13.3 kg OF COBALT*

39.9 kg OF NICKEL*

66.3 kg OF GRAPHITE*

Sources: IEA, APM Research Lab, U.S. Department of Energy, World Economic Forum, Wilson Center
(1) Examples of some of the metals necessary
(2) Demand from the renewable energy industry only
*In cars with combustion engines, these minerals do not play a role or they play an irrelevant role. This indicates the need to build new supply chains.

REGULATORY GAPS

But progress is needed: studies conducted by Ibram, CETEM and CEBRI reinforce the lack of a specific regulation for critical minerals. For strategic purposes, Brazil should have a differentiated concession system that reflects the government's priorities, such as a specific auction system, similar to what is currently applied to oil and gas. Regulatory advances could be included in the Critical and Strategic Minerals Bill proposed within the scope of the National Congress.

There are also fully solvable challenges related to the volume of resources for research and development, the use of Mineral Fund resources by research institutions and the use of environmental compensation resources by local governments, according to the Postgraduate Program in Infrastructure Engineering and Energy Development (PPGINDE) of the Federal University of the State of Pará (UFPA).

Recent policies such as Nova Indústria Brasil (Brazil New Industry) and development programs of the National Bank for Economic and Social Development (BNDES) and Financing Agency for Studies and Projects (FINEP) explicitly prioritize critical minerals, creating advantageous conditions for financing, innovation and support for the implementation of ventures. This prioritization can reduce entry barriers and accelerate early-stage projects.

Executive Order No. 10,965/2022 and ANM Resolution No. 95/2022 establish clear guidelines for Mine Closure Plans (PFM), that is, the plan for the future use of the area after the end of extractive activities, integrating environmental recovery from the beginning of the project. Furthermore, digital certification and transparency platforms, such as the Gold Transparency Portal (WWF) and Ibram's new system – PCRO, a platform to promote the responsible gold value chain – have the potential to scale up good practices and ensure trust in the mineral supply chain.

Brazil also has technological and logistical capacity due to its tradition in mining these inputs and a technology complex that is capable of supporting their responsible use. The niobium chain is a global benchmark in value adding.

With 90% of its renewable electric matrix (generated from sources such as hydroelectric, wind and solar), Brazil also has a significant competitive advantage in attracting investment in energy-intensive industries that are essential for the production of critical minerals with a low carbon footprint. The combination of digital technologies with sustainable mining practices can transform Brazilian mining into a low-impact benchmark in the production of strategic minerals for the energy transition.

Brazil's ambition is to position itself not only as a supplier of commodities, but also as a key player in global industrial chains and a maker of governance and traceability policies for these minerals. There is a strong focus on investing in mineral refining and processing to add value, reduce dependence on imports, and generate skilled jobs, including the development of technological pathways and attraction of high-tech industries, such as battery manufacturing. Promoting the circular economy, such as the example of steel and aluminum recycling in Brazil – a world leader in circularity in both chains – is a strategy to optimize the use of resources, reduce waste, and integrate the links of the value chain, according to Ibram.

CBMM provides a case study on the topic. Not only did it transform Brazil into a global leader in niobium, but it also structured a value chain based on innovation. The company has been investing in research for decades and collaborated with centers of excellence in Brazil and abroad to promote new applications of niobium in batteries, electric mobility, and sustainable construction. Its model is a benchmark in the creation of value added with sustainability, whereas its research is aimed at reducing cobalt consumption and accelerating rapid recharging. The company is also developing projects that seek to improve the performance of lithium-ion batteries that use niobium oxides. The results indicate promising advantages, such as greater thermal stability, significantly reduced recharge time and increased durability.

There are interactions with electric vehicle manufacturers to discuss applications in public transportation and heavy equipment, according to Poli-USP. A prototype electric bus with a niobium battery is scheduled for 2025, according to UFMG.

Also, according to researchers of this university, the federal government has been discussing policies to include strategic minerals in energy transition planning, with incentives for green lithium production, the creation of processing zones, and partnerships with countries interested in diversifying the global supply chain. The formulation of a robust and integrated National Policy for Critical and Strategic Minerals (PNMCE) is seen by Ibram as a crucial step for Brazil to use its potential and position itself as a leader in the new green economy.

GOVERNANCE AND TRANSPARENCY

For green mining to advance in a concrete and scalable way, continuous improvement in governance is essential. It is essential to strengthen inspection bodies (National Mining Agency, environmental bodies) and invest in remote monitoring and AI technologies for large-scale monitoring.

The integration of public policies on mining, the environment and territorial development is crucial for long-term planning and a balance between production and conservation. Another point is the strengthening of transparency mechanisms, such as public data platforms and mineral traceability.

The extraction of rare-earth elements involves environmental and social risks, particularly because many of these deposits are located in areas of high ecological sensitivity or close to vulnerable communities. To make production compatible with environmental conservation and social justice, rare-earth elements mining must be subject to territorial planning instruments, such as Ecological-Economic Zoning (EEZ).

This helps avoid conflicts with protected areas, ecological corridors and indigenous territories, while directing investments towards regions with lower environmental risk.

By being aware of the areas where minerals occur, it is possible to map possible mining operations that would have a lower social or environmental impact. Legal mining has a limited exploration area and the type of activity allows the area to be recovered as the project is implemented.

Furthermore, as indigenous leaders emphasize, projects must ensure active social participation and consultation with potentially affected communities, particularly in indigenous territories, either traditional or protected areas, in accordance with Convention No. 169 of the International Labor Organization (ILO). Strengthening local councils, expanding whistleblowing channels and ensuring access to public information are essential steps.

To ensure the safety and well-being of communities, the "social license to operate" (SLO) is also crucial, requiring open and transparent dialogue and the participation of communities in decisions about the future use of mined areas. According to Ibram, companies are encouraged to go beyond mandatory compensation, investing in local development, economic diversification, and professional training for communities, preparing them for post-mining.

We – Brazil and the world – are at a decisive moment: there are clear opportunities, but responsible mining needs to become the rule and a component of a fair energy transition, that is, with distribution of opportunities and benefits. This requires coordinated action between governments, the productive sector, academia, and society.

[solutions]

Promising outputs: sustainability, technology and value addition

The main technological innovations shaping the future of mining in Brazil include a deepening in the use of digital technologies, as Brazil is making progress in consolidating its role as a supplier of strategic minerals, in a growing effort to add value locally

Brazil presents promising solutions in the field of critical minerals, including applied research in sustainability and digital technologies, as well as in business models and value addition.

The main technological innovations shaping the future of mining include a deepening in the use of digital technologies – such as artificial intelligence (AI), machine learning (ML), the Internet of Things (IoT), big data, and analytics – to optimize processes and prospecting. Combined with automation, robotics, and autonomous vehicles, these technologies will provide new gains in safety, productivity and efficiency in the use of water and energy.

Meanwhile, with respect to business models and value addition along the supply chain, Brazil is making progress in consolidating its role as a supplier of strategic minerals, in a growing effort to add value locally. Companies are moving towards the chemical transformation of lithium, producing battery-grade lithium hydroxide and lithium carbonate, adding value locally. Furthermore, aluminum-can recycling in Brazil is a successful model in the circular economy *(learn more on page 169)*, with high recovery rates and reduced environmental impacts, which can inspire other sectors.

Brazil already partially supplies clean-energy value chains through the export of minerals such as lithium, nickel, copper, graphite, rare-earth elements and niobium. Although the export of mineral concentrates is still predominant, there are concrete signs of connection with global companies investing in Brazilian lithium and niobium projects with a view to local supply and processing.

Companies like Sigma Lithium focus on producing "green lithium," which attracts investment and differentiates the product in the international market. Expanding traceability and certification of sustainable origin is essential for Brazilian minerals to meet global demands for decarbonization and social responsibility.

Conservation, restoration and environmental management

Mitigation of impacts

Large mining companies operating in Brazil, despite working in mega-biodiverse areas, do not cause deforestation in large areas and have been demonstrating consolidated conservation and reforestation practices

Companies in the sector are accumulating knowledge to apply regenerative actions that restore degraded landscapes, control erosion, and promote water resilience, including water retention systems and reforestation with native species.

Additionally, mining activity can generate positive impacts as it shares information about the area. To operate, companies need quality local data on soil, topography, climate and any variables that may affect their productivity and assets. When used appropriately in partnership with local governments, companies from other sectors, and the third sector, this data can have a multiplying environmental and social effect by supporting various mitigation, adaptation, and land-use planning projects, according to the Humana consultancy.

Regarding restoration, Brazil has been significantly improving processes, in particular with the introduction of legislation on mine closure plans, aligned with international best practices, according to the Research Center for Responsible Mining of the Polytechnic School of the University of São Paulo (Poli-USP). The recovery or restoration of mined areas is always carried out on site, according to information from the Mineral Technology Center (CETEM), a research unit of the Ministry of Science, Technology and Innovation (MCTI).

The obligation to restore degraded areas is a requirement set forth by the Federal Constitution. This requirement refers to the area of influence of mining (direct or indirect), construction site and access roads. This total area must be recovered or rehabilitated to return to its previous condition or to a destination that is compatible with the region and the environmental quality parameters required for that area. This restoration will meet the criteria established in the licensing process, which appear as conditions with their own schedule to be met and measurable targets and results.

Topographical restoration, replacement of topsoil, erosion control, soil quality correction and revegetation are frequent activities adopted for the environmental recovery of mining areas. Environmental restoration and compensation practices have been effective in mitigating the impacts of mining, according to Ibram.

Practices for recovering degraded areas carried out from the beginning of the operation have proven to be more effective from both financial and environmental aspects. However, no matter how good the technique used in restoration is, it is hardly likely that the restored area will return to its initial condition, particularly in terms of biodiversity. With respect to deforestation, the trend is to reduce the area to be deforested as much as possible, both in access ways and in the area to be explored, and there is an effort to recover the degradation, simultaneously with the production process.

Therefore, according to CEBRI, recovery must be planned from the beginning of the operation, with the concept of progressive mine closure, including modeling of topography and plant cover to restore ecological functions; use of native species for reforestation; and transformation of areas into parks, artificial lakes or multiple-use ventures.

Regarding good initiatives outside mining areas, one of the most sophisticated cases is reported by Belterra Agroflorestas, a B corporation (Benefit Corporation, committed to generating positive social and environmental impacts). With an investment from the Vale Fund, Belterra has been implementing agroforestry and regenerative agricultural practices at six complexes in four states, reaching three biomes.

The proposal of the initiative, presented by the Vale Fund in 2020, is to reach 100,000 hectares. Belterra's operations, which now cover more than 6,000 hectares, started to have a multiplying effect by fostering new businesses related to reforestation.

Mature outputs: environmental compensation, vegetation restoration and strip mining

Among the already mature solutions in environmental conservation, restoration and management of areas impacted by mining are strategic environmental compensation, the so-called Mine Closure Plans (PFMs) and the practice of strip mining – which allows for the progressive mining of the deposit, followed by almost immediate environmental recovery of the mined area, while production moves to a nearby area.

In addition to on-site restoration, environmental compensation is required for significant impacts, in particular for licensed projects in areas of ecological significance. This compensation may occur in areas other than the mine, such as the creation or maintenance of conservation units; through investments in research, reforestation or recovery of springs in indirectly affected regions; or also through mandatory financial contributions, as provided for in legislation (Law of the National System of Conservation Units – SNUC).

Compensation generally does not occur in the mined area itself, but rather in locations defined as ecological equivalents or priorities for conservation, according to the environmental body's criteria. It usually occurs when it is not possible to fully meet the expected recovery, allowing the expected target for the restored or degraded area to be achieved.

Both restoration and compensation should preferably be carried out in the mined area or in a contiguous area, or in the same biome, or in the same river basin, so that the environmental results are comparable, that is, there is no environmental loss. When there is a possibility of loss, environmental compensation increases.

Several companies are committing to restoration targets that exceed those required for licensing, demonstrating responsible action or partnering with bodies in which common targets are set. In addition to on-site recovery, mining companies invest in environmental compensations to preserve or restore ecosystems in other regions, often linked to conservation units.

Meanwhile, the Mine Closure Plans (PFMs) introduce a fundamental change: environmental recovery and the future destination of the mined area are no longer a final stage and become part of the venture's life cycle itself, from its initial conception. This allows us to anticipate risks, mitigate impacts, and ensure that mining activities coexist with other forms of land use and biodiversity conservation.

Executive Order No. 10,965/2022 and ANM Resolution No. 95/2022, which regulates it, set technical guidelines and criteria, mandatory content, requirements for financial guarantees and deadlines for the presentation and updating of PFMs. Legislation requires that the recovery of degraded areas be planned from the beginning of the project as a part of environmental licensing and the Degraded Area Recovery Plan (PRAD).

Mine closure is a process that integrates sustainability criteria to mitigate environmental, social and economic impacts. Proper planning for closure and environmental rehabilitation are aimed at ensuring that the sector's legacy brings benefits to companies and society, according to Ibram.

Finally, strip mining is a well-established practice. The technique minimizes landscape impacts and erosion, in addition to facilitating the reintroduction of vegetation. It is applied not only in large-scale projects, but also in smaller-scale mines with good technical planning, according to the Humana consultancy.

EXAMPLES OF BUSINESS PERFORMANCE

Alcoa, Hydro and MRN - Mineração Rio do Norte: companies in the bauxite sector that successfully apply strip mining, carrying out progressive recovery and continuous monitoring of fauna and flora.

In the case of Alcoa, in Juruti (state of Pará), the company also implemented sensors to control soil moisture and drones to map and monitor rehabilitated vegetation. The results show that more than 80% of the mined area has already been rehabilitated or is in the process of recovery, a percentage that is considered a benchmark for the mineral industry.

Hydro Paragominas (state of Pará) uses strip mining combined with the tailing dry backfill methodology, returning inert tailings to already mined areas, which eliminates the need for new storage areas. The operation applies geotechnical and hydraulic control techniques to minimize soil compaction, which favors the return of biodiversity. The company has developed an Integrated Environmental Mine Management System, which enables the monitoring of the progress of rehabilitated areas using satellite images and artificial intelligence. The reforestation program follows the target of rehabilitating one hectare for every mined hectare, excluding infrastructure areas, within two years after mining. Between 2009 and 2024, Mineração Paragominas had rehabilitated 3,467 hectares[29].

Alcoa and **Hydro** maintain partnerships with local institutions specializing in the Amazon biome, such as the Museu Paraense Emílio Goeldi (Emílio Goeldi Pará State Museum), Brazilian Agriculture and Livestock Company (Embrapa), UFPA, and ICMBio, to monitor the fauna and flora in rehabilitated areas, with multiannual monitoring, which has shown a progressive return of the forest's original biodiversity.

Located in Oriximiná (state of Pará), **MRN** applies strip mining techniques with progressive recovery of tropical forest vegetation, a major technical challenge. The company conducts research with Embrapa and universities, focusing on the functional recovery of the ecosystem. More than 7,000 hectares have already been reforested, with continuous fauna and flora monitoring. This is a scalable and replicable model, including for strategic minerals with similar mining, according to the Research Center for Responsible Mining of the Polytechnic School of the University of São Paulo (Poli-USP).

The company's bauxite project, located in the Saracá-Taquera National Forest, occupies only 4.24% of the total area of this conservation unit. The mining company has several programs and initiatives in the Flona region to assist in forest conservation, with a robust action plan for seedling production and planting; flora and soil monitoring; tree and shrub species monitoring, among other actions that help forest restoration.

One of these initiatives is the development of the Flora Rescue, Salvage, Multiplication and Reintroduction Program (PRSF), to be implemented after the end of mining activities. Since 2016, MRN has been preserving botanical materials to compose its scientific collection. In total, 892 plant specimens have already been stored. This rescue activity interfaces with the Degraded Area Recovery Program, as it provides specimens for environmental enrichment of areas undergoing forest restoration.

Anglo American: has compensation programs that include ecological corridors and protection of springs outside operational areas.

CBA - Companhia Brasileira de Alumínio (Zona da Mata – state of Minas Gerais): the first mining company to receive, in 2025, the Declaration of Environmental Recovery of Mined Areas, issued by the State Environmental Foundation (FEAM) of the State of Minas Gerais, it is an international reference for implementing high-quality ecological restoration projects in medium and small-scale bauxite operations in the Zona da Mata region.

These projects promote the restoration of native vegetation, water protection, and integration with local communities, generating environmental and social benefits and contributing to the resilience of regions in the face of climate change. A study conducted in partnership with the Federal University of Viçosa (UFV) revealed the return of more than 60 plant species and 53 bird species following environmental restoration efforts[30].

CBMM (Araxá, state of Minas Gerais): the company preserves more than 1,200 hectares of the Cerrado (Brazilian scrubland) region, including areas for research and conservation of fauna and flora.

Mineração Taboca: develops technologies in partnership with Embrapii for the concentration and extraction of rare-earth elements (REE) from tin mining tailings[31]. This is a concrete solution that adds value to waste, reduces environmental impacts, and expands the use of strategic substances for energy transition.

Furthermore, the co-investment model of the Brazilian Industrial Research and Innovation Company (Embrapii), with more than 90 research centers and 162 ongoing projects in the mineral field, is consolidating itself as an effective way to boost technological innovation in companies of all sizes. Work on topics such as waste reuse, advanced mineral processing, and digitalization of operational processes is proving to be essential to align Brazilian mining with the demands of the energy transition.

MG LIT - Lithium Ionic (Jequitinhonha Valley – state of Minas Gerais): the company has been linking mining with environmental and social projects. In addition to investing

in solar energy to feed its operations, the company plans to invest R$ 750 million in the Jequitinhonha Valley, with a focus on job creation. The initiative also maintains a seedling nursery for native species with a focus on environmental restoration and education. So far, 1,200 seedlings have been planted[32].

Serra Verde (Minaçu – state of Goiás): the rare-earth elements mine applies cleaner technological routes, with the appreciation of by-products, reduced waste generation and low use of reagents. It planned the progressive environmental recovery of the mined area, inspired by prior experiences with phosphate and nickel.

Sigma Lithium (Jequitinhonha Valley – state of Minas Gerais): in addition to low-impact lithium mining, the company invests in reforestation and compensation programs in the Cerrado (Brazilian scrubland) areas, planting native species. This model is aimed at creating ecological corridors and promoting social inclusion in environmental restoration, integrating biodiversity and generation of income.

Vale - Águas Claras Mine (Nova Lima – state of Minas Gerais): after Vale terminated its iron extraction activities, the area underwent a process of soil rehabilitation and revegetation, with the introduction of native Atlantic Forest species. Today, part of the area is integrated into the green belt of the Belo Horizonte metropolitan region and is used for research, environmental education and leisure, being considered an example of sustainable reuse of the mined landscape.

Of the mine's total area of 1,908 hectares, 1,225 hectares are designated for environmental protection, including the Mata do Jambreiro Private Natural Heritage Reserve (RPPN), which covers 912 hectares and is an important remnant of the Atlantic Forest. The recovery of the mine area also includes geotechnical works to ensure the safety of mining structures, according to the company.

Vale - Carajás Complex (state of Pará): the company helps protect and manage the Mosaico region, a group of six conservation units in the South and Southeast of the state of Pará that is home to the largest continuous area of Amazon rainforest in the region. Additionally, it promotes the reforestation of pasture areas in Serra Sul, creating ecological corridors and restoring fauna and flora. The company uses species that are native to the region, such as those from the Carajás National Forest, for planting in Permanent Preservation Areas (APP). The Mosaico region is a crucial part of Vale's plan to protect 1.2 million hectares of forests "outside the fence."

In the Carajás region, the protected area is 800,000 hectares and the operation has an impact on 3% of this area (or, due to the mining operation, 97% of the area, 776,000 hectares, are protected). The model includes monitoring in partnership with ICMBio and an "economic occupation" of the area that creates jobs and reduces the room for illegal activities. The company is committed to protecting and restoring an additional 500,000 hectares of biomes in Brazil, with a focus on the Amazon, by 2030; and reached an additional 220,000 hectares in 2024 (200,000 of which are for preservation and 20,000 for recovery).

Credit in the markets

Brazil is a fertile ground for the implementation of projects aimed at generating carbon credits, due both to its extensive tropical forests area and its potential to generate energy from renewable sources and to the development of an arsenal of agricultural techniques that capture and store carbon. The legal framework sanctioned in 2024 is yet to be regulated but is already a climate policy instrument that is expected to engage the private sector, funds and governments

From the former Kyoto Protocol to the very current ecosystem restoration projects, the carbon market increasingly establishes itself as a climate-policy instrument of conservation and of financing the transition to an inclusive and low-carbon economy. Brazil is a fertile ground for the implementation of projects aimed at generating carbon credits, due both to its extensive tropical forests area (*learn more on page 57*) and its potential to generate energy from renewable sources (*learn more on page 93*) and to the development of an arsenal of agricultural techniques that capture and store carbon (*learn more on page 27*). Due to these competitiveness factors, it tends to establish itself as provider of solutions in this field inside and outside Brazil, in particular due to having already accumulated experience in projects that have been generating carbon credits since the 2000's, to already having a voluntary market in operation and to the new legal framework on the regulated market, approved at the end of 2024.

The origin of the carbon market dates back to 1997, at COP 3, held in the city of Kyoto, Japan, when the signatory countries to the United Nations Framework Convention on Climate Change (UNFCCC) agreed to assume more rigid commitments to reduce greenhouse gas emissions. The Kyoto Protocol was the first global agreement aimed at this purpose and established, for the first time, a greenhouse gas emissions trading system. Under this system, countries could trade bonds called Certified Emission Reductions (CERs), giving rise to the first carbon credits. Many of these credits were generated through the Clean Development Mechanism (CDM) aimed at developing countries that voluntarily invested in emission reduction projects.

CARBON PRICING IN THE WORLD

THE MAP SHOWS JURISDICTIONS THAT HAVE IMPLEMENTED CARBON PRICING INSTRUMENTS, SUCH AS COMPLIANCE INSTRUMENTS (ETS* OR CARBON TAXES) AND/OR VOLUNTARY CARBON MARKET MECHANISMS

MECHANISMS
Compliance instruments**:

- 37 ETS
- 43 Carbon taxes***
- 33 Voluntary mechanisms****

113 TOTAL

WHERE ARE THEY APPLIED?

- 55 National jurisdictions
- 44 Subnational jurisdictions

REVENUE GENERATED IN 2024

- US$ 69 billion EU ETS
- US$ 33 bilhões Carbon taxes

US$ 102 billion TOTAL

PRICES
(1 credit = 1 t CO_2e):

US$ 0.1 <···> US$ 158.8

TOTAL EMISSIONS COVERED BY COMPLIANCE MECHANISMS:

14.7 $GtCO_2e$ <···> 28% of global GHG emissions

- 23% ETS
- 5% carbon taxes

Source: World Bank
*Emissions Trading Systems. With these, governments impose a limit to the amount of GHG emissions from the entities covered. Entities must submit emission units (or "allowances") to cover their emissions within a compliance period. Each emission unit represents the right to emit a given volume of emissions (typically 1 tCO2e) and may be traded between the covered entities or, sometimes, with other traders.
**Compliance instruments include Emissions Trading Systems (ETS) or carbon taxes, in which covered entities are required to pay for emissions from their economic activities. Participation in carbon credit allocation, on the other hand, is optional, with participants earning "credits" in recognition of quantified and verified emission reductions or removals.
***Carbon tax: Through it, the government charges covered entities a fee for their GHG emissions, providing a financial incentive for emission reduction. In this type of tax, the government sets the price of emissions (the tax rate). The resulting volume of emission reductions achieved by the policy is determined by the response of the emitting entities to the set price.
****In the scope of a carbon credit mechanism, tradable credits (representing 1 tCO2e) are generated through voluntary emission reduction activities. Carbon credits are issued for activities that reduce emissions, according to protocols aimed at ensuring that each credit represents a genuine reduction in emissions. The credits may then be sold to buyers, generating revenue.

Therefore, since Kyoto, the first regulated carbon markets have arisen, where only the developed countries had emission reduction targets and, to this end, they could buy credits from developing countries through CDM projects, such as reforestation, energy substitution or carbon capture in sanitary landfills, for example. Carbon has become an exchange currency for the purchase and sale of credits between countries, so that each credit is equivalent to one metric ton of carbon (and other greenhouse gas equivalents) that was no longer released in the atmosphere. Trading in the scope of the Kyoto Protocol lasted 20 years until the Paris Agreement, which was signed at COP 21 in 2015.

Brazil, by the way, was the first signatory country to the Kyoto Protocol to internally regulate the treaty and also the first to have a CDM project registered at the UN – of energy recovery from biogas in the sanitary landfill of Nova Iguaçu, state of Rio de Janeiro, in 2024. The experience with the CDM was a major milestone for both Brazilian diplomacy, which led the negotiations over the topic, and Brazilian society as a whole, which started to see this carbon pricing process as an opportunity to also attract investments and generate wealth linked to environmental protection. This rationale endured and expanded with the approval of the Paris Agreement, which established even more sophisticated mechanisms in terms of cooperative approaches to mitigate emissions – since Paris, all countries started to sign environmental commitments, presupposing common responsibilities, although different ones.

After the U.S. subprime mortgage crisis in 2008, the market was impacted by the instability of prices, and the evolution of negotiations about climate change itself changed the scenario, so that the developing countries also started to assume commitments to reduce their own emissions. However, the bases for the many carbon pricing initiatives to be adopted by countries, regions, and cities had already been launched.

According to the World Bank, the world currently has 113 carbon pricing initiatives,

VOLUNTARY MARKET

VCR* PROJECTS REGISTERED IN SOUTH AMERICA AND WORLDWIDE

Brazil is a leading player in the voluntary carbon market in South America, accounting for 40% of total projects and 25.6% of annual emission reductions.

Asia leads the global landscape, accounting for 68% of projects and 59% of annual emission reductions, with a predominance of renewable energy projects.

Source: Systemica/ Aliança Brasil NBS
*VCR = Acronym for Verified Carbon Standard, or projects accredited to offer credits in the market

divided into compliance instruments and voluntary mechanisms. The first group includes emission trading systems (ETS) and the taxes on carbon that together generated a revenue of US$102.2 billion in 2024 and covered 28% of the global greenhouse gas emission *(see infographic).*

On the other hand, the voluntary carbon market mechanisms were simultaneously created – and inspired based on the regulated market. In this market, companies and subnational governments can trade carbon credits in a bilateral relationship and not subject to regulation. It is based on the acquisition of carbon credits with no legal obligations towards emission reduction, with entities committing to voluntarily offset the CO_2 emitted into the atmosphere.

Brazil is a leading player in the voluntary carbon market in South America, accounting for 40% of total projects and 25.6% of annual emission reductions. Most initiatives are REDD+, an acronym for Reducing Emissions from Deforestation and Forest Degradation which is an instrument created by the UN that provides for the payment for results in reducing carbon emissions associated with deforestation and forest degradation. Globally speaking, 68% of the projects that generate carbon credits aimed at the voluntary market are in Asia, in particular renewable energy projects, with 59% of the annual reduction emissions.

Legal framework expands possibilities

The opportunities in the carbon market in Brazil are expanding even further after the definition of the legal framework, which took place in December 2024 after the sanctioning of Law No. 15,042/24.

Approved by the National Congress after a long negotiation period, in different documents, the law establishes the bases for the regulated carbon market in Brazil by allowing the emissions of pollutant gases to be converted into tradable financial assets, increasing the possibilities of attracting foreign investments.

The legal framework creates the Brazilian Greenhouse Gas Emissions Trading System (SBCE) and sets greenhouse gas emission targets for economic activities that will be covered by law – emitters of over 25,000 metric tons of CO_2 equivalent/year, which is expected to include industrial, energy, transportation and waste sectors. Accordingly the companies that do not reach their reduction targets may buy emission allowances named Brazilian Emission Units (CBEs) of companies that are under the limit.

This mechanism, which is internationally known as cap-and-trade, enables a system of purchase and sale of these emission units in which the government determines the total cap of emissions allowed for Brazil. With the regulation of this market, Brazil starts to have a mandatory and supervised system, unlike the voluntary market, where the participation of companies is not mandatory. The SBCE is expected to operate also as a green competition tool by encouraging investments in low-carbon production technologies, whereas those that are emission-intensive will be subject to additional costs.

Developed with the participation of sector entities and the private sector, the law stimulates the participation of companies in the decarbonization agenda. In 2016, soon after the approval of the Paris Agreement, the debate about the establishment of a carbon pricing instrument in Brazil gained more ground in the public agenda, opening a door for entities from the corporate sector to take a stand.

One of the most active was the Brazilian Business Council for Sustainable Development (CEBDS), which, in 2017, released an open letter together with the Business Initiative on Climate (IEC) showing the support of the private sector to carbon pricing in Brazil, which was signed by 25 CEOs and CFOs of large Brazilian companies. The document

The SBCE is expected to operate also as a green competition tool by encouraging investments in low-carbon production technologies, whereas those that are emission-intensive will be subject to additional costs.

delivered to the then Minister of the Environment, José Sarney Filho, made room for a more in-depth discussion between the corporate sector and the Brazilian government on this topic – but it was not yet clear which type of instrument would be more adequate to the Brazilian context.

The debate evolved after the conclusion that a regulated carbon credit market would be the best regulatory model to handle the issue due to the cost-effectiveness of this system, which allows for a lower-cost decarbonization trajectory for economy as a whole, and to Brazil's recent experience with the Clean Development Mechanism in the scope of the Kyoto Protocol, which enabled the trading of credits from clean energy projects.

Until its approval, the current legal framework was negotiated for four years at the two houses of the Legislative Branch and is seen today as one of the pillars for Brazil to reach the target contained in the new Nationally Determined Contribution (NDC) presented at COP 29, in Baku, Azerbaijan. Brazil's commitment to the Paris Agreement provides for the reduction between 59% and 67% of its emissions by 2035 as compared to 2005, and the expansion of the carbon markets is one of the strategies to reach it. The regulated carbon market is also one the items that compose the Ecological Transformation Plan led by the Ministry of Finance.

STAGES

The implementation of the SBCE will be gradual, divided into five main stages so that the expectation of the federal government is that the regulated carbon market is fully operational within five years. This controlled transition, according to the Ministry of Finance, seeks to ensure predictability and legal security for regulated companies and avoid sudden impacts on economy, offering companies the opportunity to gradually adjust to the new regulation. The stages are as follows:

Stage 1 (12 to 24 months after approval):
Initial regulation, creation of the management body and definition of the sectors that will be regulated. At this stage, the definition of the operational details of the system and the legal bases for the operation of the market are also provided for.

Stage 2 (12 months):
Operation of the monitoring, reporting and verification system (MRV) of greenhouse gas emissions. It is through this system that companies will report their emissions in a standardized manner, creating a database that will allow market inspection.

Stage 3 (24 months):
This will mark the beginning of the obligation of reporting emissions and monitoring

plans, which will provide the data for the first National Allocation Plan (NAP), which will determine the rules for the distribution of units and the initial volume available to the market.

Stage 4:
Beginning of the first cycle of allocation of Brazilian Emission Units (CBEs) and organization of the first auctions. At this stage, the NPA will be published and the first units will begin to be issued and traded with the participation of the regulated companies.

Stage 5:
Full implementation of the market, with the first auction of CBEs and the beginning of the secondary market, which will enable the trading among companies.

In practice, in the legally established schedule, the first two years will be dedicated to regulation; then, there will be a period for the creation of measurement mechanisms for the companies that emit more than 25,000 metric tons of CO_2 equivalent/year and only after that, the cap and distribution among the sectors will be defined with the National Allocation Plan (NPA). During this regulation period, Brazil will count on the technical support of the World Bank, which maintains a program that contributes to the development of carbon markets in many countries.

NEXT STEPS
In the current stage 1 (August 2025), the regulated carbon market management body, which will be a provisory extraordinary department within the Ministry of Finance, is being defined. This body will be responsible for carrying out the regulation of the Brazilian Greenhouse Gas Emissions Trading System (SBCE) for as long as there is not a definitive body to supervise the cap and trade system. The activities of this department include the beginning of the establishment of a central emissions record – which will work as a kind of an accounting book of the regulated market – and the creation of standardized models for the regulated companies to report their carbon footprints.

Once the department is set up, an Implementation Plan will be published – a detailed document prepared with the support of the World Bank, to guide the market agents through the different stages of the regulation. To complete governance, the federal government expects to establish over the coming months a Consulting Technical Committee and a Regulatory Affairs Chamber, which are also provided for in the legal framework.

At the same time, the Ministry of Finance is working on a proposal of a bill for the creation of a regulatory agency to assume the management of the regulated market – the ministry expects it to be operational at the same time as the National Allocation Plan, in stage 3 of the implementation. It will also be necessary to strengthen other bodies that are part of the carbon ecosystem and the future national authority, which will look after the following stages that involve the so-called interoperability between the regulated and the voluntary market, the authorization of international transfers and the eligibility of carbon credits.

Different markets should coexist

The recent experience with the Clean Development Mechanism (CDM) gave Brazil the capacity to develop carbon credit projects related to the energy field that recommend the replacement of more pollutant fossil fuels by other less pollutant and/or renewable fuels; renewable energy generation projects (wind farms, solar plants, biomass); recovery of methane in sanitary landfills and energy efficiency projects.

After REDD and REDD+, projects related to forest conservation and management took the lead in the voluntary market and also made room for restoration projects known as ARR (Afforestation, Reforestation and Revegetation), which are aimed at recovering degraded areas and ecosystems, such as forests, pastures and agroforestry systems). In the same flow, agriculture and livestock projects through which rural producers can generate credits are on the rise with the adoption of low carbon and regenerative agricultural practices, such as the use of bioinputs, no-tillage farming, crop rotation and integrated crop-livestock-forestry (ICLF) systems.

After the regulation of the legal framework, different carbon markets are expected to coexist in Brazil: the already operational voluntary market, the Jurisdictional REDD+, which is a new niche within the voluntary market *(see box)*, is taking its first steps, and the regulated market, via SBCE. In the opinion of experts, the legal security provided by the law will enhance markets in many ways, in particular with respect to integrity and transparency.

ACTIVITIES THAT MAY GENERATE CARBON CREDITS

SUPPLY (SELL SIDE):
Carbon credits may represent emission reductions achieved through prevention (preventing GHG emissions from entering the atmosphere) or removal (withdrawing GHGs from the atmosphere)

-RENEWABLE ENERGIES
-REDD+
-JURISDICTIONAL REDD
-NATURE RESTORATION
-ENERGY EFFICIENCY
-FUEL EXCHANGE
-CARBON ENGINEERING

DEMAND (BUY SIDE):
This may come from compliance instruments (ETS or carbon taxes that allow the use of offsets), countries with targets to meet under their Nationally Determined Contributions (NDCs) under the UN Framework Convention on Climate Change; voluntary offsetting (sometimes linked to internal carbon pricing), or results-based climate finance.

CONCEPTS:
REDD+: acronym for Reducing Emissions from Deforestation and Forest Degradation is an instrument created by the UN that provides for the payment for results in reducing carbon emissions associated with deforestation and forest degradation. REDD+ is a large portion of the carbon credits traded on the voluntary market in Brazil.

JURISDICTIONAL REDD+: an approach that works by accounting for emission reductions within the boundaries of a specific territory, whether a country, state or municipality.

Source: Proprietary, World Bank, Aliança Brasil NBS, B3

Voluntary market: the search for high integrity

In the case of the voluntary market, which has had some of its credibility damaged due to fraudulent episodes involving forestry projects, it is time to review methodologies and reduce the issuance of credits. This is the assessment of Aliança Brasil NBS (Nature-Based Solutions) (NBS Brazil Alliance), a group that brings together 15 members, including carbon credit project developers and third sector organizations, accounting for 70% of the carbon credits issued since 2022, linked to nature-based solutions and land use, agriculture and forests. According to Aliança, one of the signs that the voluntary market is entering a phase of greater maturity is the fact that the volume of issuance of new credits arising from forestry projects has been decreasing, whereas retirements (when the credit is used to make a compensation and goes out of circulation) are increasing.

According to an analysis made by Systemica[1] expert consultancy, in the first three months of 2025 the global issuance of new credits in the voluntary market reached 61.8 $MtCO_2e$ (million metric tons of CO_2e), a drop of 27.5% in relation to the previous year, driven mainly by a sharp reduction in the issuance of credits from nature-based solutions, particularly from REDD+ projects. In contrast, retirements exceeded 55 $MtCO_2e$, representing the fourth-highest quarterly total amount to date. The overall surplus remained just above 1 billion tCO_2e, with a slowdown in its growth rate. Based on current issuance and retirement trends, the surplus is projected to increase by less than 1% by the end of 2025.

The balance between supply and demand in the voluntary market suggests not market stagnation, but a search for higher quality

CARBON PROJETS LINKED TO LAND USE

In the alphabet soup of the United Nations Framework Convention on Climate Change, carbon projects linked to land use can fall under the Agriculture, Forestry and Other Land Use (AFOLU) category, which can follow different methodologies: avoided deforestation (REDD); avoided deforestation with community gains (REDD+); forest restoration (ARR), agriculture (ALM), and forest management (IFM). In Brazil, avoided deforestation (82%) and forest restoration (16%) projects are predominant, according to a 2023 study by Aliança Brasil NBS.

credits – or, in the segment jargon, high integrity. Today, the main buyers of these bonds are companies with climate-neutrality targets that are part of the SBTi (Science-Based Targets initiative) program, which brings together more than 10,000 companies worldwide and is aimed at mobilizing the private sector and financial institutions to commit to emission reduction targets aligned with the latest climate science and the objectives of the Paris Agreement.

Due to these commitments, the amount moved in 2024 was approximately US$1.4 billion in 2024[2], followed by a demand exceeding 180 million $MtCO_2e$ for the third consecutive year. Bloomberg's forecasts suggest a potential market value from US$500 billion to US$1 trillion per year, depending on the integrity of the credits.

The SBCE will enable a connection with the voluntary carbon market through compensations – known as offsets – which may "migrate" to the regulated market, provided they meet requirements to be described in future regulations. This is the so-called "interoperability" between markets. The legal framework already establishes that these should be credits with high integrity and additionality, originating from projects with methodologies recognized by the SBCE and with the guarantee that there is no double counting of credits. In the view of carbon market analysts, this interoperability should also contribute to provide greater robustness, legal security, and protection against fraud in the voluntary market.

THE VOLUNTARY MARKET IN NUMBERS

US$ 1.4 billion
AMOUNT MOVED IN 2024

+ 180 million
$MTCO_2E$ FOR THE THIRD CONSECUTIVE YEAR

US$ 500 billion to US$ 1 trillion/year
POTENTIAL MARKET VALUE, ACCORDING TO BLOOMBERG

Furthermore, it paves the way for the promotion of new decarbonization projects in varied sectors that will be able to offer credits in the system – not only in the segments that will have targets to meet, which should help Brazil achieve the targets contained in the NDC. For the Ministry of Finance, in parallel with reducing emissions in the most carbon-intensive industries, which will be regulated, the SBCE will encourage other industries to invest in decarbonization projects to feed the demand for credits. In the ministry's view, this will boost new production chains, science, and low-carbon innovation, creating a virtuous effect on the Brazilian economy. Including in the agribusiness sector, which was left out the regulated market but contributes with a share of almost 30% of Brazil's greenhouse gas emissions.

Stock markets getting ready

The stock market environment is already preparing for the increase in transactions involving carbon credits, whether through the voluntary market or credits after SBCE regulation. The Commodities & Futures Exchange (BM&F, currently B3) was a pioneer in the trading of credits from the former CDM in the 2000's. In 2010, B3 launched the Efficient Carbon Index, a portfolio of shares composed solely of publicly-held companies that carry out greenhouse gas emissions inventories. More recently, B3 began to trade Decarbonization Credits, or CBIOs (more in the box) on its over-the-counter market[3].

In 2023, B3 took a step forward and created its own carbon credit registration environment, along the same lines as it offers for other products of financial capital markets, and announced a partnership with ACX (AirCarbon Exchange), a global trading platform focused on environmental assets, headquartered in Singapore. The agreement was aimed at developing a platform for the carbon-credit market in Brazil that is integrated with the registration structure provided by B3, joining the two ends.

This means that B3 customers now have broad access to ACX's international trading platform. The partnership was made possible by BlockC, a blockchain technology company focused on the carbon market, which has been accumulating experience in the development of carbon projects with a focus on energy since the 2000's, when it operated under the name Ecoinvest.

HIGH INTEGRITY

Carbon credits that represent verified reductions or removals of greenhouse gas emissions, following the standards of ICVCM (Integrity Council for the Voluntary Carbon Market). To be considered as such, credits must also meet additional requirements that measure positive social and biodiversity impacts, in addition to economically benefiting the region where they are generated.

ADDITIONALITY

The reductions or removals from the mitigation activity must be additional – that is, they would not have occurred in the absence of the incentive created by the carbon market.

A look at the region

Most recent addition to the REDD+ system, Jurisdictional is a new approach that works by accounting for emission reductions within the boundaries of a specific region, which can be a municipality, a state or a country. In the scope of carbon markets, the jurisdiction is the regional basis on which deforestation reduction targets and carbon projects are established. This mechanism results from an improvement of the REDD+ concept for subnational levels, that is, aimed at states and municipalities – the central idea is that the resources generated through carbon credit projects subsidize public policies to combat deforestation and promote sustainable development.

The projects designed to date are based on the principle of payment based on results. The reduction assessment is made in relation to the amount of carbon that was emitted in the jurisdiction before the REDD+ project. These governments can then use Jurisdictional REDD+ funds to maintain protected areas, control deforestation, and improve policies of deforestation command and control, forest management, and containment of wildfires and forest degradation.

The principle of payment for environmental conservation results is not new – it was already present in public policies designed by Brazilian states such as Acre and Mato Grosso, which participated in the REDD+ Early Movers Program of Germany's KfW bank. What is new now is the growing interest of the private sector in the initiative, in particular through the voluntary carbon market, and the participation of civil society organizations as providers of technical support. With this push, several Brazilian states are designing their Jurisdictional REDD+ policies, such as Tocantins, Pará, Piauí, Maranhão and Amazonas.

RESULTS-BASED PAYMENTS IN THE FORESTRY SECTOR

The Warsaw Framework for REDD+, which establishes the requirements for the recognition of mitigation results in the forestry sector and for obtaining payments for REDD+ results at the national level of countries, was created in 2013 within the scope of the UNFCCC. Under this mechanism, proven forest carbon emission reductions are rewarded through "payments for results," where payment is linked to emission reductions measured against a jurisdiction-wide baseline. These payments are made for mitigation results, measured in metric tons of CO_2 equivalent, and are channeled through international sources, in particular the Green Climate Fund (GCF). Brazil has already received payments for results from its national REDD+ programs from GCF and from the government of Norway, through the Amazon Fund.

Examples of this new approach are the LEAF Coalition, which brings together governments and companies to finance forest protection, particularly in the tropical and subtropical parts of the world, and Switzerland's Mercuria Energy Group, which has businesses in the sale of oil and gas, electricity, biofuels, agricultural products and metals. In 2023, the group entered the carbon segment with the launch of the Silvania fund, focusing on investments in nature-based solutions. Among its businesses is the contribution to the Jurisdictional REDD+ program of the states of Tocantins *(learn more in the box)* and Piauí.

The LEAF Coalition (or Reducing Emissions through Accelerating Forest Finance[4]) is aimed at raising global climate ambition and contributing to halting tropical and subtropical deforestation and forest degradation by 2030. It is a voluntary global coalition that brings together companies and governments to finance the conservation of tropical and subtropical forests commensurate with the scale of the climate change challenge. The group of participants brings together the governments of Norway, South Korea, the United Kingdom, and the United States as donors and more than 30 major companies such as Amazon, Airbnb, Bayer, BCG, SAP, McKinsey, Nestlé, Salesforce and Unilever.

The initiative, which has already received 27 proposals from different jurisdictions, expects to mobilize US$1 billion in financial commitments, and US$270 million is already being allocated in contracts signed with Costa Rica, Ecuador, Ghana and the government of the Brazilian state of Pará.

COMMITMENTS AND RESULTS

27
PROPOSALS RECEIVED FROM DIFFERENT JURISDICTIONS

US$ 1 billion
EXPECTED IN FINANCIAL COMMITMENTS

US$ 270 million
ALREADY ALLOCATED IN CONTRACTS SIGNED WITH COSTA RICA, ECUADOR, GHANA, AND THE GOVERNMENT OF PARÁ

JURISDICTIONAL REDD+: ORIGINALITY, COMPLEXITY AND VARIETY OF SOLUTIONS

The Jurisdictional REDD+ has entered the radar of Amazonian states, which are structuring policies aimed at a mechanism that makes the resources generated from the sale of carbon credits subsidize initiatives to combat deforestation and promote sustainable development and the bioeconomy. Today, eight states in the Legal Amazon, as well as Piauí, are at different phases of policy development, with Tocantins and Pará leading the way, with negotiations that have already been closed.

Pressured by high rates of deforestation and expansion of the agricultural frontier in the region known as Matopiba[6], the state of Tocantins took the lead among Brazilian states in structuring a Jurisdictional REDD+ program. The basis for this were two legal frameworks: the first, established in 2008, was the State Policy for Environmental Conservation and Sustainable Development (PEMC), which paved the way for REDD+ initiatives at the state level and authorized Tocantins to trade carbon credits in national or international markets.

The second legal framework was the State Policy for Payment for Environmental Services (PEPSA), published in 2023, which described the state's purpose of recognizing efforts to reduce emissions and conserve carbon inventories in native vegetation in its two biomes, the Cerrado (Brazilian scrubland) (present in 91% of its area) and the Amazon (9%). Tocantins has also made climate commitments to reduce forest carbon emissions.

To generate jurisdictional credits, the state government implemented actions throughout the area to systematically reduce deforestation and forest degradation, with plans to prevent fire and encourage low-carbon agriculture (ABC+TO Plan), and created a governance structure that could guarantee the participation of stakeholders – from large rural producers to family farmers, indigenous peoples, quilombola communities and traditional populations.

Then, a baseline was established to calculate actual reductions in forest carbon emissions, based on the average historical emissions from deforestation and degradation caused by wildfires from 2015 to 2019. In practice, the difference between the annual deforestation recorded after the implementation of REDD+ and the baseline corresponds to avoided emissions, which are converted into carbon credits for trading.

The next step was to check, through an independent audit, whether the methodology met the requirements of the ART Trees standard – the most recognized for Jurisdictional REDD+ projects since it encompasses more rigorous social safeguards. After this stage, Tocantins was the world's first subnational jurisdiction to file the registration document with ART Trees, in November 2024, during COP 29, in Baku, Azerbaijan. It brought with it a 44.3% reduction in deforestation between June and October 2024 in relation to the same period of the previous year.

To develop the project, the government of the State of Tocantins entered into a partnership with the Swiss commodities and energy company Mercuria Energy Group, which contributed with R$ 20 million to the initiative and, as a trader, will be able to sell the credits resulting from this venture. Mercuria, through its independent fund Silvania, will acquire credits generated by the state until the end of the decade, with a potential projection of more than 50 million credits, which can represent an estimated additional revenue of more than R$ 2.5 billion by 2030.

The resources will be invested in Tocantins' own environmental public policies, generating a virtuous cycle, and will also fund the sharing of benefits from the sale of credits. The state government is in the final stages of a total of 52 workshops with traditional peoples, agribusiness, and public bodies to determine the best way to allocate the resources, seeking to actively listen to the communities involved. One of these hearings, held at the end of July, was with the indigenous population of the Karajá ethnic group, on Bananal Island, within the process of free, prior and informed consultation of Convention 169 of the International Labor Organization (ILO)[7] – one of the safeguards required by the certification process.

According to the Environment and Water Resources of Tocantins State Department (Semarh), the state's Jurisdictional REDD+ project brought visibility to the environmental policy of the state, which has been consulted on the topic by other regions inside and outside Brazil. It also opened doors to new partnerships for restoration projects, such as an agreement to reforest 12,000 hectares in Cantão State Park, a transition zone between the Cerrado, Pantanal (Brazilian wetland), and Amazon biomes.

A HISTORIC AGREEMENT

In September 2024, the government of the State of Pará signed a historic agreement to sell nearly R$ 1 billion in carbon credits and secure funding from the LEAF Coalition to support its efforts to reduce deforestation. The state government entered into an agreement with Emergent, coordinator of the LEAF Coalition, which provides for the purchase of up to 12 million high-integrity forest carbon credits generated by reductions in deforestation in Pará between 2023 and 2026. Each credit, which represents one metric ton of carbon emission reductions resulting from cuts in deforestation, will be purchased at the price of US$15 per metric ton.

Starting this year, the resources will be used to finance programs aimed at reducing deforestation, as well as supporting the way of life of traditional peoples and sustainable development. These programs will equitably share the economic benefits with indigenous peoples, quilombola communities, extractive communities, and family farmers that are on the front line in the fight against deforestation. The idea is that 85% of the resources will be transferred directly to these populations, with a fraction allocated to protection and regional planning actions.

Land use changes and deforestation accounted for 74.8% of Pará's greenhouse gas emissions between 2018 and 2022. Through the Amazônia Agora (Amazon Now) State Plan (PEAA), the main platform for fighting forest loss, the state was able to reduce deforestation rates by 21% in 2023 compared to the previous year, signaling a real possibility of achieving the state's goal of reducing emissions by 37% by 2030. The Jurisdictional REDD+ program thus contributes to this goal since the progressive reduction of deforestation rates in Pará requires the structuring of a climate financing strategy that promotes the continued reduction of deforestation rates while fostering changes in the production matrix, promoting new economic activities based on standing forests, such as the bioeconomy.

Forest restoration is the hot topic – and other trends

The carbon market is one of the catalysts for ecosystem restoration and recovery projects, known by the acronym ARR (Afforestation, Reforestation and Revegetation), which are gaining momentum. Companies and startups focused on projects of this nature have been created in the past five years, fed by resources from investment funds, development banks, and large companies, attentive to the potential for both mitigating emissions and increasing the value of forest assets. Brazil's commitment under the Paris Agreement to restore 12 million hectares of vegetation by 2030 and the offer of concessions of public forests with degraded areas for restoration to the private sector – with credit lines from the National Bank for Economic and Social Development (BNDES) dedicated to this purpose – also contribute to the recent boom in restoration initiatives.

The ARR projects are aimed at restoring degraded areas and ecosystems, such as forests, pastures and agroforestry systems (AFS), and intended to remove carbon from the atmosphere – unlike the REDD+ projects, which seek to prevent deforestation and degradation. Restoration projects require long-term contracts and tend to be more expensive to implement because they require the acquisition or lease of land, and involve costs related to protecting the areas, planting seedlings (inputs, labor), sowing and carrying out natural regeneration, among other techniques.

In the wake of restoration projects, agriculture and livestock projects are also emerging, where rural producers can generate credits by adopting low-carbon and regenerative agricultural practices, such as the use of bioinputs, no-tillage farming, crop rotation, and ICLF systems. Several of these technologies are already present in Brazilian agribusiness, but producers' interest in certifying them and selling credits in the voluntary market is still incipient.

However, as carbon measurement tools in agriculture improve, this horizon tends to expand.

Embrapa Territorial carried out a meta-analysis based on more than 30 scientific studies on carbon pricing in agriculture and livestock published between 2004 and 2024 in several countries and reached an estimated amount of US$11.54/tCO$_2$e[5] for Brazil.

RESTORATION: CREDITS FOR BIG TECHS

The voluntary carbon market has enabled investments in reforestation in the Amazon and the Atlantic Forest, with business models characterized by partnerships with funds and investors attentive to the opportunities of gains arising from the sale of carbon credits to large technology companies eager to offset their greenhouse gas emissions. With the advancement of artificial intelligence (AI) technologies, whose data centers require high energy consumption, the business has become even more promising as forest restoration projects are efficient in capturing carbon from the atmosphere.

Aiming at recovering 1 million hectares, re.green has nine forest restoration projects in its pipeline, distributed across four states – Bahia, Pará, Maranhão and Mato Grosso, totaling more than 30,000 hectares. Of these, 12,000 hectares are already in the process of active restoration, with almost 6 million planted seedlings. The company's business model consists of acquiring or leasing land, carrying out restoration activities – generally in areas with degraded pastures – capturing carbon and selling the credits in the voluntary market.

The company has been entering into agreements with major technology companies, including Microsoft, for the sale of 3 million carbon credits resulting from the reforestation of 16,000 hectares in the Amazon and the Atlantic Forest. Another important agreement was entered into with Nestlé and provides for the restoration of 2,000 hectares in the south of the state of Bahia by planting 3.3 million native trees, and the generation of 880,000 carbon credits over 30 years. This action is part of a strategy to support the food giant in adopting regenerative practices in the field, with a focus on cocoa and coffee producing regions.

In addition to trading credits in the voluntary market, re.green is betting on the future demand that may arise from both the regulated market in Brazil and the regulation of Article 6.4 of the Paris Agreement, which will enable the purchase and sale of credits between countries. In both cases, credits linked to carbon removals through restoration will need to be accepted into the cap-and-trade system – there is a proposal for the European ETS, for example, to accept up to 3% of credits from other countries starting in 2036.

According to the Brazilian Agriculture and Livestock Company (Embrapa), this amount can serve as a reference for public policies to encourage the reduction of emissions in agribusiness and also for payment strategies for environmental services aimed at farmers.

The methodologies that support projects aimed at generating carbon credits are constantly evolving, so the main global companies that work with the standards of this market, such as Verra and Gold Standard, frequently update their list of new methodologies. Examples of this are the development of standards for issuing credits from biochar obtained from the pyrolysis of biomass, which can generate credits by quantifying the removal of CO_2 from the conversion of biomass into biochar and its subsequent application as soil amendments or in construction materials, such as concrete.

The methodology for CCUS – carbon capture, utilization, and storage, a technology known as CCUS – is also being reviewed. This technology provides for the reduction of emissions by capturing and locking in carbon in geological formations that are deep underground. These technologies are used by companies that produce oil and natural gas – such as Petrobras, which has distinguished itself due to a large CCUS program in the Santos Basin pre-salt layer.

Another unprecedented project in Brazil, currently under review, is the replacement of light bulbs in street lighting. Future Climate, a climate business platform that includes consulting, financing, and structuring of carbon credit projects across different fields, has obtained certification for a project with this profile, which is based on reducing electric energy consumption in two cities from Northeastern Brazil – Aracaju, in the state of Sergipe, and Feira de Santana, in the state of Bahia. By replacing traditional street lighting with LED lighting, cities not only improve their energy efficiency but also reduce greenhouse gas emissions and secure a new source of revenue from carbon credit trading.

The Public Lighting in Brazil Grouped Project is expected to avoid the emission of approximately 9,200 metric tons of CO_2 into the atmosphere per year in both cities, totaling 116,359 LED bulbs installed. In Aracaju, the replacement took place from 2021 to 2024 and 60,033 lighting points were replaced, resulting in a reduction in energy consumption of 67.2% (from 4,332,505 kWh to 1,420,952 kWh). Meanwhile, in Feira de Santana, more than 46,000 light bulbs were replaced, including the installation of lamps with chips for preventative maintenance. The projected financial savings in this municipality of Bahia was 50%. In addition to the savings, there is a modernization of the urban electrical grid and improvements in lighting, benefiting the population.

The project was registered and approved with the Verra certification company as a credit generator, and the next step will be an audit along the lines of MRV (monitoring, reporting and verification system. After approval of the data, the credits will be traded in the voluntary market. Since this is a "grouped" project, it allows for the inclusion of new cases — that is, other Brazilian cities that are replacing conventional, high-energy consumption light bulbs with more efficient LED bulbs. The reduction in energy consumption resulting from this modernization is what generates carbon credits and this inclusion of new cities is possible for initiative beginning on or after November 2021. The next city to be incorporated into the project's monitoring is Campinas (state of São Paulo).

Biodiversity credits

Another trend expected to take shape in the coming years is the development of methodologies that combine carbon removal with benefits for fauna and flora and generate tradable financial assets. One of the main experiences in this field comes from Australia, which created EcoAustralia, a program in which each credit is equivalent to one metric ton of carbon equivalent (CO_2e) of avoided emissions plus 1.5 square meters of native vegetation protected and accredited by the government – a measurement locally called ABU (Australian Biodiversity Unit). These credits may be traded in both well-established carbon markets and biodiversity offset purchase and sale system, created in 2016 in Australia to promote the conservation of areas of strategic ecological interest.

In Brazil, an example of a methodology that combines the measurement of carbon and ecosystem services is the PSA Carbonflor, developed by Eccon environmental consultancy and used by Legado das Águas, a 31,000-hectare preserved area of Atlantic Forest in the Ribeira Valley, in the south of the state of São Paulo, maintained by Reservas Votorantim. The project combines a payment methodology for environmental services with carbon removals through avoided deforestation (along the lines of REDD+), which generates credits called Carbon+ (C+) – that is, credits associated with biodiversity. To trade these credits, B3 created a registration environment for projects that generate credits associated with this new methodology.

Carbon market analysts are betting on a closer connection between carbon and biodiversity credits, driven by three main factors: the recognition of the economic value of biodiversity; the growing pressure on companies to fight their environmental impacts based on the new Global Biodiversity Framework (Kunming-Montreal Agreement), which established specific targets for the private sector; and the potential integration of biodiversity credits in emerging markets.

Although methodologies are still being tested and there is no international reference standard yet, the growing connection between climate and nature solutions paves the way for the construction of high-integrity biodiversity credit markets with environmental and social safeguards, considering the voices of indigenous peoples and local communities, with established minimum prices and updated international governance agreements.

Advances in modeling a global regulated market

One of the most celebrated outcomes of COP 29, held in 2024 in Baku, Azerbaijan, was the progress made in the negotiations of Articles 6.2 and 6.4 of the Paris Agreement, which broaden the horizons for the creation of a regulated global carbon market. Article 6.2 regulates ITMOs – an acronym for Internationally Transferable Mitigation Outcomes, a mechanism that allows countries to reduce emissions by investing in projects in other countries.

To use ITMOs to reduce their own emissions, it was necessary to advance the regulation, which happened in Baku. On the other hand, Article 6.4 seeks to define a centralized mechanism to certify ITMO projects and transactions. The expectation is that this regulation will advance further at COP 30 in Belém, making room for the expansion of the use of ITMOs to support countries in more ambitious NDCs.

The regulation of Article 6.4 of the Paris Agreement also provides for the allocation of a portion of the income from the generation of carbon credits to the Adaptation Fund created under the Climate Convention, the UNFCCC, to support strategies to adapt to climate change in vulnerable countries. This was already a prerogative of CDM projects in the Kyoto Protocol, which provided for a 2% rate applied to all Certified Emission Reductions (CERs) issued.

Over the course of about 10 years, CDM has allocated more than US$200 million of a total of more than US$1 billion in Adaptation Fund resources. In the Paris Agreement, the percentage allocated to the Adaptation Fund went up to 5% of the Emission Reduction Units (new name of the assets) generated within the new mechanism, which will be retained. According to experts, this is one of the ideas that can be "copied" by the Brazilian regulated carbon market, based on the SBCE regulation.

B3: CBIOS, A TRIAL BALLOON FOR THE REGULATED MARKET

The stock exchange was the pioneering environment in Brazil in the sale of carbon credits of the former Clean Development Mechanism (CDM), proposed by the Kyoto Protocol. The former Commodities & Futures Exchange (BM&F, now B3), auctioned, in 2007, a total of 808,400 carbon credits generated by the municipal government of the City of São Paulo. As a result of the control of methane that was no longer released into the atmosphere by the Bandeirantes sanitary landfill, which operated in the district of Perus, in the North Zone of the capital city of São Paulo, and which was subsequently decommissioned, the credits were acquired by Netherlands' Fortis Bank NV/SA, which paid R$ 34 million for the lot – the credit was negotiated at €16.20 per metric ton of carbon equivalent, 27.5% more than the minimum price.

More than a decade has passed before the capital market environment became the stage for another model for trading Decarbonization Credits, the CBIOs. Established in 2017 by Renovabio, a public policy aimed at expanding Brazilian biofuel production, CBIOs were designed as financial assets issued by ethanol or biodiesel producing companies that demonstrate greenhouse gas emission reductions and are certified by the National Oil, Natural Gas and Biofuels Agency (ANP).

In the market that came into effect in 2020, the buyers of these credits are biofuel distributors, as a way to reduce emissions from the sale of fossil fuels. For this year, ANP set a trading target of 40.39 million credits, and each CBIO corresponds to one metric ton of carbon that was no longer released into the environment. To make this environment operational, B3 created a registration environment focused on CBIOs, along the lines of other financial assets that traded on the stock exchange, such as debentures, derivatives and financial bills. B3 works as an infrastructure, recording and disseminating information on transactions that are carried out on the over-the-counter market, aimed at entities regulated by Renovabio. The actual buying and selling is carried out by financial institutions, and the assets can be part of funds and purchased by other investor profiles.

And, although CBIOs do not connect with the voluntary market carbon credits, the creation of a registration infrastructure allowed B3 to carry out a trial run of how a similar infrastructure could be used for the regulated carbon market. One of the changes introduced by the legal carbon market framework is the classification of Brazilian Emission Units (CBEs) as securities, a necessary step to expand the trading of these securities, as it occurs in more mature carbon markets. B3 is part of the working group that discusses details of the law's regulation and is expected to become a trading environment.

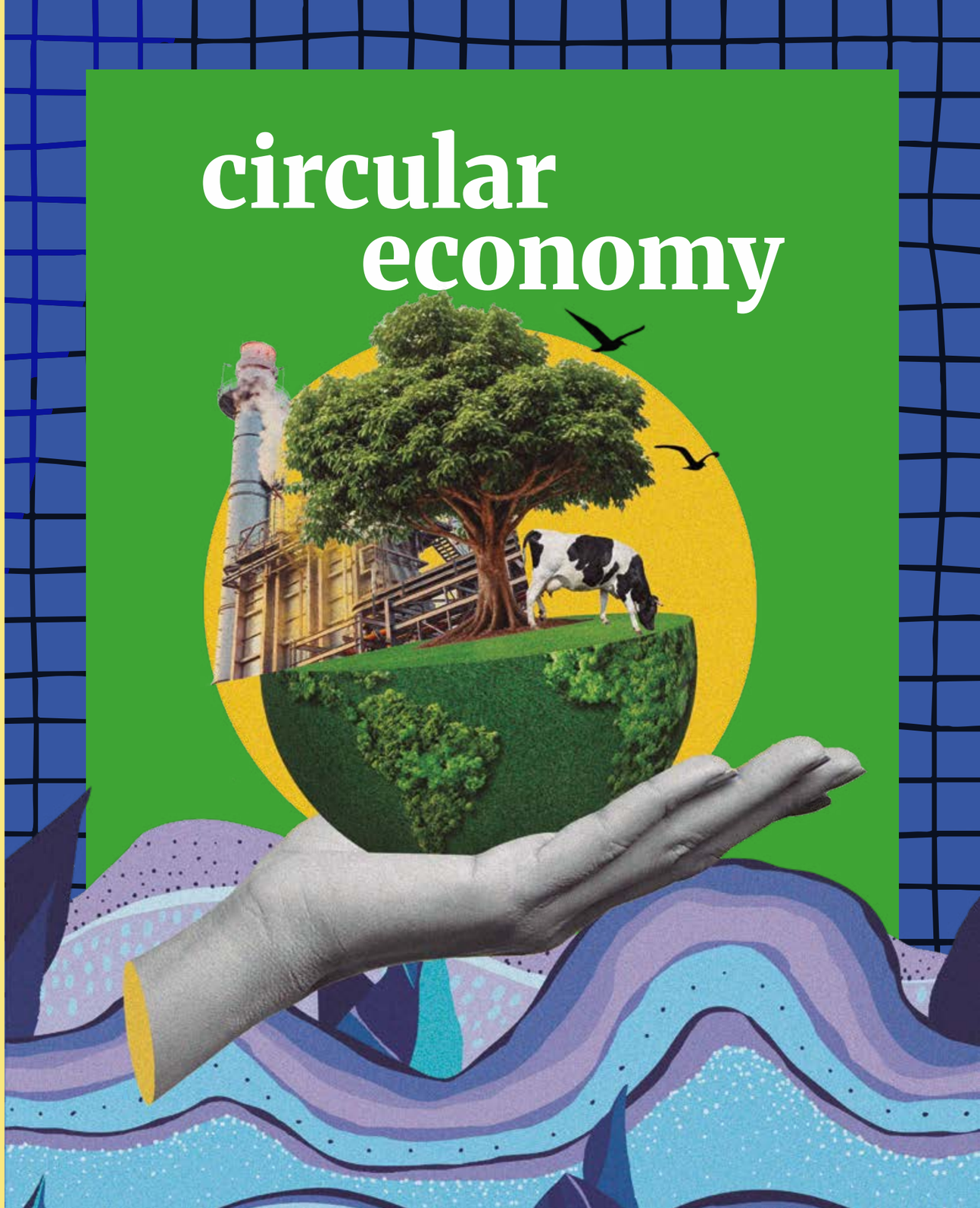
BLOCKC AND TEMBICI: SHARED BICYCLES GENERATE THE FIRST ACTIVE MOBILITY CREDITS

Shared bicycles from mobility company Tembici – known as "Itaú's little orange bicycles" – are already part of the landscape of large cities like São Paulo, Rio de Janeiro and Salvador, in Brazil, and Buenos Aires, Bogotá and Santiago, in South America. Used for both work and leisure, the bicycles were the subject of the first carbon credit auction by an urban micromobility company in the world in 2022.

Two lots of 750 carbon credit units were placed for sale, with a minimum bid of US$7 per unit, which is equivalent to one metric ton of CO_2e avoided, that is, which was no longer released into the atmosphere from the time the user chose a bicycle instead of a car. Although the volume of 1,500 credits was small compared to what is usually traded in voluntary markets, the initiative had an educational character and also inaugurated the Bolsa Verde do Rio (Green Stock Exchange of Rio), an initiative of the municipal government of the City of Rio de Janeiro to create a hub for trading environmental assets.

The idea of offering carbon credits came with Tembici's joining the Bikes for the Planet initiative – the world's first micromobility carbon credit generation project – for which the mobility startup has issued 2,400 credits certified by the international Verified Carbon Standard (VCS) since 2019.

Responsible for designing Tembici's strategy, BlockC, a company specializing in blockchain technology focused on the carbon market, also made the ACX (AirCarbon Exchange) platform available for the virtual auction, which had StoneX Financial and Climate Seed, both associated with the France's BNP Paribas bank, as buyers of the lots, at a price of US$8.50 per metric ton of carbon.



The necessary redesign

Except for isolated initiatives, circularity is still an incipient concept in Brazil. Recycling is the most advanced pillar, even though it is the last solution in a circular value chain. This situation may change, as Brazil expects to complete its set of crucial policies to leverage the model later this year

With great potential to mitigate the climate crisis, circular economy is based on three principles: eliminating waste and pollution, circulating products and materials and regenerating nature. The value contained in products, materials and natural resources must circulate in production processes for as long as possible, reducing the extraction of raw materials to a maximum and reducing the generation of waste as to a minimum.

Design, key to a circular economy, goes far beyond aesthetic or functional concepts. It is the phase in which the lifecycle of a product is defined, including environmental impact, durability, reuse, remanufacturing and recyclability.

CLOSING THE CYCLE

THE STAGES OF THE CIRCULAR ECONOMY

Source: European Parliament Research Service

THE KEY POINTS OF DESIGN IN THE CIRCULAR ECONOMY

Extending the lifecycle: increases the durability of products and makes repair or upgrade easier, reducing the need for frequent replacement.

Ease of reuse and recycling: considers materials that can be more easily disassembled, reused or recycled, avoiding loss and the generation of waste.

Choice of materials: chooses renewable or recyclable materials or materials with a lower environmental impact to reduce the extraction of natural resources.

Business model: rethinks business models that encourage reverse logistics and conscious consumption, such as service provision, rental or sharing.

Waste and pollution reduction: eliminates the concept of "garbage" by transforming waste into inputs for new products.

With a structure of systemic solutions to address global challenges, the circular economy contrasts with the linear economic model, limited to the logic of extraction-production-consumption-disposal, prevalent in the current production and consumption system. Public policies that are in force in Brazil and in much of the world still subsidize growth based on this mentality, encouraging the triple environmental crisis that humanity faces: global warming, pollution caused by excess waste in the environment and the loss of biodiversity on an unprecedented scale.

It is known that a large part of the solutions to mitigate climate change also involve the transition to renewable energy *(more on energy on page 93).* However, according to a survey by the Ellen MacArthur Foundation, although the energy transition is crucial for countries to achieve net zero emissions by 2050, as dictated by the Paris Agreement (2015), a fully renewable energy system will only account for 55% of the reduction needed to achieve the target. The other 45% of emissions are due to the linear structure of production and consumption of goods and food.

Circular economy is therefore the other key piece to the success of the Agreement.

A study called *Completing the Picture: How the circular economy helps tackle climate change* (2019)[1] estimates that the circular economy could reduce global industrial emissions by 40% – equivalent to 3.7 billion metric tons – by 2050 through two practices: keeping products and components active for longer through reuse and recycling; and eliminating waste through designs that reduce raw material extraction.

According to the Circle Economy Foundation[2], although circular economy has reached megatrend status – the volume of discussions, debates and articles on the concept has almost tripled in the past five years – global circularity is in decline. The Global Resources Outlook 2024[3], from the United Nations Environment Programme (UNEP), confirms that in fact there was a setback. The share of secondary materials (post-consumption materials, industrial waste, and scrap) consumed by the global economy fell from 9.1% in 2018 to 7.2% in 2023 – a 21% drop over five years.

CIRCULARITY NUMBERS

3x more talk
ABOUT CIRCULAR ECONOMY IN THE PAST FIVE YEARS — THE TOPIC HAS BECOME A MEGATREND.

From 9.1% to 7.2%
THE SHARE OF SECONDARY MATERIALS IN THE GLOBAL ECONOMY BETWEEN 2018 AND 2023.

21% decline
IN GLOBAL CIRCULARITY, ACCORDING TO THE 2024 GLOBAL OVERVIEW OF RESOURCES.

Source: Pnuma

In Brazil, except for isolated initiatives, circularity is still an incipient concept. However, this situation can improve, as the government expects to complete its set of policies needed to leverage the model by the middle of this year. Meanwhile, recycling continues to be the most advanced pillar of the circular economy, even though Brazil only transforms around 4% of discarded recyclable material.

According to the System of Estimates of Greenhouse Gas Emissions and Removals (SEEG), an initiative of the Climate Observatory, the waste sector accounted for 4% of Brazil's CO_2 emissions in 2021. A large part of these emissions was the result of the inadequate disposal of material in landfills, controlled landfills, sanitary landfills and the environment[4]. According to data from the Brazilian Institute of Geography and Statistics (IBGE), until 2023 landfills were still in use in 73.8% of municipalities in the Northern Region, 51.6% in the Northeast, 52.9% in the Mid-West, 12.1% in the Southeast and 5.7% in the South[5].

Common Seas, a UK organization that sees the circular economy as the solution to ocean pollution caused by the inappropriate disposal of plastic packaging, highlights that recycling is the last solution in a circular value chain. The main purpose is the durability of consumer goods and their return to the production chains of origin at the end of their lifecycle. However, in the absence of an integrated production process with repair, reuse and remanufacturing, recycling will always be preferable to disposal.

Laws and regulations must foster the transition

In the past two years, Brazil's regulatory distance narrowed in relation to the other Latin American countries in the race for economic circularity

Brazil is urgently seeking to establish its set of circular economy policies. As a result, it seeks to match its 16 Latin American neighbors that started this process in 2021 by joining the Circular Economy Coalition for Latin America and the Caribbean, a forum composed of governments, companies and academia to promote the transition from linear economy to circular economy.

At that time, the Brazilian government ignored the invitation from the United Nations Environment Programme (UNEP) to participate in the initiative, and only in 2023 it agreed to join the group of Latin American countries, including Mexico, Colombia, Chile and Argentina. In the past two years, Brazil's regulatory distance narrowed in relation to the other Latin American countries in the race for economic circularity.

The Bill that creates the National Circular Economy Policy (Bill No. 1,874) is currently being processed at the National Congress. The text addresses the circular economy as a systemic solution to the linear economic model and defines the bases for all institutional developments on the topic. The Bill has already been passed on an urgent basis at the Federal Senate and is now at the Chamber of Deputies awaiting a vote, also on an urgent basis.

In 2024, Brazil launched the National Circular Economy Strategy (ENEC), through presidential decree no. 12,082, indicating the directions for defining public policies. More recently, in February this year, the National Circular Economy Forum was launched, co-led by the Ministry of Development, Industry, Commerce, and Services (MDIC) and the Ministry of the Environment and Climate Change (MMA). This joint body is composed of 36 representatives from government, civil society and industry, to monitor and assess the implementation of ENEC.

Brazil is also making progress in the elaboration of its National Circular Economy Plan for the next ten years (2025-2034), which will guide the formulation of public policies by the federal government. The Plan was open for public consultation until March 19 this year and received 1,627 contributions from society, a volume that exceeded the expectations of the MDIC and other sectors of the government.

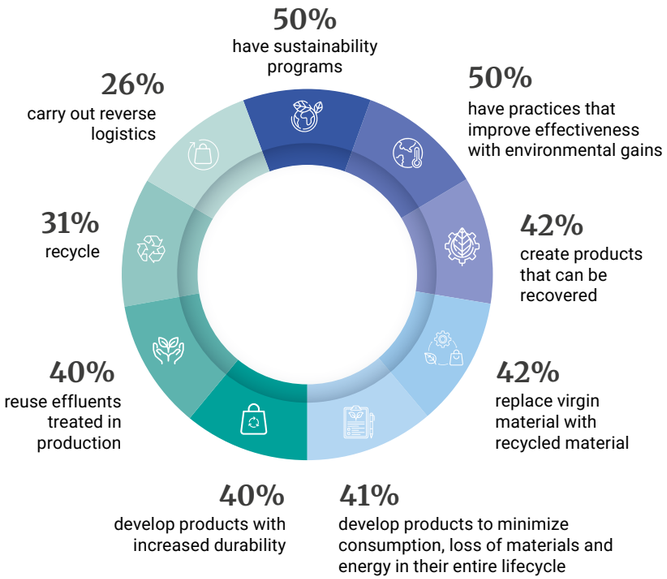
WHAT TO EXPECT FROM THE NATIONAL CIRCULAR ECONOMY PLAN

Launched on May 8, 2025, the National Circular Economy Plan is structured around five major axes. The first provides for regulatory improvement, with the formulation of laws and executive orders to accelerate and enable the transition of the economy. A second is aimed at fostering innovation, guiding government agencies that work with investments in R&D to introduce resources into initiatives to improve, for example, the design of materials.

In a third initiative, the Plan works with simultaneous solutions to reduce waste production, facilitate reverse logistics and fight planned obsolescence. The fourth axis is focused on the creation of financial instruments to leverage the transition and the fifth works on interfederative coordination – according to information from the Green Economy Department, there is a coordinated effort to close the almost two thousand landfills that are still in operation in Brazil. The idea is to connect municipalities to the circular economy strategy, contributing to selective garbage collection plans, establishing environmental awareness campaigns and, above all, strengthening cooperatives of recyclable material collectors.

STEPS OF BRAZILIAN INDUSTRY TOWARDS THE CIRCULAR ECONOMY

WHAT ARE THE MOST USED PRACTICES BY COMPANIES



Source: National Industry Confederation (CNI)

Reinforcing a trend for Brazil to lead the advancement of this transition in Latin America, the World Circular Economy Forum – the most emblematic event on the topic – was held in São Paulo between May 13 and 16 for the first time in a Global South country. The Federation of Industries of the State of São Paulo (Fiesp) hosted the meeting, conceived by the Finland's Sitra foundation and co-organized by the National Industry Confederation (CNI), Apex Brasil and Senai.

The fact that Brazil began formulating its public policies a bit later does not mean the topic has been "hibernating" in recent years. A milestone was the 2010 National Solid Waste Policy (Law No. 12,305), which differentiated reusable and recyclable waste from non-recoverable waste and established reverse logistics with proper final disposal, for example, of post-consumer pesticide packaging. Industry —especially multinational companies — as well as other sectors like agriculture and energy have also continued to seek innovations to make their value chains more sustainable, a fundamental step toward implementing a circular economy, though still at a pace below what is ideal given the climate urgency.

According to the National Industry Confederation (CNI), several Brazilian industries have already taken one or more steps towards the circular economy. The survey *Circular Economy: barriers, opportunities and practices in the industry*[6] shows that six out of ten Brazilian industries have already adopted at least one circular economy practice. The most frequent action is product recycling, which is present at one third of the companies surveyed. Next comes the use of secondary raw materials in production processes (30%) and the development of products with attention to durability (29%). The survey interviewed 1,708 companies from the extractive, manufacturing and civil construction industries between February 3 and 13, 2025.

The industry, which is central in the transition to a circular economy, points to some obstacles that prevent greater agility in the transition process, including regulatory barriers, such as the lack of incentives for the use of secondary resources; economic barriers, related to the need for high initial investments; technological barriers, related to the lack of solutions for new processes; and cultural and educational barriers, which involve resistance to changes and lack of knowledge about the advantages of the circular economy.

A previous investigation by CNI, conducted in 2024 with the industrial base in partnership with the Center for Research in Circular Economy of the University of São Paulo (USP),

found that 85% of them developed at least one circular economy practice. This survey interviewed 253 manufacturing and construction industries between May 17 and July 30, 2024. See in the image above how these practices are distributed.

According to CNI, the two surveys are not comparable, as the current survey prioritized circular economy practices with a greater degree of maturity, in addition to a greater number of participating companies.

The Ellen MacArthur Foundation believes that all the current movement involving the regulatory system, the large events and the broad participation of productive sectors and civil society, represent a watershed in the economic transition in Brazil. And the Foundation is not the only one to see changes on the horizon.

The report *How to Prepare for the Circular Economy*[7], released in February by the Circular Economy Hub, the Brazilian Institute of Circular Economy, and Exchange 4 Change Brasil, considers that, based on legislation favorable to the transition, the circular economy will become a strategic agenda for business and a powerful tool for achieving net zero strategies and tackling climate change.

RECYCLING, A PARTIAL SOLUTION

In Brazil, recycling has gained considerable room within the linear economic system as a partial solution for circularity. According to the Brazilian Recycling Atlas, for every ten kilos of recyclable material that enters the recycling industry, nine kilos come from the work of waste pickers[8]. This practice was encouraged by public policies, including as a form of social inclusion.

However, despite the important environmental service provided to society, the vast majority of this category does not receive any type of subsidy. Many of the approximately 800,000 Brazilian collectors live in a situation of insecurity or social vulnerability, due to the low value of scrap. The main flag of the National Movement of Recyclable Material Collectors is the payment for services rendered.

In the past few months, three state initiatives for the payment for urban environmental services emerged, in Minas Gerais, Ceará and Bahia. At the end 2024, the government of the State of Ceará implemented the Waste Picker Assistance Program (PAC), through which it provides a monthly financial compensation corresponding to ¼ (one fourth) of the minimum salary to more than 3,600 waste pickers, upon proof of a minimum monthly production of 500 kilos of recyclable material[9].

However, the National Solid Waste Policy (No. 12,305/2010) is vague on this matter. It only requires companies to encourage the work of recycling cooperatives.

At the same time, the state of Minas Gerais started to make a transfer, on a quarterly basis, to 72 waste-picker associations and cooperatives linked to the program and expects to help 1,421 waste pickers from all regions of the state[10]. In Bahia, the government recently sent a bill to the State Legislature that creates the State Policy for the Payment for Environmental Services.

Strengthening the circularity of the economy can also bring more stability to recycling industries, which face market volatility, in particular in the plastics sector. The cost of recycled plastic is higher than that of the virgin product, since it involves a complex collection, transportation and processing process. New policies for circular economy promise to review the taxation of the recycled material, that is, double taxation, since every discarded product has already been taxed at its origin.

EXTENDED RESPONSIBILITY

Common Seas advocates that reverse logistics involved in the circularity process should be subsidized, not by the government, but by manufacturing companies, as is already the case in European Union countries. This is the so-called Extended Producer Responsibility (EPR) law, according to which European production sectors must sponsor effective processes and infrastructure for collecting, sorting and recycling waste generated by their respective activities.

The European Community's regulatory framework is also imposing guidelines to promote the right to repair electric and electronic products. If Brazil were to implement a policy in this regard, it would have to overcome the barriers that make it more worthwhile to purchase a new product than to repair an old one: planned obsolescence, the high cost of spare parts and labor, and the poor training of technical support.

IS BIOPLASTIC A SOLUTION?

Plastic is a fossil-based product considered a major polluting villain of soil and oceans. Research on large-scale production of bioplastics of diverse plant origin, which promises to be a circularity solution for many companies, is advanced. But from the point of view of its compostability, not so much. Bioplastic, although it is plant-based, does not decompose easily in natural environments – in general, it requires controlled high temperatures, ventilation and humidity.

However, even though it is not compostable, it has positive impacts on the climate, by reducing the use of fossil raw materials, by using organic waste and by creating jobs and generating income for rural and extractive communities. However, in the context of the circular economy, the contribution of bioplastics ends there. In other words, if it is not compostable, the product is no different from conventional plastics in the post-consumer stage and, when mixed with fossil-based plastics, it can compromise recycling, since there is no way to tell them apart.

Research to make them compostable in the environment is in progress. The same occurs with fossil-based plastics that receive additives to accelerate their decomposition by microorganisms, the so-called biodegradable ones. Without well-managed degradation in a controlled environment, biodegradable plastics can quickly transform into microplastics, creating an even bigger environmental problem.

There is no definitive solution for the circularity of bioplastics yet, but when it comes, it will be much celebrated, mainly because it could eliminate once and for all the major villain among the polymers, the flexible plastic. With a very low recycling rate, it is the one that pollutes the environment the most[11].

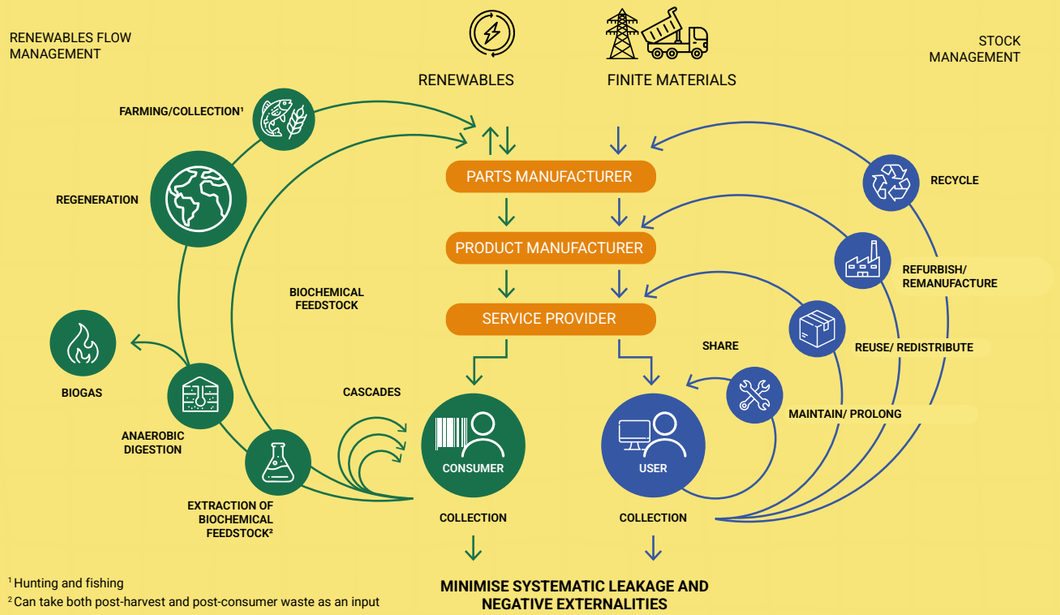
Technical and biological cycles

The circular economy presents emblematic examples in the technical cycle, although few in number.

According to the Ellen MacArthur Foundation, the flows of materials used in industry are divided into two cycles – the cycle of finite materials, called the technical cycle, and the cycle of biological materials, called the biomaterials cycle. The circular economy presents emblematic examples in the technical cycle, although few in number. Meanwhile, in the biomaterials cycle, the countries in the Global South, with much to teach and innovate in the field of bioeconomy, can become the epicenter of circular economy innovation to inspire and teach the world and transform their value chains.

THE FLOWS OF MATERIALS IN THE INDUSTRIAL CHAIN

HOW DO THE BIOLOGICAL AND TECHNICAL CYCLES RELATE



Source: Ellen MacArthur Foundation

The universal bottle

In the technical cycle, Latin America has the world's best example of packaging reuse, perhaps the only with proven gains in scale, which is the universal PET bottle developed by Coca-Cola in Brazil. This reuse system currently covers more than a third of the company's portfolio in Latin America and has a progressive impact on reducing emissions. The more the reuse system progress, the more Coca-Cola is able to reduce its emissions and drastically reduce the generation of waste and pollution.

An innovation of such scope was only possible because there was a Brazilian design project that created a universal bottle to be able to scale up the different products in the company's portfolio. If before there was a bottle design for each soft drink, a universal bottle that was the same for all products was defined. Thus, a logistics and a business model were then created, with benefits for the consumer as well, who, when returning the bottle to the point of sale, pays only for the liquid when purchasing a new product. The universal bottle can be reused 25 times before being recycled.

This is a highly scalable case that is gaining share of Coca-Cola's portfolio. The environmental benefits are clear and grow as it gains scale. From a business standpoint, it is also positive because, despite the high cost of operations, higher than in the conventional model, the company builds customer loyalty by reducing the price of the beverage. It is an important model for explaining how to scale a practice within the technical cycle, always bearing in mind that, without the redesign of the bottle, the project would not exist.

SCALABLE CASE STUDIES IN THE ELECTRONIC PRODUCTS INDUSTRY

There are scalable case studies, particularly in the electronic products industry, but which are less fundamental than Coca-Cola's because the design choices do not yet enable a more lasting circulation of materials. In the electronic products industry, it is common for design decisions to happen in one company, whereas the production is carried out at another company, and in these cases, establishing partnerships can be essential to create feedback on feasibility to increase circularity.

HP Brazil and Sinctronics Innovation Center, a provider of recycling solutions for the IT industry, established a partnership for a robust reverse logistics scheme to recover end-of-use electronic equipment and create value. Sinctronics has a system for tracking the lifecycle of its customers' electronic products. End-of-life products are collected and taken to the Sustainable Technology Innovation Center.

There, these products are recycled, but not in a downgrade system – when the material loses quality or usefulness in relation to its original state. The recycling technique applied maintains a high standard of quality of the material that can be reinserted into the production chain of origin, helping companies get closer to zero emissions targets. Sinctronics is able to reincorporate 97% of the collected materials and components, with a cost reduction of around 30% for HP[12].

REINSERTING WASTE INTO THE PRODUCTION CHAIN

At Dexco – a Brazilian multinational company that operates in several industries, such as industrialized wood panels, coatings, bathroom fixtures and fittings – the most mature initiatives aimed at the circular economy are related to the reuse of waste. The Matéria line, from the Castelatto brand, is a unique architectonic concrete coating developed based on circular economy principles. Its unique feature is the use of ceramic waste (called "pitcher") arising from the production of bathroom fixtures of the Deca brand, also owned by Dexco. More than 70% of the product's composition is made with reused materials, including parts with aesthetic defects that would otherwise be discarded. This reuse avoids sending waste to landfills and replaces traditional inputs, such as sand and stone, reducing the extraction of natural resources.

In the Wood division, the main raw material comes from forest plantations for the production of panels and generation of energy through biomass. The waste generated in the initial processing of wood (chopping and shredding) is used as biomass, whereas the waste generated in the manufacturing processes of MDP and MDF panels is reused for packaging, partitions or as an additional source of energy. In the Agudos, state of São Paulo, and Uberaba, state of Minas Gerais, units, the sludge from the Effluent Treatment Plant and the ash from the boilers are processed in internal composting plants and used as organic fertilizer in the forests.

In the packaging industry, Dexco also implements a compensation program for products that reach the end user through the acquisition of recycling credits – certificates issued by recycling cooperatives, which collect and dispose of waste equivalent to the volume of packaging sold.

BIOLOGICAL CYCLE, A WORLD TO EXPLORE

In the biological cycle, there is a world that is still little explored for the development of the circular economy. On the one hand, there is the emergence and advancement of circular economy policies and, on the other hand, the same thing is happening in the bioeconomy. Although these two sectors do not yet communicate with each other, the Ellen MacArthur Foundation sees this as a great opportunity for countries in the Global South to pay attention to these connections, not only because they are two "hot" areas in terms of public policies under construction, but because there are immense possibilities.

In the planted-forest sector, Brazil has examples of companies that are concerned with the elimination of pollution residues and the regeneration of nature. Suzano Papel e Celulose and Klabin apply regenerative and non-toxic methods in the production of eucalyptus for the generation of cellulose pulp and paper *(learn more about forests on page 57)*.

It is important to monitor how regenerative and compostable bioinputs circulate within subsequent chains, whether paper in the packaging sector, or cotton in the fashion design sector. The idea of the regenerative and non-toxic format is based on a return to nature to restore the soil's natural capital. Circularity is "broken" when, for example, chemical additives such as dyes and pigments are applied on these materials.

Other examples of a circular economy with a biological cycle come from the Connect the Dots (LoP) project, an initiative created to promote the sustainable development of a rural area in the extreme south of the city of São Paulo, which became an important example of circular economy. The LoP supports around 160 local farmers in the transition to regenerative agricultural practices and the result is a local production of high-quality food that restores the soil's health, promotes biodiversity, helps fight climate change and eliminates or reduces the use of synthetic fertilizers and pesticides[14].

The administrative office of the City of São Paulo buys the production from these farmers to offer healthy food to people in situation of social vulnerability. The strategy of the program, sponsored by Bloomberg Philanthropies, is to connect the dots, establishing a value chain between farmers, suppliers, entrepreneurs, self-employed professionals, consumers and citizens in favor of the environment, citizenship and sustainable economic development.

REGENERATIVE COTTON FOR THE FASHION INDUSTRY

Brazil is the largest exporter of regenerative cotton with the BCI seal, which meets the sustainability standards of the Better Cotton Initiative. More than 40% of the regenerative cotton used worldwide comes from Brazil, according to the Ellen MacArthur Foundation *(more on regenerative agriculture on page 43).* A large part of this cotton is intended for the global fashion industry, whose reputation was strongly shaken in 2021 – at the time, images showing the "dump" of clothes discarded in the Atacama Desert, in Chile, circulated on the Internet and shocked the world[13]. Now the industry is trying to reposition its image.

Biodiversity supply chain

Natura, one of the world's largest cosmetics companies, is included among the relevant case studies selected by the Ellen MacArthur Foundation, in particular for its results related to the third principle of the circular economy, the regeneration of nature[15]. To manufacture a line of products, including soaps, lotions and shampoos, whose inputs come from the rich Amazon biodiversity, Natura helps to conserve more than two million hectares of rainforest, with the target of increasing this area to three million hectares by 2030.

Natura's supply chain includes 44 types of biodiversity assets (plant-derived ingredients) and involves more than 10,000 families in 51 supplier communities – 87% in the Amazon region. In 2023, the company also reached the mark of 86.2% recyclable, reusable and compostable packaging, and incorporated at least 50% recycled material into its plastic packaging and prioritized the biodegradability of formulas, reaching a minimum of 95% of this characteristic in its products, according to the Natura &Co 2023 Integrated Report.

EXAMPLES OF A CIRCULAR ECONOMY IN THE AGRIBUSINESS

The farm of the Kompier Group, located in Montividiu, state of Goiás, is considered a model in circular regenerative agriculture. Biomass resulting from maize and soybean production is fermented to produce bioinputs, which are returned to the field. Part of the grain production is transformed into feed, which goes to the production of milk. The cows are raised in the compost barn system, in sheds that offer more comfort and increase milk productivity, both through ventilation and by covering the floor, which is formed by a layer of organic material. By changing the lining, also called bedding, organic fertilizer is produced that is returned to the crops, reducing the use of agrochemicals[16]. Manure is used in a biomethane structure that generates biogas. This, in turn, is used as energy in the farm, closing the cycle.

Also in the field of circular economy, there is the example of Tupy, a foundry that has three bioplant projects – which collect and treat the waste generated in operations, stopping methane emissions, in addition to generating direct and indirect jobs. According to the company, the emissions avoided in its three bioplants (Primato, Seara and Granja Rancho da Lua) total around 165,000 metric tons of carbon-dioxide equivalent (tCO_2e) per year, with a direct impact on the emissions inventory of partner companies.

Through a partnership with Primato agricultural cooperative in Ouro Verde do Oeste, state of Paraná, this bioplant comprises a herd of approximately 65,000 pigs and serves 27 cooperative members, including the partner's own farm. The project is estimated to produce more than 10,000 metric tons of organomineral fertilizers a year with a formulation that is suitable for the region's crops.

In 2024, Tupy entered into a partnership with Seara for a bioplant designed to manufacture organomineral fertilizer, biomethane and carbon dioxide from pig and poultry farming waste. Located in the municipality of Seara, state of Santa Catarina, the project will comprise a herd of approximately 200,000 pigs and 1.7 million broilers.

Meanwhile, through a bioplant, Granja Rancho da Lua, in Divinópolis, state of Minas Gerais, will process the waste from around 500,000 laying hens to generate electricity in the property. The partnership also includes the production and sale to third parties of organomineral fertilizer obtained from the process, with an annual capacity of approximately 25,000 metric tons[17].

Another example is the pig-farming company Nutribras, a group from the state of Mato Grosso that slaughters 3,000 pigs per day and is a pioneer in the production of biogas, according to information from the company. The cycle works like this: the animals slaughtered in the slaughterhouse produce effluents that are treated in biodigesters, producing biofertilizers and biogas. The biofertilizers fertilize the soybean and maize crops, which, in turn, generate feed grains to feed the animals on the farms. Meanwhile, the biogas generates renewable energy for the farms and the processing industry[18].

THE SOCIAL FACE OF RECYCLING

Waste pickers are co-responsible for Brazil's world leading position in aluminum can recycling. According to Recicla Latas, Brazil recycled more than 390,000 metric tons of aluminum for beverages in 2022, reaching 100% of all cans produced in the period[19]. By reintroducing the cans into the production chain, the industry reduces the extraction of bauxite from the environment and the energy consumption related to the smelting of materials. With recycling, it consumes up to 95% less energy than when extracting and processing the ore. Every kilogram of recycled aluminum saves five kilograms of bauxite.

Another highlight is the Plastic Hub, the largest plastics-management plant in Latin America, opened in late 2024 by the National Association of Recyclable Material Collectors (Ancat), as a result of a partnership with Coca-Cola Femsa Brasil and the Banco do Brasil Foundation. In an area of 1,250 sq. m, in Mogi das Cruzes, state of São Paulo, the goal of the facility is to optimize the sorting and sale of recyclable plastics.

The unit expects to reach a monthly production of 200 metric tons of plastics – the result of the work of 80 collectors, who will have access to better working conditions and income[20]. Ancat intends to scale the Plastic Hub project to other regions of Brazil. The partners of this first facility are assessing the expansion of the program to Belo Horizonte and Brasília.

The Citizenship Hub is another project of Ancat, this one of a social nature, carried out in partnership with the Heineken Institute. The project operates with a mobile, itinerant unit that travels around neighborhoods in the city and has a team made up of psychologists, social workers, nurses, nutritionists, public policy advisors and other professionals.

The idea is to provide waste pickers with services that will empower them as citizens. When they sign up, independent waste pickers receive a Waste Picker Kit, which includes a safety vest, a cap, a pair of gloves, a bag, and a plastic bottle. With almost two years of experience in São Paulo and 1,300 independent (with no ties to cooperatives) waste pickers registered, a new version of the hub will be launched still in 2025 in Salvador, with support from Tetra Pak[21].

The Federation of Industries of the State of São Paulo (Fiesp) and the CNI launched a public call in 2024 to identify exemplary case studies of circular economy in Brazil and in seven countries in Latin America and the Caribbean. The investigation resulted in the e-book Circular Economy in the Industry – Best Practices, which describes 49 case studies, out of a total of 204 selected[22].

Launched in May 2025, during the World Circular Economy Forum, in São Paulo, the e-book was curated by independent experts who evaluated the projects based on criteria such as impact, innovation, scalability and environmental relevance.

Brazil is a world reference in reverse logistics in the farming industry

Despite its continental size, Brazil has become a global example of shared responsibility and environmental innovation with its empty pesticide packaging management program. Coordinated by the National Institute of Empty Packaging Processing (Inpev), which represents the agricultural pesticide manufacturing industry, the Campo Limpo System (SCL) is the initiative that promotes the reverse logistics of this waste.

Since its creation, the program has correctly disposed of more than 800,000 tons of packaging, achieving 100% proper disposal of the rigid plastic materials received, in addition to post-usage leftover pesticides. With these results, Brazil has established itself as a global reference in agricultural reverse logistics, surpassing countries with a long tradition of environmental policies.

In accordance with Law No. 9,974/2000 (which provides for the proper disposal of empty pesticide packaging, its components and similar products), the system involves 411 fixed receiving units distributed throughout Brazil and a network of itinerant operations that especially reaches small producers in hard-to-reach regions. The program also strengthens the circular economy by transforming waste into raw materials for new products, such as sewer pipes, conduits, and even new packaging for non-agricultural usage, reducing the risks of soil, water, and human health contamination.

Inpev works as a coordinator of various links in the pesticide chain: farmers, distribution channels, manufacturers, the public sector, and recycling or incineration companies. The operation involves, for example, guidance to rural producers on triple washing of packaging, proper storage and return to registered units.

In 2024, the institute took another step toward innovation with the implementation of a digital traceability system that allows real-time monitoring of packaging bales from the time they are returned by the farmer to their final disposal. This technology reinforces environmental safety, improves system governance, and ensures compliance with legislation.

From 2002 to 2023, Inpev, in partnership with the Eco+ Foundation, conducted annual eco-efficiency studies to measure the environmental contributions of the Campo Limpo System. Based on life-cycle assessment analyses, the studies compared the program's impact with a hypothetical scenario without reverse logistics. The data showed that, in two decades, the System prevented the emission of 1.05 million metric tons of CO_2 equivalent.

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