# HOW TO UNLOCK THE POTENTIAL OF A BRAZIL NEUTRAL IN GHG BY 2050?

## Paths of decarbonization for the Brazilian economy

This report is an adaptation, prepared by CDP Latin America, of the document "Plano de Descarbonização para o estado de Minas Gerais dentro de um Brasil clima neutro em 2050". The research was entirely conducted by the Center for Energy and Environmental Economics (Cenergia), within the Energy Planning Program (PPE) of Alberto Luiz Coimbra Institute for Graduate Studies and Research in Engineering (COPPE), at the Federal University of Rio de Janeiro (UFRJ). The original document is only available in Portuguese and can be accessed by clicking here.

**April, 2022**

Photo: Adobestock

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**How to cite this report**
Garcia, M.; Ouro, A.; Rocha, R.; Tulio, F. How to unlock the potential of a Brazil neutral in GHG by 2050? Paths of decarbonization for the Brazilian economy. Sao Paulo: CDP Latin America, 2022, p. 1-20.



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# About this report

This report is based on research facilitated by CDP Latin America and developed by the Cenergia Laboratory of COPPE-UFRJ (the Alberto Luiz Coimbra Institute for Graduate Studies and Research in Engineering from the University of Rio de Janeiro). Its main objective is to present the results from the integrated modeling for a Brazil neutral in greenhouse gas (GHG) emissions by 2050.

Two reference scenarios are analyzed. One considers the current climate policies as business as usual (REF scenario), and another one, net-zero (NETZERO scenario), considers mitigation actions in different economic sectors[1]. Based on these scenarios, structural changes for the Energy, Transport, Agriculture, Forestry and Other Land Use (LULUCF) and Residue sectors are outlined, as they can support Brazil's greatest mitigation efforts.

All presented data, when considered together, demonstrate the seriousness of the climate agenda and the need to act immediately. The report is useful to understand the Brazilian climate reality and how the different national sources of GHG emissions contribute to making Brazil the sixth biggest emitter in the world[2].

Therefore, CDP Latin America hopes that these scientific results presented will support the formulation of sectoral strategies and public policies that will definitively place Brazil in the climate neutrality trajectory, supporting the economic and social development of the country.

This report is organized as follows: after an introduction about the emergency of the climate crisis worldwide and in Brazil, the main results of the study for a Brazil neutral in GHG by 2050 are presented. In the end, there is an annex detailing the evolution of Brazil's Nationally Determined Contributions (NDCs), as it is essential to align domestic climate action with those commitments submitted to the UNFCCC.

**1** Climate neutrality scenario is understood as a trajectory scenario that aims at net-zero GHG emissions by 2050. **2** World Resources Institute Brasil. The countries that emitted greenhouse gases the most in the last 165 years.



Foto: Istock

## Key messages

- There are two variations of the term net-zero. Net-zero Carbon or Carbon neutral means the balance between emissions and removals of $CO_2$ only. The term net-zero emissions or climate neutrality represents the balance between emissions and removals of all GHG ($CO_2$, $CH_4$, and $N_20$). The report used the climate neutrality approach to build the Brazilian transition scenario.
- For the target of net-zero emissions to be achieved by 2050, all sectors are impacted some way, contributing differently to the national mitigation.
- All GHG emissions not zeroed by 2050 have to be offset by negative emissions. Among the different options for compensation, there in the recovery of degraded pastures and forest restoration.

## Sector of Agriculture, Forestry and Other Land Use (AFOLU)

- The recovery of degraded pastures and the preservation of native forests is preponderant in a scenario of GHG neutral Brazil in 2050.
- There is an increase in the participation of integrated systems (ILP, in the Portuguese acronym) and agroforestry (ILPFc and ILPFn) in 2050. The baseline scenario foresees 7 million hectares for these systems. The scenario of net-zero by 2050 indicates about 18.3 million hectares.
- The reduction of areas of degraded soil is important to reduce the pressures on natural vegetation areas, which arise from the need to expand arable land for the production of food and inputs for the production of biofuels in the climate neutrality scenario.

## Energy sector

- The net-zero by 2050 scenario will require an increase in the participation of renewable sources in the domestic offer from the current 48% to 73%. The highlight for the increase in the participation of wind, solar, and mainly, biomass energy.
- The integrated modeling for the net-zero scenario uses cellulose biofuels for two main reasons: Decarbonization of the transport sector, such as air, maritime, and cargo transport modes, and the capture and the storage of atmospheric $CO_2$.
- Carbon capture and storage (CCS) processes can be applied in various production processes, such as in some industrial sectors, and advanced biofuel production processes.

## Industrial sector

- The highlight for the industrial sector – with a focus on the steel industry – is the increase in the use of charcoal from renewable sources to replace the mineral coal of fossil origin.
- The increase in the use of biomass in 2050 is also significant for the industry.

## Transport sector

- The two main strategies to decarbonize this sector are (i) progressive electrification of light vehicles and (ii) the replacement of fossil fuels with biofuels, mainly for use in heavy vehicles.

## Residue sector

- The analyses for this sector include treatment of effluents, incineration of hospital solid waste, and treatment of urban solid waste. The implementation of flares – avoid the emission of methane gas by burning it – in sanitary landfills increases significantly.
- The participation in the use of sanitary and controlled landfills will be zero in 2050.

## Building sector

- The building sector is not addressed in the report due to its low contribution to the total national GHG emissions.



Foto: Adobestock

# How have we reached a state of climate emergency?

**Climate change is real and affects millions of people around the planet.** Recent studies indicate[3] that approximately 80% of the land surface of the planet has already suffered the impacts of climate change in some way. The scenario is so worrying that more than 13,000 scientists, representing around 150 countries, have signed a declaration[4] stating that climate emergency is the most appropriate term to describe the moment we live in.

According to the United Nations Environment Program (UNEP)[5], **the human influence on the Earth's temperature rise is unequivocal.** The consequences are heatwaves, floods, droughts, and other kinds of climate incidents with increasing higher frequency and intensity. For example, 2019 set global temperatures records[6] and a study from 2021[7] indicates that approximately 30% of the global population is exposed to deadly heatwaves for at least 20 days a year.

According to the latest report of the Intergovernmental Panel on Climate Change (IPCC)[8], the world's leading authority on global warming, the scenario is critical for several reasons. First, **some impacts of climate change are already irreversible**. Furthermore, different parts of the planet are affected to a greater or lesser extent, depending on their adaptability and their vulnerability levels. The study shows that Latin American populations, for example, will be one of the most susceptible to climate impacts.

According to the report, an increase in global average temperature by 1.5°C above the pre-industrial levels in short terms (until 2040) "would cause unavoidable increase in multiple climate hazards and present severe risks to the ecosystems and the human beings". (IPCC, 2022). **We have already reached a level of warming in which, even with immediate actions to limit warming to 1.5°C, some of the risks caused by climate change cannot be avoided.** The only way to avoid climate events that will cause fatal consequences for the planet is to reduce GHG emissions by 50% by 2030 and achieve net-zero carbon emissions by 2050.

This task, due to its complexity and magnitude, requires global and cooperative mobilization aimed at (i) strengthening intergovernmental mechanisms, such as multilateral conferences (the Conference of the Parties, – COP – of the – UNFCCC; (ii) the growth of international cooperation to face climate change, considering both actions to mitigate the emission of GHG and adaptation actions; and (iii) increase in the financial flows to a low carbon economy.

**3** Washington Post. At least 85 percent of the world's population has been affected by human-induced climate change, new study shows. **4** Scientificamerican. We Are Living in a Climate Emergency, and We're Going to Say So. **5-6** UN Environment Programme. Facts about climate emergency. **7** UN Environment Programme. Cooling and Climate Change. **7** IPCC - Climate Change 2022: Impacts Adaptations and Vulnerability. **8** Nexo Jornal. How do cities try to adapt to climate change?

# How climate change affects Brazil

Regionally, it must be considered that most of the impacts related to the increase in global temperature will fall on cities. According to the Brazilian Panel on Climate Change (PBMC)[9], in addition to concentrating around 86% of the Brazilian population, they are especially vulnerable to climate change due to their urbanization process. In general, Brazilian cities **"grew in an accelerated and disorderly way, with the occupation of risky areas, advance on the valley and river bottoms and series of changes in the natural environment. The urban expansion produced neighborhoods with high density and few green areas"[10].**

The risks are even higher when considering coastal cities. According to the PBMC report[11], **60% of the Brazilian population lives in coastal cities. This huge population contingent would be subject to " sea-level rise, changes in the frequency and intensity of storms, and increase in rainfall and temperature of the oceans"[12]**, among other risks. Among the most vulnerable cities, there are large Brazilian metropolitan centers, such as Santos, Rio de Janeiro, Salvador, Recife, and Fortaleza.

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**IN 2021, 84 BRAZILIAN CITIES REPORTED CLIMATE RISKS THROUGH CDP. THE MOST MENTIONED RISKS WERE: STORMS (26%), FLOODS (16%), AND WATER SHORTAGE (14%). THE CITIES THAT REPORTED RISKS THE MOST WERE: RIO DE JANEIRO (16 REPORTED RISKS), SANTOS (10), AND NITERÓI (9).**

**In addition to the physical risks caused by extreme climate events and their social impacts, a major concern is the economic impacts of climate change.** An article published in 2021 by the Brazilian Journal of Rural Economy and Sociology[13] analyzed the potential economic impacts of climate change in Brazil until 2040. The study considered two scenarios – intermediate and severe – and, in both cases, Brazil should suffer a decrease in the real GDP. This impact should be greater in regions that depend on agriculture the most, especially soybean cultivation, mainly the Center-West region and part of the Northeast region. However, different economic sectors, including the industrial, may feel the impacts of the climate deregulation caused by temperature increases, such as changes in hydrological cycles, which may cause a shortage in reservoirs and impact electricity production.

**9** Nexo Jornal. How do cities try to adapt to climate change? **10-11-12** Brazilian Panel on Climate Change. Impact, vulnerability and adaptation of the Brazilian coastal cities to climate change. **13** Santos, C. V., Oliveira, A. F., & Ferreira Filho, J. B. S. (2022). Potential impacts of climate change on agriculture and the economy in different regions of Brazil. Revista de Economia e Sociologia Rural, 60(1), e220611.

# Brazil's decarbonization trajectory

**The study of the climate neutrality trajectory of a Brazil neutral in GHG emissions by 2050 is the result of a partnership between CDP Latin America and Cenergia Laboratory - COPPE/UFRJ.** The purpose was to present a mapping of the necessary structural changes for the energy, transport, AFOLU (Agriculture, Forestry and Other Land Use), and residue sectors in Brazil, so the country can achieve a net-zero balance of greenhouse gas emissions (GHG) by 2050.

## Decarbonization plans and transition scenarios

A decarbonization plan can be made considering (i) only the compensation of $CO_2$ released into the atmosphere; or (ii) offsetting the emission of the three main GHGs of anthropogenic origin: carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$). The difference between these approaches is systematized in the following table.

### Definition of the concepts

| CONCEPTS | MEANING | EXAMPLE |
|---|---|---|
| NetZero Carbon or Carbon Neutral | Balance between $CO_2$ emissions and removals from the atmosphere | China will be carbon neutral by 2060 |
| NetZero Emissions or Climate Neutrality | Balance between emissions and removals of all GHGs from the atmosphere | Paris agreement targets: to balance all GHG emissions ($CO_2$, $CH_4$, and $N_2O$) |

Source: Elaborated by Cenergia Laboratory/PPE/COPPE/UFRJ

For the projections, the study designed a 'NetZero scenario' of Emissions or Climate Neutrality. Thus, all Brazil's GHG emissions would have to be offset by removing a volume of $CO_2$ from the atmosphere capable of offsetting non-$CO_2$ gas emissions as well. As it is not possible to remove $CH_4$ and $N_2O$ gases from the atmosphere, their total emission was calculated in $CO_2$-equivalent, a measure that accounts for the global warming power of the different GHGs.

The study established two future perspectives for Brazil. In the 'Reference Scenario' ('REF scenario') the country follows the current trend of macroeconomic and environmental policies. There would be no significant changes regarding energy policies, industrial matrix, agricultural production technologies, deforestation projections, etc. The 'NetZero scenario' projected net-zero GHG emissions in 2050. According to the assumptions adopted in the report:

- The sum of the emissions from all sources and sectors of the economy must be offset by technologies or means of removal of GHGs from the atmosphere, as for reforestation and afforestation;
- There is a restriction in the trajectory of GHG emissions, which leads to considering innovations and technological breakthroughs as a way to achieve climate neutrality by 2050;
- A zero deforestation trajectory is assumed as of 2030 and the decarbonization goals of the International Maritime Organization (IMO) and the International Air Transport Association (IATA), as of 2023.

**14** To make the calculation, the emission of each gas is multiplied by its global warming power over 100-year period (global warming potential – GWP100). As a reference, the values from the Fifth Assessment Report of IPCC (2014) were used:- 1 ton of CH4 is equivalent to 28 tons of $CO_2$. - 1 ton of $N_2O$ is equivalent to 265 tons of $CO_2$.

### Transition scenarios

**Transition scenarios are used to explore different mitigation options to achieve a given climate result. They represent an illustrative trajectory that organizes a set of possibilities based on given assumptions. Therefore, they should not be understood as a prediction of the future or as an indication of the most likely way.**

**However, such scenarios play a fundamental role in supporting public policymakers to comprehend the best options in terms of investment in infrastructure, research, among other areas, to reach the international target of 1.5°C, which also benefits the country in the reduction of the environmental and the socioeconomic consequences generated by the increase in the temperature of the planet.**

**According to the COPPE-UFRJ study, the modeling for the definition of a transition scenario is built by optimization logic. For example, it is more cost-effective to use nature-based carbon capture and storage techniques, such as avoiding deforestation in the Amazon Rainforest, than it is to reduce GHG emissions in sectors with greater decarbonization challenges, such as maritime and aviation.**

Fonte: Adaptado do relatório elaborado pelo Laboratório Cenergia/PPE/COPPE/UFRJ.

## Methodology

The modeling of the transition scenario was made from the integration of an economic model[15] and a technological model. The macroeconomic assumptions incorporated in the first model are based on Shared Socioeconomic Pathways (SSPs), which describe different trajectories in the evolution of society, economy, and ecosystems until the end of the century[16]. The SSP2 scenario has outlined a relatively stable social, economic, and technological pathway at the global level, marked by historical standards. This scenario reflects the updating of historical GDP growth rates, based on the years 2011 to 2019, and the impacts of Covid-19 on economic activity. Within this model, GDP in 2050 is about 95% higher than that observed in 2011.

The technological model used was BLUES - Brazilian Land-Use and Energy System model, which aims to meet the demand for energy services in the country at the lowest possible cost. Together with two other Integrated Assessment Models, Cenergia Laboratory can draw "representations of energy systems, land use, water resources and environmental impacts used to build medium-long term scenarios".

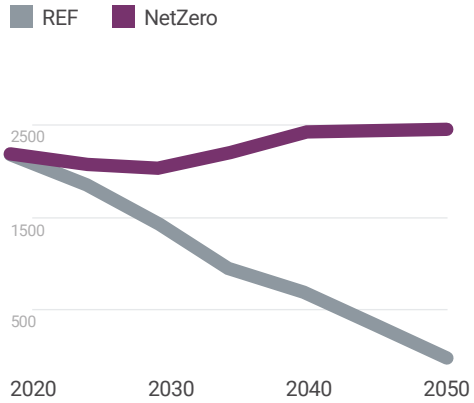
## What will we achieve?

For Brazil to achieve the 'NetZero scenario' by 2050, there must be several structural changes:

- It will be necessary to prevent approximately 21 billion tons of CO2 from being released into the atmosphere.
- The AFOLU sector will offset 79.5% of GHGs in 2050, becoming the main responsible for offsetting the gases emitted by other sectors.
- The energy sector is expected to achieve negative emissions after 2035.
- The transport sector is expected to reduce its emissions by 36% from 2020 to 2050.

**15** For further details on the methodology, see section 2 and Annex B to the report. Annex A provides a glossary of the technologies and their definitions. **16** Riahi, K., Van Vuuren, D.p., Kriegler, E., Edmonds, J., O'neill, B.c., Fujimori, S., et al. The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. Glob Environ Chang 2017; 42:153–68.

## GHG emissions for 'REF' and 'NetZero' scenarios ($MtCO_2e$)

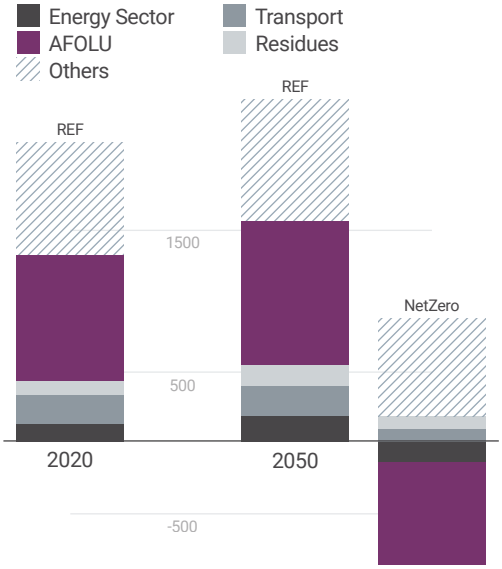



Source: Prepared by Laboratory Cenergia/PPE/COPPE/UFR

Following graph shows how all mapped sectors would undergo substantial changes in their emissions profile. It shall be pointed out that the AFOLU sector is currently the one that emits most GHGs in the country, mainly due to agricultural and livestock activity. The report presents a scenario in which this sector undergoes a sudden decrease in emissions by 2030, and Brazil manages to eradicate deforestation, fulfilling the targets of its NDC.

**The transport sector would reach emission neutrality in 2050.**

## GHG emissions by sector for 'REF' and 'NetZero' scenarios ($MtCO_2e$)




Note: Others = not considered in the described sectors. Source: Own elaboration.

As of 2040, the AFOLU sector would contribute negatively to the emissions by capturing $CO_2$ from the atmosphere. To reach this stage, the report points out that it would be necessary to adopt other mitigation measures in addition to the fulfillment of the NDC, such as the recovery of pastures, planted forests, and implementation of integrated or agroforestry systems. The 'NetZero' scenario by 2050 works with the offset of the CH4-AFOLU emission coming from the agricultural activity, which would still be positive[17].

The energy sector would also contribute to negative emissions as of 2035. According to the report, this would occur mainly by the capture and storage of carbon installed in the advanced biofuel production processes, an important step to achieving the climate neutrality goal.

**17** For details about the total greenhouse gas emissions in Brazil, see figure 15 of the attached report.

Finally, the transport sector would reach emission neutrality in 2050. This would occur thanks to the process of electrification of part of the vehicle fleet and replacement of fossil diesel and aviation kerosene with fuels produced from biomass.

## Long-term scenarios for Brazil

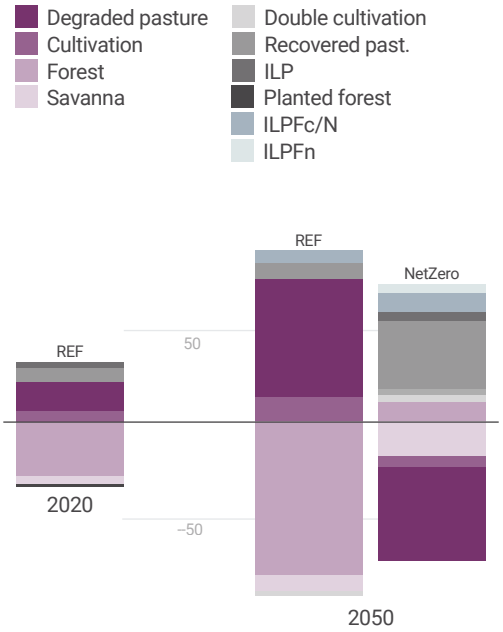
### Agriculture, Forestry and Other Land Use (AFOLU)

Changes in the AFOLU sector are indispensable to ensure a climate neutrality plan which guarantees the survival of ecosystems and preservation of biodiversity in the country. Three main findings of the modeling were:

- Climate Neutrality is directly related to the ability to recover degraded pastures and preserve native forests;
- It is necessary to increase the area of planted forests responsible for the production of biofuels by 3.6 million hectares (Mha);
- It is essential to expand the participation of crop-livestock integration systems (ILP, from the Portuguese acronym) and agroforestry (ILPFc and ILPFn, from the Portuguese acronyms) systems, which would occupy around 18.3 million hectares in the 'NetZero scenario' by 2050.

Graph in the next column shows that the 'REF scenario' in 2050 is marked by significant forest loss and pasture degradation. To achieve the 'NetZero scenario' by 2050, it is necessary to reduce the forest loss, restore pastures and increase the participation of the previously mentioned integrated systems.

**Change in the land use (Mha)**



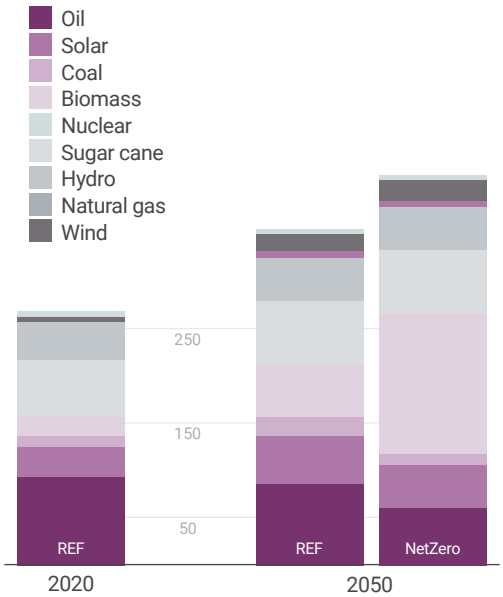

The importance of the recovery of pastures and the maintenance of native forests, according to the report, is intrinsically related to the possibility of underground carbon storage. The plantation of new forest areas also contributes to this storage, in addition to being essential for the increase of the production of biofuels (see the specific sections on the energy and transport sector). Finally, the importance of integrated systems lies in the possibility to implement different creations and crops in the same place, increasing local biodiversity and reducing the consumption of chemical products.

## Energy Sector

Currently, Brazil is among the countries that have invested the most in the diversification of their energy matrix. Primary renewable energy sources account for 48% of the country's capacity, while the other half comes from fossil sources. This makes Brazil a country with a renewable energy matrix well above the world average, only 14%.[18]

For the 'NetZero scenario' to be achieved, the participation of renewable energy sources in Brazil must jump to 73% by 2050. Graph below presents a detailed overview of this transition to different types of primary energy.

### Primary energy consumption in Brazil for the 'Ref' and 'NetZero' scenarios




Note: Mtep = million tons oil equivalent (energy unit)

In 2050, fossil sources (coal, natural gas, and oil) would represent only 27% of the total primary energy. To make the decarbonization of the transport sector feasible, there would be a significant increase in the production of biokerosene and diesel produced from biomass, which would become the main source of energy in the country. This means that, to achieve the 'NetZero scenario', Brazil will face a big challenge to reduce its current fossil energy consumption by approximately 80%.

Brazil will also face specific challenges in each of the energy sectors. The study indicates the following pathways:

### Eletric sector

According to the report, both 'REF' and 'NetZero' scenarios show a similar trajectory, as the Brazilian power generation matrix has a high installed capacity of renewable energy. The main changes would be:

### Transition in the scenario of the installed power capacity

| | HYDRELETRIC | WIND | SOLAR |
|---|---|---|---|
| **2020** | 55% | 9% | 2% |
| **2050 NetZero or climate neutrality** | 38% | 27% | 10% |

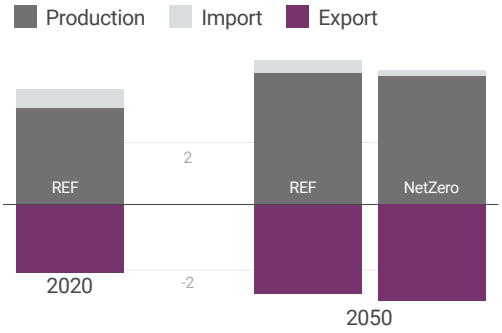
### Oil and natural gas sector

By 2050, Brazil would necessarily have to reduce its domestic consumption of oil derivatives, such as gasoline and diesel. However, the modeling obtained results that may initially be counterintuitive about the oil and natural gas market in Brazil.

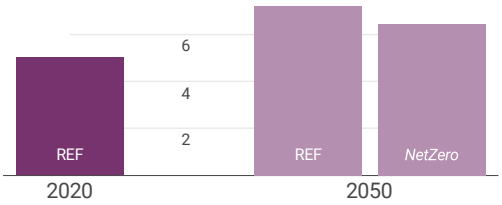
**18** EPE, 2021. Balanço Energético Nacional 2021. Rio de Janeiro, RJ, Empresa de Pesquisa Energética.

- There would be an increase in Brazilian oil production destined for export, as the global external demand would grow (Figure A). This would occur, among other reasons, to account for the global production of inputs that use oil as raw material and to assist in the energy transition of countries that depend on more polluting energy sources than oil, such as mineral coal, and would have to replace it.
- Due to the increase in this external demand, the use of refining would decrease in the 'NetZero' by 2050 scenario (Figure C), as there would be less need for the processing of crude oil to transform it into the derivatives consumed in Brazil.
- The apparent consumption of Natural Gas (NG) increases in the 'NetZero scenario' by 2050, compared to the 'REF scenario' in 2020 (Figure B). This is because the 'NetZero scenario' has a greater penetration of intermittent sources, requiring the use of open-cycle natural gas thermal plants to compensate for such intermittent generation.

**Oil market, A (million barrels/day)**




**Natural gas production and import, B (millions of cubic metters/day)**




**Refine use factor, C (%)**

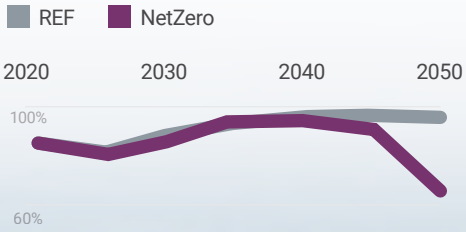


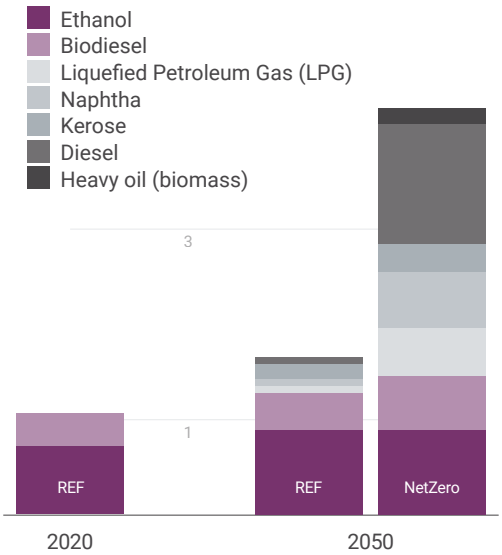



Foto: Adobestock

## Biofuel sector

Biofuels are characterized as renewable because they are produced from organic matter and its derivatives. Following graph shows that cellulosic biofuels, like biokerosene, green diesel, and others produced through routes such as Biomass-to-Liquid (BTL), are considered central in the 'NetZero scenario' for Brazil.

### Production of biofuel (PJ/year)




Note: Petajoule (PJ) is the energy unit corresponding to 1 quadrillion Joules ($10^{15}$J). Source: Own elaboration.

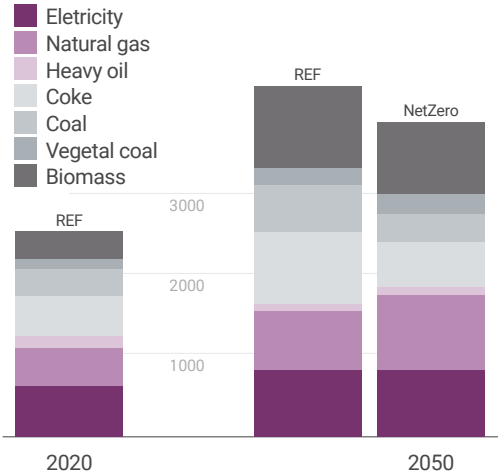
Cellulose biofuels are capable of (i) decarbonizing different sectors of the economy, such as the transport, air, maritime, and cargo transport sectors; and (ii) capturing and store atmospheric $CO_2$. This carbon capture and storage process can be done by the plant itself, which returns $CO_2$ to the soil, or by a process known as Carbon Capture and Storage (CCS). In general, this process enables $CO_2$ that would be released in the production process of these biofuels to be stored in geological reservoirs, instead of being returned to the atmosphere.

In its Special Report on Climate Change and Land, the IPCC raised some warnings about the use of plants that generate Bioenergy with Carbon Capture (BECCS). Among the main red flags, there is the risk of expansion of cultivated areas, which could increase deforestation, disrupt ecosystems, and impair other sustainability goals[19]. Thus, large-scale use of cellulose biofuels would have to take into account the ecological dangers of the expansion of single crops and green deserts, as well as the necessary means to avoid them.

## Industrial Sector

The following figure systematizes total energy consumption in the industry, by type of energy source. The computed sectors in the calculation are those who consume the most energy. According to the National Energy Balance, they are: cement, ceramics, chemical sector, food and beverage, steel, metallurgy, mining, ferroalloys, paper, cellulose, and textile.

### Energy consumption of the industrial sector (PJ/year)




Note: Petajoule (PJ) is the energy unit corresponding to 1 quadrillion Joules ($10^{15}$J). Source: Own elaboration.

**19** World Resources Institute Brasil. How effective is soil for capturing and storing of carbon? Word to IPCC.

Among the main conclusions of the modeling, the following stand out:

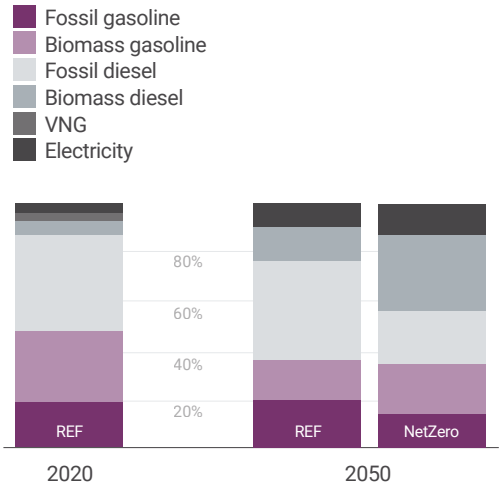
- In the NetZero scenario, there is an increase in the use of charcoal from renewable sources, of approximately 81% between 2020 and 2050, instead of mineral charcoal, especially in the steel industry.
- There is an increase in the use of biomass in 2050 by the industrial sector, in both scenarios.
- There is an increase in electrification and the application of measures to increase the efficiency of different production processes.

## Transport Sector

The transport sector is one of the main ones responsible for global warming. The constant displacement of people and goods makes it urgent to think about alternatives to the consumption of fossil fuels. The results of the study indicate the following conclusions:

- Two strategies are necessary to decarbonize the transport sector: (i) the progressive electrification of light vehicles; and (ii) the replacement of fossil fuels with biofuels, especially to meet the demand for heavy vehicles in road transport.
- Light vehicles (motorcycles, automobiles, and light commercial vehicles), as they make short distances and are used for a shorter time during the day, are more adaptable to the electric battery charging routine. On the other hand, heavy vehicles face long travel distances in the country, which would make the electrification logistics of this fleet more difficult; therefore, the transition to advanced biofuels is more adequate in this case.

**Share of fuels per km of road (%)**




Graph above makes clear how biomass electricity and diesel gain space in the 'NetZero scenario', while biomass gasoline also helps to compose the renewable energy matrix.

## Residue Sector

The residues considered for the integrated modeling of the two scenarios were effluents, hospital solid waste, and urban solid waste. Although it is an insignificant sector in the overall picture of Brazilian emissions, the results indicate essential measures for the contribution of this sector to the 'NetZero scenario' by 2050.

In general, the 'NetZero scenario' by 2050 would require a fundamental change in the treatment of solid waste, coming from the elimination of sanitary landfills and controlled landfills, which would be replaced mainly by flaring landfills. Recycling is also an important point in the 'NetZero scenario' and treats approximately 20% of the solid waste, according to the estimate made.

### Treatment of solid urban waste (%)

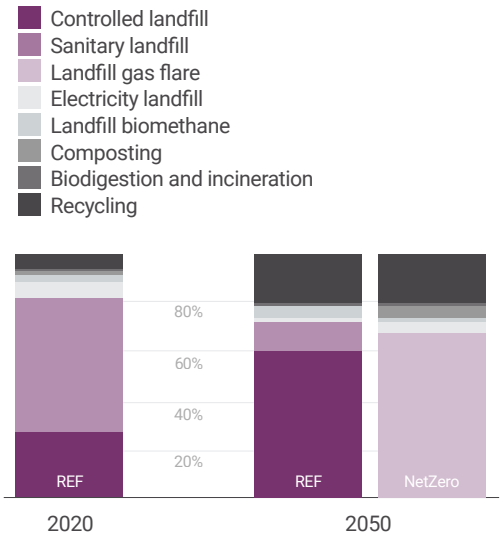





Foto: Adobestock

# Final remarks

Brazil faces huge challenges in the fight against global warming and the destruction of its ecosystems. To overcome them, solid scientific studies must encourage public debate and guide the formulation and implementation of public policies, so that the Federation and the States can decide on the pathways they intend to follow. This is the only way to leverage the Brazilian contribution to the global climate agenda.

In this context, the purpose of this report was to contextualize a possible scenario of structural changes for Brazil to become GHG neutral by 2050. This is a fundamental step for the elaboration of the Decarbonization Plan of Minas Gerais, which will consider the changes that must be made in the national scenario, as well as the possible impacts and the necessary adjustments for the economy of Minas Gerais, based on the macro-context presented by the modeling.

The main conclusions of the study of the decarbonization trajectory for neutral GHG Brazil by 2050 can be summarized in three main axes: (i) preservation and valuation of its biomes; (ii) drastic reduction of emissions in the electricity sector; (iii) need for technological innovations in all sectors.

Regarding the first axis, Brazil must preserve its native forests, eradicate deforestation by 2030, recover big areas of pasture and invest in planted forests.



Foto: Istock

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For the production of advanced biofuels, although Brazil has the agro-industrial experience and available area to invest in planted forests, the large-scale use of cellulose biofuels should consider the ecological dangers of the expansion of single crops and green deserts, as well as the necessary means to avoid these, as pointed out by the Special Report on Climate Change and Land of IPCC.

Together, these measures would make it possible to store and stock $CO_2$ in the soil, fundamental to offset the remaining GHG emissions, while assuring the preservation of biodiversity and the fulfillment of other sustainability goals.

As for the second axis, the drastic reduction in emissions in the electricity sector should reach approximately 80% of the current levels in the scenario projected for 2050. Among the main findings, Brazil would increase the production of wind and solar energy, while the main energy sources in the industrial sector would become biomass, natural gas, and electricity.

Finally, technological innovation appears to be a cross need. Among the main challenges, we highlight the production of bioenergy with carbon storage technology, the progressive electrification of the transport and industrial sectors, the increase in the efficiency of different production processes, and the replacement of sanitary landfills and controlled landfills with flaring landfills.

The analytical exercise proposed by the construction of a decarbonization scenario enables public policymakers to guide their actions based on scientific results. Brazil plays a fundamental role in the achievement of the targets of the Paris Agreement and the building of a GHG neutral world by 2050.

# Annex: Brazil's climate commitments (NDCs)

Brazil was one of the developing countries to present, before COP-21, an iNDC (Intended Nationally Determined Contribution) for the entire economy. This target was confirmed in 2016 as the first NDC of the country and aimed an reduction in greenhouse gas emissions by 37% and 43% by 2030, both based on Brazil's emission levels in 2005.

The NDC presented in December 2020 reaffirmed the same targets. The difference is that the 2005 emission baseline was updated considering the release of an updated emissions inventory (3rd inventory). As the new scientific methodology increased the total emissions for the considered year, this resulted in an equivalent increase of the baseline. In other words, Brazil did not present a more ambitious commitment, and in practice was authorized to emit more than in the first NDC.

The 2016 NDC had an annex indicating a series of specific commitments: to achieve zero illegal deforestation in the Amazon region by 2030, restore 12 million acres of forests by 2030, and improve the sustainability of forest management systems. The 2016 NDC does not update these sectorial commitments, so one can only imply their maintenance.

In the context of COP26, which was held in 2021, Brazil formalized the commitment to achieve climate neutrality by 2050, ten years earlier than indicated in previous NDCs. Moreover, it has signaled its intention to update its NDC.

Brazil announced a 50% reduction in emissions by 2030, using the same base year, but concerning the figures from the last national inventory (4th inventory). Furthermore, the government mentioned its intention to bring forward the commitment to zero illegal deforestation in two years and to restore an additional 6 million acres of forest by 2030.

The NDC officially submitted to UNFCCC in 2022 confirms these commitments. However, according to an analysis by the Talanoa Institute, it maintains for the 2030s a higher level of emissions than that the country presented in 2016, in the original NDC. This is contrary to the Paris Agreement's principle of increasing climate ambition. Despite the setback in its most recent NDC, it is imperative to continue having as a reference the reduction of emissions by half by 2030, as well as the climate neutrality in the following updates, in line with the IPCC.

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