



BRAZILIAN NATIONAL DETERMINED CONTRIBUTIONS: CURRENT CHALLENGES AND WAY FORWARD

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1. INTRODUCTION

Brazil is the largest country in South America.¹ It is the fifth largest country in the world, covering an area of 8,510,295 km², and has a long coastline of over 7,491 km along the Atlantic Ocean in the east.³ It borders Bolivia and Peru to the west; Paraguay, Argentina, and Uruguay to the southwest; Colombia, Venezuela, Guyana, Suriname, and French Guiana to the northwest.⁴ The country's borders include several oceanic islands, such as Fernando de Noronha, Abrolhos, and Trindade. Brazil is the most biodiverse country in the world ⁵ home to a wide variety of ecosystems and an abundance of flora and fauna, including the Amazon forest, the Pantanal wetlands (which include the world's largest wetland area on the western border), the Atlantic Forest (forests extending along the Atlantic coast), the Cerrado (central plateaus covering 21% of the country), the Caatinga drylands in the north-east covering 14% of Brazil's territory but already the size of France and Spain combined.⁶

Brazil is also home to almost a third of the world's tropical forests⁷ famous worldwide for its diversity, ecosystems, and abundant natural resources.⁸

¹ WorldCrops, 'Brazil' <https://worldcrops.org/country/brazil/index.html> accessed 24 April 2025.

² World Bank Climate Change Knowledge Portal, <https://climateknowledgeportal.worldbank.org/> accessed 24 April 2025.

³ World Bank Climate Change Knowledge Portal, <https://climateknowledgeportal.worldbank.org/> accessed 24 April 2025.

⁴ World Bank Climate Change Knowledge Portal, <https://climateknowledgeportal.worldbank.org/> accessed 24 April 2025

⁵ United Nations Environment Programme World Conservation Monitoring Centre UNEP-WCMC, 'Megadiverse Countries Definition| Biodiversity A-Z' (1988) <<https://www.biodiversitya-z.org/content/megadiverse-countries>> accessed 1 February 2021.

⁶ C Roberto Pinheiro Junior and others, 'Shallow Soils in Dryland Ecosystems: Drivers of C Accumulation and Land Management Implications' (2024) 38 Geoderma Regional e00849.

⁷ IPAM - Amazon Environmental Research Institute, 'CERRADO: How Cerrado deforestation exacerbates global overheating and drought' <https://ipam.org.br/how-we-act/biomes/cerrado/> accessed 24 April 2025.

⁸ Daniel Santos and others, 'Fatos Da Amazonia' <<https://amazonia2030.org.br/fatos-da-amazonia-2024/>>.

The national territory comprises six distinct biomes: the Amazon, Pampa, Cerrado, Amazon, and Atlantic Forest. Humid, seasonal forests like those in the Amazon and Atlantic Forests are home to significant biodiversity. The Caatinga is distinguished by its semi-arid climate and dry vegetation. Three of South America's main watersheds are located in the Cerrado (the Paraná-Paraguay, Araguaia-Tocantins and São Francisco River basins)⁹, being also the richest savannah in the world in terms of biodiversity, registering more than 10 thousand species of plants 837 species of birds, 67 genera of mammals with 161 species have been identified, 19 of which are endemic, 150 species of amphibians and 120 species of reptiles.¹⁰ As of 2019, Brazil's population was 211 million, growing at an annual rate of 0.8%.¹¹ By 2030, there will be 223.8 million people, and by 2050, 228.9 million.¹² The percentage of people living in urban areas is expected to increase from an estimated 86% today to 92% by 2050.¹³ The main drivers of the country's economy are agriculture, services, and industry. Brazil is the largest net exporter of agricultural products, a major global supplier of soybeans, coffee, cars, and cattle, contributing more than 20% of the country's GDP and more than 30% of all jobs.¹⁴

Climate change is one of the triple crises¹⁵ together with biodiversity loss and pollution, that humanity must face in the coming decades. Global warming is an unequivocal phenomenon¹⁶ caused mainly by increased

⁹ C Coleoni and T Carvalho, 'Navigating the (yet) unseen waters of Cerrado, the Brazilian savanna' (2021) 2 *Water Science Policy* 51.

¹⁰ IPAM - Amazon Environmental Research Institute, 'CERRADO: How Cerrado deforestation exacerbates global overheating and drought' <https://ipam.org.br/how-we-act/biomes/cerrado/> accessed 24 April 2025.

¹¹ WorldCrops, 'Brazil' <https://worldcrops.org/country/brazil/index.html> accessed 24 April 2025.

¹² Ibid.

¹³ Ibid.

¹⁴ Yuri Clements Daglia Calil and Luis Ribera, 'Brazil's Agricultural Production and its Potential as Global Food Supplier' (2019) 34 *AAEA* 1..

¹⁵ United Nations Framework Convention on Climate Change (UNFCCC), 'What Is the Triple Planetary Crisis?' (2022) <https://unfccc.int/news/what-is-the-triple-planetary-crisis> accessed 9 August 2024.

¹⁶ Intergovernmental Panel on Climate Change (IPCC), 'AR6 Climate Change 2021: The Physical Science Basis' (2021) <https://www.ipcc.ch/report/ar6/wg1/#SPM> accessed 24 April 2025.

emissions of greenhouse gases (GHG) into the atmosphere due to anthropogenic actions, with increasing adverse effects on human and natural systems. Recognizing the need to address it, the adoption of the Paris Agreement¹⁷ in 2015 set a worldwide goal of keeping the average global temperature well below 2°C above pre-industrial times, with efforts to reach 1.56°C.¹⁸ Nationally determined contributions, or NDCs, are a key component of the Paris Agreement and are necessary to achieve these long-term goals. The NDC is a representation of each country's efforts to reduce national emissions and get ready for the effects of climate change. In compliance with Article 4, paragraph 2 of the Paris Agreement, each Party shall prepare, communicate, and maintain consecutive nationally determined contributions (NDCs) that it expects to achieve. The parties will pursue domestic mitigating measures to fulfil the objectives of their contributions.¹⁹

Brazil stands out in global climate discussions due to its significant contributions. It is responsible for approximately one-third of greenhouse gas (GHG) emissions in Latin America and the Caribbean.²⁰ In addition, Brazil's role is amplified in environmental discussions by the importance of the Amazon Rainforest and its biofuel programs. According to the latest National Emissions Registry System - SIRENE official platform, managed by the Ministry of Science, Technology and Innovation (MCTI)²¹, the largest share of 2020 CO_{2eq} emissions, amounting to 1.7 Gt, can be attributed to land use, land use change, and forestry (LULUCF), at

¹⁷ United Nations, UN, 'Acordo de Paris' <<https://treaties.un.org/doc/Publication/UNTS/No%20Volume/54113/A-54113-China-080000028047bf86.pdf>>.

¹⁸ Intergovernmental Panel on Climate Change (IPCC), 'AR6 Climate Change 2022: Mitigation of Climate Change' (2022) <https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/> accessed 7 April 2022.

¹⁹ The Paris Agreement (adopted 12 December 2015, entered into force 4 November 2016) UN Doc FCCC/CP/2015/10/Add.1, art 4(2).

²⁰ NB Carvalho, D Berrêdo Viana, MS Muylaert de Araújo, J Lampreia, MSP Gomes and MAV Freitas, 'How likely is Brazil to achieve its NDC commitments in the energy sector? A review on Brazilian low-carbon energy perspectives' (2020) *Renewable and Sustainable Energy Reviews* (Elsevier Ltd).

²¹ SIRENE (Sistema de Registro Nacional de Emissões), *Emissões de GEE por Setor* (MCTI, Brasília, 2023) <https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/sirene> accessed 19 August 2025.

38.0%. The agricultural sector is the second largest responsible, with 28.5%, while the energy sector is third, accounting for 23.2% of emissions.²²

Brazil embraced the Paris Agreement and submitted in 2016 its first NDC, committing to reducing its greenhouse gas emissions by 37% by 2025 and 43% by 2030, compared to the levels of 2005. In 2016, the Ministry of Environment also created the National Plan for Adaptation to Climate Change (PNA), which is an instrument designed by the Federal Government in collaboration with civil society, the private sector, and state governments, aiming at promoting the reduction of national vulnerability to climate change and carrying out risk management associated with this phenomenon.

In 2020, Brazil revised its NDC to the United Nations Framework Convention on Climate Change (UNFCCC) to adapt its commitments to climate change as well as its ongoing goals for social and economic prosperity. Additionally, Brazil has committed to addressing how the nation's environment, forestry, energy, agriculture, and health sectors are being impacted by climate change. In 2022, Brazil revised once again its commitment and submitted an update to its NDC by changing the commitment for 2030 to a 50% reduction in its greenhouse gas emissions levels compared to 2005.²³

In June 2023, Decree No. 11.550/2023 created the Interministerial Committee on Climate Change. The purpose of the committee is to monitor the implementation of actions and public policies within the Federal Executive Power relating to the National Policy on Climate Change (PNMC).²⁴ According to item 4 of the actual NDC, the

²² Ministério da Ciência Tecnologia MCTIC Inovações e Comunicações, 'Relatório de Atualização Bialnal do Brasil (BUR5)' (*Ministério da Ciência, Tecnologia e Inovação*, 2024) <<https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/sirene/publicacoes/relatorios-de-atualizacao-bienal-BUR/index>> accessed 22 August 2025.

²³ Henrique Morgado Simoes and Angelos Delivorias, 'Brazil's climate change policies state of play ahead of COP27' (European Parliament, October 2022) [https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/738185/EPRS_BRI\(2022\)738185_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/738185/EPRS_BRI(2022)738185_EN.pdf) accessed 16 August 2024.

²⁴ Federal Law No 12.187 of 2009 (National Policy on Climate Change), created the National Policy on Climate Change ("PNMC"). According to the law, the PNMC aims at (i) making

Interministerial Committee on Climate Change is currently working on the implementation of the National Policy on Climate Change and its sectoral plans for mitigation and adaptation plans, including the regulation of the Brazilian Emissions Trading System (SBCE)²⁵. Brazil's role in global climate governance has grown with its leadership in preserving the Amazon Rainforest, advancing renewable energy, and implementing innovative mitigation strategies. The COP29 summit in Dubai emphasized urgent collective action to limit global temperature rise to 1.5°C, with nations like Brazil leading the charge through more ambitious NDC. During the G20 Summit in November 2024, Brazil emphasized its leadership in global climate governance by pressing for expedited net-zero objectives, encouraging governments to commit to 2040 or 2045 rather than 2050. While Brazil is committed to reaching carbon neutrality by 2050, this proposal demonstrates its desire to press for more rapid international action. However, the government has difficulties in combining its rising oil production ambitions—to become the world's fourth-largest oil producer—with its climate pledges, notably disputed plans to explore oil deposits near the Amazon River.²⁶ These goals are accompanied by expanded initiatives in sustainable agriculture, forest restoration, and the operationalization of the SBCE by 2025. Brazil has made substantial progress in decreasing deforestation, with rates falling by 30.6% in the Amazon and 25.7% in the Cerrado from August 2023 to July

economic and social development compatible with the protection of the climate system; (ii) reducing anthropogenic greenhouse gas emissions in relation to their different sources; (iii) strengthening anthropogenic removals by greenhouse gas sinks in the national territory; (iv) implementing measures to promote adaptation to climate change by the 3 (three) spheres of the Federation, with the participation and collaboration of the economic and social agents concerned or beneficiaries, in particular those especially vulnerable to its adverse effects; (v) preserving and recovering environmental resources, with particular attention to the large natural biomes considered to be National Heritage; (vi) consolidating and expanding legally protected areas and encouraging reforestation and the restoration of vegetation cover in degraded areas; and (vii) encouraging the development of the Brazilian Emissions Reduction Market (MBRE).

²⁵Voluntary National Review: Brazil 2024' https://www.gov.br/secretariageral/pt-br/cnods/RNV_Brasil/english/VNR_BRAZIL_FULL.pdf accessed 16 August 2024.

²⁶ Brazil urges G20 leaders to move faster on net zero climate targets' *Reuters* (19 November 2024) <https://www.reuters.com/world/g20-leaders-turn-focus-climate-change-rio-summits-last-day-2024-11-19/> accessed 16 February 2025.

2024.²⁷ This represents the largest reduction in 15 years, preventing the release of 400.8 million tons of CO₂ into the environment. These initiatives are supported by improved enforcement procedures, increased satellite monitoring systems, and sustainable development policies that strive to balance environmental preservation and economic growth.²⁸

Brazil, until 2024, had formally presented only one NDC, in 2015, which was ratified in 2016, together with the ratification of the Paris Agreement, and updated three times—in December/2020, April/2022, and November/2023, respectively. The third and most recent update of the First NDC, Brazil's Second NDC was informed by the Global Stocktake (GST, 2023) with an absolute reduction in emissions of 37 per cent by 2025 and 50 per cent by 2030, based on 2005 levels with an intermediate target for 2035, aligning emissions with the path towards climate neutrality in 2050.

The new Brazilian NDC aims to cut net greenhouse gas emissions by 59% to 67% by 2035, relative to 2005 levels. This will result in an absolute reduction of 850 million to 1.05 billion tons of CO₂ equivalent.²⁹ It introduces a band target instead of a fixed figure, reflecting the complexity of long-term scenario planning and allowing flexibility to adjust ambition depending on global cooperation, technological progress. Brazil confirms its commitment to being climate neutral by 2050, in line with the global goal of limiting warming to 1.5°C above preindustrial levels. These

²⁷ 'In one year, deforestation and Conversion Falls 30.6% in the Amazon and 25.7% in the Cerrado' WWF (2025) <https://www.wwf.org.br/?90200%2FIn-one-year-deforestation-falls-306-in-the-Amazon-and-257-in-the-Cerrado#:~:text=The%20annual%20deforestation%20rate%20in,a%20rate%20of%208%2C174%20km%C2%B2> accessed 24 February 2025.

²⁸ 'In one year, deforestation and Conversion Falls 30.6% in the Amazon and 25.7% in the Cerrado' WWF (2025) <https://www.wwf.org.br/?90200%2FIn-one-year-deforestation-falls-306-in-the-Amazon-and-257-in-the-Cerrado#:~:text=The%20annual%20deforestation%20rate%20in,a%20rate%20of%208%2C174%20km%C2%B2> accessed 24 February 2025.

²⁹ UNCCC, 'Brazil Second NDC | UNFCCC' (November 2024) <<https://unfccc.int/documents/6433337>> accessed 27 February 2025.

upgraded objectives replace prior agreements and reflect Brazil's increased climate ambition.³⁰

Key priorities include achieving zero illegal deforestation, restoring 12 million hectares of native vegetation by 2030, scaling up low-carbon agriculture through the Low Carbon Agriculture Plan - ABC+ Plan, and converting degraded pastures under the PNCPD (National Program for Conversion of Degraded Pastures) into sustainable production systems. In the energy sector, Brazil commits to further expanding its already renewable-heavy electricity mix (89.2% in 2023) by increasing the share of wind and solar power, alongside the development of biofuels and low-carbon hydrogen.³¹ This includes scaling up the use of ethanol and biodiesel in the national energy matrix, while integrating carbon capture and storage practices into biofuel production. The strategy also emphasizes the development of bioenergy-based value chains, fostering technological innovation, and advancing domestic solutions to address the challenges of sustainable mobility and clean electricity generation.

Achieve net zero emissions in all economic sectors, biodiversity conservation, and restoration of Brazilian biomes, implementation of plans to protect ecosystems, and guarantee the integrity of biomes. To this end, some policies of the ABC+ plan focus on the implementation of sustainable practices such as no-till farming, Crop-Livestock-Forest Integration (ILPF), and the recovery of degraded pastures, expanding integrated systems, ensuring an increase in agricultural productivity and carbon sequestration in the soil. Specific targets include the recovery of 15 million hectares of degraded pastures, summing up to the reforestation or sustainable planting on 12 million hectares by 2030.

In addition to converting degraded areas into more productive agricultural systems, promoting emissions mitigation and improved efficiency in food production, sustainable biofuel and fiber production. Specifically, the PNCPD seeks to transform degraded areas into highly productive

³⁰ Planalto, 'Brazil Presents Its New Climate Target Aligned with Mission 1.5°C' (16 February 2025) https://www.gov.br/planalto/en/latest-news/2024/11/brazil-presents-its-new-climate-target-aligned-with-mission-1.5oc?utm_source=chatgpt.com accessed 16 February 2025.

³¹ UNFCCC (n 29).

agricultural and forestry systems over 10 years, promoting high-yield systems with lower carbon emissions.

The National Plan for Adaptation to Climate Change (PNA) in the part about agriculture seeks to adapt food systems to climate change, with a focus on resilient and low-carbon practices, increasing production efficiency in areas already under cultivation, reducing the need to open up new areas and, consequently, reducing deforestation, as well as reducing greenhouse gas emissions in agriculture, mainly methane (CH₄) and nitrous oxide (N₂O), with a focus on more efficient livestock production systems.

The purpose of this research, therefore, is to provide an analysis of Brazil's current climate actions and the progress made towards achieving its NDC goals. This work shows the steps that Brazil has taken to mitigate and adapt to climate change across various sectors, as well as highlights the challenges and obstacles faced during this process. By submitting the new NDC, Brazil aims to showcase its commitment to transparency, accountability, and sustainable development in the fight against climate change on both a national and global scale. The paper is organized as follows: Section 2 summarizes Brazil's revised NDC, covering major objectives and policy actions. Section 3 investigates the major obstacles Brazil confronts in meeting these promises, including deforestation, agricultural emissions, and governance issues. Section 4 investigates the role of carbon capture, utilization, and storage (CCUS), bioenergy with carbon capture and storage (BECCS), and nature-based solutions (NBS) in Brazil's climate plan. Section 5 explores prospective low-carbon solutions and their implementation issues. Finally, section 6 provides findings and proposals to improve Brazil's climate efforts.

2. BRAZILIAN GOALS AND TARGETS

Compared to the first NDC, Brazil's new NDC increased its ambition level. The emission levels for 2025, considering the base year of 2005, were

estimated to be 2.1 GtCO₂e in the first NDC and decreased to 1,32 GtCO₂e in the actual NDC.³²

Significant research has been released since the Paris Agreement was ratified, indicating that nations must raise their ambition levels to achieve the goal of keeping global warming to 1.5°C by the end of the century.

Brazil's revised NDC provide a robust commitment to integrating renewable energy, low-carbon agriculture, and NBS. The energy transition forms a cornerstone of Brazil's strategy, with a commitment to generating 92% of electricity from renewable sources by 2030. This includes significant investments in solar, wind, and bioenergy projects. Offshore wind energy capacity is set to expand dramatically, supported by newly approved regulatory frameworks aimed at attracting international investments.³³ Deforestation reduction remains a critical component of Brazil's climate strategy. The government reaffirmed its goal of achieving zero illegal deforestation in the Amazon by 2030, complemented by innovative economic incentives and enhanced enforcement mechanisms. Expanded satellite monitoring programs, such as DETER/PRODES, now cover all six major biomes, enabling more comprehensive tracking of deforestation activities.³⁴ CCUS technologies are explicitly prioritized, with Brazil targeting the capture of 20 MtCO₂ annually by 2035. Partnerships with international entities will help integrate CCUS within biorefinery complexes, contributing to emission reductions in both energy and agricultural sectors.³⁵

The targets will be translated into policies and measures to be detailed and implemented by the Brazilian federal government. The national inventory

³² UNFCCC, *Federal Republic of Brazil Nationally Determined Contribution (NDC) to the Paris Agreement* <https://unfccc.int/sites/default/files/NDC/2023-11/Brazil%20First%20NDC%202023%20adjustment.pdf> accessed 16 August 2024.

³³ Brazilian Government, *Brazil's Second Nationally Determined Contribution (NDC)* (2024).

³⁴ Brazilian Ministry of Environment, *Revised NDC Submission 2023* (2023) <https://mma.gov.br> accessed 24 April 2025.

³⁵ Brazilian Government, *The Process of Building the New NDC – Q&A* (2024); Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa (SEEG), *Emissões Totais Brasileiras* (2025) https://plataforma.seeg.eco.br/total_emission accessed 24 April 2025.

³⁶ is a transparency mechanism, and its results shall be used to subsidize action plans to reduce greenhouse gas emissions and form Brazil's official database on the matter. It concentrates all the information on GHG emissions related to the following sectors: (i) Energy; (ii) Industrial Processes and Product Use (IPPU); (iii) Agriculture; (iv) Land Use, Land Use Change and Forestry (LULUCF); and (v) Waste. Each sector has sub-sectors, categories, and sub-categories covering more than 100 activities.³⁷

According to a Technical Note of the Brazilian Climate Observatory, considering the short timeframe that the country has to fulfill the target, it is in the land use changes that the emissions reduction shall concentrate, especially in the Amazon.³⁸ But other sectors, such as energy, industrial process, and waste, also have great potential for reducing emissions.³⁹ It is essential to make structural changes for the fulfilment of the 2030 target and total decarbonization of the economy before 2050.⁴⁰

In item 5(g) of the actual NDC, Brazil informed that domestic measures together with internationally transferred mitigation outcomes (ITMOs), as defined in Article 6 of the Paris Agreement will complement national efforts to achieve Brazil's NDC. Article 6 establishes a framework for voluntary cooperation in implementing the NDCs

Brazil will also provide projects to be achieved as ITMOs. International cooperation is central to Brazil's climate agenda, particularly through mechanisms outlined in Article 6 of the Paris Agreement. Brazil has committed to participating actively in carbon market mechanisms, focusing on ensuring transparency and environmental integrity in trading mitigation outcomes. The establishment of an ITMO framework by 2025 is expected to attract private investments while maintaining robust

³⁶ MCTIC (n 21).

³⁷ Federal Republic of Brazil, Ministry of Science, Technology and Innovations, *Fourth National Communication of Brazil to the UNFCCC* (2020) https://www.gov.br/mcti/pt-br/centrais-de-conteudo/publicacoes-mcti/quarta-comunicacao-nacional-do-brasil-a-unfccc/executive_summary-4nc_brazil_web.pdf accessed 16 August 2024.

³⁸ CDP, *Nature-Based Solutions in Brazil: An Overview of Policies and Experiences* (2024).

³⁹ Ibid actual.

⁴⁰ Brazilian Climate Observatory, *Technical Note: Will Brazil achieve its "new old" NDC by 2025?* (March 2024).

accountability.⁴¹ Collaboration with the European Union and the United States is pivotal in funding large-scale reforestation projects across degraded lands, with a target to restore 10 million hectares by 2030. These efforts support Brazil's Planaveg initiative, which prioritizes the recovery of native vegetation.⁴² Additionally, technology transfer agreements will drive advancements in the bioeconomy and hydrogen production, solidifying Brazil's role as a leader in sustainable innovations.⁴³

In Item 6(a) of the actual NDC⁴⁴ Brazil informed that, according to the Action Plan for Prevention and Control of Deforestation in the Legal Amazon Brazil (PPCDAm)⁴⁵ commits to achieving zero deforestation by 2030. Federal Decree No. 11.367/2023⁴⁶ created the Permanent Interministerial Commission for the Prevention and Control of Deforestation, which will define and coordinate inter-ministerial actions to reduce deforestation rates in the national territory. This represents phase five of the PPCDAm related to the action plan on the matter for the period of 2023 to 2027.⁴⁷

The involvement of the different players is required for the implementation of mitigation and adaptation measures. According to item 3(d) of actual NDC the review of the National Plan on Climate Change shall be composed by a National Adaptation Strategy, with fourteen sectoral/thematic adaptation plans covering (i) socio-economic

⁴¹ Agência Brasil, 'COP29: Brazil commits to reducing emissions by 67% by 2035' (2024) <https://agenciabrasil.ebc.com.br> accessed 19th August, 2025.

⁴² SEEG, 'Brazilian Greenhouse Gas Emissions Data' (2022) <https://seeg.eco.br> accessed 19th August 2025.

⁴³ Intergovernmental Panel on Climate Change (IPCC), *AR6 Climate Change 2021: The Physical Science Basis* (2021) <https://www.ipcc.ch> accessed 19th August 2025.

⁴⁴ Paris Agreement, item 6(a), Brazil submission on fairness and ambition in its nationally determined contribution (NDC).

⁴⁵ Brazilian Government, 'Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm) – 5th Phase' (2004, resumed in 2023) <https://www.gov.br/mma/pt-br/assuntos/combate-ao-desmatamento/amazonia-ppc> accessed 20 August 2025.

⁴⁶ Federal Decree No 11.367/2023, art 1.

⁴⁷ Brazilian Government, 'Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm) – 5th Phase' (2023) 18 <https://www.gov.br/mma/pt-br/assuntos/combate-ao-desmatamento/amazonia-ppc> accessed 20 August 2025.

implications of the transition to climate neutrality; (ii) education, research, development and innovation; (iii) means of implementation; (iv) mechanisms for monitoring, evaluation and transparency; and (v) losses and damages associated with extreme events.⁴⁸

The NDCs initiatives must take into consideration the Sustainable Development Goals (SDGs) established by member countries of the United Nations (UN), for, among others, priorities, protect the environment, and combat climate change. In Brazil, the SDGs are monitored in each city by the Brazilian Institute of Geography and Statistics (IBGE)⁴⁹ and the Institute for Applied Economic Research (IPEA).⁵⁰ According to the International Chamber of Commerce, the inclusion of co-benefits—such as biodiversity conservation, social improvements, and ecosystem protection—enhances the importance of climate commitments and increases the market value of carbon credits relating to the practices. Programs such as Gold Standard and VCS (Verified Carbon Standard) now require projects to identify their contribution to specific SDGs.

Climate Action (SDG 13) has the highest number of associated projects. Decent Work & Economic Growth (SDG 8) and Life on Land (SDG 15) follow as the most frequently targeted SDGs. Four projects in 2022 were aligned with all SDGs. Brazilian forest carbon projects under the Climate, Community and Biodiversity Standard (CCB standard) made significant contributions to SDG 15. In terms of distribution, Brazilian carbon credit projects supported SDG 1 (No Poverty) through 13 initiatives, SDG 13

⁴⁸ Brazil, 'Brazil's Nationally Determined Contribution (NDC)' (November 2024) item 3(d) [https://unfccc.int/sites/default/files/2024-11/Brazil_Second%20Nationally%20Determined%20Contribution%20\(NDC\)_November2024.pdf](https://unfccc.int/sites/default/files/2024-11/Brazil_Second%20Nationally%20Determined%20Contribution%20(NDC)_November2024.pdf) accessed 20 August 2025.

⁴⁹ Instituto Brasileiro de Geografia e Estatística (IBGE), *Estudos e Pesquisas, Informação Demográfica e Socioeconômica: Síntese de Indicadores Sociais – Uma Análise das Condições de Vida da População Brasileira* (2019) 40 https://biblioteca.ibge.gov.br/visualizacao/livros/liv101678.pdf?utm_source=Mailing+Sema n%C3%A1rio&utm_campaign=1355fa16a0-EMAIL_CAMPAIGN_2019_05_21_08_55_COPY_01&utm_medium=email&utm_term=0_723d7d1345-1355fa16a0-209892933 accessed on 19th August, 2025..

⁵⁰ Instituto de Pesquisa Econômica Aplicada (IPEA), *Ipea – Objetivos do Desenvolvimento Sustentável* (2025) <https://www.ipea.gov.br/ods/index.html> accessed 1 February 2025.

(Climate Action) as the most frequently reported contribution, SDG 15 (Life on Land) primarily through forest-based projects, and SDG 8 (Decent Work and Economic Growth) as the second most aligned target. Projects delivering multiple co-benefits—such as water conservation, biodiversity monitoring, and social impact—received premium pricing in carbon markets.⁵¹

Carbon pricing and credit valuation are closely tied to the co-benefits and sustainability credentials of each project. As Brazil refines its NDC, the incorporation of high-quality carbon credit mechanisms will be essential to meeting emissions reduction targets and strengthening climate finance. By promoting robust carbon projects aligned with the SDGs, Brazil can enhance market valuation, attract greater international investment, and reinforce its long-term commitment to global climate action.

A schematic outline of Brazil's NDC is presented in Table 1 to facilitate communication and allow further analysis later. It consolidates the most relevant aspects of mitigation, adaptation, and additional measures reported from the first revision to the most recent NDC. Each NDC is represented by a chain of elements, each chain registered by a number (NDC#).

Table 1 – Schematic outline of Brazil's NDC

Mitigation	Mitigation target	Emission reduction	NDC#1
		Climate neutrality	NDC#2
		Preference for national actions	NDC#3
		Carbon market negotiations	NDC#4
	Methodological approach	GHG inventories	NDC#5
		Removals according to IPCC	NDC#6
Adaptation	Objectives	Water security	NDC#7

⁵¹ Brazilian International Chamber of Commerce, *Opportunities for Brazil in terms of Carbon Market* (2022) 34 https://www.iccbrasil.org/wp-content/uploads/2022/10/RELATORIO_ICCBBR_2022_final.pdf accessed 19th August 2025.

		Energy security	NDC#8
		Food safety	NDC#9
		Social and environmental security	NDC#10
	Actions	Water resources management	NDC#11
		Diversification of energy sources	NDC#12
		Adaptation in the agricultural sector	NDC#13
		Urban resilience	NDC#14
		Social resilience	NDC#15
Additional Measures	Sustainable use of bioenergy	Bioenergy target	NDC#16
		Expansion of biofuels	NDC#17
	Land-use change and forestry	Zero deforestation target	NDC#18
		Restoration and reforestation	NDC#19
		Sustainable forest management	NDC#20
	Energy sector	Renewable energy target (with hydro)	NDC#21
		Renewable energy target (w/o hydro)	NDC#22
		Renewable electricity target (w/o hydro)	NDC#23
		Energy efficiency target	NDC#24
	Agricultural sector	Sustainable development	NDC#25
		Restoration	NDC#26
		Integrated crop-livestock-forest (ICLP) systems	NDC#27
	Industrial sector	Clean technologies	NDC#28
		Energy efficiency	NDC#29
		Low-carbon infrastructure	NDC#30
	Transportation sector	Energy efficiency	NDC#31
		Low-carbon infrastructure	NDC#32

3. MAIN CHALLENGES FOR BRAZIL TO ACHIEVE ITS GOALS AND TARGETS

Brazil has always been struggling with deforestation, which is a significant contributor to greenhouse gas emissions. According to SEEG (Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa) and the Brazilian Climate Observatory, deforestation is responsible for 48% of the national emissions, according to the database from 2022.⁵² Balancing economic development with environmental conservation remains a challenge that must be faced by Brazil, as industries such as agriculture and logging often clash with conservation efforts.

In the Fourth National Communication,⁵³ the balance of Brazilian emissions in 2020 was 28.9 percent from the energy sector, 33.2 percent from agriculture, 4.5 percent from waste, 6.4 percent from IPPU (Industrial Processes and Product Use), and 27.1 percent from LULUCF (Land Use and Land Use Change). Agriculture and livestock can be significant sources of emissions and removals, as can forests. However, the Fourth National Communication⁵⁴ only calculated removals from forests. The agricultural balance sheet showed only emissions from enteric fermentation (19.3%), cattle rising (18.7%), manure management (1.5%), rice cultivation (0.6%), soil management (10.4%), agricultural waste burning (0.03%), liming (1.1%), and urea application (0.3%).

The challenges and opportunities of reducing emissions from agriculture and tackling climate change while ensuring global food security, and at the same time providing other natural ecosystem services, more bio-based fuels, fiber, feed, without deforestation⁵⁵, and bringing income to farmers,

⁵² Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa (SEEG), *Emissões Totais Brasileiras* (2022) https://plataforma.seeg.eco.br/total_emission accessed 19th August 2025..

⁵³ Ministério da Ciência, Tecnologia, Inovações e Comunicações (MCTIC), *Quarta Comunicação Nacional do Brasil à UNFCCC* (Brasil, 2020) <https://repositorio.mcti.gov.br/handle/mctic/4782> accessed 4 October 2024.

⁵⁴ MCTIC (n 40).

⁵⁵ Danielle Mendes Thame Denny and others, 'Carbon Farming: Nature-Based Solutions in Brazil' (2023) 1 *Green and Low-Carbon Economy* 130 <https://ojs.bonviewpress.com/index.php/GLCE/article/view/887> accessed 5 February 2024..

developing rural communities, are converging into a kind of complex puzzle for Brazil.⁵⁶

Socioeconomic disparities can aggravate vulnerability to climate change impacts, particularly among marginalized communities. Addressing social inequality and ensuring that climate policies are equitable and inclusive is essential for the achievement of Brazil's targets. The political landscape is also a factor to be considered in the analysis of hindering actors to an effective climate action, since the instability may lead to competing interests and short-term priorities taking precedence over long-term sustainability goals. Strengthening governance mechanisms, promoting transparency, and fostering international cooperation are critical for overcoming political barriers.⁵⁷

Given that NDCs applies to the entire economy and covers the entire national territory, requiring efforts from the whole of society, the participation of civil society is essential for the planning of a viable NDC, which is the reason for public consultation to discover public opinion regarding the national policy on climate change.⁵⁸ The revision of this policy, the new Climate Plan, was also constructed with a structured public consultation with civil society, both the adaptation strategy and its sectoral targets,⁵⁹ which was launched first, and the consultation of the national strategy and sectoral targets of the mitigation pillar,⁶⁰ through a robust website called Brasil Participativo.

⁵⁶ Silva and others (n. 21).

⁵⁷ Ibid.

⁵⁸ Ministério do Meio Ambiente, 'Consulta Pública sobre o Projeto de Lei de Atualização da Política Nacional de Mudança do Clima' (2021) <https://www.gov.br/participamaisbrasil/consulta-publica-pnmc> accessed 19th August 2025.

⁵⁹ Ministério do Meio Ambiente, 'Plano Clima: Governo federal lança consulta pública dos Planos Setoriais e Temáticos de Adaptação' (2025) <https://www.gov.br/mma/pt-br/noticias/plano-clima-governo-federal-lanca-consulta-publica-dos-planos-setoriais-e-tematicos-de-adaptacao> accessed 22th August 2025.

⁶⁰ Ministério do Meio Ambiente, 'Governo federal inicia consulta pública aos planos setoriais de mitigação climática' (2025) <https://www.gov.br/mma/pt-br/noticias/governo-federal-inicia-consulta-publica-aos-planos-setoriais-de-mitigacao-climatica> accessed 22th August 2025.

Concerning civil society participation in climate change policies, Brazil's NDC highlights the involvement of Indigenous peoples and local minority communities through mechanisms such as the Brazilian Climate Change Forum (FBMC), the Interministerial Committee on Climate Change, ILO Convention 169 on Indigenous peoples, and constitutional provisions (Articles 5, 231 and 232) safeguarding citizens' rights, especially those of women and Indigenous groups. In practice, however, these legal provisions and policy instruments were not effectively applied to promote dialogue or public engagement in the NDC review process, and members of the FBMC were not even consulted during the preparation of the 2020 NDC.

With regards to civil society participation in climate change policies it is also important to mention that Brazil highlights the participation and the involvement of indigenous peoples and local communities, through mechanisms such as the Brazilian Climate Change Forum (FBMC), the Interministerial Committee on Climate Change, the ILO Convention 169 on indigenous peoples, and articles 5, 231 and 232 of the Federal Constitution on the rights and guarantees of citizens, especially women and indigenous peoples.⁶¹ In practice, however, these legal provisions and public policies instruments were not effectively applied to promote dialogue and public engagement in the NDCs review process, and members of the FBMC were not even consulted over the plan for the 2020 NDC.⁶²

Despite the increase in the ambition level of the current NDC, the contribution does not address the planning process for the development or update of the NDC, including measures to enhance public participation or involvement of interested parties, whether part of minority communities or not, as required by the legislation mentioned in the last

⁶¹ Brazil, 'Brazil's Nationally Determined Contribution (NDC)' (November 2024) item 4(a)(i) [https://unfccc.int/sites/default/files/2024-11/Brazil_Second%20Nationally%20Determined%20Contribution%20\(NDC\)_November2024.pdf](https://unfccc.int/sites/default/files/2024-11/Brazil_Second%20Nationally%20Determined%20Contribution%20(NDC)_November2024.pdf) accessed 20 August 2025.

⁶² WWF, 'New Brazil's NDC Reduces the Country's Climate Ambition, against the Spirit of the Paris Agreement' <https://www.wwf.org.br/?77508/New-Brazilian-NDC-reduces-the-country-s-climate-ambition-against-the-spirit-of-the-Paris-Agreement> accessed 19th August, 2025.

paragraph. In addition, the current NDC does not provide clear information on the mitigation benefits of adaptation actions, which is an aspect that needs to be further developed, given that Brazil does not have an NDC centered on adaptation. Brazil's targets are absolute and economic in scope and not based on individual policies and measures. The actual NDC is not clear on how the short-term aligns with the long-term goal of climate neutrality by 2050, and how these contribute to the overall objectives of gas emissions reduction, limiting warming to 1,56 °C.⁶³

One of the critical aspects that emphasizes the need for improvement in Brazil's NDC is the absence of a clear and documented process of public participation and consultation. The submitted document does not transparently detail how the government has involved or plans to involve civil society, indigenous communities, the private sector, and other stakeholders in the construction of its climate strategies. This lack of inclusion in dialogue and decision-making can limit the representativeness and effectiveness of the targets set, as well as jeopardize the acceptance and implementation of the proposed actions.

Acknowledging this vulnerability, Brazil has strengthened support for Indigenous-led conservation projects under the Indigenous Peoples part of the Climate Action Plan, which emphasizes the integration of traditional ecological knowledge into national climate policies to ensure sustainable and inclusive solutions. Brazil has implemented a comprehensive adaptation strategy aimed at building resilience across its regions. Investments in water security feature prominently, with additional funding directed towards rehabilitating critical watersheds and deploying desalination technologies in semi-arid areas like the Caatinga biome. Urban resilience strategies have been expanded to protect 70 million urban residents from climate impacts by 2030. Key measures include strengthening flood defenses and implementing heat mitigation strategies in metropolitan areas such as São Paulo and Rio de Janeiro.

⁶³ Talanoa, *Brazil's NDCs with Corrected Targets for 2025 and 2030: Technical Note 4, Series "NDC brasileira"* (Rio de Janeiro, 2023) <https://institutotalanoa.org/documentos> 19th August, 2025..

These efforts are part of an enhanced National Adaptation Plan (NAP) tailored to address city-specific vulnerabilities.⁶⁴

As a developing country, Brazil confronts the difficulty of contributing to global efforts to reduce emissions under the principle of shared but differentiated responsibilities⁶⁵ while also implementing adaptation measures to deal with the effects of climate change on its territory.

The IPCC's sixth report⁶⁶ listed the main risks arising from rising temperatures for the Central and South American regions, which are (i) Risk to water security; (ii) Serious health effects due to increased epidemics, in particular vector-borne diseases; (iii) Degradation of coral reef ecosystems due to coral bleaching; (iv) Risk to food security due to frequent/extreme droughts; and (v) Damage to life and infrastructure due to flooding, landslides, sea level rise, storm surges and coastal erosion.⁶⁷

Reducing vulnerability in the areas of food, energy, water, and social and environmental security is the goal of the adaptation measures included in the actual NDC. This could lead to synergies with the 2030 Agenda's implementation and increase the positive social and economic effects. Strengthening the management of water resources, improving energy efficiency, diversifying energy sources, developing agricultural sector adaptation strategies to ensure food security, and developing urban landscape adaptation plans to ensure population and infrastructure

⁶⁴ Brazilian Government, *Brazil's Second Nationally Determined Contribution (NDC)* (2024).

⁶⁵ Mendes Thame Denny and Douglas de Castro, 'Colonialismo Ou Justiça Climática?', *Tribunais internacionais em perspectiva decolonial* (ABDI) <<https://sites.usp.br/netiusp/wp-content/uploads/sites/920/2024/02/TRIBUNAIS-INTERNACIONAIS-EM-PERSPECTIVA-DECOLONIAL.pdf>>.

⁶⁶ Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2023 Report* (2023) 24 https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/sirene/publicacoes/relatorios-do-ipcc/arquivos/pdf/copy_of_IPCC_Longer_Report_2023_Portugues.pdf accessed 19th August 2025.

⁶⁷ Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2023 Report* (2023) 24 https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/sirene/publicacoes/relatorios-do-ipcc/arquivos/pdf/copy_of_IPCC_Longer_Report_2023_Portugues.pdf accessed 19th August 2025.

resilience in Brazil are the goals of adaptation measures based on the second cycle of the NAP.⁶⁸

Adaptation policies will be based on the most current science on climate change and national situations. The system, developed by the Ministry of Science, Technology, and Innovation (MCTI) to consolidate and provide information to better understand the impacts of climate change in Brazil, including projected future impacts, serves as the scientific foundation for national policy development. The MCTI, the National Institute of Space Research (INPE), and the National Network for Research and Teaching (RNP) work together to keep the tool updated.⁶⁹

The federal government will support subnational entities in their planning efforts in addition to the national adaptation efforts by mainstreaming the topic of climate change adaptation into sectoral plans, promoting scientific knowledge of the subject, and incorporating resilience criteria into policies and strategic plans.⁷⁰

For Brazil to successfully achieve its ambitious GHG reduction targets, it will need to invest in compensation mechanisms such as carbon capture sources, planting forests, restoring biomes, and other technologies. Access to clean technology and financing for climate adaptation and mitigation efforts, combined with the investment in research and development focused on low-carbon technology, can be a powerful tool for the country to succeed in its goals and targets.⁷¹

A schematic description of topics addressing Brazil's primary concerns was developed and shown in Table 2, focusing on critical factors related to climate change response, emission sources, energy, and the environment to facilitate comprehension and subsequent analysis. These themes

⁶⁸ Elena Grigorieva, Alexandra Livenets and Elena Stelmakh, 'Adaptation of Agriculture to Climate Change: A Scoping Review' (2023) 11(10) *Climate* 202.

⁶⁹ UNFCCC, 'Federal Republic of Brazil, Paris Agreement Nationally Determined Contribution (NDC)' (21 March 2022).

⁷⁰ Paris Agreement, art 7(11) (In line with Article 7, paragraph 11, of the Paris Agreement, the adaptation component of this NDC is also the first communication on adaptation presented by Brazil).

⁷¹ *Ibid.*

covering the main challenges for Brazil are represented by a chain of keywords, each chain registered by a number (KW#).

Table 2 – Schematic outline of themes covering main challenges for Brazil

Climate change response	Mitigation	Emission reduction	KW#1
		Emission removal	KW#2
	Adaptation	Resilience of populations	KW#3
		Ecosystem resilience	KW#4
		Infrastructure resilience	KW#5
		Resilience of production systems	KW#6
Emission sources	Related to energy use		KW#7
	Related to industrial processes		KW#8
	Related to agriculture and livestock		KW#9
	Related to waste management		KW#10
	Related to LULUCF		KW#11
	Fugitives		KW#12
Energy	Energy performance	Energy efficiency	KW#13
		Behavioral/operational changes	KW#14
	Low-carbon sources	Bioenergy	KW#15
		Renewable electricity	KW#16
Environment	Forestry	Forest preservation	KW#17
		Forest recovery	KW#18
	Land-use and Land-use change	Low-carbon agriculture	KW#19
		Sustainable land use	KW#20

This schematic description of the main concerns and their associated elements could be used to assess the connection with the structure of government action plans, relevant regulatory aspects, programs under

development, as well as other interfaces that could present a clear vision of their addressing at the national level, creating additional credibility to the Brazilian proposals presented in the NDC.

4. CCUS, BECCS, NBS TECHNIQUES

The NDCs aim to reduce GHG emissions through a combination of renewable energy expansion, forest conservation, and technological innovation. One example is Carbon Capture and Storage (CCS), and Carbon Capture and Use (CCU) are technologies designed to mitigate the release of carbon dioxide (“CO₂”) emissions into the atmosphere. Another is Bioenergy with Carbon Capture and Storage (“BECCS”) combines the removal of CO₂ by capture and permanent storage or the destination of the gas to fabricate other assets exclusively from a process where biomass is converted into fuels or directly burned to generate energy.⁷² Additionally, another NBS normally captures CO₂ back into nature; they refer to strategies that harness the power of nature to address environmental challenges and boost climate change positive outcomes. NBS include the protection, restoration, and sustainable management of natural and semi-natural ecosystems such as forests, wetlands, and grasslands to enhance their capacity to sequester carbon dioxide from the atmosphere.⁷³

4.1 CCUS - Carbon Capture and Use and Storage

Together, CCUS, BECCS, and NBS approaches offer a multifaceted toolkit for addressing the challenges of climate change. The United States of America (USA) launched the Regional Carbon Sequestration Partnership Initiative, which includes over 400 organizations from forty-three (43) states to fund research on carbon storage through field initiatives. Canada has undertaken nineteen (19) small-scale field research

⁷² International Energy Agency (IEA), ‘What is BECCS?’ <https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage/bioenergy-with-carbon-capture-and-storage> accessed 19th August 2025..

⁷³ Aline C. Soterroni and others, ‘Nature-based solutions are critical for putting Brazil on track towards net-zero emissions by 2050’ (2023) *Global Change Biology* October <https://onlinelibrary.wiley.com/doi/10.1111/gcb.16984> accessed 19th August, 2025.

investigations across four provinces, developing the necessary framework to evaluate geological carbon storage.⁷⁴

Underground geological storage, comprising oil and gas reserves, coal beds, and saline aquifers, has an estimated capacity of 10,000 to 200,000 GtCO₂ worldwide. However, site building would be costly and time-consuming.⁷⁵ The storage capacity of several reservoirs in the United States and Canada ranges from 2.618 to 21.978 GtCO₂, enough to store anthropogenic CO₂ for two centuries. A hybrid computable general equilibrium (CGE) model for China, on the other hand, indicated that by 2060, the yearly carbon removal from bioelectricity with CCS, biofuels with CCS, and afforestation will be 2.118, 170, and 617 MtCO₂, respectively.⁷⁶

Concerning the industrial power plants, involves the process of capture, separation, and compression of CO₂ emissions from industrial processes or power generation plants that use either fossil fuels or biomass as fuel.⁷⁷ After its capture, if not used on-site, the CO₂ may be transported by means of pipeline, ship, rail, or truck to be used in the fabrication process of a range of products or to be stored in an underground location, usually geological formations such as depleted oil and gas reservoirs or saline aquifers⁷⁸. Conversion of CO₂ from waste into other assets may result in valuable products such as chemicals, fuels, or building materials, contributing not only to the CO₂ emission reduction but also to economic

⁷⁴ D Rassool, C Consoli, A Townsend and H Liu, *Overview of Organisations and Policies Supporting the Deployment of Large-Scale CCS Facilities* (Global CCS Institute, Washington DC, 2020).

⁷⁵ Intergovernmental Panel on Climate Change (IPCC), 'Underground Geological Storage' https://www.ipcc.ch/site/assets/uploads/2018/03/srccs_chapter5-1.pdf accessed 3 March 2025.

⁷⁶ Y Weng, W Cai and C Wang, 'Evaluating the use of BECCS and afforestation under China's carbon-neutral target for 2060' (2021) 299 *Applied Energy* 117263.

⁷⁷ International Energy Agency (IEA), 'Carbon Capture, Utilisation and Storage: What is carbon capture, utilisation and storage (CCUS)?' <https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage> accessed 19th August, 2025.

⁷⁸ International Energy Agency (IEA), 'Carbon Capture, Utilisation and Storage: What is carbon capture, utilisation and storage (CCUS)?' <https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage> accessed 19th August, 2025.

opportunities.⁷⁹ A study that included industrial CCS in a global multi-region multi-sector energy economic model validated the CO₂ mitigation potential in industrial sectors, particularly in the chemicals, steel, and cement industries.⁸⁰ For this work, CCS and CCU shall be jointly referred to as “CCUS”.

According to a CO₂ source-sink mapping analysis, nearly all stationary CO₂ emissions from major industrial sources in China could potentially be stored for 367 years. This storage capacity exists in saline aquifers and offshore oil and gas reservoirs located within 350 km of the coast.⁸¹ The analysis includes approximately 1.7 Gt of CO₂ emitted annually in China from power plants, refineries, iron and steel mills, and cement factories.⁸² Norway is the pioneering country establishing an action plan to develop CCUS projects by creating the "Climate Settlement 2007" to achieve net zero emissions.⁸³ Japan was among the early adopters of carbon capture technology, legalizing CO₂ injection into subterranean saline aquifers through legislation passed in 2007.⁸⁴ Following suit, the United States implemented an incentive in 2018 to make CCUS economically feasible. Studies suggest that government funding could significantly impact CCUS implementation. With 50% government funding for infrastructure development, it's estimated that 19 million tonnes of CO₂ could be economically captured and transported annually. Increasing this to 100% funding could potentially lead to a 50% improvement in the oil recovery sector.⁸⁵

⁷⁹ International Energy Agency (IEA), *Putting CO₂ to Use: Creating Value from Emissions* (September 2019) https://iea.blob.core.windows.net/assets/50652405-26db-4c41-82dc-c23657893059/Putting_CO2_to_Use.pdf accessed 19th August, 2025.

⁸⁰ S Paltsev, J Morris, H Kheshgi and H Herzog, 'Hard-to-Abate Sectors: The role of industrial carbon capture and storage (CCS) in emission mitigation' (2021) 300 *Applied Energy* 117322.

⁸¹ S Cornot-Gandolphe, *Carbon Capture, Storage and Utilization to the Rescue of Coal* (Global Perspectives with Focus on China, SAD 2019).

⁸² Including the 1.7 Gt of CO₂ emitted annually in China from power plants, refineries, iron and steel mills, and cement factories.

⁸³ A Shii and O Langhelle, 'Toward policy integration: Assessing carbon capture and storage policies in Japan and Norway' (2011) 21(2) *Global Environmental Change* 358.

⁸⁴ *Ibid.*

⁸⁵ Shii and Langhelle (n. 50).

Despite these initiatives, the progress made by CCS and CCUS is currently insufficient to attain net-zero emissions. In major economies such as China, Japan, the USA, and the European Union, the use of CCS technology remains limited, applied to only 3% of power-generating facilities. This underscores the need for more widespread adoption and integration of these technologies. In the United Kingdom, the Climate Change Committee has proposed a strategy involving diverse technologies in the energy generation sector. Their goal is to meet emission reduction targets of 50–100g CO₂ per kWh. This approach is visualized through a methodology that uses two surfaces (ACDB and cdb) to represent different technology mixes. For instance, one point (A) on this model represents pure nuclear power generation at 31 GW, while another point (C) represents a mix of wind (56 GW) and nuclear (18 GW) without gas-based CCS. This methodology could potentially serve as a model for other jurisdictions in establishing their own strategies for reaching climate change targets.⁸⁶

Research has shown that the risk associated with implementing CCS projects rises with plant capacity, and larger plants are more vulnerable to this risk.⁸⁷ For instance, if the yearly plant capacity is increased by one million tonnes of CO₂, the chance of failure rises by fifty percent.⁸⁸ Nonetheless, incremental upscaling and enhanced policy support for market expansion would balance the risk and return. Additionally, the authors contended that the current level of support is insufficient to reduce the risk associated with scaling up CCS projects. When it comes to the implementation of CCS technologies, carbon taxes are thought to be a preferable choice than emission trading.⁸⁹ The recent implementation of the 45Q tax credit in the United States of America encouraged the private sector to deploy CCS, laying the groundwork for subsequent CCS initiatives. The practicality of CCS/CCUS in coal-based power plants

⁸⁶ Ibid.

⁸⁷ N Wang, K Akimoto and G Nemet, 'What Went Wrong? Learning from Three Decades of Carbon Capture, Utilization and Sequestration (CCUS) Pilot and Demonstration Projects' (2021) 158 *Energy Policy* 112546.

⁸⁸ Ibid.

⁸⁹ N Wang, K Akimoto and G Nemet, 'What Went Wrong? Learning from Three Decades of Carbon Capture, Utilization and Sequestration (CCUS) Pilot and Demonstration Projects' (2021) 158 *Energy Policy* 112546.

would depend on market developments, scientific advancements, and policy design, even though it helps decarbonize coal-based power plants.⁹⁰

Carbon financing programs have the potential to benefit both poor and industrialized countries. A study conducted in Alberta, Canada, found that carbon incentives for afforestation and agricultural cultivation for new income crops are advantageous. China has implemented CCUS for future carbon mitigation activities, which has had a significant impact on progress; nonetheless, the Chinese CCUS strategy was found to be insufficient for further development.⁹¹ It is also underlined that CCUS can meet developing countries' energy consumption and CO₂ emission reduction targets and is critical for decarbonizing the energy sector. The existing energy system can be decarbonized using CCUS, which can be done at a reasonable cost using hydrogen storage and renewables. However, the building of new power plants without CCS receives more public support compared to the plants with CCS due to higher taxes to fund the CCS approach. Therefore, a specific policy is required to shape the public support for the deployment of large-scale CCS projects. Furthermore, public support for CCS appears to be low, which must be increased to ensure the effective deployment of CCS projects.⁹²

4.2 BECCS - Bioenergy with Carbon Capture and Storage

BECCS is one of the negative-emissions technologies that is effective in Brazil, because the country is the leader in biomass energy production with the record sugar cane cultivation, and energy crop for excellence,⁹³ and at the same time with CO₂ capture and storage. BECCS presents a unique opportunity for Brazil, a country with this vast bioenergy potential, to both decarbonize its energy sector, improve technology and

⁹⁰ J Han and others, 'Coal-Fired Power Plant CCUS Project Comprehensive Benefit Evaluation and Forecasting Model Study' (2023) 385 *Journal of Cleaner Production* 135657.

⁹¹ K Jiang, P Ashworth, S Zhang, X Liang, Y Sun and D Angus, 'China's Carbon Capture, Utilization and Storage (CCUS) Policy: A Critical Review' (2020) 119 *Renewable and Sustainable Energy Reviews* 109601.

⁹² *Ibid.*

⁹³ J Goldemberg and others, 'Energy Balance for Ethyl Alcohol Production from Crops' (1978) 201 *Science* 903 <http://science.sciencemag.org/content/201/4359/903> accessed 14 June 2017.

actively remove CO₂ from the atmosphere. Once Brazil's NDC includes commitments such as reducing GHG emissions by 50% by 2030 and achieving carbon neutrality by 2050 (Brazil, 2022), as we have been arguing in this paper, and given the country's extensive use of biofuels, sugarcane ethanol, and biomass energy, integrating BECCS into the national energy mix can significantly contribute to these targets achieving Brazil's NDC.

BECCS is well-suited to Brazil's energy situation, considering the country's leadership in biofuel production, notably sugarcane ethanol. By incorporating carbon capture into bioenergy operations, BECCS provides a scalable path to zero emissions while also strengthening Brazil's position in global decarbonization efforts. Brazil's considerable usage of biofuels, sugarcane ethanol, and biomass energy makes BECCS an obvious extension of the country's low-carbon growth plan. Implementing BECCS in ethanol production and biomass power plants can help Brazil meet its NDC targets.⁹⁴ Implementing BECCS in Brazil's ethanol business might reduce up to 0.3 GtCO₂ annually, considerably contributing to the country's 2050 climate neutrality objective. Expanding BECCS in bagasse cogeneration facilities might boost carbon sequestration while also improving energy security.

According to Fajardy et al,⁹⁵ BECCS has the potential to sequester up to 10 gigatonnes of CO₂ annually worldwide, depending on technological advancements and biomass availability. In Brazil, sugarcane ethanol production and bagasse combustion for electricity generation are ideal candidates for BECCS deployment. Studies highlight that implementing BECCS in the ethanol industry alone could remove up to 3.60 GtCO₂ cumulative removal, which corresponds to 0.3 GtCO₂/year, with a network abatement cost of US\$42/ton of CO₂. The inter-modal and the single-hub scenarios presented a network abatement cost of US\$67.7/ton

⁹⁴ BHM Silveira, HKM Costa and EM Santos, 'Bioenergy with Carbon Capture and Storage (BECCS) in Brazil: A Review' (2023) 16(4) *Energies* 2021 <https://doi.org/10.3390/en16042021>.

⁹⁵ M Fajardy and A Köberle, 'BECCS Deployment: A Reality Check' [2019] Imperial College London Briefing Papers 28 <https://www.imperial.ac.uk/media/imperial-college/grantham-institute/public/publications/briefing-papers/BECCS-deployment---a-reality-check.pdf>

of CO₂ and US\$63.63/ton of CO₂, respectively, reinforcing its crucial role in achieving Brazil's long-term climate commitments.⁹⁶

In addition to bioethanol, bagasse cogeneration plants offer a significant opportunity for BECCS integration. These facilities, which burn biomass waste to generate electricity, could capture and store CO₂ emissions in Brazil's deep saline aquifers and depleted oil fields. The development of carbon storage hubs in regions such as the Santos Basins could further enhance Brazil's carbon sequestration capacity, enabling large-scale BECCS deployment. But Sustainable Development Goals (SDGs) must be used as a framework for evaluating clean energy initiatives, including BECCS⁹⁷ because while BECCS can contribute to emissions reductions, land use, and water consumption, the social impacts must be carefully managed. A multi-dimensional assessment framework could help policymakers align BECCS projects with broader sustainability objectives.

Accordingly, despite its potential, BECCS faces several challenges, including high costs, technological limitations, and policy uncertainties. To accelerate BECCS adoption, Brazil must enhance carbon pricing mechanisms, provide financial incentives, and develop regulatory frameworks that support carbon removal projects. Moreover, land-use competition and sustainability concerns must be addressed to avoid conflicts with food production and biodiversity conservation. A large-scale bioenergy expansion could lead to indirect land-use changes, potentially offsetting climate benefits if not carefully managed. Therefore, integrating BECCS with sustainable agricultural practices and ensuring

⁹⁶ BHM Silveira, HKM Costa and EM Santos, 'Bioenergy with Carbon Capture and Storage (BECCS) in Brazil: A Review' (2023) 16 *Energies* 2021 <https://www.mdpi.com/1996-1073/16/4/2021> accessed 1 February 2025.

⁹⁷ KL Mascarenhas and others, 'Sustainable Development Goals as a Tool to Evaluate Multidimensional Clean Energy Initiatives' in Walter Leal Filho, Paulo R Borges de Brito and Fernanda Frankenberger (eds), *International Business, Trade and Institutional Sustainability* (Springer International Publishing 2020) https://doi.org/10.1007/978-3-030-26759-9_37 accessed 31 January 2025.

compliance with Brazil's Forest Code will be critical to maximizing its environmental and social benefits.⁹⁸

BECCS can contribute to emissions reductions, but land use, water consumption, and social impacts must be carefully managed. A multi-dimensional assessment framework could help policymakers align BECCS projects with broader sustainability objectives.⁹⁹ It represents a high-impact, scalable solution for Brazil's climate strategy, aligning with the country's NDC by enabling negative emissions while leveraging its bioenergy strengths, helping Brazil to become a global leader in carbon-negative bioenergy. Successful BECCS deployment will not only contribute to net-zero emissions but also support energy security, economic growth, and environmental sustainability in the long term.

Despite its promise, BECCS has several hurdles, including high prices, regulatory uncertainties, and land-use disputes. To speed up BECCS implementation, Brazil must establish a clear legislative framework, include BECCS in its carbon trading system, and give financial incentives for industrial-scale projects.

4.3 NBS - Nature-Based Solutions to Climate Change

Given that land use change and agriculture together account for approximately 70-80% of total emissions,¹⁰⁰ Brazil's ability to meet its NDC will heavily depend on policies aimed at: reducing deforestation and enforcing land conservation, promoting sustainable agricultural practices such as agroforestry, low-carbon livestock management, and regenerative farming, enhancing carbon sequestration through reforestation, focusing on land restoration, sustainable land use, and agricultural innovation, all examples of NBS that can significantly cut emissions while also ensuring

⁹⁸ Observatório do Código Florestal OCF, 'PUBLICAÇÃO: CÓDIGO FLORESTAL NOS BIOMAS, DESAFIOS E SOLUÇÕES - Observatório do Código Florestal' (5 December 2023) <https://observatorioflorestal.org.br/publicacao-codigo-florestal-nos-biomass-desafios-e-solucoes/> accessed 15 February 2024.

⁹⁹ Mascarenhas and others (n 90).

¹⁰⁰ Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa (SEEG), 'Emissões Totais Brasileiras' (2025) https://plataforma.seeg.eco.br/total_emission

food security, producing fibres, biofuels, feed and improving economic stability.

The main definition of NBS is in UNEA-5's resolution as: "actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits."¹⁰¹

Brazil's forests act as a global carbon sink, absorbing vast amounts of CO₂ from the atmosphere. However, deforestation and land degradation threaten this capacity, particularly in the Amazon and Cerrado regions. Reforestation alone¹⁰² could sequester up to 5.6 gigatonnes of CO₂ annually worldwide, with Brazil having one of the highest potentials for carbon removal through afforestation and ecosystem restoration.

Brazil's Forest Code mandates the preservation of 80% of native vegetation in the Amazon and 35% in the Cerrado on private lands, yet enforcement remains a challenge of political will to fight criminality. Strengthening protected areas, Indigenous land rights, and sustainable land management practices are critical to maximizing the carbon sequestration benefits of NBS.

Agriculture can be both a driver of deforestation and a sector highly vulnerable to climate change, but if well managed, it can also serve as a carbon sink. Adopting regenerative agriculture, agroforestry, and low-carbon farming practices can significantly contribute to Brazil's NDC. Research by ¹⁰³ indicates that restoring 12 million hectares of degraded

¹⁰¹ United Nations Environment Programme UNEP, 'Ministerial Declaration: UNEA-5' (Environment Assembly, 2022) <http://www.unep.org/environmentassembly/inputs-ministerial-declaration-unea-5> accessed 8 February 2024.

¹⁰² Bronson W Griscom and others, 'Natural Climate Solutions' (2017) 114 *Proceedings of the National Academy of Sciences* 11645 <https://www.pnas.org/doi/full/10.1073/pnas.1710465114> accessed 30 June 2024.

¹⁰³ Bernardo BN Strassburg and others, 'When Enough Should Be Enough: Improving the Use of Current Agricultural Lands Could Meet Production Demands and Spare Natural Habitats in Brazil' (2014) 28 *Global Environmental Change* 84

lands with agroforestry could sequester 1.2 GtCO₂ by 2030, while also improving food security, biodiversity, and rural livelihoods.

Cities can also provide NBS through Urban Green Infrastructure for Sustainable Cities, such as green roofs, urban forests, permeable pavements, and reforested riparian zones can reduce heat stress, improve air quality, and enhance water management. Cities like São Paulo and Rio de Janeiro are already integrating NBS into climate action plans through programs like the Urban Trees Initiative and ecosystem restoration in the Atlantic Forest. Singapore is a step forward, has become a City in Nature, focusing on ecosystem restoration, biodiversity enhancement, and climate resilience. With over 47% of its land covered by green spaces, Singapore showcases how a dense urban environment can coexist harmoniously with nature. Scaling up these efforts can help mitigate urban heat islands, enhance biodiversity, and contribute to carbon neutrality.

Programs such as the ABC+ Plan promote crop-livestock-forest integration, no-till farming, and improved pasture management to reduce emissions and increase soil carbon storage. Expanding these initiatives can enhance the resilience of Brazil's agricultural sector while lowering its environmental footprint.

Brazil has a significant potential for blue carbon, originating from the restoration of mangroves and wetlands, such as the Pantanal and the coastal ecosystems. These biomes provide critical carbon storage, flood protection, and biodiversity conservation. Mangroves are five times more effective at carbon sequestration than terrestrial forests.¹⁰⁴ However, urban expansion and pollution have been threatening these ecosystems for decades. Nature-based coastal adaptation strategies, such as mangrove reforestation, wetland conservation, and ecosystem-based flood defences,

<https://www.sciencedirect.com/science/article/pii/S0959378014001046> accessed 26 July 2022.

¹⁰⁴ Felliipe AO Mello and others, 'Soil Health and Ecosystem Services in Mangrove Forests: A Global Overview' (2024) 16 Water NA <https://go.gale.com/ps/i.do?p=AONE&sw=w&issn=20734441&v=2.1&it=r&id=GALE%7CA821985279&sid=googleScholar&linkaccess=abs> accessed 30 January 2025.

can protect vulnerable communities from sea level rise, extreme weather events, and erosion while contributing to Brazil's adaptation goals.

Despite their proven benefits, NBS face challenges related to funding, governance, and land-use conflicts. Weak enforcement of environmental laws limits the effectiveness of conservation efforts. Although carbon markets and green finance mechanisms are growing, many NBS projects lack stable funding. Agriculture, urbanization, and infrastructure development often compete with conservation efforts.

The government needs to strengthen enforcement of environmental policies, including the Forest Code and Indigenous land protections, while expanding carbon pricing and ecosystem service payments, such as REDD+ (Reducing Emissions from Deforestation and Forest Degradation) encourage public-private partnerships to scale up NBS projects, and integrate NBS into national climate policies to ensure alignment with the 2030 and 2050 carbon neutrality goals.

The Brazilian government has committed to large-scale reforestation, forest protection, and sustainable agriculture methods that are consistent with the NDC's adaptation and mitigation aims.¹⁰⁵ NBS is integrated into programs like the ABC+ Plan and the National Plan for Adaptation to Climate Change, which promote agroforestry, soil carbon sequestration, and wetland restoration.¹⁰⁶ However, long-term finance and enforcement of conservation regulations remain difficult to secure. Strengthening Brazil's legislative framework for NBS, particularly by integrating it into carbon credit systems and environmental laws, will be critical to meeting the country's emissions reduction objectives.

¹⁰⁵ Brazil, 'Brazil's Nationally Determined Contribution (NDC)' <[https://unfccc.int/sites/default/files/2024-11/Brazil_Second_Nationally_Determined_Contribution_\(NDC\)_November2024.pdf](https://unfccc.int/sites/default/files/2024-11/Brazil_Second_Nationally_Determined_Contribution_(NDC)_November2024.pdf)> accessed 3 March 2025.

¹⁰⁶ Addressing forestry and agroforestry in national adaptation plans, ADDRESSING FORESTRY AND AGROFORESTRY IN NATIONAL ADAPTATION PLANS | NDC PARTNERSHIP, <https://ndcpartnership.org/knowledge-portal/climate-toolbox/addressing-forestry-and-agroforestry-national-adaptation-plans> (last visited Mar 3, 2025).

4.4 Other technological solutions

In addition to CCUS, BECCS, and NBS, other technological solutions can be mentioned. As levers to achieve emission reduction, it is worth highlighting the adoption of renewable energy and energy-efficient technologies. Complementary to the technological solutions, there are also low-carbon management solutions, including energy management, carbon management (including carbon accounting), and resource management.

For better comprehension and to facilitate further analysis, a schematic overview of potential low-carbon solutions (LCS) for Brazil was established and given in Table 3, encompassing strategies for both the reduction and removal of carbon emissions, as well as low-carbon management approaches. These possible low-carbon solutions for Brazil are represented by a chain of aspects, each chain registered by a number (LCS#).

Table 3 – Schematic outline of possible low-carbon solutions for Brazil

Carbon Emission Reduction Solutions	Renewable energy technologies	Adoption of renewable electricity	LCS#1
		Adoption of renewable fuel gases	LCS#2
	Efficient technologies	Efficient use of energy	LCS#3
		Efficient use of natural resources	LCS#4
	CCUS	Carbon dioxide capture	LCS#5
		Carbon dioxide transportation	LCS#6
		Carbon dioxide storage	LCS#7
		Carbon dioxide utilization	LCS#8
Carbon Emission Removal Solutions	BECCS	CCS in biofuel production	LCS#9
		CCS in the paper industry	LCS#10
		CCS in the industry using biomass	LCS#11
	NBS	Actions on forests and wetlands	LCS#12

		Soil carbon sequestration (including biochar use)	LCS#13
		Improved weathering (terrestrial or oceans)	LCS#14
Low carbon management	Energy management		LCS#15
	Carbon management	GHG Inventory and Carbon Footprint	LCS#16
		Carbon neutrality assessment	LCS#17
	Natural resource management		LCS#18
	Recycling and circular economy		LCS#19

Table 3 represents an exercise in consolidating the main and potential initiatives, but it is not exhaustive. However, it serves as a guideline for reflection and taking concrete actions to encourage objective mechanisms to combat climate change, in alignment with Brazil's NDC. Additional analyses should be developed with the aim of detailing the incentive mechanisms necessary for implementing each of the solutions available for a low-carbon economy in Brazil.

5. CONNECTIONS BETWEEN NDCS, LCS, AND THE MAIN CHALLENGES FOR BRAZIL

This paper now analyses the relationship of initiatives in reducing and removing CO₂ emissions (low carbon solutions, or LCS) with the main challenges for Brazil's NDC, aiming to obtain a better overall picture and facilitate the development of recommendations for enhancing Brazil's contribution to global climate action. The illustration of these relationships will be considered in the context of science mapping.

Finding representations of intellectual links throughout the constantly evolving body of scientific knowledge is the goal of science mapping. Network analysis is one of the approaches used to depict the overall state of scientific knowledge. Building networks is accompanied by data clustering when the nodes of a network are divided into clusters in which

the connection is greater between the nodes of the same cluster compared to those of different clusters.

A simplified approach to schematic representation of the network analysis process is adopted, considering cross-relationships between Brazil's NDC and possible low-carbon solutions for Brazil to themes covering the main challenges for Brazil. A graph view was obtained by plotting the combination of these relationships, and it is presented in Figure 1, with an overall network between Brazil's NDC, themes covering main challenges, and possible low-carbon solutions for Brazil.

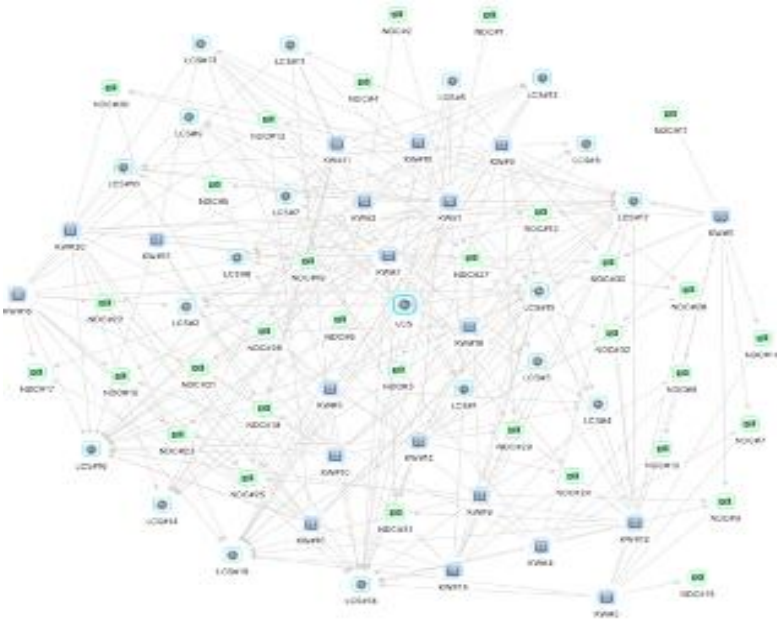


Figure 1 – Overall network between Brazil's NDC, themes covering main challenges, and possible low-carbon solutions for Brazil

Considering the overall network, Brazil's NDC have an average of 3 links per NDC, while the median of this group is 4. The group of NDCs covering additional measures has an average of 4.3 and a median of 4 links per NDC, while the mitigation group has an average, and a median, of 1

link per NDC and the adaptation group an average, and a median, of 3 links per NDC. Brazil's NDC with the highest number of links are NDC#27 (Additional Measures; Agricultural sector; Integrated crop-livestock-forest (ICLP) systems) with 6 links. This NDC is further analysed in Figure 2.

Still considering the overall network, the low carbon solutions have an average of 8 links per LCS, while the median of this group is 5. In fact, there are two distinct groups of solutions: the technological solutions with an average, and median, of 5 links per LCS and the management solutions with an average of 15 and a median of 16 links per LCS. The LCS with the highest number of links is LCS#17 (Low carbon management; Carbon management; Carbon neutrality assessment) with 19 links. This LCS is further analysed in Figure 3.

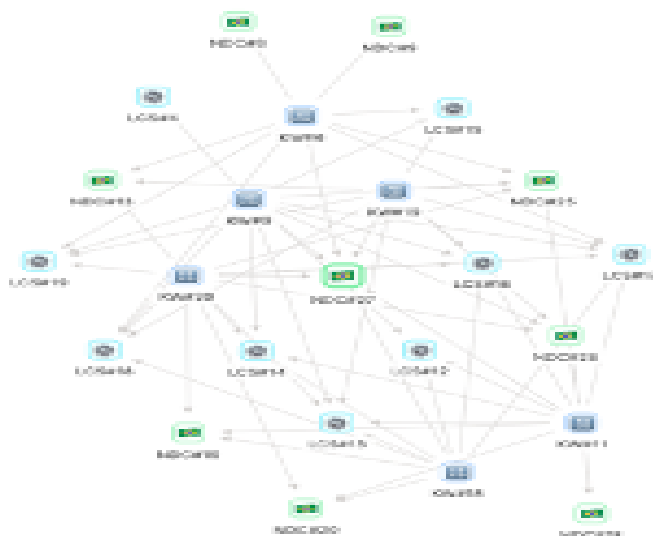


Figure 2 – Network of the most interconnected Brazil's NDC (NDC#27) with themes covering main challenges and related possible low-carbon solutions for Brazil

NDC#27 (Additional Measures; Agricultural sector; Integrated crop-livestock-forest (ICLP) systems) shows links towards KW#6 (Climate change response; Adaptation; Resilience of production systems); KW#9 (Emission sources; Related to agriculture and livestock); KW#11 (Emission sources; Related to LULUCF); KW#18 (Environment; Forestry; Forest recovery); KW#19 (Environment; Land-use and Land-use change; Low-carbon agriculture); and KW#20 (Environment; Land-use and Land-use change; Sustainable land use). Linking to these themes covering the main challenges for Brazil was straightforward, as they encompass the main relevant emission sources and environmental aspects related to ICLP systems.

By means of these links, NDC#27 is connected to the following low carbon solutions: LCS#4 (Carbon Emission Reduction Solutions; Efficient technologies; Efficient use of natural resources); LCS#12 (Carbon Emission Removal Solutions; NBS; Actions on forests and wetlands); LCS#13 (Carbon Emission Removal Solutions; NBS; Soil carbon sequestration (including biochar use)); LCS#14 (Carbon Emission Removal Solutions; NBS; Improved weathering (terrestrial or oceans)); LCS#15 (Low carbon management; Energy management); LCS#16 (Low carbon management; Carbon management; GHG Inventory and Carbon Footprint); LCS#17 (Low carbon management; Carbon management; Carbon neutrality assessment); LCS#18 (Low carbon management; Natural resource management); and LCS#19 (Low carbon management; Recycling and circular economy). These links show that ICLP systems are mainly achieved by removal measures through NBS, being also supported by the range of low-carbon management solutions considered.



Figure 3 – Network of the most interconnected possible low-carbon solution for Brazil (LCS#17) with themes covering the main challenges and related to Brazil’s NDC

LCS#17 (Low carbon management; Carbon management; Carbon neutrality assessment) shows links towards all themes covering main challenges expected by KW#3 (Climate change response; Adaptation; Resilience of populations). Similarly, by means of these links, LCS#17 is connected to all of Brazil’s NDCs except for NDC#15 (Adaptation; Action; Social resilience). NDC#15 and KW#3 are closely related, and they are linked to LCS#18 (Low carbon management; Natural resource management) and LCS#19 (Low carbon management; Recycling and circular economy). These latter two are backlinked to LCS#17 by means of different themes (KW).

6. NEAR FUTURE

Brazil needs to reinforce its commitment to addressing the Global Methane Pledge (GMP) an international commitment launched at COP26 in 2021 to reduce methane (CH₄) emissions by at least 30% by 2030, relative to 2020 levels. Since methane has a global warming potential (GWP) approximately 28 times higher than CO₂, controlling CH₄ emissions is crucial for short-term climate mitigation, and its sources are livestock production, waste management, and fossil fuel. The Nitrous Oxide (N₂O) Pledge is a more recent initiative focused on reducing emissions of nitrous oxide, a potent GHG with a global warming potential 273 times higher than CO₂. N₂O emissions largely originate from synthetic fertilizers, manure management, and industrial processes. Brazil, with its large agricultural sector, is a key player in global N₂O emissions. Although Brazil has not yet made a formal N₂O Pledge, its low-carbon agriculture policies (ABC+ Plan), nitrogen-use efficiency strategies, and NDC commitments align with the objectives of reducing nitrogen-related emissions. And the country can potentially become the leader in carbon farming¹⁰⁷. By effectively implementing policies aligned with the methane and N₂O Pledges, Brazil can accelerate its emission reduction target by 2030, enhance its position in global climate negotiations, and improve food security while reducing emissions from agriculture.

The 30th Conference of the Parties (COP30) under the United Nations Framework Convention on Climate Change (UNFCCC), in Belém, Brazil, in 2025, is an opportunity to renew its Nationally Determined Contributions under the Paris Agreement, advocate for stronger climate finance mechanisms, and position itself as a global leader in NBS, bioeconomy, and carbon markets. The conference will serve as a platform for Brazil to showcase its progress in reducing deforestation, advancing bioenergy, and integrating climate resilience into economic development

¹⁰⁷ D M T Denny and others, 'Carbon Farming: Nature-Based Solutions in Brazil' (2023) 1 Green and Low-Carbon Economy 130
<https://ojs.bonviewpress.com/index.php/GLCE/article/view/887> accessed 5 February 2024.

while also addressing the challenges of balancing sustainability with economic growth.

Brazil's NDC is currently committed to reducing greenhouse gas (GHG) emissions by 50% by 2030 (compared to 2005 levels) and achieving carbon neutrality by 2050. However, hosting COP30 provides an opportunity for the country to enhance its ambitions, particularly in methane and N₂O reduction, carbon pricing mechanisms, and renewable energy expansion. One of the central themes at COP30 will be the protection of the Amazon Rainforest, which plays a critical role in global carbon sequestration. Brazil is expected to reinforce its zero-deforestation pledge by 2030, strengthen conservation policies, and expand financing for Indigenous-led forest protection initiatives. Additionally, nature-based solutions such as forest restoration, regenerative agriculture, and blue carbon projects (mangroves and wetlands) will be key areas of discussion, reinforcing Brazil's capacity to lead the global sustainability agenda.

Another crucial topic at COP30 will be climate finance and international cooperation. Developing countries, including Brazil, require significant financial resources to implement ambitious climate policies. Brazil will likely advocate for reforming international climate finance mechanisms, securing greater funding for developing economies, and operationalizing the Loss and Damage Fund to support vulnerable communities. Additionally, the conference will be a pivotal moment for strengthening global carbon markets under Article 6 of the Paris Agreement, potentially attracting international investment in sustainable projects across forestry, agriculture, and clean energy.

Despite its strong positioning, Brazil faces several challenges ahead of COP30. One of the main difficulties is balancing economic development with climate goals, particularly in the agriculture and energy sectors, which are key drivers of GHG emissions. Furthermore, ensuring a long-term commitment to deforestation reduction amidst political and economic pressures remains a crucial test. However, these challenges also present opportunities. Brazil can leverage its leadership in bioenergy and carbon-negative technologies such as BECCS to drive global climate action. Additionally, expanding low-carbon agriculture and methane reduction initiatives—particularly through the Global Methane Pledge—

can serve as a model for other developing nations seeking to transition to a sustainable economy.

As the host of (the recently concluded) COP30, Brazil can shape global climate discussions, refine its NDC commitments, and influence international cooperation efforts. By leveraging its strengths in Amazon conservation, bioeconomy, and climate finance, the country can ensure that COP30 becomes a transformational moment for both Brazil and the global effort to combat climate change. To maximize this opportunity, Brazil must strengthen its NDC with ambitious yet realistic targets, secure greater international financing, and position itself as a leader in climate-resilient development. With COP30 approaching, Brazil stands at a defining moment—one that will shape its role in global climate governance for years to come.

Agriculture was expected to play a pivotal role at COP30, with discussions expected to focus on the decarbonization of food production, methane and N₂O reduction, sustainable land use, and climate finance for farmers. The primary official platform for agricultural negotiations under the UNFCCC was the Koronivia Joint Work on Agriculture (KJWA), which addresses the integration of climate action into the global food system. The KJWA aims to develop policies that reduce emissions in the agricultural sector, enhance climate resilience in food production, and ensure food security while maintaining sustainability standards. Building on its outcomes, Parties adopted at COP27 the **Sharm El-Sheik Joint Work on Implementation of Climate Action on Agriculture and Food Security**, which broadened the scope of negotiations from agriculture alone to encompass the entire food system. This new framework seeks to move from technical discussions toward implementation, prioritizing actions that both reduce emissions in agriculture and enhance food security and resilience, particularly in developing countries.

Brazil was represented at COP30 through multiple key institutions and coalitions focused on sustainable agriculture to shape debates on how countries operationalize the Sharm El-Sheik work program, ensuring that agricultural mitigation and adaptation measures are effectively linked to national NDCs and long-term climate strategies. The Ministry of Agriculture and Livestock (MAPA) plays a central role in presenting

Brazil's initiatives for low-carbon agriculture, methane reduction strategies, and land restoration programs. Additionally, organizations such as the Brazil Climate, Forests, and Agriculture Coalition will bring together private sector stakeholders, civil society, and researchers to advocate for sustainable supply chains, carbon markets, and financial incentives for regenerative farming. The Brazilian Agricultural Research Corporation (Embrapa) will contribute through scientific research and innovation, particularly in integrated crop-livestock-forestry systems (ILPF), biological nitrogen fixation, and soil carbon sequestration techniques. Furthermore, the Governors' Climate and Forests Task Force (GCF Task Force) will represent states heavily involved in agriculture and deforestation control, working to strengthen the balance between economic development and environmental protection.

Arguably, COP30 exercised the aggregating spirit of the Rio conference and can be said to be just as transformative. With agriculture being one of the largest sources of GHG emissions, the sector's engagement at COP30 is essential in aligning Brazil's NDC with international climate goals, reinforcing the country's position as a leader in carbon farming.

7. CONCLUSION

Brazil's updated NDC demonstrates growing ambition but also exposes persistent challenges in enforcement, governance, and balancing growth with sustainability. By leveraging its strengths in bioenergy, CCUS, BECCS, NBS, and innovative policies, and by securing international finance, Brazil can position itself as a leader in global climate governance at COP30.

The agricultural sector, one of Brazil's largest GHG emitters, plays a pivotal role in this transition. Brazil can lead global discussions on low-carbon farming, methane and N₂O reduction, and sustainable land use management. Expanding ILPF systems, regenerative agriculture, and enhanced nitrogen-use efficiency will be crucial for reducing emissions while maintaining agricultural productivity. Furthermore, Brazil's vast biodiversity and ecosystem-based solutions can serve as a model for scaling NBS, with particular emphasis on forest restoration, wetland conservation, and blue carbon initiatives.

Moving forward, enhanced policy integration, financial incentives, and multi-sector collaboration will be essential for accelerating Brazil's climate transition. Strengthening carbon markets, implementing more ambitious methane and N₂O reduction strategies, and enforcing anti-deforestation policies will be key to meeting mid- and long-term climate targets. Moreover, by leveraging its bioeconomy, innovation in sustainable agriculture, and investments in clean energy, Brazil can establish itself as a global leader in low-carbon development.

Ultimately, Brazil's ability to bridge environmental conservation with economic resilience will define its role in global climate governance. By reinforcing its commitment to sustainability, transparency, and inclusive policymaking, Brazil can ensure that its NDC translate into meaningful action, setting an example for emerging economies in their path toward net-zero emissions.

A simplified network analysis was developed to evaluate the relationship between Brazil's NDC, themes covering the main challenges, and possible low-carbon solutions for Brazil. The analysis showed that NDCs for additional measures are much more interdisciplinary, resulting in a larger number of links towards KW and LCS, compared to NDCs associated with mitigation and adaptation targets, which are more focused. In terms of LCS, management solutions stood out by showing a significantly higher number of links per LCS compared to the technological solutions. The most interconnected NDC is related to ICLPp systems, which showed off as a removal solution by NBS, also supported by a range of low-carbon management solutions. Finally, despite no LCS being a "one size fits all" solution, carbon management focused on carbon neutrality assessment almost reaches all NDCs and KWs.

Brazil still does not include in its emissions inventory the removals resulting from correct soil management and the recovery of degraded pastures, sewage prevented to be discarded in the oceans are not accounted as well, on the other hand forest fragmentation and fires does not reflect because the numbers are only on the declared special protected area as a whole, unfortunately repeatedly being invaded and set on fire.

At least in part because of the success of a Brazilian public policy incentivizing low-carbon agriculture, a range of sustainable practices has been adopted nationwide. These include the good practices such as reclaimed soils from degraded pastures; planted forests; biodigesters in pig farms; crop-livestock-forest integration; adoption of no-till farming (no removal of straw, organic matter that protects the soil, during harvesting); no-till only and no-till (which includes the use of cover crops, minimum tillage, planting in the green and other more complex techniques); biological nitrogen fixation; agroforestry systems; cattle slaughtered early; special feed; use of cover crops.

The country needs to include these removals, as well as emissions not accounted for by fire and forest fragmentation, which tend to fall as deforestation is also combated, in inventories to obtain a more accurate picture of its net emissions for transparency in complying with current and future NDCs. One of this paper's significant contributions is an examination of the links between Brazil's NDC, LCS, and the country's primary obstacles in meeting its climate commitments.

The network analysis offered a formal framework for determining the most effective mitigation and adaptation methods. The data show that LCS are not stand-alone efforts, but rather vital parts of Brazil's overall decarbonization plan. The study shows that management-based solutions—such as carbon neutrality assessment and emissions monitoring—are inextricably linked to technology solutions like CCUS, BECCS, and NBS. This emphasizes the need for cross-sectoral cooperation and policy integration in maximizing Brazil's climate action effect. By stressing these links, the report presents a roadmap for improving the efficacy of Brazil's NDC pledges, making the LCS analysis an important deliverable for politicians and scholars alike.

Through analysing the targets set by Brazil, the cross-relationship of these with relevant subjects, and the measures taken to achieve them, we have found that while progress has been made, there is still much work to be done. Brazil must continue to prioritize sustainability, implement effective policies to meet its NDC, and contribute to global efforts to address climate change.