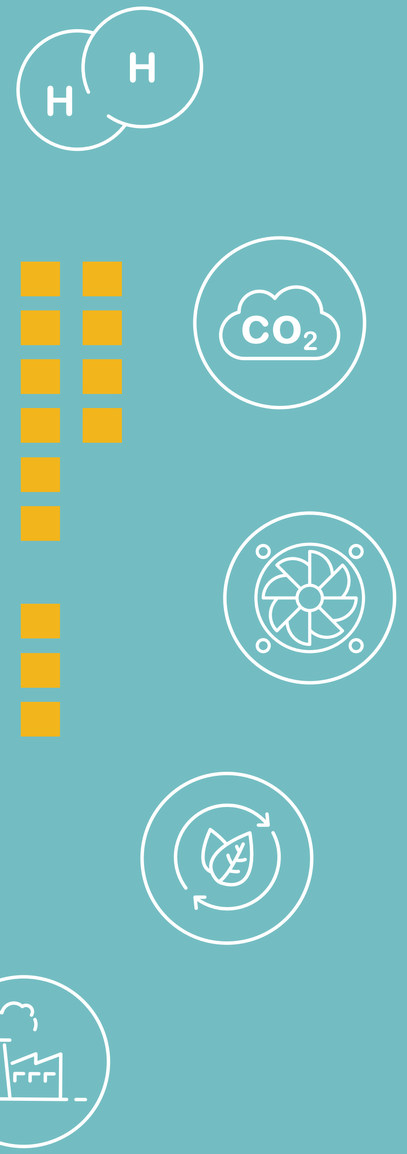
1st Annual CCS Report in Brazil

2022/2023



CCS Brasil

Credits

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Methodological notes

For the sake of estimation and references, CCS Brasil databases were employed, gathering data and information in the range of 2020 to 2022 term from sources such as ANP, EPE, CNI, CIBIOGÁS, SEEG and IBGE, as well as the analyses provided by researchers and specialists upon several topics deemed in the document. This report warns the numbers and maps hereby has the intention of serving as a reference for magnitude surveying orders and indicating proper ways to identify opportunities for CCS projects, being the legal use and engineering purposes utterly disallowed due to great uncertainties associated with data collection and treatment.

Summary

CCS Brasil Message

Every single emerging economic activity presents initial challenges in regard to the missing reliable data and information, the absence of established standards, legal uncertainty as a result of lack of regulatory framework, along the construction of the supply chain up to the need of a better workforce training.

On one hand, if these obstacles harms the full development of an activity in development, on the other, it brings the opportunity of a collective and participative setting up, observing an entire sector best practices.

By structuring this first Annual CCS Report in Brazil, we seek for contributing to lay out a manner leading to the structuring of the entire sector of carbon capture, transport and storage, overcoming the initial challenges and collaborating to consolidate CCS projects acknowledgment as part of Brazil's decarbonization strategy.

We know that information is power. We believe that by sharing it in a clear and accessible way, we are helping to strengthen the foundations of a fairer and more sustainable economy.

Our goal is to provide accurate and relevant information to the various actors involved in CCS activities, whether they are entrepreneurs, investors, researchers or public managers.

Our report structuring contemplates the necessary investments in the future of CCS activities. We believe our mission and work can amplify the success of these initiatives, and we are committed to contributing to a fairer and more sustainable world.

You will find in this document

This document is divided into five parts.

The first part aims to contextualize the role that CCS technologies can play in some of the emission reduction scenarios to meet the goals of limiting the Earth's temperature. In addition, the numbers related to the CCS projects in operation are presented, as well as the projects announced in 2022.

The second part of this report focuses on the main applications for CCS in Brazil, with surveys and preliminary estimates regarding the potential for carbon capture projects and identification of areas of interest for geological storage of CO_2. Relevant aspects of logistics are also presented, especially regarding the transport of CO_2 between capture sources and potential locations for storage.

The third part summarizes relevant aspects for CCS development in Brazil in 2022. Institutional, regulatory and incentive aspects for the implementation of CCS projects will be properly addressed. Brazilian projects, announced and in progress, will be also presented, as well as the advances in Research & Development projects.

The fourth part presents analyses and perspectives for the coming years. In this section, we consolidated the perspectives of representatives from several sectors, a brief analysis of the bases for an attractive institutional environment for projects, an analysis of how Brazil can learn from other countries.

The fifth and last part introduces the 06 strategic points needed for the development of CCS projects in Brazil, with Brazilian CCS vision to accelerate the implementation of complete chains of these technologies on a large scale.

What is

happening worldwide?

A Decarbonization and Climate Urgency

With the increasing concentration of greenhouse gases in the atmosphere, which results in negative events related to global warming, leaders and companies around the world consider the production chain adaptations to a low carbon economy as an agenda priority.

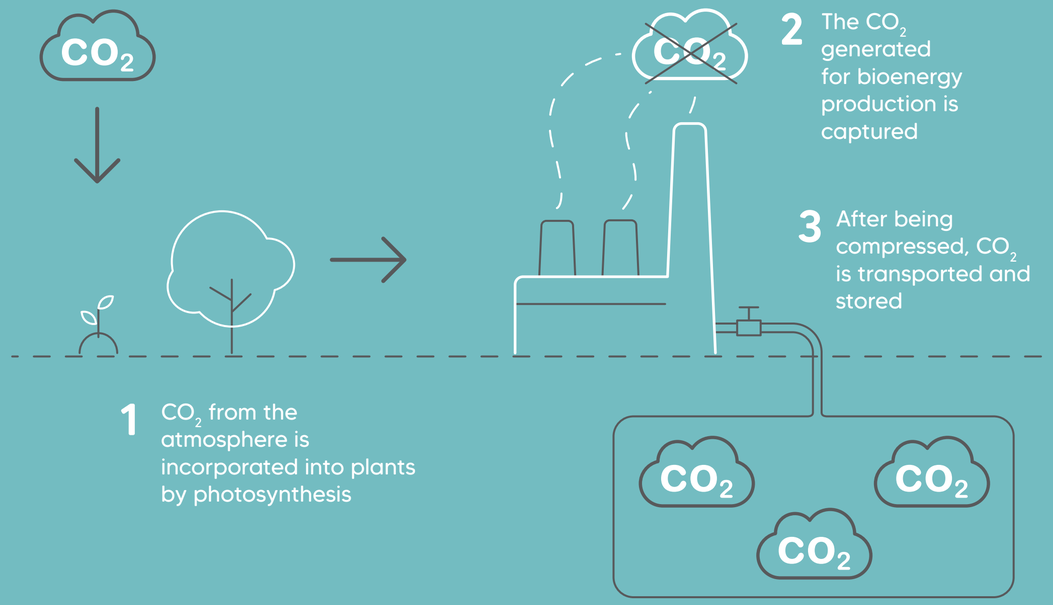
At the end of 2021, the UNFCCC (United Nations Framework Convention on Climate Change) released a special report consolidating the Nationally Determined Contributions (Portuguese for Contribuição Nacionalmente Determinada, or NDCs according to the acronym of the original expression in English) submitted by the countries. The objective of the document was to clarify the impact of the countries' decarbonization targets in relation to the remaining carbon budget by 2050. The finding was in the sense that even if all the indicated targets are met, emissions in 2030 should be 16.3% higher than in 2010. In other words, it means that 89% of the carbon budget will be consumed by 2030, with around 55 $GtCO_2$ of carbon remaining for the period 2030 to 2050.

These numbers show that, although political and diplomatic advances have been relevant to strengthen the climate issue, the declared commitment of countries is not enough, and emissions continue to rise. In order to have a reasonable chance of staying below the 2°C threshold in relation to pre-industrial levels, the world needs to reverse current emission trends, but this is not an easy task. Although the technological solutions available, the ways to reverse this emission trend are determined by local opportunities, as well as the technical and economic limitations when adopting one technology. In other words, there is not an unique standard strategy to be applied across the world.

The IPCC simulates possible methods and scenarios for keeping average global warming below 2°C this century, based on Integrated Assessment Models (IAMs), which combine perspectives from different syllabi to create a dynamic description of scenarios that put together energy, economics, land, and climate – the main contributors to greenhouse gas emissions. The interaction of these different sectors in a single interface allows the visualization of changes in the whole system, as well as the articulation among these sectors and the issues surrounding the climate change mitigation.

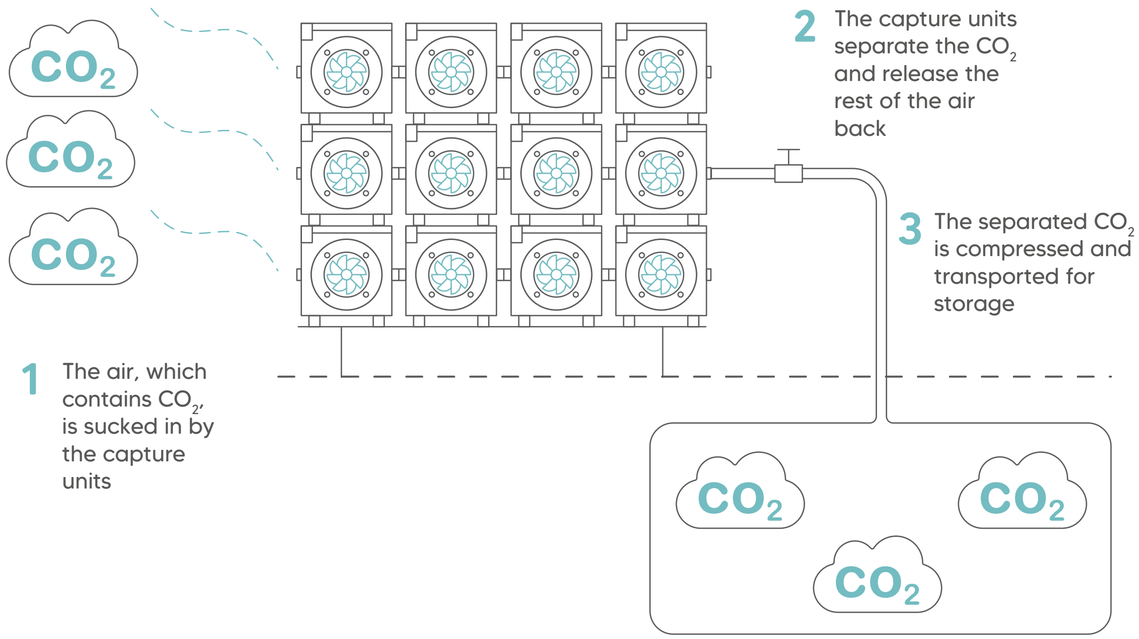
The most recent IPCC (AR6) report considers several forms of emission mitigation in key sectors as decarbonization strategies. These strategies include processes aimed at efficiency and reuse of materials, replacement of energy matrices for sustainable fuels and the incorporation of CCS (Carbon Capture and Storage) projects either in emissions-intensive industries, such as in the cement, steel and fertilizer industries, and in combination with the biofuel production or direct air capture. Despite the diversity of techniques available to reduce the carbon footprint of these activities, the scenarios provided by the IPCC are plenty of a strong dependence on carbon removal or negative carbon (CDR - Carbon Dioxide Removal) techniques to offset emissions from other sources which face greater technical difficulty in reducing their emissions. Carbon removal refers to a set of techniques for removing CO_2 from the atmosphere, including carbon storage from bioenergy plant capture (BECCS) or direct air capture (DACCS), afforestation and reforestation, biochar, weathering acceleration and mineral carbonation.

BECCS Carbon Removal



The BECCS process starts with the carbon arrest by vegetation with the duty of originating the bioenergy production. The CO_2 in the air is employed during photosynthesis.
The vegetables are then processed for transformation into bioenergy products (such as ethanol, biomethane and bioenergy), and release CO_2, which would be emitted into the air again.
In the capture unit, CO_2 is separated from the other gases produced and then goes through compression to be transported to the injection site for permanent storage in deep geological formations.

DACCS Carbon Removal



The direct air capture process with CCS, known as DACCS or DAC, is a relatively new technology, consisting of capture units drawing the air.
The CO_2 in the vacuumed air is separated from other components by chemical processes, then released back again into the atmosphere.
After this purification, the CO_2 is compressed and transported to be injected and permanently stored in great depth geological formations.

B Economic Incentives / Carbon Market

In technological terms, the world has advanced at an accelerated pace towards the creation of solutions and instruments enabling the economy decarbonization. Currently there is no lack of technological routes, already relatively mature, nevertheless an important obstacle is yet to be overcome: their implementation cost.

However, there are several ways to encourage the adoption of clean technologies. One of them is fostering financial incentives, such as subsidies and tax credits, which can help offset the high costs associated with decarbonization. In addition, market incentives can also play an important role in the adoption of decarbonization technologies. Carbon credits, for example, have proven to be an attractive way for companies to reduce their carbon emissions and generate revenue at the same time.

No further difference about CCS, whose financial incentives have played a fundamental role regarding implementation all over the world. With the support of governmental and market incentives, the number of projects under development and announced around the world has grown exponentially.

It is possible to observe a direct relationship between the existence of economic incentives and a growing number of projects in certain regions over the years.

The existence of public policies, economic incentives and carbon pricing mechanisms have become an established practice all over the world. According to data from the World Bank repository, there are already 70 carbon pricing initiatives implemented in the world.

In addition to pricing, there are also a few project financing mechanisms and related policies.

Considering that this report focuses on the events that took place in 2022, we highlight below four initiatives that represent direct or indirect economic incentives for CO_2 projects.

USA

The 2022 Inflation Reduction Act: among other powers, this law defines an investment of US$ 369 billion to finance projects focused on climate and energy, in addition to promoting changes in the 45Q, a federal program designed to offer financial incentives to companies capable of carbon dioxide capturing and storing.

Canada

Tax Credits: The 2022 Canadian federal government's budget provides for tax credit spending for CCUS projects that permanently store captured CO_2 through dedicated geological storage or concrete CO_2 storage.

European Union

In 2022, the European Parliament passed the creation of the Carbon Frontier Adjustment Mechanism, a taxation system on good imports from third party countries without pricing for carbon emissions like similar mechanisms applied in the EU. The imposition of a border tax can encourage non-EU industries to adopt cleaner technologies such as CCS towards the reduction of their carbon emissions and the avoidance of higher taxes charges.

Malaysia

Tax Incentives: an import and sales tax exemption policy on equipment for CCS technology was approved, coming into full force from January 1, 2023 to December 31, 2027.

Can Europe and America's Net Zero Framework Support Carbon Capture Storage in Brazil?

Fernando Hernandez, Forbes Contributor, Business Ambassador to Scotland - Energy Sector and Chairman of CCS Brasil's International Board

Europe and America's net zero and ESG pressures are forcing International Oilfield Companies (IOCs) to take a low carbon approach to their global hydrocarbon portfolio, extending to regions like Brazil. IOCs now have to meet ESG and net zero targets passed in their home nations, driving a global approach. For instance, BP issued its net zero declaration and is rebalancing its global portfolio to be greener. However, BP still has a hydrocarbon position in Brazil's offshore sector, along with Equinor, Shell, and TotalEnergies.

Equinor and ExxonMobil have been sequestering millions of tons of CO_2 in offshore reservoirs via Carbon Capture Storage (CCS) since 1996 at Sleipner in Norway. Brazil, with extensive offshore experience in hydrocarbon production, can leverage this method for CCS. Though the regulatory framework supporting CCS in Brazil needs advancement, pressure on IOCs continues, potentially bolstering Brazilian CCS pursuits. Financial pressure is also rising outside of government mandates, such as ExxonMobil receiving board seats to ESG activists, while Petrobras secured a $1.25 billion international sustainability/green loan in July 2022.

There are ESG benchmarks and assessments that eliminate an IOC's regional silos and evaluate their hydrocarbon operations in a global ESG portfolio. The environmental effects of a company on the environment can be measured, impacting its market position and green-investment worthiness. Brazil has shown interest in pursuing a net zero future, requiring the passage of laws that incentivize sequestering CO_2, such as the 2022 Inflation Reduction Act (IRA) in the US. The IRA raised the price per tonnage of CO_2 that is sequestered in America, spurring CCS in the US and combating ESG pressure for oil companies.

Brazil faces the challenge and opportunity to decarbonize, providing a framework to bolster the advancement of CCS in Brazil with monetary incentives and attracting investments. Brazil can decrease the anthropogenic CO_2 it releases into the biosphere while taking a decarbonization leadership role in South America, without entirely preventing hydrocarbon production. The country can leverage what the IRA has set in motion and explore other areas, such as hydrogen, low carbon, and clean technologies, to expand its economy outside of hydrocarbons. As the leading oil producer in South America, Brazil has the emission sources to deploy CCS in a unique and scalable way.

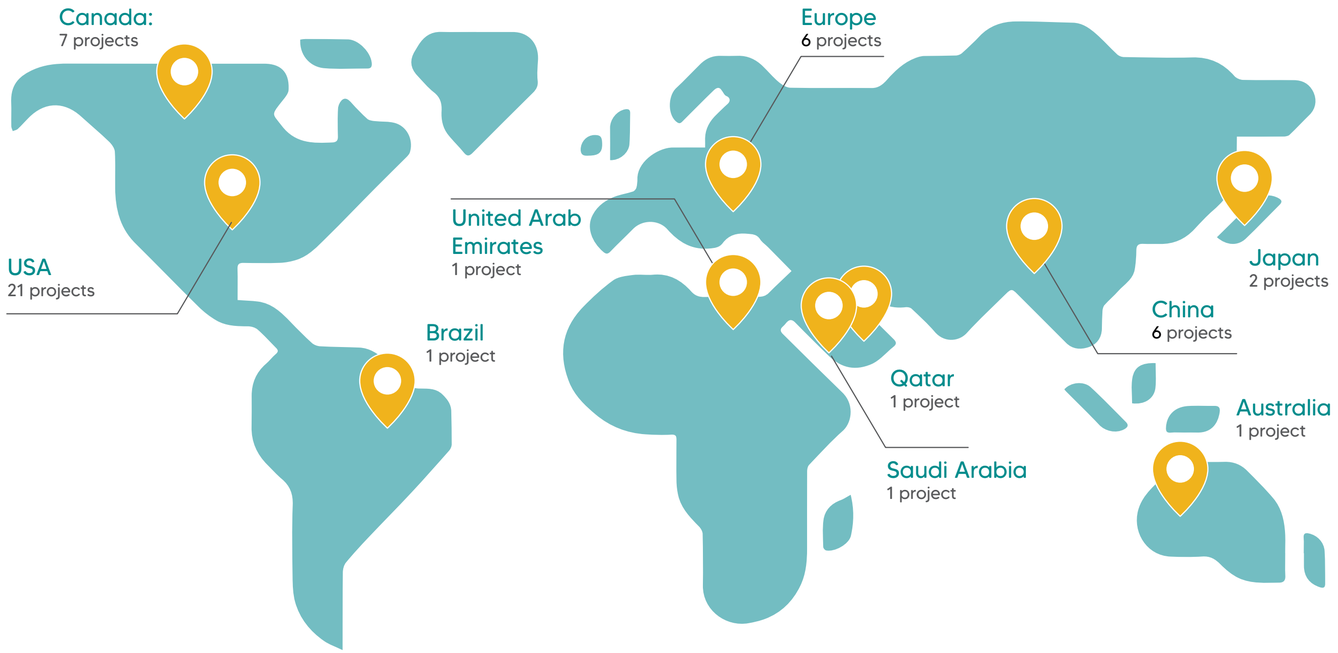
D Projects Around the World

According to the International Energy Agency database, there are currently 47 CCS projects in operation worldwide, which together have an estimated capacity ranging from 74 to 82 CO_2 Mt captured per year. The projects are mostly concentrated in developed countries, as shown in the map.

In recent years, the resurgence of very positive expectations in the market regarding CCS projects around the world took place, especially in 2022. Moreover, according to the International Energy Agency, 159 new projects were announced, distributed in 56 ones of capture projects, 34 about storage, 14 for transport and storage, 18 for transport only, and 33 embracing the complete chain.

The boom of announced projects last year indicates a positive sign of a growing awareness of the carbon capture and storage technologies importance for the planet's decarbonization goals achievement, being likely witnessed to the private sectors' investments in climate crisis solutions. Nevertheless, it is also important developing country governments support these efforts by promoting favourable public policies and financial incentives for CCS technologies to be implemented on a large scale.

Projects announced in 2022



Complete chain: 33 projects	**Only capture:** 3 projects	**Only utilization:** 3 projects	**Only storage:** 1 project	**Only transportation:** 7 projects

According to the data from the International Energy Agency, there are currently 47 CCS projects operating in the world, with an announced capacity ranging from 74 to 82 million tons of CO_2 captured per year. As shown on the map, these projects are mostly concentrated in developed countries.

The Circular Carbon Economy - A Case for Utilising the Carbon that we Capture

Beena Sharma, CEO/Co-Founder - CCU International

The global focus is shifting towards achieving net zero emissions, a crucial goal outlined in the Paris Agreement to limit global warming. The push towards net zero presents opportunities for countries around the world, including economic benefits, investments, enhanced reputation, and mitigating climate risk. However, achieving net zero emissions will require the deployment of carbon capture technologies.

Governments globally have recognised that Carbon Capture Utilisation and Storage (CCUS) technology will be a key player in achieving net zero by 2050 and beyond. CCUS technology would allow countries to decarbonise until the next generation of carbon energy technologies become available, thus bridging the gap and providing a solution during the energy transition.

CCUS projects involve energy intensive capture from complex industry emissions, compression/liquefaction of captured CO_2, transportation of CO_2, extensive geological surveys to qualify storage sites, obtaining legal permits and insurance, and once sequestered underground, the constant monitoring. Cost is a barrier as well as the timescales for CCS projects. However, there are several innovative ways to recycle captured CO_2, such as using it for aggregates for building and construction material, commodity chemicals, and sustainable transport fuels.

By capturing CO_2 emissions at the source before it enters the atmosphere and purifying it for use in industry, we can create a circular carbon economy. Captured CO_2 can be liquified for resale into industry creating a revenue stream for any organisation involved in capturing emissions. Captured CO_2 can also be reused to create products for reuse/sale.

The largest barrier that 'storage' poses is cost. However, by utilising the captured CO_2 using FluRefin technology, we can reduce the cost of capture substantially over existing amine systems and we can effectively turn a cost associated with disposal of CO_2 in underground reservoirs into multiple revenue streams by using the CO_2 as a carbon resource.

International cooperation plays a critical role in advancing global climate change agenda, addressing new challenges and opportunities, and developing the technologies of tomorrow through shared lessons and learning.

CCS Applications

in Brazil

A Key-Sectors

The potential for CCS projects implementation is mainly related to the presence of activities in the energy and industry sectors, the main CO_2 emitters in the world.

The most cutting-edge processes for carbon capture are applicable to large scale stationary CO_2 emission sources, like the ones found in industrial processes. For the energy sector, these sources are related to electricity generation activities in power plants, energy used in industry and fossil fuel production.

In Brazil, these stationary sources of energy and industry emit around 150 million CO_2 tons, equivalent to circa 9% of the country's total emissions, behind activities related to the Land Use Changes.

There is also the possibility of applying CO_2 capture in processes that are not accounted for in the country's emissions, such as in the bioenergy production whose generated CO_2 is biogenic, as well as in more recent processes still in charge of developing a market, which is the case of hydrogen production and Direct Air Capture.

Due to vast continental dimensions, as well as the variety of energy generation sources and the multiplicity of industrial sectors, Brazil has the potential to capture CO_2 on several fronts. In the following pages, we will analyse each sector particularly.

Main activities with potential for CCS project implementation

Power plants
Based on fossil fuels, such as natural gas and coal, or renewable fuels, such as biomass and biogas

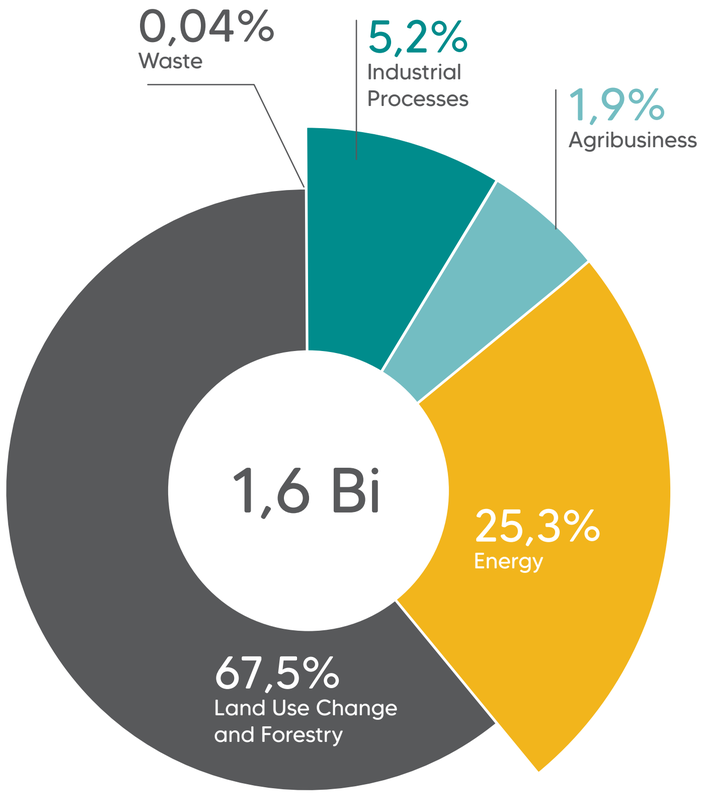
Industries
Especially those found more difficult to decarbonize, such as steel, cement, chemicals and refineries

Bioenergy production
From emissions in fermentation vats for ethanol production and separation of CO_2 contained in biogas to obtain biomethane

Hydrogen production
Based on fossil fuels such as natural gas and renewable fuels such as biomethane, biomass and ethanol

DACCS
Direct capture of the air, separating the CO_2 content from the other atmosphere gases

CO_2 emissions in Brazil



Based on SEEG data for 2021

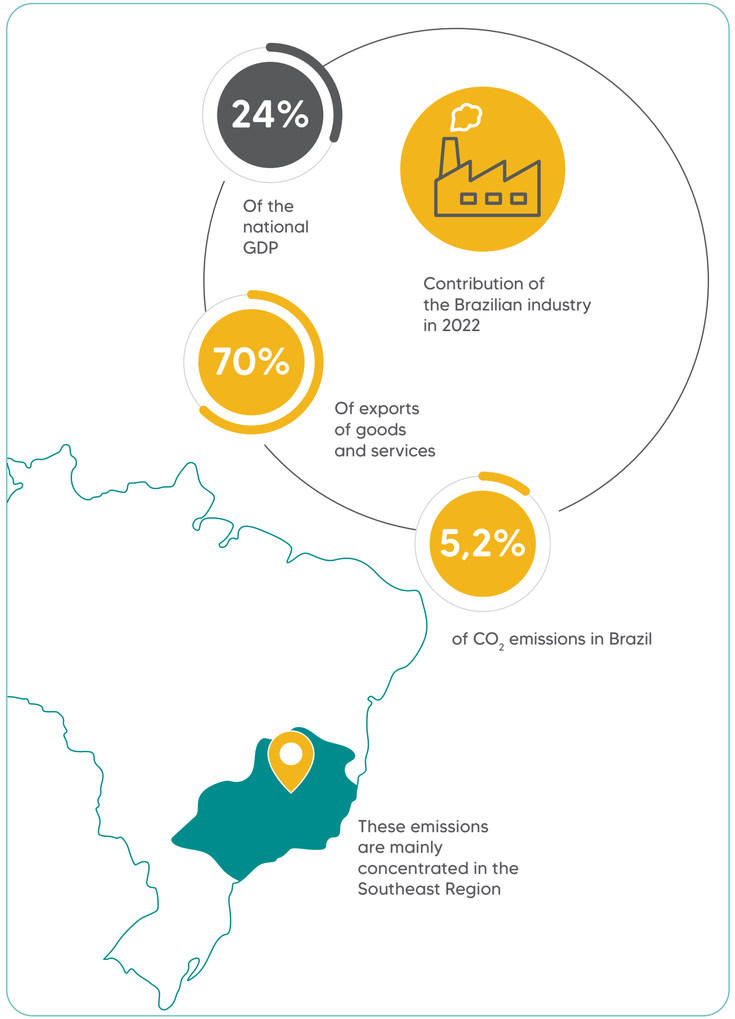
Industry

In 2022, Brazilian industry contributed with around 24% of the national GDP and 70% of the exports of goods and services, according to the CNI (Portuguese for Industry National Confederation, "Confederação Nacional da Indústria".) In face of the international efforts to meet climate goals, Brazilian industry medium and long-term competitiveness must involve planning and implementing solutions to reduce the carbon intensity of its products.

Although the share is only 5.2% of CO_2 emissions in Brazil, industrial processes reached a total emitted volume of close to 85 million tons in 2021, which represents around 57% of emissions with potential for reduction by CCS projects.

These emissions are mainly concentrated in the Southeast region.

Among the most relevant industrial segments for the CO_2 emitted volumes, the largest share in emissions refers to the metal production segment, correspondeding to almost 70% of emissions from industrial processes.



The role of CCS for the sustainable development of the industry in the world:

CCS technologies are recognized as one of the main tools for decarbonizing industrial processes, especially when alternatives for the existing industrial park are a mandatory.

The CO_2 capture unit implementation can be performed by retrofit, that is, an industrial plant already in operation can simply incorporate this unit without changing the production process.

The industrial segments with strong appeal for CCS are those depending on fossil fuels in their production processes or on high energy density fuels. This group includes industries such as steel, cement, refineries, and chemical industries in general.

These sectors are responsible for a large share of global CO_2 emissions, and implementing CCS technologies can help significantly reduce the carbon footprint. Furthermore, CCS technologies have the potential to make these sectors more sustainable and competitive, allowing them to continue to operate while reducing their greenhouse gas emissions.

Energy

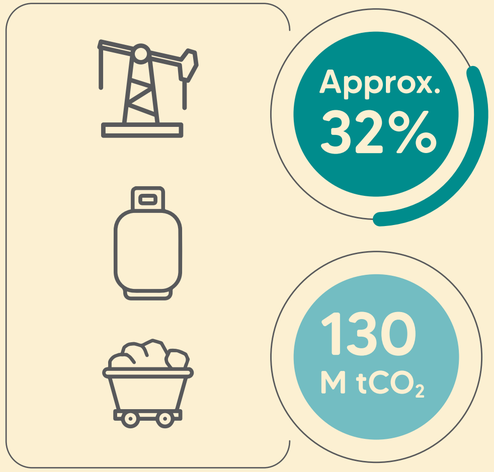
Despite Brazil having one of the cleanest energy matrices in the world, fossil sources (oil and derivatives, natural gas and mineral coal) represented just over 53% of the domestic energy supply in 2021, according to EPE data (Portuguese for Energetic Research Company, "Empresa de Pesquisa Energética").

According to SEEG (Portuguese for Estimative System for Greenhouse Effect Gas Emission and Removal) the sector accounted for 25.3% of CO_2 emissions in the country, making it the second largest contribution of emissions in the national scenario. Most of these emissions were concentrated in the Southeast and South regions of the country, with 47% and 16% of the total CO_2 generated by this sector, respectively.

The segments most suitable for implementing CCS projects include power generation, industrial applications, and fuel production. To some extent, the potential for capturing CO_2 reaches 32% of the energy sector's emissions, which could reduce around 130 million tons per year, from fossil sources. This potential represents around 8% of Brazil's total emissions in 2021.

Beyond the energy sector's decarbonization potential, CCS can also configure a technology for removing carbon from the atmosphere when coupled with renewable energy from biomass, bearing the name of BECCS.

CO_2 capture potential in the energy sector

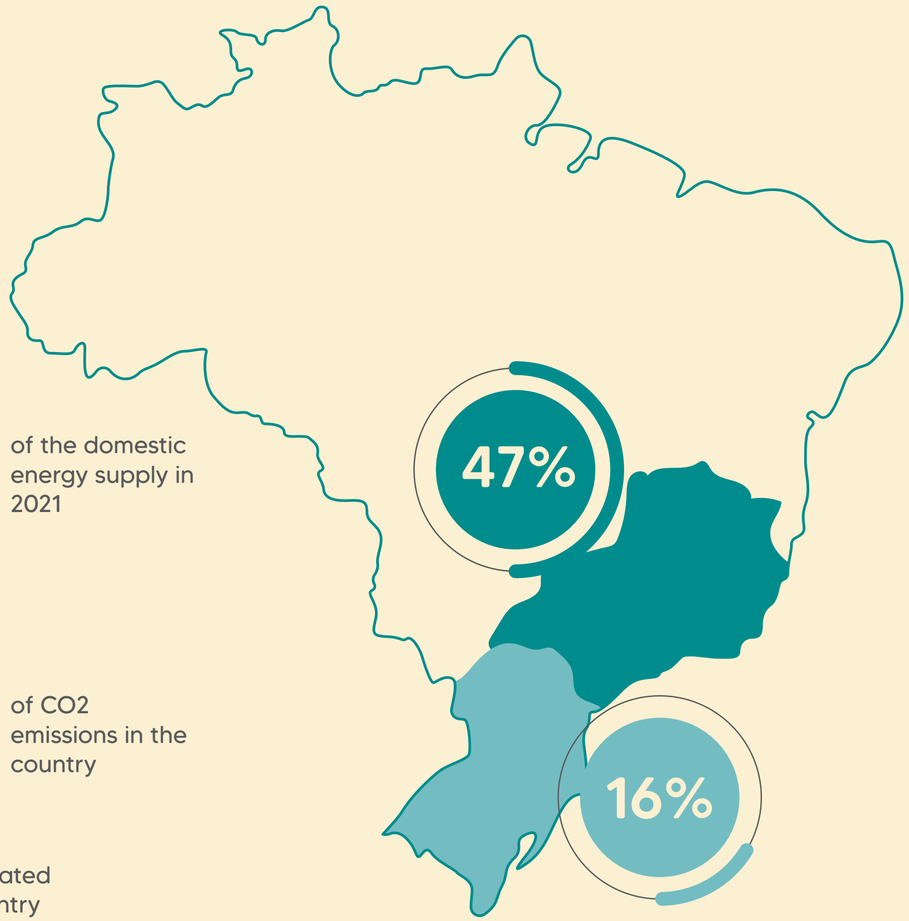


Approx. 32%

of the domestic energy supply in 2021

130 M tCO_2

of CO2 emissions in the country



The majority of these emissions were concentrated in the Southeast and South regions of the country

Hydrogen

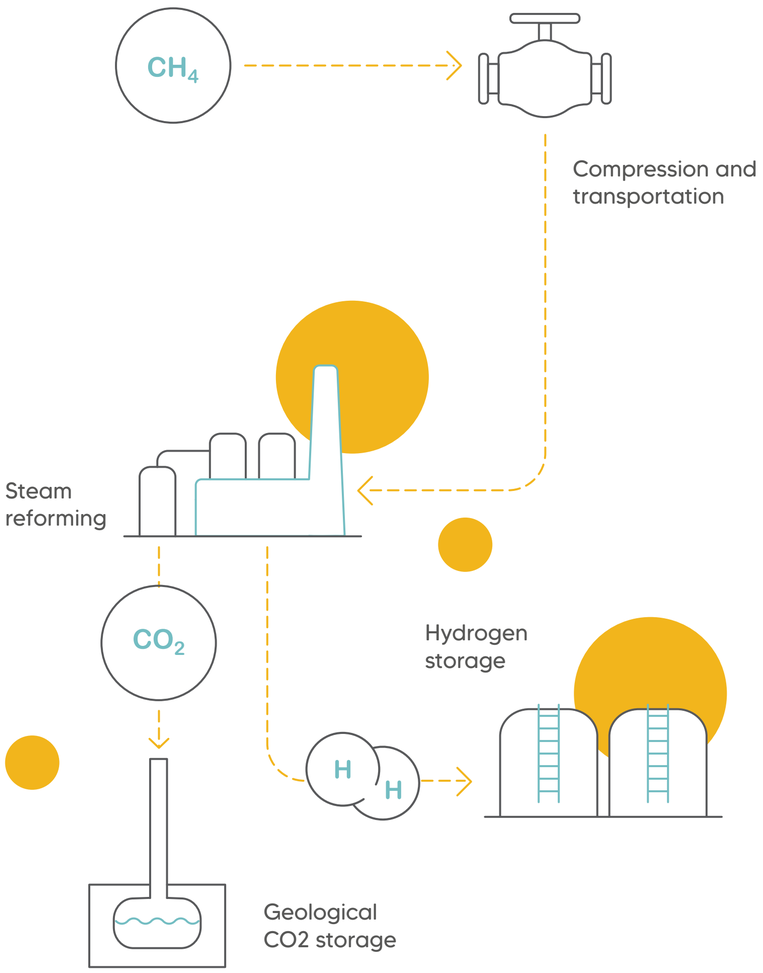
Another important CCS application is CO_2 capture from some hydrogen production routes.

The best known, and perhaps with the greatest potential for development in the short to medium term, is the production route based on the reforming of natural gas steam. By coupling CCS to this process, the known blue hydrogen is obtained, a low-carbon fuel with great national and international market potential.

The use of natural gas as a source for this sort of fuel enables important gains in scale for production, at generally lower costs compared to other low-carbon hydrogen routes.

It is also possible to couple CCS to the hydrogen production from biomethane and ethanol. As renewable sources, this combination leads to negative emissions, removing CO_2 from the atmosphere.

The Blue Hydrogen production process



Blue H2 in the world

The perspectives for blue hydrogen in the world are positive, with several in progress and upcoming projects around the world, some of them including major companies such as ExxonMobil and Shell.

Many countries have adopted public policies to encourage the development of blue hydrogen, which is the case of the United Kingdom in developing CCS clusters and hydrogen hubs.

These initiatives aim to integrate different companies and sectors, forming a blue hydrogen production, storage and distribution network with low carbon emissions.

Projections of CO_2 capture potential

Making projections for the potential of CCS for blue hydrogen can be a complex task, given the absence of official estimates on the productive potential of this fuel in Brazil. However, the potential for blue hydrogen is directly related to the country's natural gas extraction, as the technology involves capturing CO_2 generated during the gas reforming process.

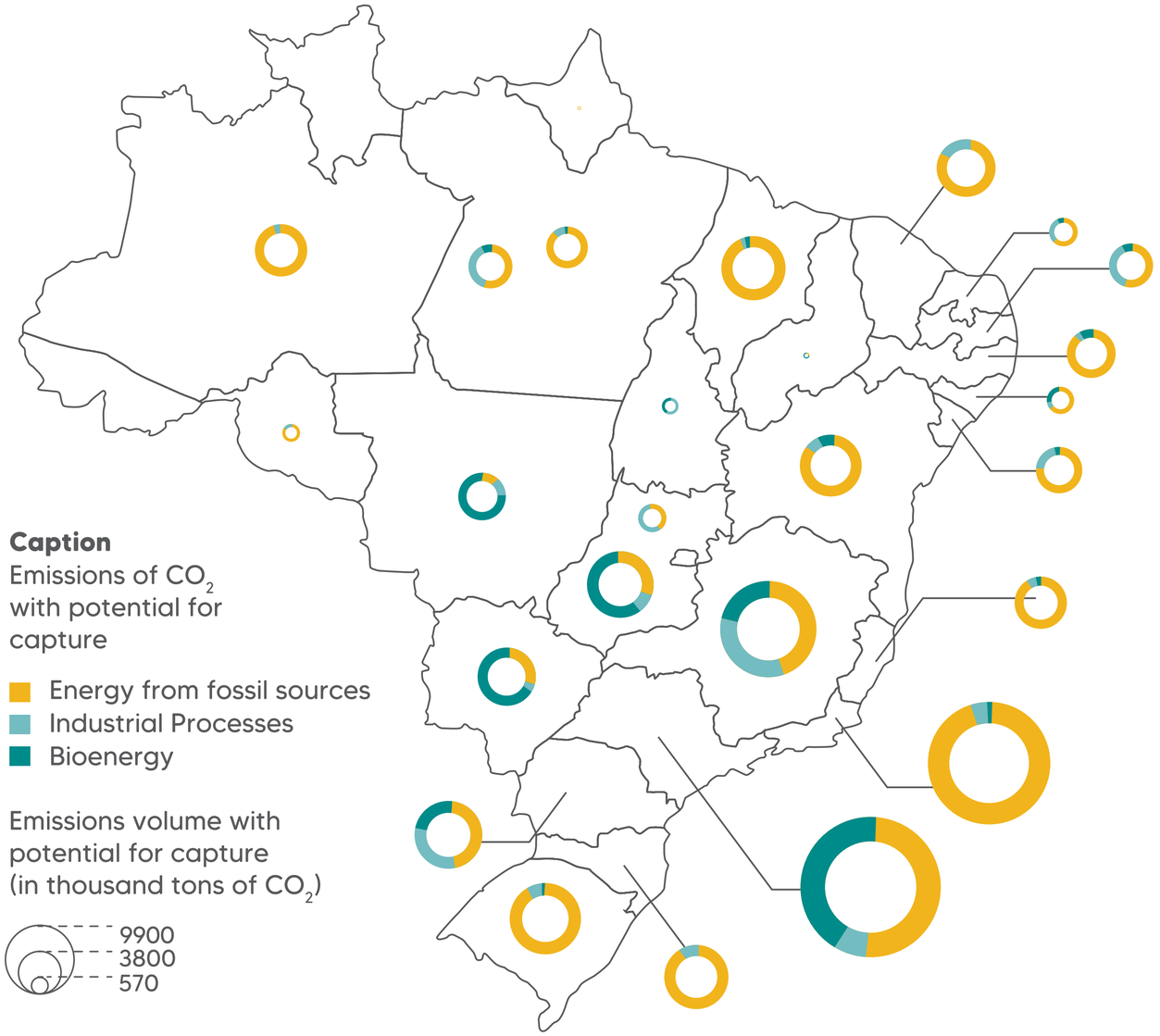
Considering the extensive reserves of natural gas in the country, it is possible the potential for this technology is very high, which would significantly expand the capacity for applying CCS in Brazil.

Carbon Capture Potential

Considering the key sectors presented for the implementation of CCS projects, Brazil's CO_2 capture potential can reach more than 190 million tons per year.

Based on SEEG, ANP, EPE, CIBIOGAS and CCEE data, between 2020 and 2021, this potential for CCS projects is led by the energy sector from fossil sources, representing more than 65% of emissions. BECCS has the second highest potential for capture at around 20%, followed by industry at less than 15%.

The Southeast region concentrates more than 48% of CO_2 capture opportunities, with prominence in São Paulo State, presenting a volume close to 40 million tons.



Carbon capture Potential (BECCS)

CCS processes when applied to the capture of CO_2 generated by renewable sources are called BECCS.

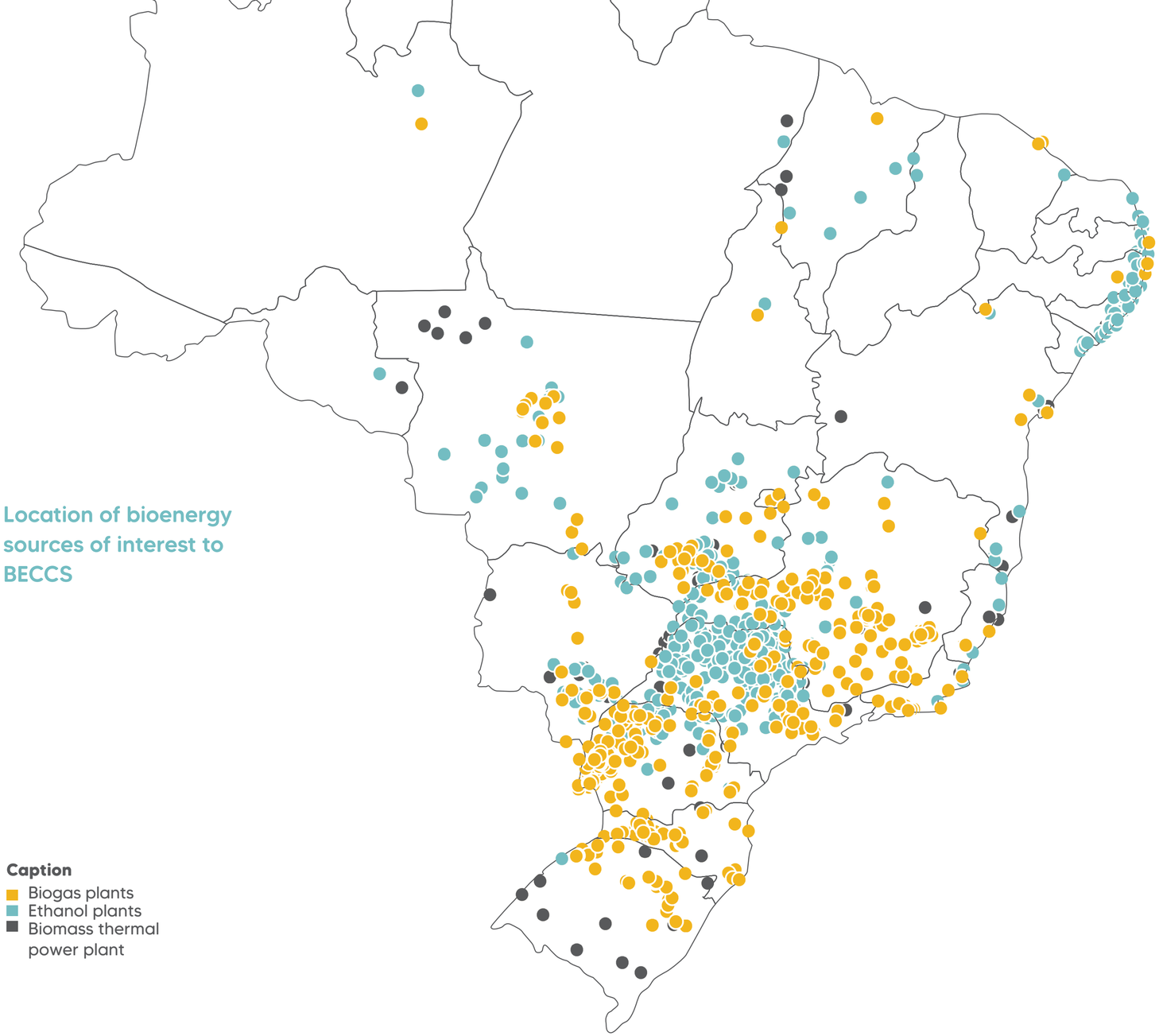
The main applications for BECCS include ethanol plants, biogas purification plants to obtain biomethane and biomass or biofuel power plants.

Brazil has one of the greatest potentials for BECCS in the world, given tradition and participation in the ethanol market, in addition to the still little explored - but growing - potential for biogas in its territory.

As shown on the map, the largest number of bioenergy plants is concentrated in the Midwest, South and Southeast. In addition, there is also a considerable number of plants along some Northeast states coastline.

The volume of CO_2 produced and concentrated in specific regions favours CO_2 hubs planning and creation.

Location of bioenergy sources of interest to BECCS

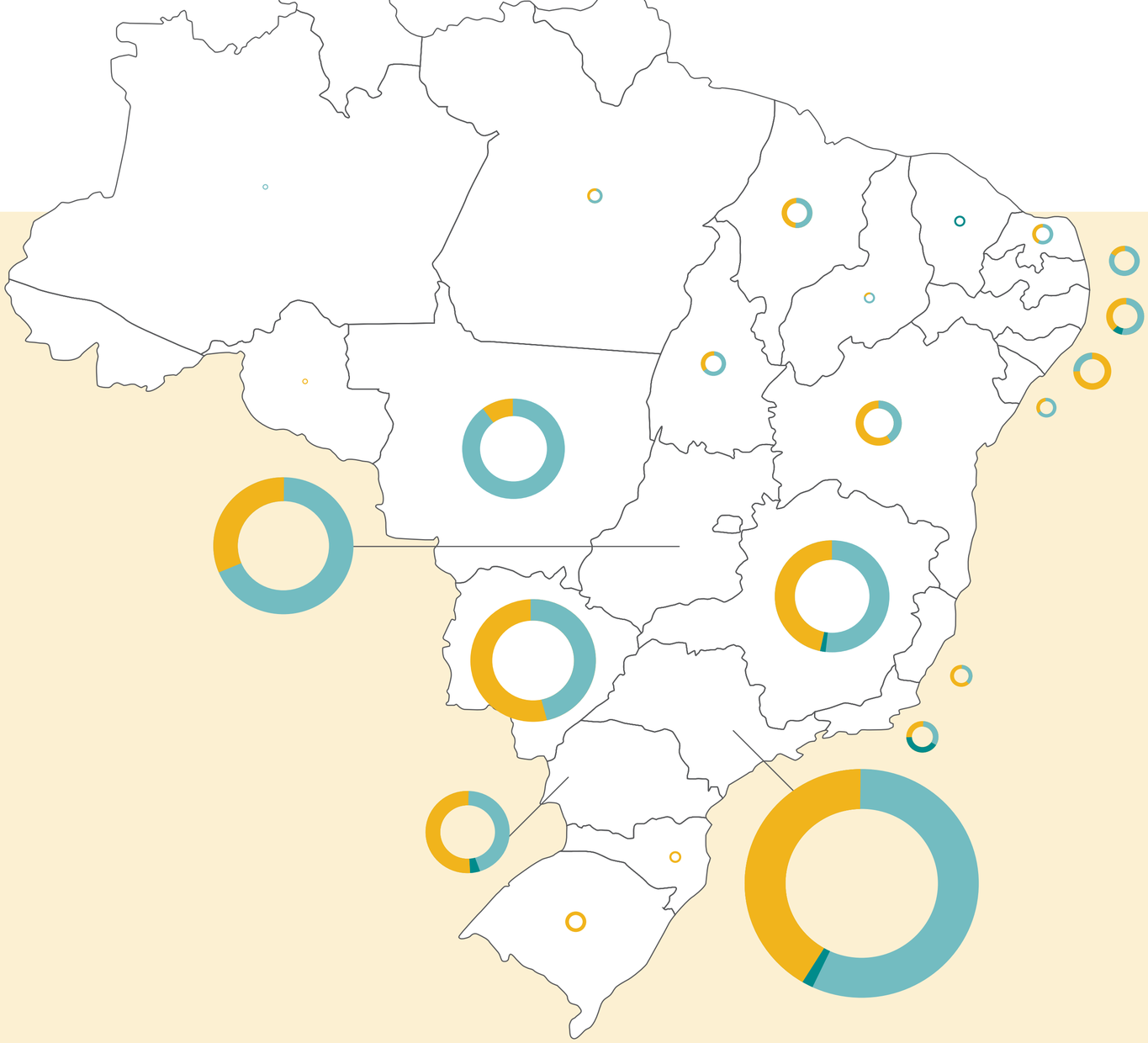


Carbon Capture Potential (BECCS)

Considering only the BECCS capture potential, the Southeast and Midwest regions concentrate the main sources of bioenergy, with a total volume of 87%.

The State of São Paulo also leads the potential for BECCS, with more than 15 million CO_2 tons, from nearly 60% of this amount coming from ethanol plants.

Carbon Capture Potential - BECCS

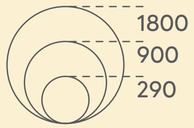


Caption

CO_2 Emissions with Potential for BECCS

- Ethanol
- Biogas
- Bioeletricity

Volume of Emissions with Potential for Capture (in thousands of tons of CO_2)



Revenue Potential for Brazil

The adoption of CCS technologies can be an important source of revenue for companies seeking to reduce their atmospheric CO_2 emissions and, at the same time, have benefits from the carbon credit sale.

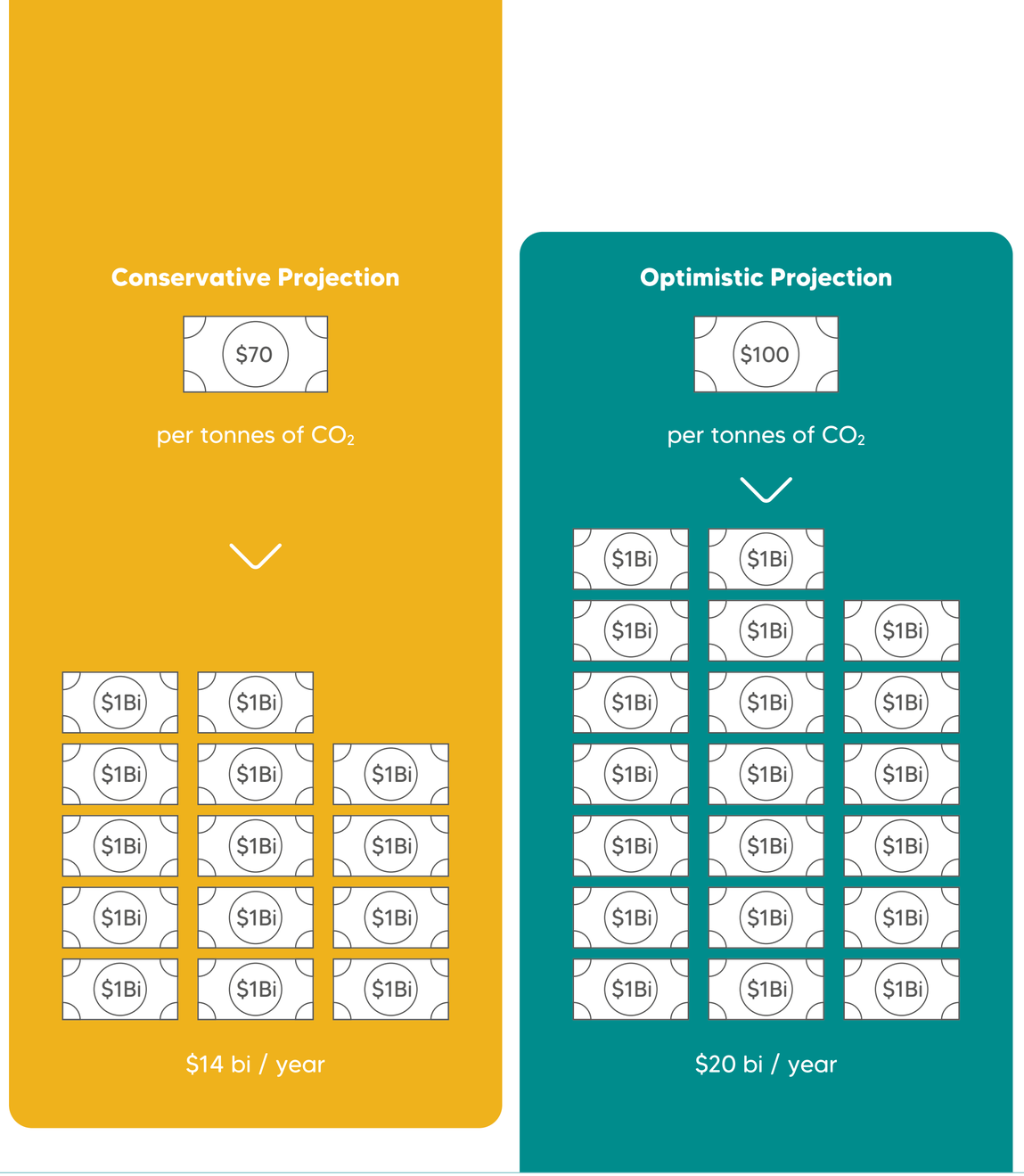
CCS projects can generate significant revenues for the emitting sources that adopt this technology, depending on the carbon credit price and the volume of avoided emissions.

In a conservative scenario with the carbon credit price at $70 dollars per tonnes of CO_2, CCS projects in Brazil could generate revenues close to $14 billion dollars per year, based on the potential CCS application as raised in this report.

In a more optimistic scenario, with the carbon credit price at 100 dollars per tonnes of CO_2, revenues can reach an amount close to 20 billion dollars a year. These values do not consider the potential for negative net emissions perfectly promoted by CDR technologies.

However, for CCS projects to be eligible for carbon credits, it is necessary that emission reduction certification methodologies are updated and consider CCS technologies.

The discussion on the eligibility of CCS projects is part of the ongoing debate with carbon credit certifying entities and on incentive policies to the emission reduction.



B Carbon storage

Geological storage is the main technology for the captured CO_2 destination, regarding the implementation of large-scale CCS projects, under processes consisting of injecting and storing CO_2 safely and permanently in suitable geological formations. The CO_2 is trapped in the pores or fractures of rocks at high pressures and can react with fluids and minerals by chemical and physical mechanisms in order to increase the storage capacity and consequently its stability, without returning to the atmosphere.

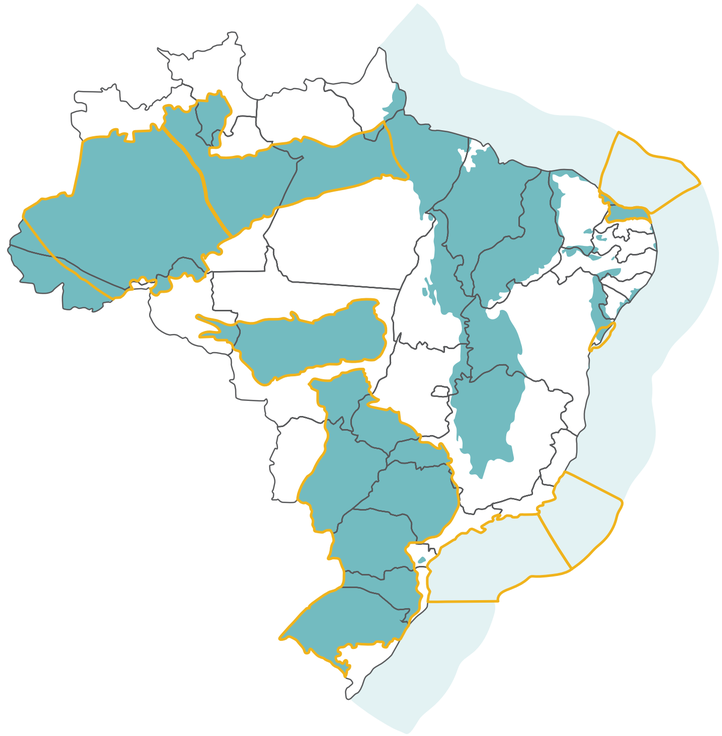
In Brazil, there are several areas with such favourable geological characteristics to this CO_2 storage. Sedimentary basins are the most promising, and the geological contexts most suitable and used for CCS projects in the world are the depleted oil and gas reservoirs, as well as aquifers portions proven to be unsuitable for human or animal consumption, or agricultural activities. Other less traditional geological contexts that may also propitiate permanent CO_2 storage include basalts, non-mineable coal and salt beds.

However, it is important to emphasize significant gaps in the available data on the country's geological formations, which are mostly concentrated in regions the research activity for the discovery of oil and gas fields was more consistent. It is necessary to invest in new research and specific campaigns to improve the identification of greater CO_2 storage potential areas in the country, especially in Sedimentary Basins without any significant hydrocarbon production.

Based on factors such as the availability of geological data and knowledge about the presence of formations and geological contexts potentially favourable to the CO_2 storage, the main areas of interest in Brazil are the Sedimentary Basins of Santos-Campos, Potiguar, Recôncavo, Amazonas-Solimões and Paraná. The Parecis Basin was included in the areas of interest due to the announcement of a CCS project under study in the region.

The effective storage potential as well as the definition of the exact locations suitable for CO_2 injection and possible specific reservoirs depends on further in-depth specialized studies of geological exploration for this purpose. Therefore, the selected areas are qualitative highlights that do not necessarily reflect an order of potential for CO_2 storage.

Potential regions for CO_2 storage in Brazil and selected areas of interest



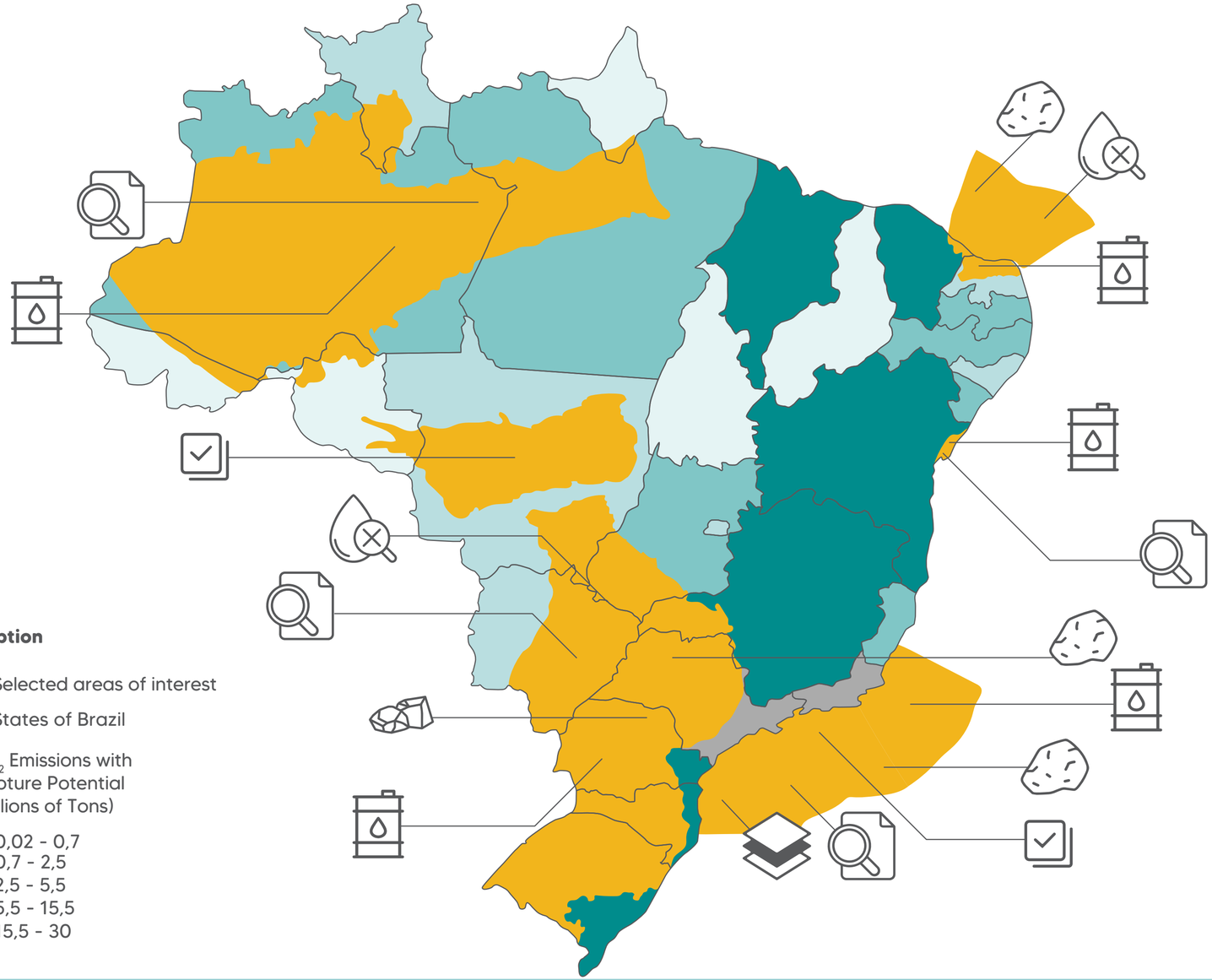
Caption

- Selected areas of interest
- States of Brazil
- Sedimentary Basins in Brazil

Selected areas of interest for CO_2 storage

Characteristics related to sedimentary basins

- Data availability
- Oil and gas reservoirs
- Aquifers unsuitable for consumption
- Salt layers
- Coal layers
- Basalts
- CCS projects announced or in operation



C Logistics

An important factor to be considered in the development of CCS projects is the compatibility between the CO_2 emission source and the storage location, mainly regarding CO_2 transport options and distances. By ensuring this balance, it is possible to maximize the efficiency of the project and optimize the employed resources.

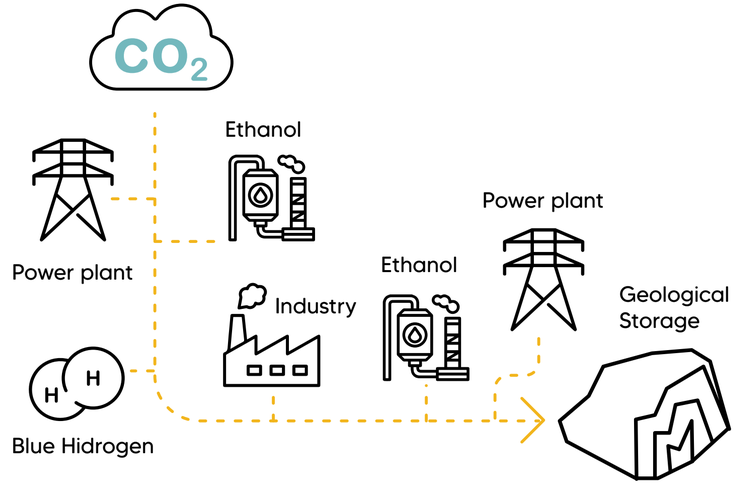
Pipelines
It is expected that the use of pipelines will be the most used transport mode for CO_2 in CCS hubs, as it allows the transport of large CO_2 quantities over long distances efficiently and with less emissions. CO_2 pipelines are built with corrosion and leak resistant materials, and can be either buried in or assembled on elevated platforms.

Ships
In some cases, transporting CO_2 by ship may be a viable option when storage sites are offshore. CO_2 tankers are designed with special technologies to keep CO_2 in a liquid state under pressure and can transport large amounts of CO2 in a single trip.

Trucks
The use of trucks is usually an option when the capture and/or storage points are located in remote areas, or the pipeline is not feasible. Tank trucks are capable of transporting smaller amounts of CO_2 compared to other transport modes, but flexible and adaptable to different demands. This use must take reckon costs, as well as the fact these current means of land transport emit CO_2.

The choice of the CO_2 transport mode, which can include pipelines, trucks, trains, and ships, must consider the physical and economic characteristics of the region and the concept of each project

In some countries, such as the United Kingdom and Norway, there is the development of CCS clusters and hubs, which concentrate CCS projects in a single region, increasing logistical efficiency and reducing implementation costs.
These initiatives also promote collaboration between companies and research institutions, accelerating technological advances and the dissemination of knowledge. Although Brazil does not have CO_2 transport routes on a significant scale, it is possible to use similar infrastructures to assess furthermost potentialities that may facilitate implementation. Among the most used infrastructures as analogues to possible CO_2 transport routes are gas pipelines, roads, railways, and electricity transmission lines.
These infrastructures can serve as a reference for potential CO_2 transport routes, with significant advantages, such as cost reduction and logistical efficiency increase. In addition, the use of existing infrastructure can avoid the need to build new transport routes, reducing the environmental impact and accelerating the CCS project implementation.



Considering the dimensions and diversification of Brazilian geography, the location of reservoirs capable of storing CO_2 and the different concentrations of industrial and primary-secondary energy generation plants, some regions have great potential to host CO_2 clusters and hubs, such as the south of Minas Gerais State, part of São Paulo and Paraná States, South of Goiás and some areas in Mato Grosso.

Infrastructure with potential for analogy to CO_2 transport routes in Brazil

Transport gas pipelines in Brazil

Caption

- Brazilian states
- Gas pipelines

Electric power transmission lines in Brazil

Caption

- Brazilian states
- Transmission tines

Road and rail networks in Brazil

Caption

- Brazilian states
- Railway network
- Road network

What happened

in 2022 in Brazil?

A Legal / Regulatory advances

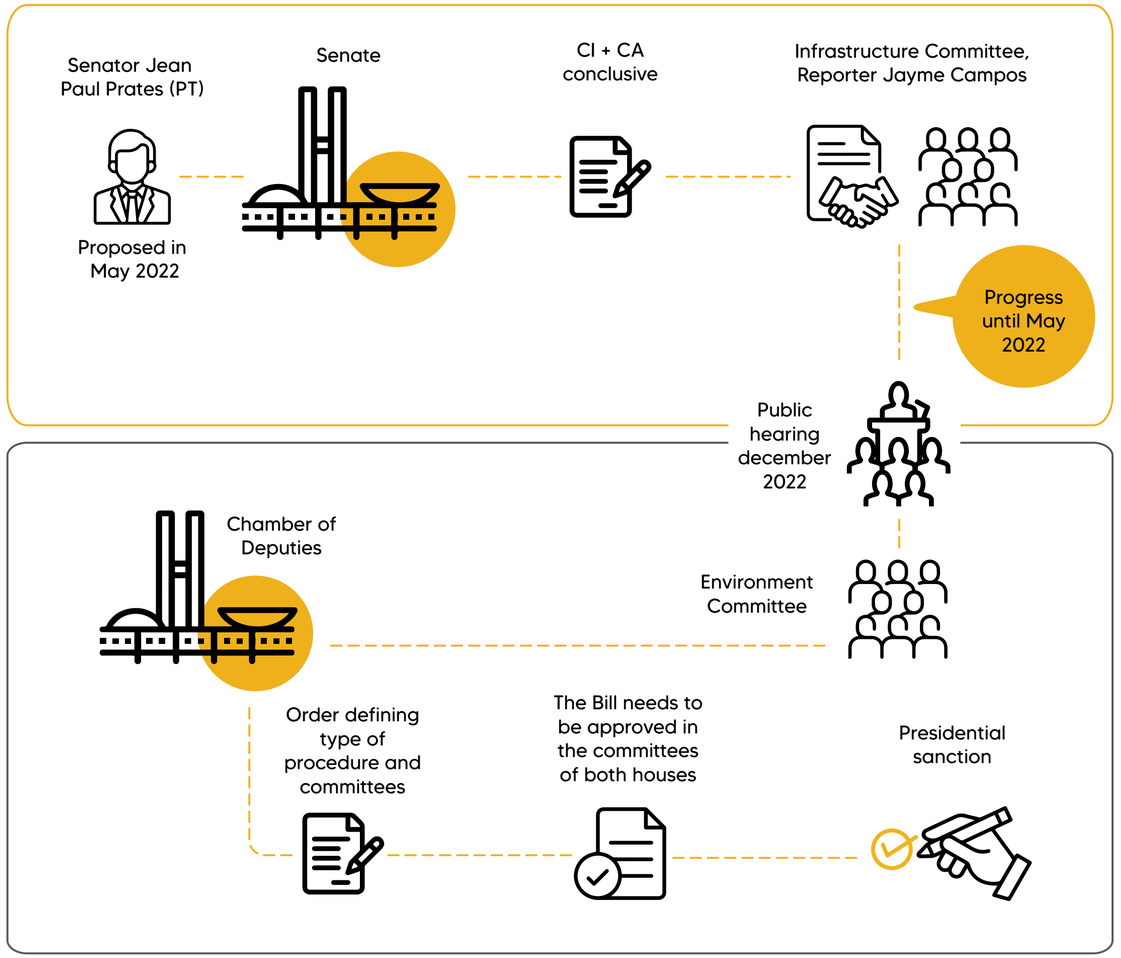
Although the country has recognized potential for the development of CCS projects, the absence of specific regulation has been an obstacle to the concrete implementation in the national territory. The initiatives towards the regulation and standardization of CCS activities in Brazil are quite recent and grew strong in 2022, with emphasis on:

(1) Future Fuel Program: In early 2021, the federal government launched the Future Fuel Program aiming at proposing measures to increase the use of sustainable and low-carbon fuels. Within the scope of this program, the ProBioCCS subcommittee was created to study the use of carbon capture and storage technology associated with the production of sustainable and low-carbon fuels. Several technical working group meetings were held in 2022. At the time of writing this report, the subcommittee had not formalized a legislative proposal.

(2) ABNT Commission: Since May 2022, the Brazilian Association for Technical Standards (English for Associação Brasileira de Normas Técnicas – ABNT) has hosted a Study Commission for the standardization of CCS technologies, coordinated by Alberto J. Fossa. At the forefront of the initiative is the Research Center for Greenhouse Gas Innovation (RCGI), a research center financed by the São Paulo Research Foundation (English for Fundação de Amparo a Pesquisa do Estado de São Paulo – FAPESP) and Shell Brazil.

(3) Legislative Initiative: On May 31, 2022, then Senator Jean Paul Prates (PT/RN, Portuguese for Partido dos Trabalhadores (Workers' Party), representing Rio Grande do Norte State (RN)) presented Bill 1,425/2022, a regulatory framework for CCS upon the economic activity of CO2 storage as an activity of public interest, as a way to reduce greenhouse gas emissions with a view to decarbonizing the economy. According to the initial forwarding, the bill will be passed on the Infrastructure Commission (English for Comissão de Infraestrutura, or CI) and, subsequently, on the Environment Commission (English for Comissão de Meio-Ambiente, or CMA), from where - once approved - it will proceed to the Lower Chamber. At CI, Senator Jayme Campos (União Party, representing Mato Grosso State – MT) was designated as its rapporteur. The last relevant fact of the project was the holding of a public hearing in November 2022.

Expected legislative progress summary of Bill 1.425/2022



Scaling up CCS in Brazil: Overcoming Regulatory and Contracting Hurdles

Campos Mello Advogados in Cooperation with DLA Piper

It seems to be a quasi-consensus that to achieve Net Zero goals by 2050, Carbon Capture and Storage (CCS) technologies and projects will be fundamental. Considering that a decarbonized future is indeed not a future without hydrocarbons (Borges, Heloisa) CCS technologies are key to allow Brazil and the world to deliver an efficient and equitable energy transition.

At this stage, CCS needs scale, regulatory support, and contracts. Scale is challenging, but Brazil has what it gets to achieve it. Regulatory support will come from the expected approval by the Brazilian congress of Bill of Law No. 1,425/2022 (the "CCS Bill of Law"), and, also from the increasing awareness among the technical people in the National Agency for Petroleum, Natural Gas and Biofuels - ANP and the federal, state and municipal (assuming an onshore CCS project) environmental regulators about the existing and the developing CCS technologies.

Contracts for newbuild vessels, storage and transportation will be measure of how well scale and regulatory support are working. Considering our firm's global and local CCS experience, in Brazil the key project contracts should at least initially follow basic models and standards from the O&G industry, particularly the drilling contracts for the drill of wells connecting to the existing underground deposits, which will naturally require those models and standards to be adapted to specific CCS technologies and the storage reality.

Although initially some standard O&G contract provisions should be the starting point to construct CCS project documents with time and scale the CCS industry shall be able to organize itself and adopt their own standards and contract models.

Further, for CCS development as a service in Brazil a basal aspect to be dealt with is the allocation of environmental liabilities and how to protect the contracting party in case of incidents involving the project operator. In Brazil, considering the joint liability between the contractor and the service provider for damages - meaning that vis-à-vis third parties a party cannot escape liability - the mechanism of liabilities allocation and the indemnities scheme have to be done contractually in clearly crafted project documents.

Another aspect that shall be regulated in Brazil is the monitoring and contingency obligations in relation to the reservoirs after the contractual periods. According to the current draft of the CCS Bill of Law, the monitoring obligations of the operator remain valid for up to 20 years. After that period, a non-for-profit entity (Storage Assets Manager) shall continue to monitor and manage the storage assets.

Many open legal and regulatory aspects will arise when structuring CCS projects in Brazil and we are proud of being in the forefront of the discussions, ready to support clients and collaborate with the government in addressing them.

Finally, CCS Brasil plays a pivotal role in all aspects of fostering CCS industry in Brazil and particularly in the development of local contractual standards and provisions to be applicable to CCS projects. Our firm is glad to support CCS Brasil in that journey.

B Decarbonization policies and incentives

CCS implementation involves significant investment, especially with the initial implementation costs of engineering, assembly, and specialized equipment. However, as more projects are implemented, the cost curves tend to flatten, making the technology more affordable in the long run.

In face of the technologies implementation urgency which allows decarbonization, governments around the world are adopting measures to encourage private agents in this regard. As pointed out at the beginning of this document, economic incentives can display different formats, however in Brazil, few of them are effectively implemented.

In terms of financing, so far, no financing lines or direct public investments in CCS projects have been identified. In terms of specific fiscal subsidies, they were not identified either at federal or state level.

Everything indicates that the policies to encourage the decarbonization of the national economy will be focused on the creation of Regulated Carbon Market structures, being this institution depending on the approval of a specific law by the National Congress.

Current incentive policies	
RENOVABIO (Law No. 13,576/2017)	VOLUNTARY CARBON MARKET - DECREE No. 11,075/2022
Currently, a mechanism similar to that of a sectoral carbon market known as RENOVABIO is into effect. Created by means of the National Biofuel Policy and into effect from 2020, this is a program that encourages biofuel industries to reduce emissions by imposing targets on fossil fuel distributors for the acquisition of carbon credits (CBIOs) emitted by biofuel producers. The certificate stems from the certification procedure for the biofuel production process. The procedure will award a score regarding energy efficiency and greenhouse gas emissions, based on a life cycle assessment.	On May 19, 2022, Decree No. 11,075 was published by the Federal Executive Office, which governs the initial procedures for the climate change sectoral plan elaboration and seeks to create legal bases for a future regulated and voluntary carbon market, through the establishment of the Greenhouse Gas Emission Reduction National System (English for Sistema Nacional de Redução de Emissões de Gases de Efeito Estufa – Portuguese acronym Sinare). However, the Decree does not set a deadline for the Federal Government to draw up sectorial plans and start Sinare. It is worth noting that, as it was established by decree, the sectorial plans are voluntary.

Carbon Market Bills

BILL 528/2021

It establishes the Brazilian Emission Reduction Market (Mercado Brasileiro de Redução de Emissão, or MBRE).
Sponsored by Congressman Marcelo Ramos (PL-AM, Portuguese for Liberal Party, representing Amazonas State)
Initiating House: Congressmen Chamber

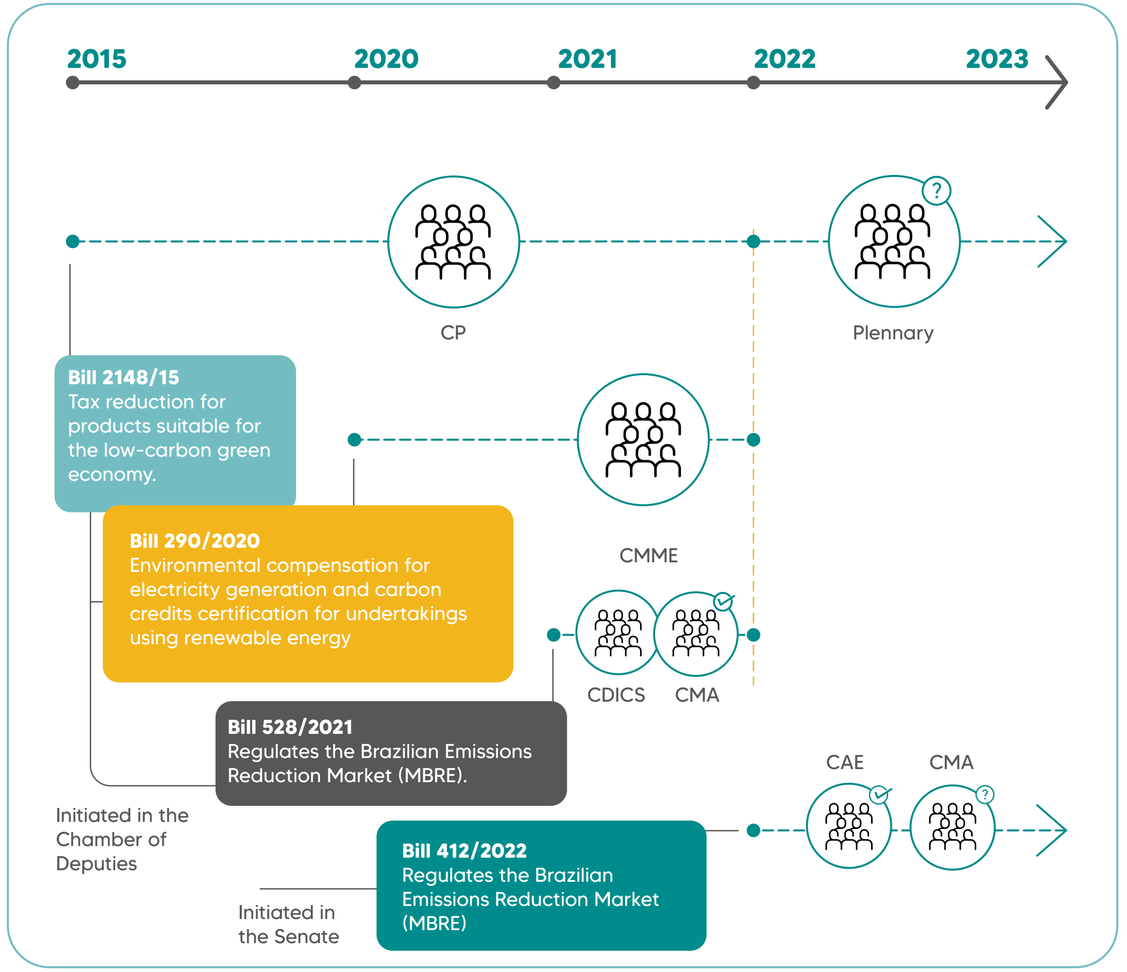
Bill No. 528/2021 aims to regulate the Brazilian Market for Emissions Reduction (MBRE) and this bill is the one with the greatest projection in the regulation of the voluntary and regulated carbon market in Brazil. By similarity, this project was attached to Bill 290/2020, which in turn is attached to Bill 2148/2015, which becomes the head of a block of Bills 10,073/2018, 5,710/2019, 290/2020 and 528/ 2021. The projects have in common the attempt at regulating the national carbon market. The current text is the third reading with Replacement presented by Congresswoman Carla Zambelli, who has been awaiting consideration by the Chamber Plenary since 08/19/2022.

BILL 412/2022

It regulates the Brazilian Emissions Reduction Market (MBRE)
Sponsorship: Senator Chiquinho Feitosa (DEM/CE, Portuguese for Democrat Party, representing Ceará State)
Initiating House: Federal Senate

Bill No. 412/2022 aims to regulate the Brazilian Emissions Reduction Market (MBRE). The original proposal, in summary, provided in general terms the regulatory bases of the MBRE. The current text of the project is the Substitute of Sen. Tasso Jereissati, which profoundly modifies the original Bill and proposes the Brazilian Emissions Management System (English for Sistema Brasileiro de Gerenciamento de Emissão – Gases de Efeito Estufa, Portuguese acronym SBGE-GEE), offering greater possibility of management, control and transparency of the SBGE-GEE. As it deals with a related topic - regulation of the Brazilian market for the reduction of greenhouse gas (GHG) emissions - the aforementioned Bill began to be processed jointly with Bills No. 2,122/2021; 4,028/2021; 3,606/2021 and 1,684/2022. It is currently on the Environment Commitee, having Sen. Leila Barros as a rapporteur, awaiting the Public Hearing.

Expected legislative progress summary of Bill 1.425/2022



Brazilian CCS Projects

Until the end of 2022, three Brazilian projects involving one or more parts of the CCS chain have been identified, each one with very different characteristics and stages of development.

The first and oldest Brazilian project is led by Petrobras and refers to the stages of CO_2 use & storage. Considered one of the largest CCUS-EOR programs in the world, the CO2 reinjection activities are carried out by Petrobras in the pre-salt fields. The project started as a pilot, in Tupi field, and was extended to the Mero and Búzios fields, currently accumulating 40.8 million of reinjected tCO_2. In 2022 alone, 10.6 million tCO_2 were injected and the expectation is to reach 80 million tCO_2 by 2025.

The second initiative is under project development phase and is led by FS Bioenergia, the largest producer of corn ethanol in the country. The company plans to invest around U$ 65 million to structure a BECCS project, which will implement CO_2 capture and storage systems at Lucas do Rio Verde (MT) plant. This project promises to be an important alternative to reduce CO_2 emissions in biofuel production and is expected to be a reference for the sector.

Finally, the third project in operation is in the City of Criciúma, Santa Catarina State, South of Brazil, and it is a research and development pilot project to capture CO_2 from coal-fired thermoelectric power generation. Although still in early stages, this project is considered very promising and can significantly contribute to reduce CO_2 emissions in power generation.

In summary, Brazil has three CCS-related initiatives at different stages of development, each one with particularities and potentialities. These are projects which can contribute to the CO_2 emission reduction and to the construction of a more sustainable and responsible economy towards the environment.

1st PROJECT	• **Responsible for the project:** Petrobras • **Project features:** Advanced Petroleum Exploration (CCUS-EOR) • **Nature:** commercial • **CO_2 injection sites:** pre-salt fields • **Total reinjected tCO_2:** 40.8 million • **Project start:** 2008 • **Perspectives and prevision:** 80 million tCO_2 reinjected by 2025
2st PROJECT	• **Responsible for the project:** FS Energi: • **Project features:** combination of CCS with ethanol fermentation process • **Nature:** commercial • **CO_2 injection site:** Lucas do Rio Verde (MT) • **CO_2 Origin/Souce:** corn ethanol production process CO_2 • **Investment:** US$ 65 million dollars • **Project storage capacity:** 420 MT CO_2/year • **Project start estimation:** Dec 2024 • **Project duration perspective:** subject to confirmation of permeability, 20 year term minimum; up to a 55 year storage potential.
3st PROJECT	• **Responsible organizations:** SATC, ENEVA, UFC (ANEEL R&D). Diamante Energia(synthetic zeolite pilot plant). NETL (USA) and ARI (USA) support. • **Project characteristics:** CO_2 capture by adsorption technology, using zeolites. • **Nature:** Research & Development - Pilot Plant • **Source of CO_2:** Burning of LPG to simulate the capture in coal and natural gas thermal units. • **Volume of CO_2 to be captured:** 2 tCO_2/day (pilot unit). • **Investments:** R$5.2 million already invested along the first phase and another R$8.8 million is being invested in the second phase. Zeolite pilot plant: R$5.4 million • **Project Duration:** Beginning of phase 2 in January, 2023 and expected end in December 2024.

D Research and Development in 2022

Investments in research and development are crucial for the progress of CCS projects

By Júlio R. Meneghini, Scientific Director of the Research Center for Greenhouse Gas Innovation

Brazil is recognized as one of the world leaders in CCS research, and the RCGI (Research Center for Greenhouse Gas Innovation) is a leading Brazilian academic centre, with important contributions to the area of CO_2 storage, BECCS, hydrogen from ethanol with CCS, mitigation of greenhouse gas emissions, social perception and regulation. The successful implementation of CCS projects in Brazil and around the world strongly depends on science and innovation. By means of investments in research and development, it is possible to improve existing technologies and develop new solutions that guarantee the safety and effectiveness of these projects.

The RCGI work is crucial to advancing important areas such as CO_2 storage, BECCS and hydrogen from ethanol with CCS, as well as addressing issues related to social perception and regulation of these projects. Research in these fields helps ensure that CCS projects are safe, effective, and socially acceptable. Moreover, science and innovation are fundamental for the development of new low-carbon solutions in several areas, such as transport, industry and power generation. These solutions can make significantly contribute to reducing greenhouse gas emissions around the world, helping to mitigate climate change.

It is therefore essential that investments in research and development continue to be prioritized over CCS projects and other low-carbon solutions. These investments will help accelerate the transition to a more sustainable and resilient economy, reducing the impacts of climate change and promoting a more prosperous future for everyone.

Projects developed at the Research Centre for Greenhouse Gas Innovation

Project name: PERSPECTIVES FOR CARBON STORAGE IN ONSHORE NON-CONVENTIONAL OIL RESERVOIRS AND OFFSHORE SEDIMENTARY BASINS IN SOUTHEAST BRAZIL

Coordinator: Colombo Celso Gaeta Tassinari (Ph.D)

Objective: To evaluate the feasibility of implementing geological carbon storage (GSC) technology in unconventional oil reservoirs, in order to contribute to the reduction of CO2 in the southeastern region of Brazil, which concentrates the main sources of carbon emissions in the country.

Project name: SIMULATION AND OPTIMIZATION OF COMPRESSOR FOR CO2 AND CO2 - CH4 MIXTURES IN SUPERCRITICAL CONDITIONS

Coordinator: Jurandir Itizo Yanagihara (Ph.D)

Objective: To develop a computational tool to simulate the flow and heat transfer and optimize the geometry of a supercritical CO2 compressor under specified operating conditions. The present project also includes the optimization of the compressor sealing labyrinth layout and the initial development of a compressor simulator for mixing CO2 and CH4 in supercritical condition.

Project name: EVALUATION OF THE ENVIRONMENTAL IMPACT OF CCS ACTIVITIES IN BRAZIL AND LEGAL ASPECTS

Coordinator: Evandro Mateus Moretto (Ph.D); Hirdan Katarina de Medeiros Costa (Ph.D)

Objective: To propose a Regulatory Framework and an Environmental Impact Assessment process designed specifically for CCS activities in Brazil.

Project name: LABORATORY FOR CHARACTERIZING THE PHYSICAL AND CHEMICAL PROPERTIES OF CO2, OIL AND NATURAL GAS IN SUB AND SUPERCRITICAL CONDITIONS – INFRASTRUCTURE

Coordinator: Claudio Augusto Oller do Nascimento (EP-PQI) Reinaldo Camino Bazito (IQ/USP) Luis Alberto Follegatti Romero (Poli/USP)

Objective: The creation of a laboratorial infrastructure for measuring the physical-chemical properties of oil, natural gas, natural gas rich in CO2 (the main contaminant in the pre-salt), pure CO2 and all mixtures of these fluids in sub and supercritical conditions.

Project name: SOFTWARE TECHNOLOGIES FOR MODELING AND INVERSION, WITH APPLICATIONS IN SEISMIC IMAGING

Coordinator: Bruno Souza Carmo – University of São Paulo

Objective: To develop a set of software technologies for numerical simulation and solution of inversion problems.

Project name: DESIGN PROJECT BASED ON OPTIMIZATION OF TEMPERATURE CHANGE ADSORPTION SYSTEMS (TSA) TO CAPTURE CO2 FROM GASES DERIVED FROM BIOMASS ON A LARGE SCALE

Coordinator: Marcelo Martins Seckler – Poli-USP

Objective: Integrate smart materials such as IPMCs into the LS design; Consider the influence of parameters in the smart LS concept, such as high shaft speed (around 20,000 rpm and shaft radius from 40 to 60 mm), different types of IPMC performance and possible smart LS configurations.

Project name: NEW TECHNOLOGIES FOR CO2 CAPTURE: DEEP EUTETIC SOLVENTS (DES) AND ADVANCED MATERIALS FOR CO2 CAPTURE MEMBRANES

Coordinator: Julio Romano Meneghini – Poli-USP

Objective: To develop new technologies for CO2 capture and/or separation based on two main approaches, composed of the two lines of work that integrate the main project: Deep Eutectic Solvents (DES) for CO2 Capture and Advanced Materials for Membranes for CO2 Capture.

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Projects developed at the Institute of Petroleum and Natural Resources of PUCRS

Project name: DEVELOPMENT AND APPLICATION OF CO2 METHODOLOGIES AND MONITORING TECHNIQUES AT THE EXPERIMENTAL LEAK SITE AT TECNOPUC- (ECO2A PROJECT)

Manager: Clarissa L. Melo

Number of researchers: 5 (five) **Execution period:** 2022/2025

Objective: To develop and evaluate monitoring techniques to verify possible CO2 leaks in a shallow subsurface environment based on dynamic CO2 flow data, electro resistivity, hydrogeochemical analysis and computational numerical modelling. In addition, the project includes the development and testing of an automated CO2 monitoring station (ECO2A) that will receive information from sensors installed in monitoring wells.

Project name: INTELLIGENT DEVELOPMENT OF CORROSION INHIBITORS OF STEEL BY CO2 FROM EXPERIMENTAL TESTS AND METHODS OF "MATERIALS INFORMATICS" (SMART PROJECT)

Manager: Victor Hugo Jacks dos Santos and Felipe Dalla Vecchia

Number of researchers: 8 (eight) **Execution period:** 2022/2025

Objective: Development of "Materials Informatics" models capable of guiding the synthesis of new molecular targets (target-specific synthesis) with high capacity to inhibit corrosion by CO2 and low toxicity. This project aims to enable the accelerated and intelligent development of new steel corrosion inhibitors against CO2. To do so, a combined approach of computational and experimental methods will be used, and the foundations for the digital transformation of knowledge about corrosion inhibitors for CO2-rich media will be established.

Project name: CCUS BRAZIL GIS PLATFORM

Manager: Clarissa L. Melo

Number of researchers: 5 (five) **Execution period:** 2022/2024

Objective: Development and availability of an online digital platform containing a spatial and georeferenced database with information on geological resources for CO2 storage in Brazil, stationary CO2 sources and possibilities of source-sink transport. Elaboration of a new CCUS Atlas in Brazil, in digital format, intended for the technical-scientific dissemination of the addressed content, highlighting the applied methodology, the data incorporated into the platform, the followed technical assumptions and the results achieved in the project.

Project name: DACCS – STUDY OF THE INTEGRATION AND OPTIMIZATION OF PROCESSES FOR REMOVING GEE FROM THE ATMOSPHERE AND INDICATION OF FAVOURABLE AREAS FOR THE IMPLEMENTATION OF NEGATIVE EMISSION TECHNOLOGIES (NET) IN BRAZIL (DAC PROJECT. SI)

Manager: Felipe Dalla Vecchia

Number of researchers: 20 (twenty) **Execution period:** 2022/2025

Objective: Project objective (short description): The DACCS project is unprecedented in Brazil, whose objectives are the study of DAC technologies, the evaluation of integration strategies and the optimization of CO2 removal processes, and the indication of favourable areas for implementation of negative emission technologies (NET) in the country, with special attention to the process of permanent CO2 storage in the basalts of the Serra Geral Group in Paraná Basin.

Project name: USE OF C AS A CARBON SOURCE FOR THE PRODUCTION OF BIOSURFACTANTS.

Manager: Clarissa L. Melo

Number of researchers: 8 (eight) **Execution period:** 2021/2025

Objective: Development and availability of an online digital platform containing a spatial and georeferenced database with information on geological resources for CO2 storage in Brazil, stationary CO2 sources and possibilities of source-sink transport. Elaboration of a new CCUS Atlas in Brazil, in digital format, intended for the technical-scientific dissemination of the addressed content, highlighting the applied methodology, the data incorporated into the platform, the followed technical assumptions and the results achieved in the project.

Projects developed at the Federal University of Rio de Janeiro

Project name: HYDROGENATION OF CO2 TO METHANOL AND DME: AN INTEGRATED APPROACH FOR A BIOGAS PLANT

Manager: Claudio J. A. Mota

Number of researchers: 7 researchers **Execution period:** 36 months

Objective: The project aims to capture CO2 from biogas streams, produce H2 by photocatalysis using visible light, and hydrogenate to methanol and dimethyl ether (DME).

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Perspectives

and necessary advances

A Sector perspectives

Brazil has enormous potential for the development of CCS (Carbon Capture and Storage) projects, regarding the competitive advantages in several areas. Besides oil and natural gas reservoirs, the country has several key industries that are considered hard-to-abate, such as steel, cement, chemicals and fertilizers, whose benefits may come straight from the CCS chain.

Brazil also has a strong vocation for ethanol production, which tends to grow in the coming years. Capturing CO_2 in this sector can contribute significantly to reduce greenhouse gas emissions and help transition to a low-carbon economy. Moreover, the country is in the formation phase of the hydrogen market, with a large capacity for the renewable hydrogen production, which can be used as a clean fuel in several sectors.

However, it is important to emphasize that the pace of CCS project development may vary between sectors and regions of the country, due to specific challenges in each area. Therefore, a coordinated and collaborative effort along business, government and civil society is needed to overcome these challenges and take full advantage of the country's competitive advantages in low-carbon technologies. Hence, it is important to listen and consider the perspectives of the various stakeholders involved, aiming at building solutions that meet the needs of all parties involved and promote socioeconomic development in a fair and equitable manner.

We have consolidated in this space some perspectives from representatives of different sectors to contribute to the discussion and debate about Brazil's potential for the development of CCS projects and the challenges yet to be overcome towards making this technology a reality in the country

> "The implementation of a regulated carbon market in Brazil is essential to enable the development of large-scale CCS projects in the country. Currently, the voluntary carbon market values emission reductions caused by CCS projects, but only the regulated market will be able to absorb the potential volume of carbon credits associated with this type of activity."
>
> **Carlos de Mathias Martins Junior, Director of Eqao**

> "The climate emergency as a state or situation that requires actions from diverse public and private actors emerges as a result of the consequences arising from the increase in Greenhouse Gas (GHG) emissions. It is essential, regarding this issue, Brazil and other countries meet the goals established in the Paris Agreement and aim at reducing their GHG emissions in favour of a climate-appropriate future. Carbon capture and storage technology (CCS - carbon capture and storage) appears as one of the possibilities to help countries meet their targets, even considering an increasingly restrictive scenario in terms of emissions."
>
> **Hirdan Katarina de Medeiros Costa, Research Center for Greenhouse Gas Innovation**

CCS is the ultimate tool to decarbonize hard to abate sectors like steel and cement and bring the Brazilian bioethanol industry to net negative CO_2 emission levels making Brazil's light vehicle transport sector even more sustainable. Brazil has a huge potential thanks to the Paraná basin saline aquifers, which are colocated with Brazil's largest emitters and well suited to store this CO_2 safely. All the CCS elements are there to make this happen.

Nick Fulford, GaffneyCline

Many countries have set ambitious goals to reduce CO_2 emissions to the atmosphere. CCUS is an essential technology that will play a vital role in CO_2 emission reduction. To scale up CCUS projects, the world needs a resilient base material sector, including steel industry. Steel pipes will be a critical element for infrastructures in this emerging market, and Vallourec has a significant role to play in meeting this challenge.

Building on our extensive and recognized expertise, combined with our proven track record in CCS, our commitment to R&D and innovation, as well as our premium line pipe and subsurface structural products, Vallourec is committed to supporting CCS projects globally.

Leila Faramarzi, Vallourec

The CCS is essential for mitigating climate effects and will be strategic for Brazil to achieve a zero carbon economy. The contribution that this technology has generated here is already remarkable, reducing CO_2 emissions in the production and exploration of oil and gas in Brazilian pre-salt layer.

Hydrocarbon production countries like Brazil accumulate expertise and may have even more competitive advantage given the geological storage capacity, especially offshore, as well as the possibility of using existing infrastructure such as depleted wells, in addition to the potential viability of sharing the gas transport grid. The possibilities are countless!

Monique Seabra, Sumitomo Corp

Heloisa Esteves, Research and Energy Company
The transition of global economies towards a low-carbon future requires not only the transition to an increasingly affordable, secure and sustainable energy future. This transition must be fair and inclusive. The combination of these ambitions requires the GHG emission sum from all sources and sectors of the economy to be, in part, offset by technologies or means of removing GHGs from the atmosphere. Carbon capture and storage plays a central role in solving this equation and will undoubtedly be a fundamental part of the decarbonization strategy and energetic transition in Brazil and in the world.

Heloisa Esteves, Empresa de Pesquisa e Energia

Brazil has a strong potential for geological storage, but there is a lack of investment to face high exploration costs. In general, CO_2 emitters are still timid, however there are already some companies setting up complete projects. Many R&D initiatives will help the industry in the following years, but we need, like the EU and the US, robust regulation and a CO_2 market with a clear price.

Vincent GEYL, Quartic

CO2 storage is an essential step to enable large-scale CCS projects and address climate change. Brazil has great potential for CO2 storage, with relevant opportunities mapped by Manacá CCS, with emphasis on the west of the state of São Paulo. It is critical to have the engineering expertise to take advantage of these opportunities safely and efficiently.

Peter Jackson, Presidente da Manacá CCS

The Brazilian O&G industry can benefit from the implementation of CCUS projects to reduce CO_2 emissions, meet climate commitments, and promote economic development in the country. Brazil has favorable geological conditions for the safe storage of CO_2 in geological reservoirs, making the projects economically viable. CCUS can also improve the competitiveness and resilience of the sector, stimulate technological development, and create skilled jobs. However, it is important to properly regulate the CCUS industry to provide legal security and encourage new investments. Bill 1,425/2022 represents an important step, but it needs improvements in line with international best practices. It is crucial to establish a stable regulatory framework to provide predictability and encourage investments in this emerging area.

Fernanda Delgado, IBP

The gas distributor plays a key role in promoting energy security in the transition context. But the climate challenge demands looking further. Investing in research and development with CCUS means taking a stand on the decarbonization agenda and opening up a pioneering space for the development of this new business in Brazil.

Letícia Dantas, Comgas

The CCUS industry in Brazil is essential to make negative emissions viable, generating development, employment, income and meeting the environmental demands of Society. It will also be able to leverage the Bio industry that could increase the carbon industry, attracting international investment to Brazil. By creating the CCUS production chain, new related industries will emerge, creating a demand for specialized labour (technical and higher education courses).

Fernando L Zancan, Presidente da ABCM

Carbon capture and storage has been successfully used globally for decades to safely store millions of tonnes of carbon under the earth's surface," says James Millar, President & CEO of the International CCS Knowledge Centre. "We have seen projects such as the first of a kind in the world Boundary Dam 3 Project in Canada capture an average of more than 90% of the flue gas that enters the CCS facility since its inception in 2014. When one looks more broadly, there are dozens of CCS success stories including two operating offshore (Sleipner and Snohvit), which have been capturing a million tonnes of CO2 a year for 27 years and 15 years respectively. Finally, from a storage perspective, Canada's ground-breaking Weyburn-Midale Project has safely stored more than 36 million tonnes of carbon dioxide since 2000.

CCS works, it is proven, safe and is the only current tool in the toolbox capable of dealing with our emissions on a large-scale to make a difference in combatting climate chang

James Millar, Knowledge Center

Producing clean and sustainable energy is an extremely positive step towards reducing CO2 emissions and mitigating the climate risks that we face ahead. However, we need to pay close attention to how our society consumes energy.

This equation of production and consumption will have a neutral balance of CO2 emissions with the use of technological resources capable of reducing emissions on both the supply side (energy production) and the consumption side (electro-intensive sectors). In this sense, CCUS technology plays a relevant role in global decarbonization and has great potential to drive the Green Hydrogen Industry! In my view, using Green Hydrogen for the synthesis of fuels with CCUS is the state of the art in this industry!

It is up to the Brazilian government to establish regulatory frameworks capable of bringing legal certainty to an industry that emerges with great potential. In this sense, the advancement of Bill 528/2021, which is being processed in the National Congress and seeks to regulate the Brazilian Emissions Reduction Market (MBRE) according to the National Climate Change Policy (Law No. 12,187/2009), is of great importance.

Frederico Freitas, INEL e H2 Verde

B

Bases for an attractive institutional environment

Like any embryonic economic activity, the existence of an attractive institutional environment is a crucial and determining aspect for the implementation of CCS projects in Brazil. Regarding that, this attractive institutional environment must be structured on three pillars: adequate regulation for the guarantee of the implementation and safe operation of these projects, clarity in decarbonization goals and obligations, and clear policies for economic project support:

Regulation

1. Despite the maturity of the technologies involved in all stages of the CCS chain, as we have seen, except for the use of CO_2 for the advanced extraction of Petrol carried out by Petrobras, there is no CCS project on a commercial scale implemented in Brazil until the moment. Among the reasons for the absence of projects is the lack of legal-regulatory definitions related, mainly, to the geological storage stage of CO_2. Among the strategic legal aspects that demand attention from national and state legislators, as well as regulators, they are:

(1) procedures and conditions for granting the exploration of the geological reservoir for CO_2 storage purposes,

(2) definition of regulatory and inspective authority in charge of the injection operation;

(3) criteria for complete closure of the operation and transfer of the reservoirs back to the Public Inventory; in addition to

(4) environmental guidelines for licensing purposes for future projects.

Decarbonization Targets

In addition to regulation, it is necessary to be clear about which and how the national CO_2 emission reduction obligations will be defined. Once economic sectors are clear about their obligations, the intensity and opportunity of CCS projects will become clearer.

Incentives And Investments Of Public Resources In CCS Projects

These incentives can come in the form of subsidized financing, tax breaks, auctions for carbon credit acquisition and other measures aiming at reducing the setting and operational project costs. Furthermore, it is important the support for CCS technologies research and development, regarding the cost reductions and existing techniques improvement.

6

Strategic points to move forward with CCS projects

6 strategic points to move forward with CCS projects

Implementing solutions to combat large scale climate change bring important challenges, from legal uncertainties, missing prioritization up to the difficulty of establishing business models.

CCS technologies are recognized as one of the fundamental alternatives for reducing CO_2 emissions and several countries are already moving forward with specific policies for the implementation of commercial projects, such as the United States, United Kingdom, Canada and Norway.

In Brazil, it is still necessary to take some fundamental steps to create the institutional environment bases favourable to CCS projects and to build capacities in the different societal segments.

We list 6 strategic actions to accelerate the development of CCS projects in Brazil.

01

Approve the regulation for CO2 storage

To encourage the CCS project implementation, it is essential a clear regulation to be established for the CO_2 geological storage. Therefore, it seems to be quite essential to forward Bill 1425/2022 proceedings, with the due debate beneath companies and society, bringing legal certainty to CCS projects.

02

Establish a carbon market affording CCS project carbon credits from CCS projects

An effective carbon market can encourage the CCS project implementation, providing a revenue source for these activities. This can be done by means of the creation of a carbon credit system that recognizes and values CCS projects.

03

Map CO2 storage opportunities

Surveying the areas with the greatest potential for CO_2 geological storage and their capacity estimates is essential to identify CCS projects opportunities.

04

Create designed financing lines for CCS projects

Structuring the CCS chain, in all stages, is capital intensive. The need for high investments in the equipment acquisition to make CCS routes viable can be driven by the creation of designed purpose financing pushed by development banks, reinforcing the role of the State in stimulating the economy decarbonization.

05

Disseminate information about CCS and its role in climate change mitigation

Public awareness about the importance of CO_2 emission reduction and the role of CCS itself is crucial for social engagement from public and private entities, as well as the encouragement in regard to the project implementation.

06

Embolden investments in technological development

The development of more efficient and lower-cost carbon capture national technologies plays an important role in making CCS a more viable option for companies seeking decarbonization alternatives. Brazil has a research centre in full excellence able to contribute a lot in this major, as well as the necessary personnel education to fulfil the demands arisen as the projects move on.

CCS Brasil