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# Paper ID OTC-35867-MS | Saline Aquifers Unlocking Brazilian Carbon Storage Pathways

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# Introduction

The Intergovernmental Panel on Climate Change issued its Sixth Assessment Report (AR6), warning that climate change cannot be addressed with global climate action's current pace and scale;

IPCC scenarios show that carbon capture and storage (CCS) can play a significant role in achieving net-zero targets, and a carbon dioxide removal system (CDR) can be necessary. Bioenergy and geological storage (BECCS) will be key components in reducing the impact of climate change;

Brazil is making significant strides in CCS beyond enhanced oil recovery (EOR). On October 8, 2024, enacting Law Nº. 14,993 assigns the National Agency of Petroleum, Natural Gas, and Biofuels (ANP) responsible for creating a regulatory framework. While Brazil shows promise in underground $CO_2$ storage, some gaps still need to be addressed;

In short, this study focuses on three case studies, two offshore and one onshore. While Case 1 (CCS-EOR) is not necessarily reliant on new legal and regulatory frameworks, Cases 2 and 3 (CCS-Hub and BECCS) will require dedicated legal-regulatory support to progress to the next TRL level following an eventual successful pilot phase.

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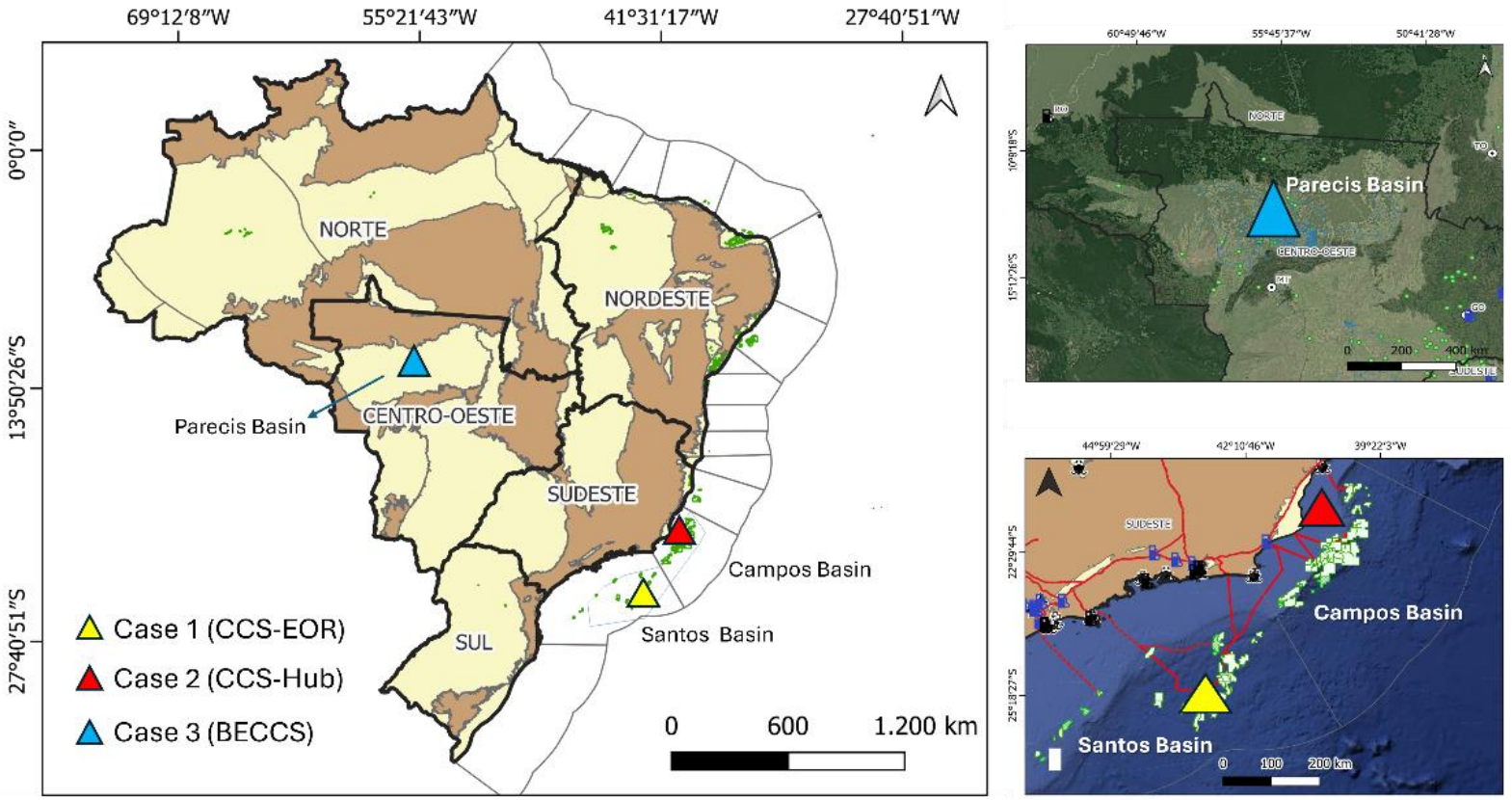
## Three case studies





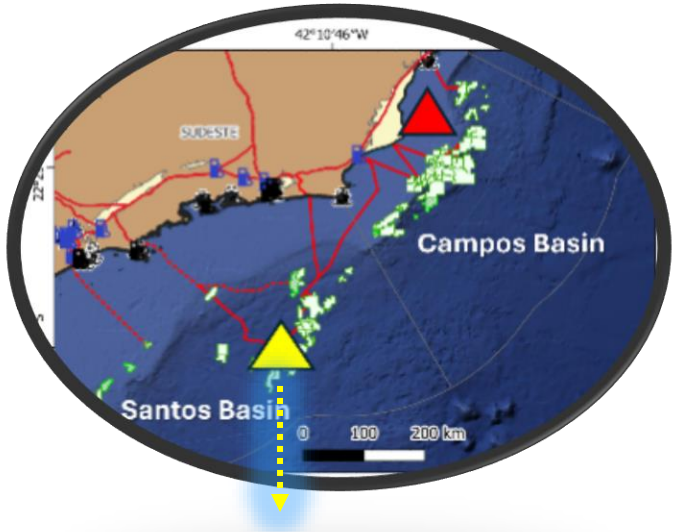





This study provides an overview of Brazil's efforts in CCS, focusing on three selected options based on Brazil's characteristics, and presents a case study for each (Fig.1):

- Case 1 concerns Enhanced Oil Recovery (Tupi Field). Pre-salt Play.
- Case 2 covers the hard-to-abate sector using a Hub System (São Tomé Formation). **Saline Aquifer.**
- Case 3 focuses on bioenergy with geological storage (Parecis Pilot Project). **Saline Aquifer.**

Fig. 1 - Map showing the position of the three case studies.




CASE 1 (COR-EOR)

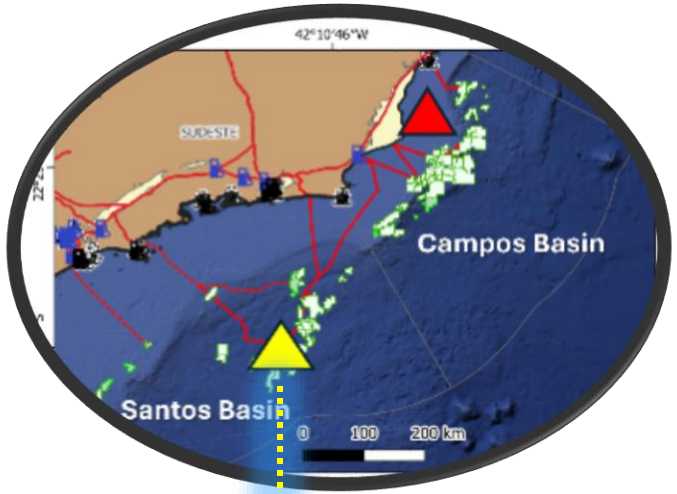
# TUPI FIELD

Tupi oilfield, the largest oil producer in the country, has 59 offshore wells, producing 751,311 barrels of oil and 37 million cubic meters of gas daily;

In 2022, Brazil reinjected 10.6 million metric tons of $CO_2$ into pre-salt reservoirs, which accounted for ¼ of the total amount reinjected globally that year. Tupi field has reinjected 40.8 million metric tons, and the operator aims to reach 80 million by 2025;

Tupi project is not designed to capture human-generated $CO_2$ (anthropogenic). Instead, its purpose is to separate geological $CO_2$ during hydrocarbon production. Once extracted, the CO2 is separated on the platform and reinjected into the reservoir using water alternating gas technology;

This process is crucial to avert contamination into the atmosphere and to support internal pressure, which aids in oil recovery. This facility meets all legal and regulatory Brazilian requirements. This sets it apart from the other two cases mentioned here.

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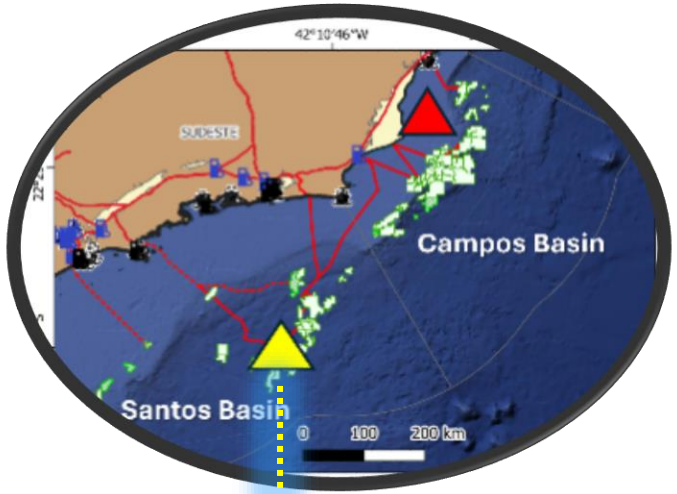


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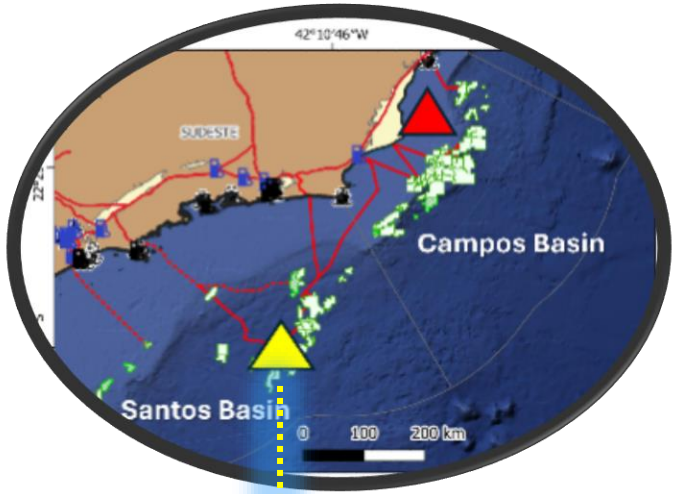


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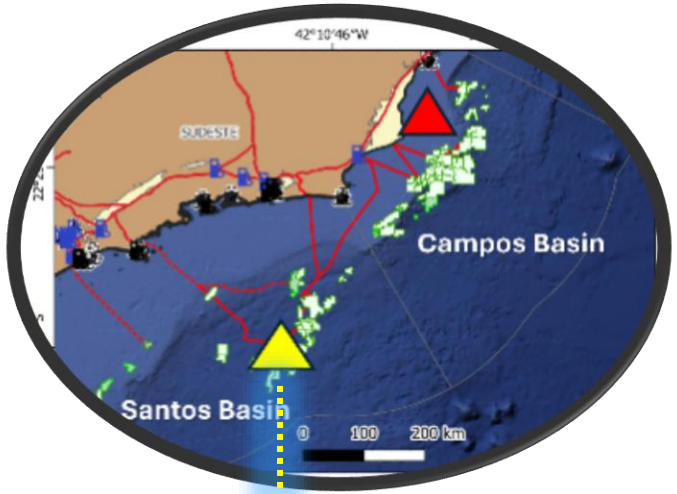


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In a recent study, Draeger et al. (2022) emphasized the importance of considering crude oil quality, climate goals, and land-use emissions to evaluate the remaining oil producers (and, as such, the stranded crude oil resources). This is particularly important when examining globally unextractable fossil fuels that must remain in the ground as stranded assets to meet the 1.5 - 2.0 °C associated carbon budget (Welsby, Price, Pye, et al., 2021);

Pre-Salt play emits less than 10 $kgCO_{2e}$/boe, lower than the Brazilian offshore average of 14 $kgCO_{2e}$/boe and the global average of around 19 $kgCO_{2e}$/boe. Brazilian Pre-Salt oil has a low carbon footprint, and oil quality matters. One possibility could be to evaluate depleted petroleum reservoirs as carbon sinks and to account for the $CO_2$ storage in their life cycle emissions;

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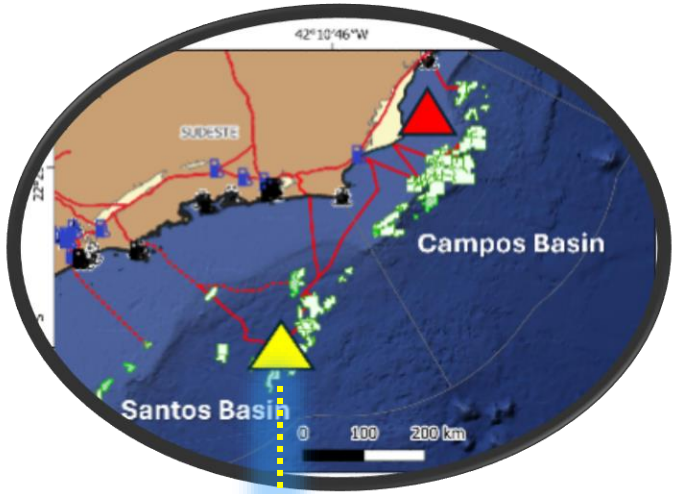


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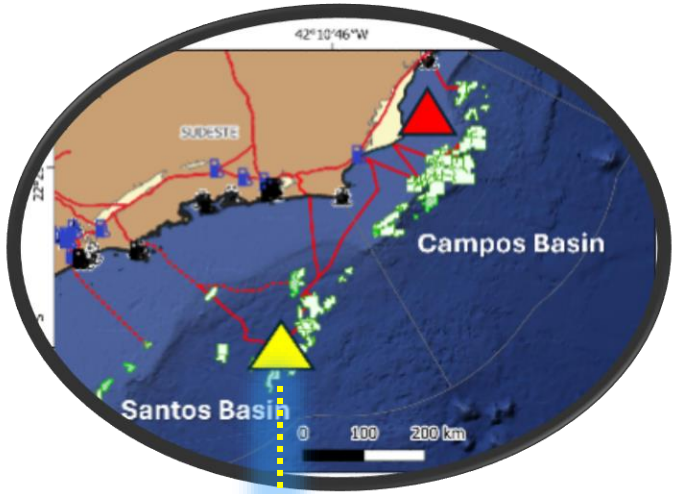


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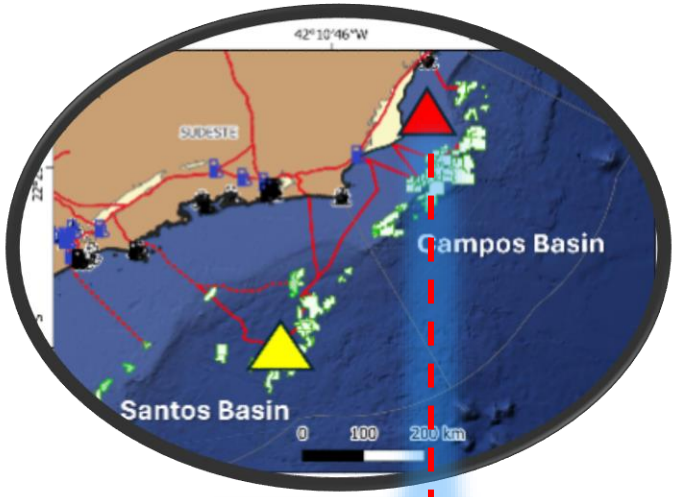


CASE 2 (CCS-HUB)

**SÃO TOME FORMATION**

Petrobras is considering installing a CCS-Hub in the northern region of Rio de Janeiro. It can involve other sectors providing services to deal with their Greenhouse Gas Emissions (GHG), such as cement and steel mills. The project is in the planning phase. In December 2023, at COP-28 in Dubai, the company signed a protocol of intentions with the Government of the State of Rio de Janeiro to jointly evaluate the implementation of the project;

Since the beginning of 2023, we conducted an independent study focusing on CCS in the north Campos Basin. This paper used public bidimensional seismic data to interpret the regional horizons of the São Tomé Member. This enabled us to define the depocenter of the sandstones, map faults, and obtain their external geometry and thickness measurements.

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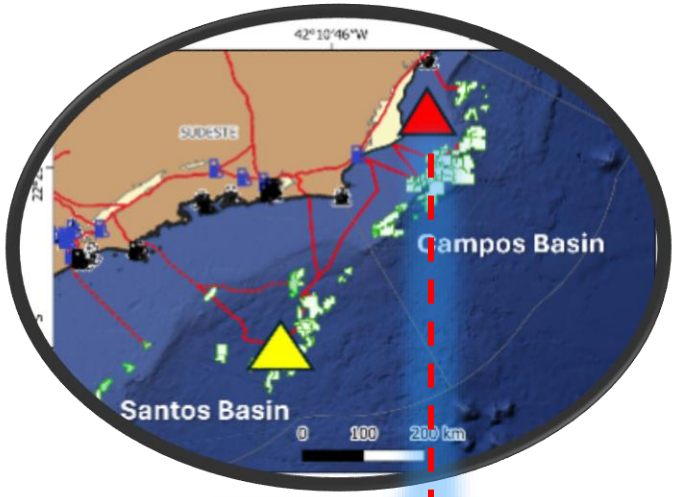


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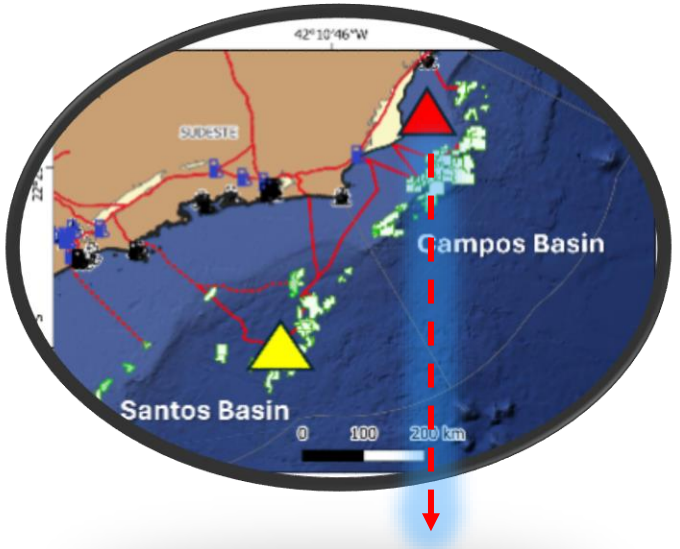


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# Case 2: São Tomé Saline Formation (CCS-Hub) - Carbon Capture and Storage in Continental Shelf

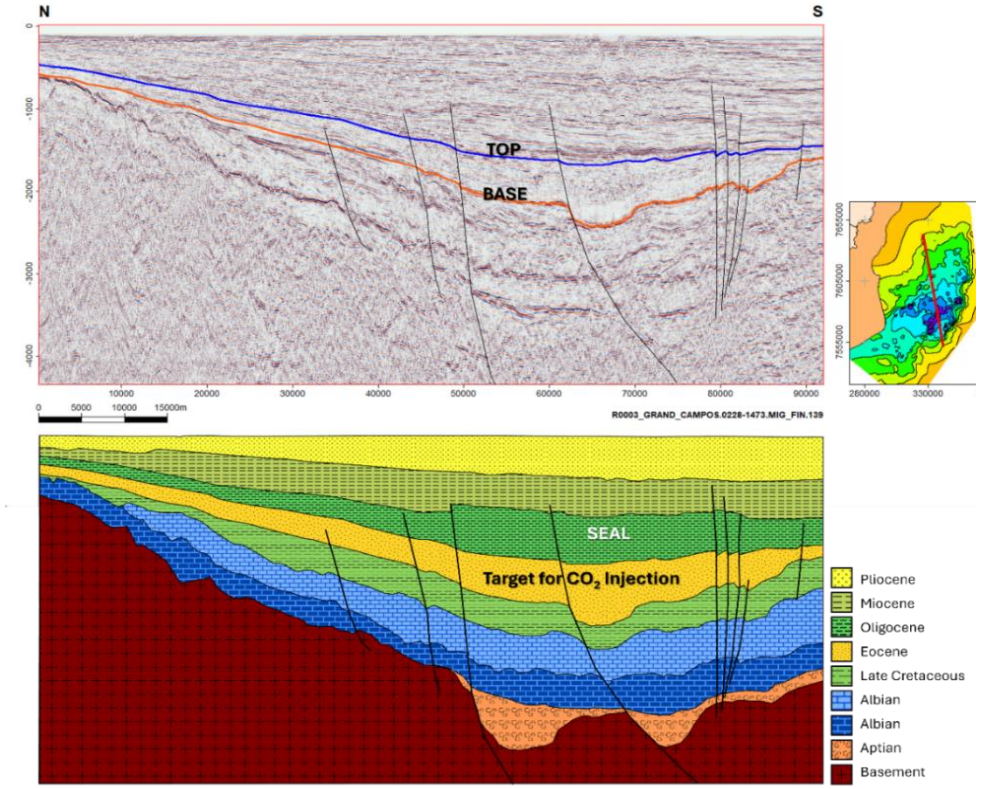


Fig. 2 - Image of 2D seismic data displays the top and base horizon mapped delimiting the target reservoir for $CO_2$ injection into São Tomé Member, below the schematic geological section.

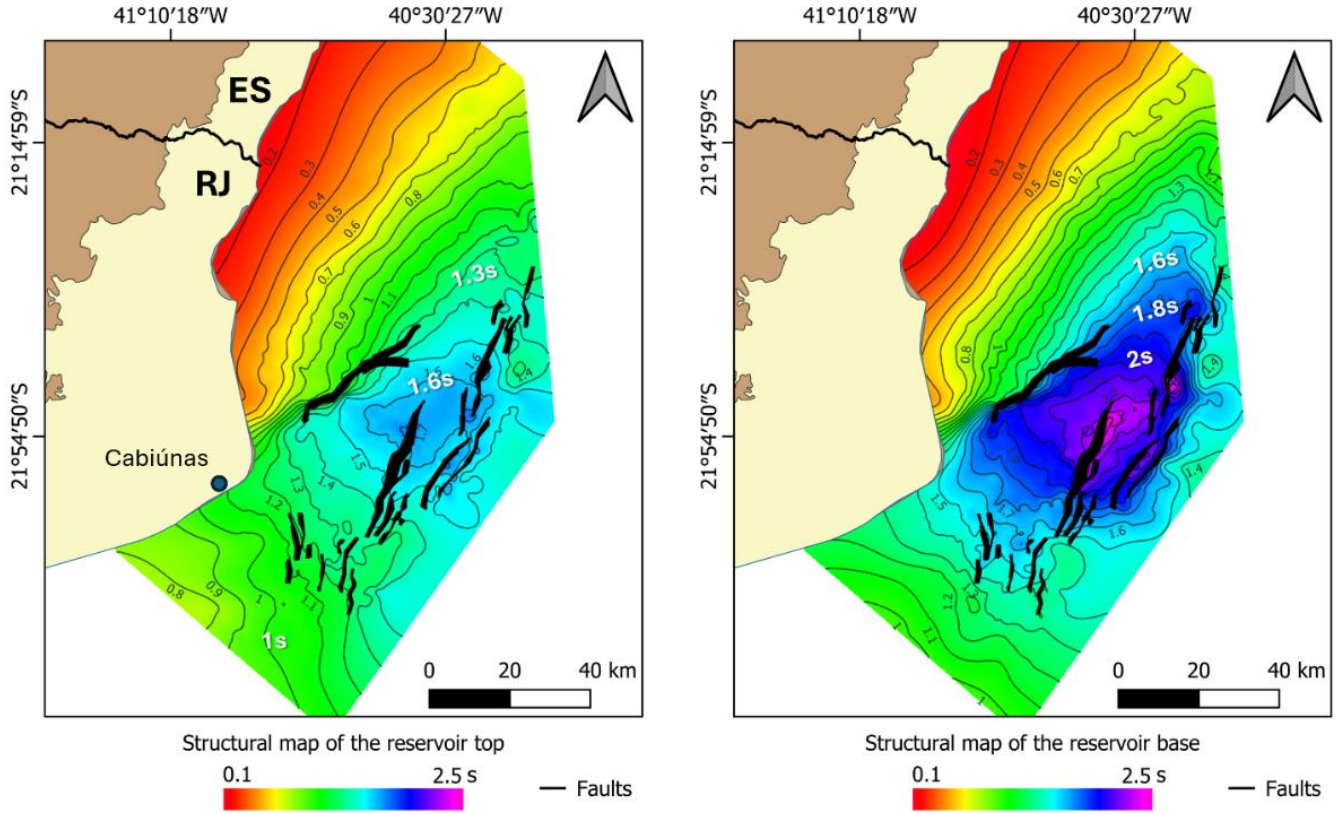


Fig. 3 - Structural maps (time domain). On the left and right top and base, respectively, showing the depocenter of São Tomé Member in Campos Basin.

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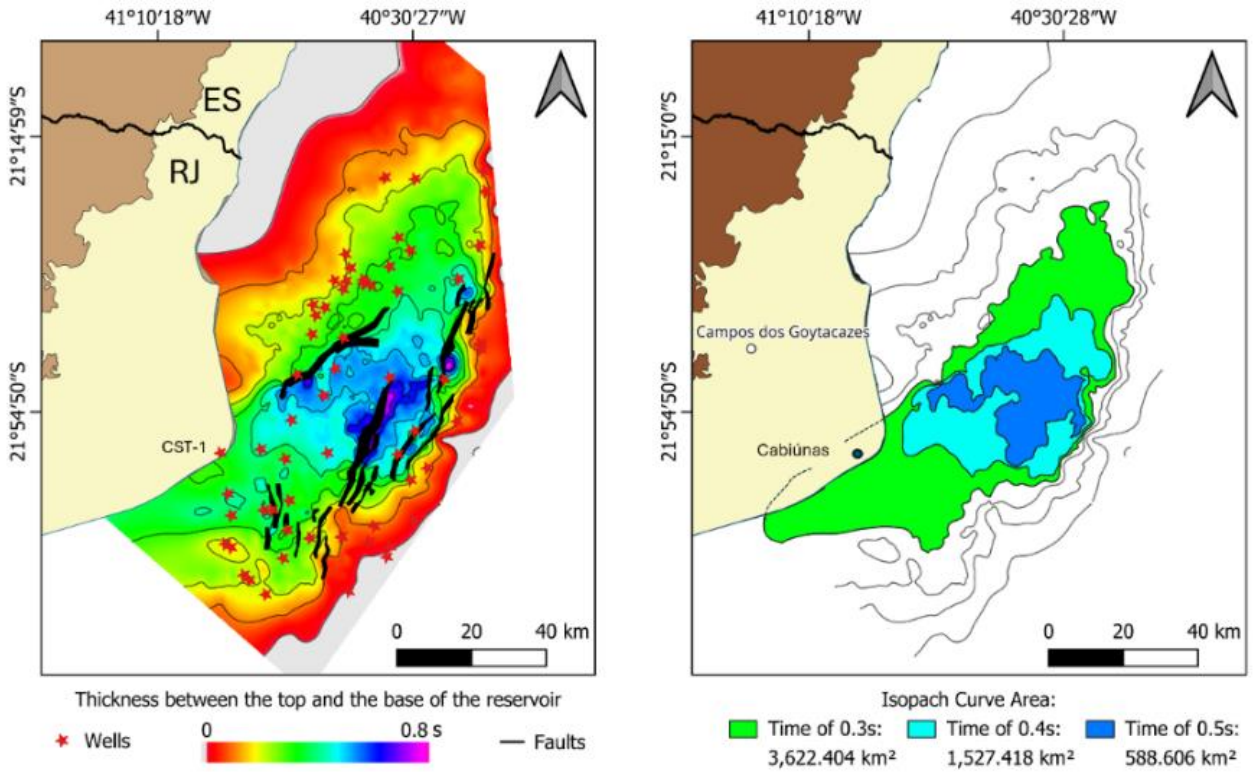
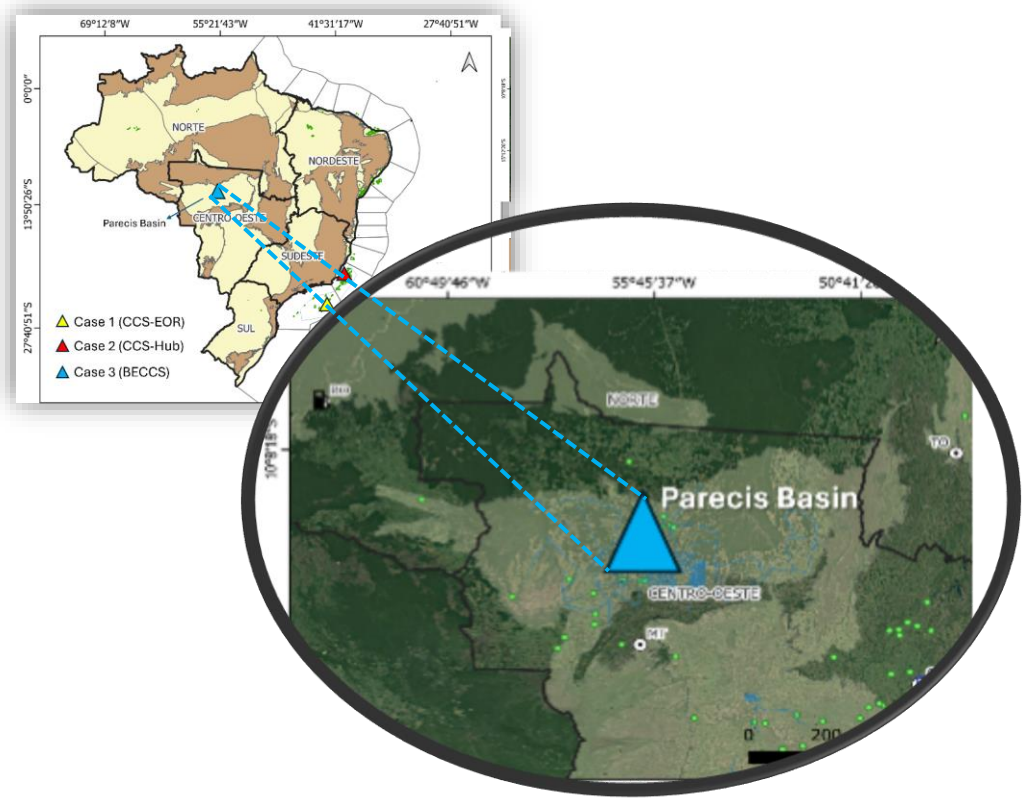



Fig. 4 - Thickness map (time domain). On the left is an isopach map that shows the old wells drilled for hydrocarbon exploration; and the main faults mapped. On the right, the selected areas correspond to the thicknesses of 0.5s, 0.4s, and 0.3s. The last one (in green) "touches the land" where the Cabiúnas pilot project is found.

São Tomé depocenter is a unique geological location with exciting potential for permanently storing anthropogenic $CO_2$. Its generous size, ranging from around 588 $km^2$ to 3,622 $km^2$ of area, provides ample pore space for the supercritical $CO_2$ phase without hydrocarbons. Nevertheless, it is not a conventional trap, especially about side closures. The depocenter is conveniently found near the coastline in the shallow water of northern Rio de Janeiro and southern Espirito Santo states, making it an ideal site for concentrated facilities for CCS-hub implementation. However, further studies are needed to ensure $CO_2$ transportation, geological injection conditions, leakage risks, and seismicity effects.

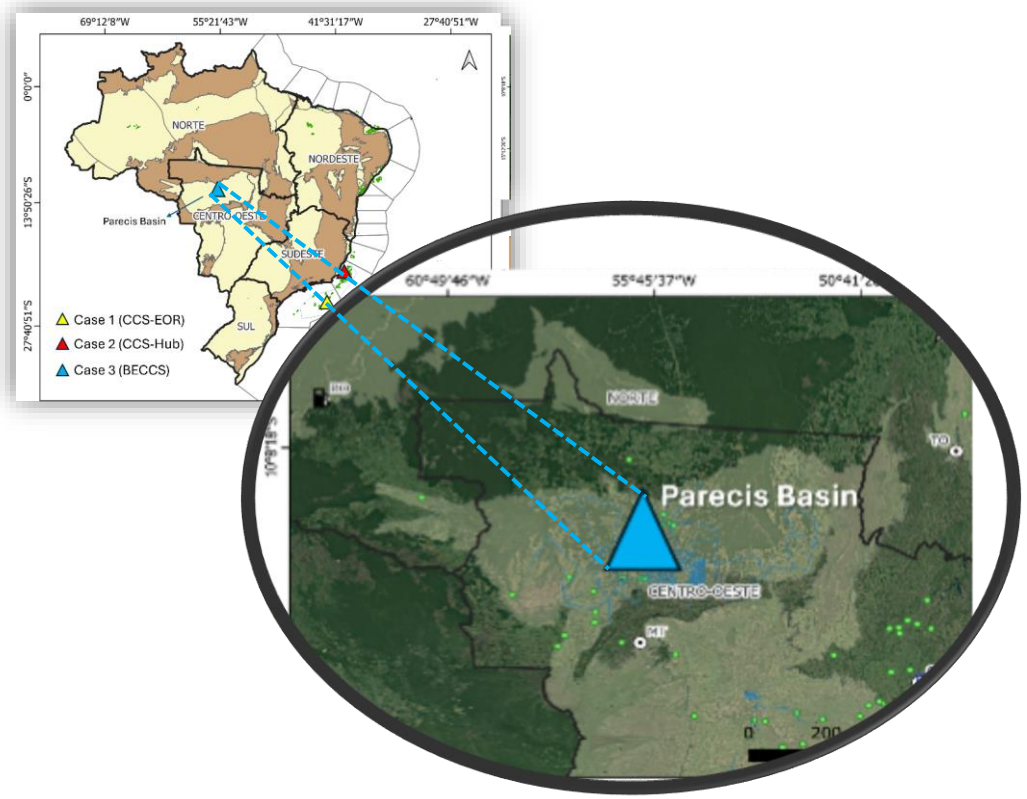



The third case presented Brazil's most advanced BECCS project, in Mato Grosso State, which includes recently acquired geological and geophysical data. This article proposes that an outstanding model to unlock the country's geological storage of $CO_2$ pathways is based on the saline aquifer reservoir, in a Hub system connecting different hard-to-abate sources or a cluster of sources on a BECCS example.

## CASE 3 (BECCS)

# PARECIS PILOT

*SALINE AQUIFERS*

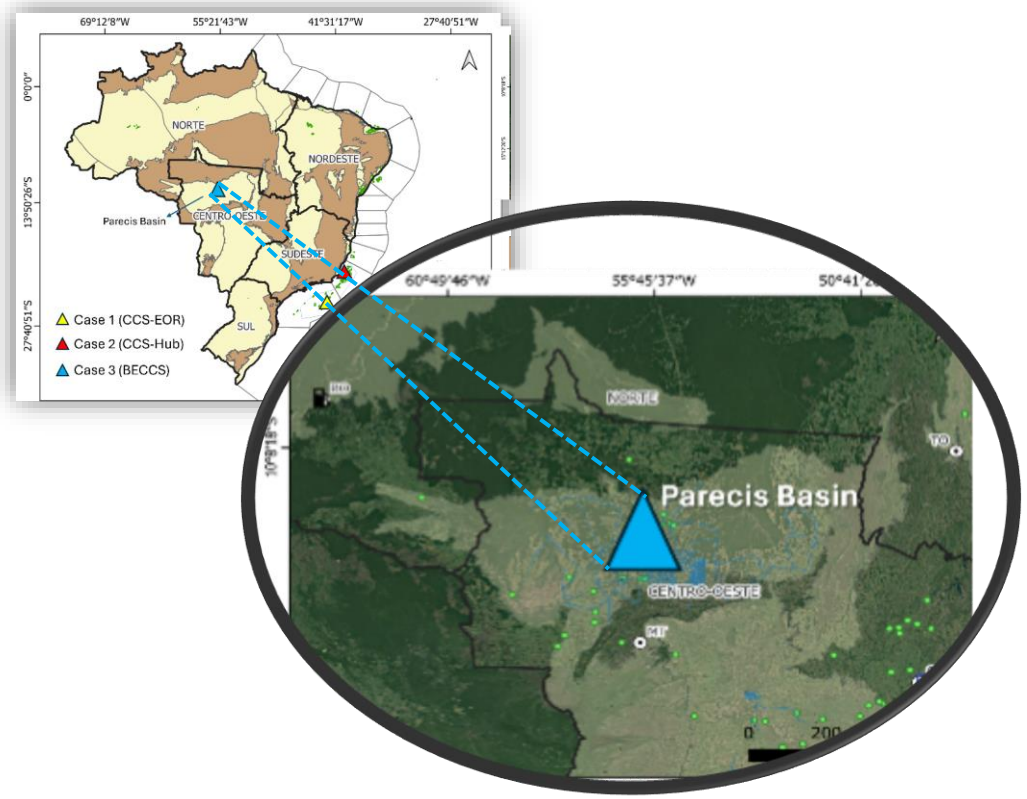



## CASE 3 (BECCS)

# PARECIS PILOT

CCS alone does not remove $CO_2$ from the atmosphere. However, it can help reduce atmospheric contaminants from industrial and energy-related sources if combined with bioenergy production (BECCS). There are two main BECCS projects under evaluation in Brazil, and the most advanced has a storage capacity of 0.423 Mtpa $CO_2$. This pilot project is related to an ethanol plant in Mato Grosso State;

Brazil is the world's second-largest ethanol producer, with enormous potential for BECCS. In 2020, the country produced thirty billion liters of ethanol, accounting for 30% of global production. The Lucas do Rio Verde project is pioneering BECCS, with low capture and transport costs due to the fermentation process that concentrates $CO_2$ and the proximity to the geological site. The Parecis BECCS pilot project started in 2020 using public data, including well 2-SM-1-MT and regional 2D seismic lines;

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## CASE 3 (BECCS)

# PARECIS PILOT

# Case 3: Parecis Pilot Project (BECCS) – Bioenergy with Carbon Capture and Storage

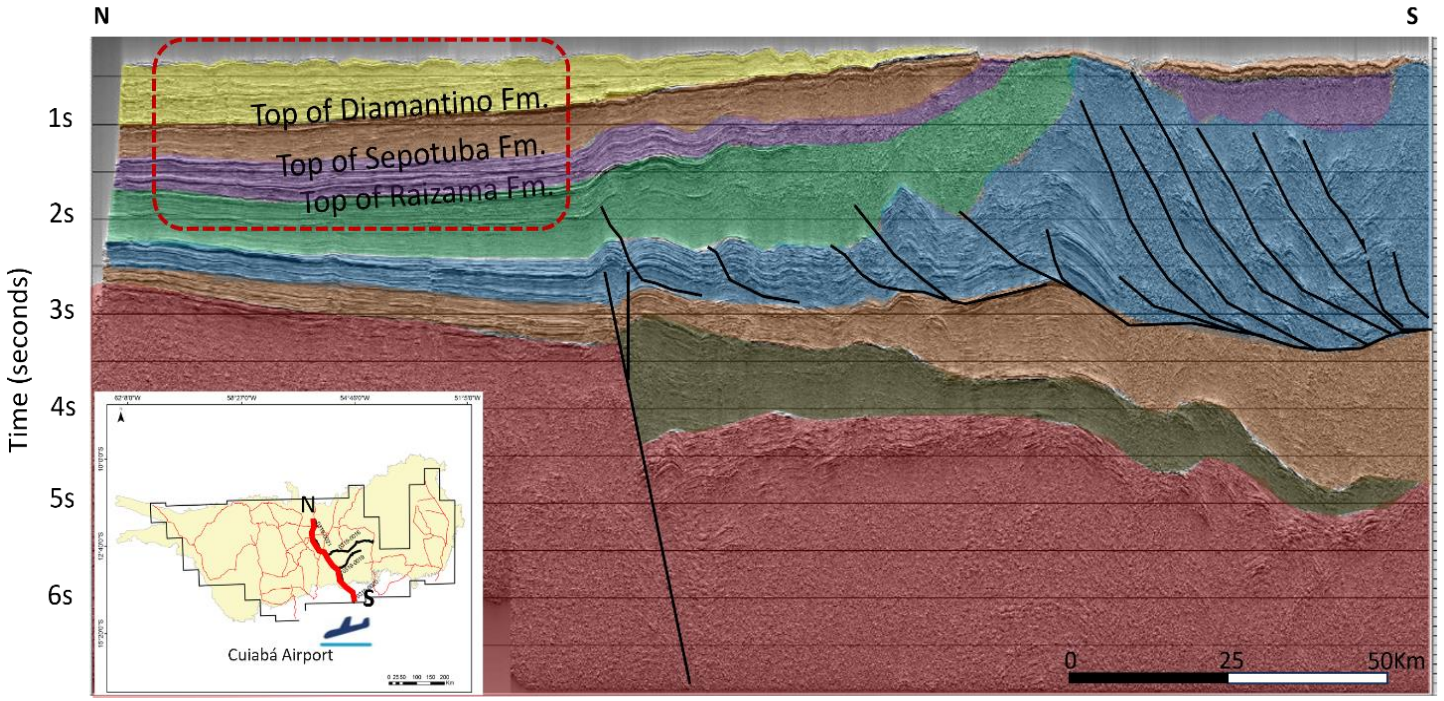
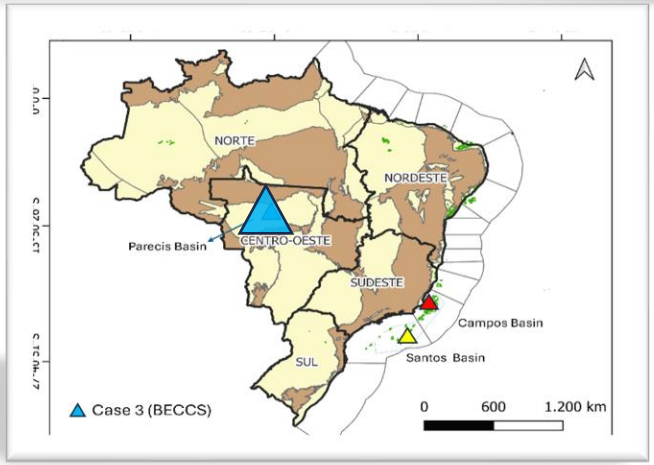
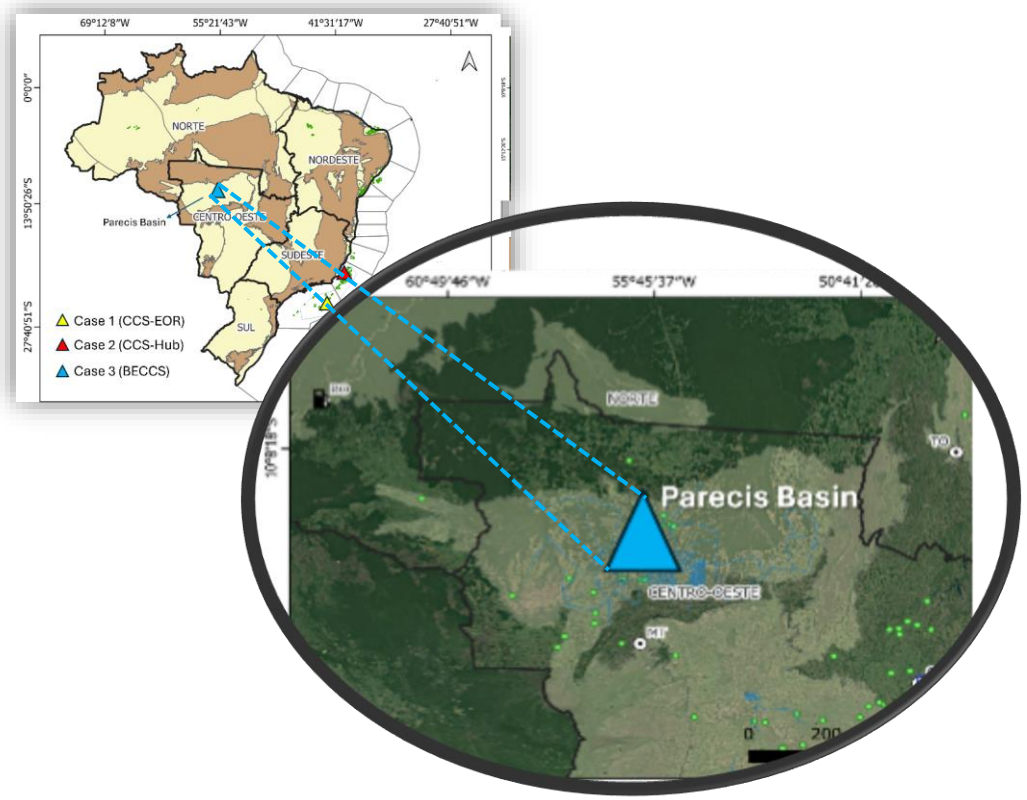



Fig. 5 - The Image of the regional public seismic line showing the structural differences between the northern and southern of the Parecis basin. The dashed-red polygon highlights the sample areas for further CCS studies.

Figure 5 visually represents the contrast between the basin's central northern and central southern parts. In the north, where the pilot project is taking place, the stratigraphic sequences are continuous and flat, with few structures. However, in the south, massive structures range from small folds to larger ones and even to rupture (faults).






The company recently acquired 3D seismic to conduct local studies and identify the geological site's characteristics for injection. Towards the end of 2023, a stratigraphic well was drilled, and its evaluation, including the pore space conditions and permeability, is underway. The next step is to determine whether the project will go ahead, and simultaneously, progress is needed in the regulatory framework to set up the rules.

## CASE 3 (BECCS)

# PARECIS PILOT

# Final Consideration

For net zero emissions, it is essential to implement CCS, particularly for CDR strategies. Although Brazil has been slow to adopt these options, it has the world's largest $CO_2$ injection project in the pre-salt play and owns the necessary ability and technology to make considerable progress towards reducing carbon emissions. Indeed, Brazil has oil fields that hold different amounts of dissolved geological $CO_2$. This has resulted in developing specialized skills, materials, and technology to manage these fields (CCS-EOR), especially in the Santos sedimentary basin. This ability can be helpful to other CCS projects, including those without hydrocarbon sources of $CO_2$. For example, it can help with saline aquifers in CCS-Hub models or BECCS, whether offshore or onshore. This paper presents valuable information concerning the Tupi oil field, referred to as Case 1. It addresses the ongoing controversy surrounding carbon capture, precisely the geological type as opposed to the anthropogenic type.

# Final Consideration

Furthermore, this study explores two options beyond EOR suitable for implementation in Brazil. Case 2 presents promising potential in assisting hard-to-abate sectors with CCS-Hub. This hub can be soon implemented in Rio de Janeiro, where $CO_2$ can be injected into saline aquifers of the sandstone reservoir of São Tomé Member in the Campos Basin, shallow water. Finally, the paper presented the most advanced BECCS project in Brazil, Lucas do Rio Verde (Case 3), which includes a recently acquired 3D seismic and a drilled stratigraphic well currently in the project evaluation phase.

# Final Consideration

Brazil has vast potential for CCS. However, establishing a robust legal system, which begins with Law nº. 14,993, recently approved, and building the regulatory framework is crucial to ensure safe, sustainable, and economic growth. Additionally, special attention is needed to improve the ability of skilled workers in multiple areas. Oil and gas professionals can bring valuable knowledge from EOR. Otherwise, BECCS and CCS-Hub need new capabilities to work with saline aquifers. Environmental concerns must be at the forefront, and economic feasibility is necessary. Society should also be involved in discussions at all stages with proper representation, as public perception matters.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