CARBON CAPTURE, STORAGE, AND UTILIZATION TECHNOLOGIES (CCUS) AND THEIR IMPORTANCE TO THE ENERGY TRANSITION IN BRAZIL

INSTITUTO BRASILEIRO DE PETRÓLEO E GÁS

WHAT IS IT?

Carbon Capture, Utilization, and Storage technologies (CCUS) are tools adopted in production systems to capture carbon dioxide (CO2), store it safely in offshore or onshore geological reservoirs, or even in tanks to reuse it as an input for manufacturing other products. These technologies can capture up to 90% of the CO2 emitted from different sources, such as the use of fossil fuels to generate electricity and those resulting from industrial processes and hard-to-abate industries (cement, steel, and fertilizer production, among others). CCUS technologies also allow CO2 emissions in the atmosphere to be removed through direct air capture and storage systems (DACCS) or bioenergy systems with capture and storage (BECCS).

HOW DOES IT WORK?

The CCUS system encompasses four main stages: **capture**, **transportation**, **storage**, and **utilization**. During the **capture** stage, CO2 is separated from other gases in large industrial facilities or directly into the atmosphere. Capture can take place in three ways: (i) pre-combustion; (ii) post-combustion; and (iii) oxy-fuel combustion. In pre-combustion systems, fossil fuels are subjected to gasification or reforming processes, allowing them to be converted into a mixture of carbon dioxide and hydrogen. Hydrogen is thus extracted and can be used to generate heat or CO2-free energy.

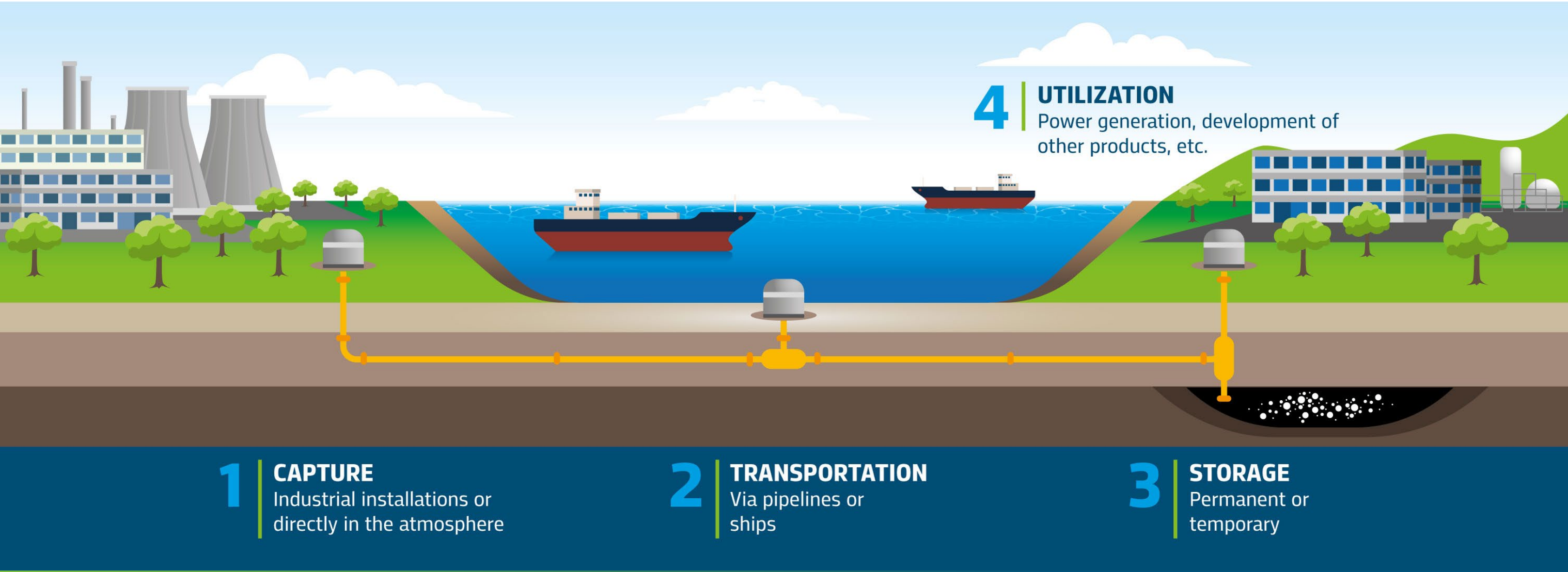
In post-combustion capture methods, CO2 is captured from the exhaust of combustion systems and absorbed in a solvent before the polluting elements are removed and compressed. CO2 can also be separated using high-pressure membrane filters or cryogenic separation processes. Finally, there is oxy-fuel combustion, which consists of burning fuel together with oxygen instead of air, allowing the resulting gas to consist of water vapor and carbon dioxide.

Once the CO2 has been captured and separated, it needs to be compressed in order to be **transported**. This requires an increase in the CO2 pressure so that it can behave as a liquid. Under these conditions, the CO2 is transported in large quantities via pipelines and, in some cases, ships.

After its transportation comes the **storage** stage, which can be permanent or temporary. In cases of permanent storage, the CO2 is injected into rock formations located underground or in offshore oil reservoirs, where it is stored safely and permanently. Possible carbon storage sites include saline aquifers, depleted reservoirs or onshore wells drilled specifically for this purpose, as is the case with BECCS.

Temporary storage, on the other hand, can take place in above-ground reservoirs meeting minimum specifications to guarantee safety in the event of leaks. These cases apply to situations in which CO2 can be reused and marketed.

Exhibit 1. **Stages of the CCUS systems**



Although storage is the most widely chosen alternative for disposing of captured CO2, it is also possible for it to be **utilized**. Nowadays, CO2 is already used as part of advanced recovery techniques for hydrocarbon reservoirs, as an input for energy generation and space heating, and for the development of commercially valuable products in the food, petrochemical and building materials sectors, among others. In this regard, studies aimed at finding new ways of using these gases in industrial processes continue to evolve, motivated by corporate interest in advancing their mitigation goals in a cost-effective way.

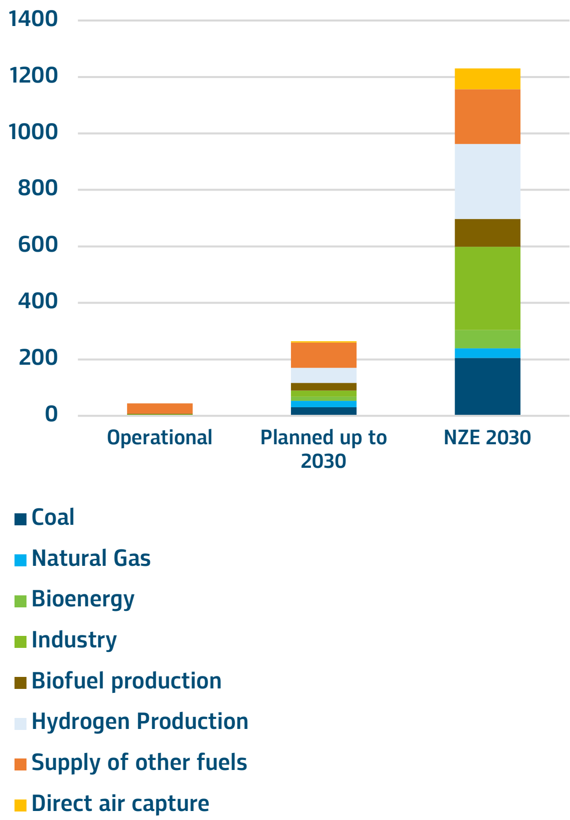
THE IMPORTANCE OF CCUS TECHNOLOGIES IN THE ENERGY TRANSITION

CCUS technologies are seen as one of the necessary tools among the technological options available to achieve the emission reduction targets by 2050. This importance is considered key to mitigating GHG emissions in hard-to-abate sectors and to removing CO2 that is already in the atmosphere.

According to data from the International Energy Agency (IEA) (2024), there are currently 45 CCUS installations in operation with a capture capacity of 50 Mt CO2/year. However, in the net zero scenario (NZE) constructed by the international agency, it is estimated that capture capacity need to reach to 1.2 Gt CO2/year in 2030 and to 6.2 Gt CO2/year in 2050 to prevent the rise in earth temperatures by more than 2 degrees compared to pre-industrial levels (chart 1).

According to data from the International Energy Agency (IEA) (2022), there are currently 45 CCUS installations in operation with a capture capacity of 50 Mt CO2/year.

Chart 1. **Projections of increased installation of CCUS technologies in the NZE scenario**
Millions of tons of CO2



Source: Designed by the authors using AIE data (2022) .[1].

Nonetheless, the diffusion of CCUS technologies on the scale needed to achieve the projections of the NZE[2] scenario, IEA's most optimistic, still needs to overcome some challenges. These challenges are associated with the economic risks involved in developing large infrastructure projects in regulatory environments with obstacles to making investments viable and enabling the generation of new business.

The diffusion of these CCUS technologies needs to be embedded in regulatory environments capable of generating legal certainty for agents, as well as allowing the implementation and gaining of a commercially viable scale for the industry. In this order, the regulatory framework for these activities must provide the conditions for organizing the industry with governance structures capable of reducing the technical and economic risks for companies.

In this sense, the organization of clusters between geographically close companies has made it possible to introduce CCUS technologies through the execution of joint projects, allowing infrastructure sharing, risk reduction, and, consequently, cost reduction through scaling.

[1] 2022. IEA. https://www.iea.org/reports/world-energy-outlook-2022.

[2] The Net Zero Emissions by 2050 (NZE) scenario is an IEA normative framework that estimates the efforts that need to be made in the energy sector to achieve net-zero CO2 emissions by 2050.

THE IMPORTANCE OF CCUS TECHNOLOGIES FOR THE BRAZILIAN O&G INDUSTRY

The implementation of CCUS systems is a great opportunity for the Brazilian O&G industry, given its extensive expertise in CO2 separation, transportation, and reinjection activities (used on a large scale in pre-salt reservoirs for advanced oil recovery) and its knowledge of the country's geology. Leveraging these opportunities could help these companies reduce GHG emissions in their own operations (platforms, refineries, thermoelectric plants, and natural gas treatment units), making them potential large-scale users of this technology. There is also the possibility of using the existing pipeline infrastructure of surface and subsea facilities and depleted reservoirs, which is also an opportunity to reduce costs and consequently make the CCUS industry viable in Brazil.

In recent years, Brazil has also made progress on climate policy with the potential to encourage the adoption of CCUS technologies. In 2024, Brazil updated its decarbonization targets, setting new levels for its Nationally Determined Contribution (NDC), which guides sectoral plans for climate change mitigation and adaptation, and will establish a national emissions reduction system

Petrobras currently has the largest CO2 capture, use and geological storage program in operation in the world and the first to be implemented in ultra-deep waters. Located in the pre-salt fields, the systems have the capacity to process 7 Mt CO2/year (9.3% of the world's total capacity in 2022). Between 2008, the year the company first implemented a CCUS system, and September 2021, Petrobras has already reinjected 28.1 Mt CO2 and expects to reach 80 Mt CO2 by 2025[3].

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The consolidation of a robust CCUS industry in the country is one of the ways for the O&G industry and other relevant sectors of the Brazilian economy to advance in the low-carbon energy transition. Therefore, considering the growing need to accelerate national efforts to reduce GHG emissions, as well as the importance attributed to CCUS technologies to contribute to the mitigation plans of countries and companies, the establishment of a regulatory framework with the appropriate incentives is crucial to stimulate the development of this industry in Brazil.

Find out more about the IBP's position on the Energy Transition through the link: https://www.ibp.org.br/posicionamentos/.

[3] 2022. Petrobras. https://petrobras.com.br/fatos-e-dados/novo-plano-estrategico-2023-2027-preve-investimentos-de-us-78-bilhoes-nos-proximos-cinco-anos.htm.

[4] 2024, Ministério do Meio Ambiente e Mudança do Clima. https://www.gov.br/mma/pt-br/assuntos/noticias/nova-ndc-do-brasil-representa-paradigma-para-o-desenvolvimento-do-pais-diz-marina-na-cop29

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IBP - Brazilian Petroleum and Gas Institute
52 Almirante Barroso Ave - Floors 21 and 26 - RJ - Phone +55 21 2112-9000
ibp.org.br | relacionamento@ibp.org.br