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INSTITUTO
BRASILEIRO DE
PETRÓLEO E GÁS

PATHWAYS TO DECARBONIZATION

JANUARY | 2024

BRAZIL
THE COUNTRY'S POTENTIAL FOR RENEWABLE ENERGY GENERATION AND DECARBONIZATION

Brazil has the potential to play a leading role in the process of decarbonization and reduction of greenhouse gas emissions (GEE) in the oil and gas sector; in the development of low-carbon technologies; and, in the production of bioenergy. Brazil's prominent position is due, above all, to its capacity in terms of renewable energy generation; the harnessing of synergies between the O&G industry and new low-carbon sources; and for developing one of the lowest carbon emission intensities in hydrocarbon production.

Thus, Brazil can be considered a key player in the global decarbonization efforts.

The world needs to reduce emissions by 7% each year to limit global warming to 1.5°C by the end of the century. The oil and gas sector will need to rapidly decarbonize its operations, in addition to contributing to the decarbonization of its clients' operations. For Brazil, it is essential to position itself strategically in the low-carbon economy based on its recognized potential.

In its leading role in the energy transition process, Brazil has made great progress on integrating to its O&G sector production chains, new sustainable technologies.

The transition to a low-carbon economy imposes challenges, but also creates opportunities for countries like Brazil, that benefit of significant renewable energy potential.

As a representative of this very important sector, IBP brings valuable information on the opportunities and alternatives for decarbonization.

Good reading!

Roberto Furian Ardenghy
IBP President

THE IMPORTANCE OF A JUST ENERGY TRANSITION FOR O&G PRODUCING COUNTRIES

INSTITUTO BRASILEIRO DE PETRÓLEO E GÁS

WHAT IS THE CONCEPT OF JUST ENERGY TRANSITION?

The term "just transition" was first used by the labour movement in the United States in the 1970s, to warn about the negative economic impact that increased regulations could have on employment and income of workers in industries considered to be polluting. Since then, the term has evolved and spread among environmental justice groups, union movements, international organizations and the private sector.

In the energy sector, the concept of just transition is often associated with the adoption of criteria and measures to mitigate the negative economic and social impact in:

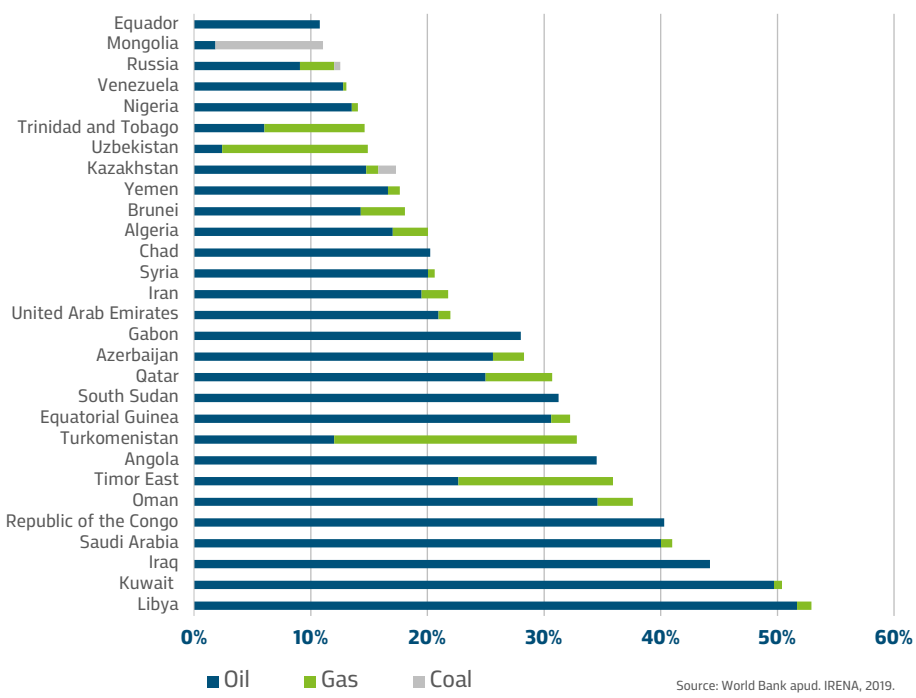
- **Fossil fuel industry workers**
- **Poor communities without resources to mitigate or adapt to climate change**
- **Countries, regions or localities that specialize in the production of fossil fuels**

IMPLICATIONS OF THE ENERGY TRANSITION IN O&G PRODUCING COUNTRIES

Productive activities associated with O&G extraction are the main source of wealth generation and employment in many producing countries. For this reason, a low-carbon energy transition must consider:

- **Assets valued in trillions of dollars**
- **Millions of direct and indirect jobs**
- **The sources of income that sustain national and sub-national economies**

Fossil fuel revenue as a percentage of GDP
(Average2007-2016)



Source: World Bank apud. IRENA, 2019.

AN INORDINATE ENERGY TRANSITION MAY CAUSE:

- **Deteriorating of socio-economic indicators in O&G producing countries**
- **Social and political tensions**
- **Other phenomena such as the forced migration of people for economic and social reasons**

The implementation of plans aimed at reducing the impacts of the energy transition in O&G-producing countries presents major challenges, especially for developing countries. For example:

- Difficulties in efficiently managing income from the O&G industry
- Challenges to improve socio-economic indicators
- In some cases, a high level of debt or poorly developed financial systems

At COP 27 in 2022, the difficulties faced by developing countries in financing their climate action plans, estimated at US$ 5.9 trillion by 2030, were highlighted.

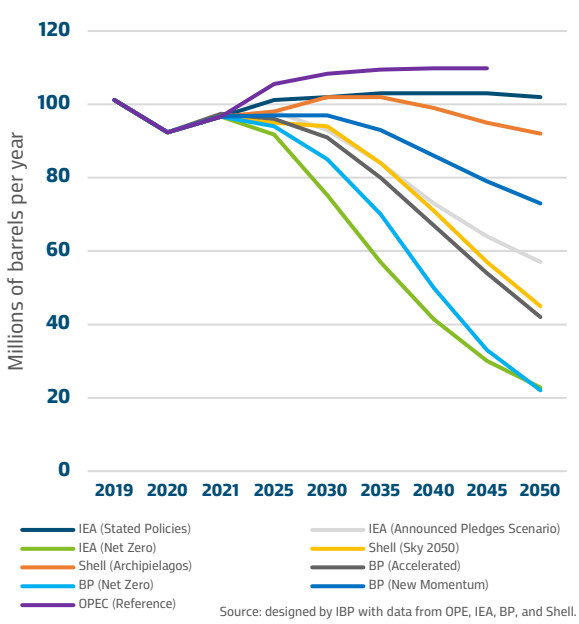
In recent years, developed countries and financial institutions have reduced credit lines for fossil fuel-based energy projects in developing countries.

At COP 26 in 2021, developed countries set an annual target of US$100 billion in joint financing for mitigation actions in developing countries. However, this target has not yet been reached.

DOES THE DECREASE IN O&G PRODUCTION IN DEVELOPING COUNTRIES CONTRIBUTE TO CLIMATE ACTION?

The reduction in O&G production needs to be aligned with decarbonization plans capable of encouraging a reduction in the demand for fossil energy sources in the main consumer markets and mitigation goals beyond the energy sector.

Global oil demand projections (mbd)



Source: designed by IBP with data from OPE, IEA, BP, and Shell.

According to more conservative scenarios, oil consumption should continue to grow for at least the next two decades

Main drivers of the demand for fossil fuels:

Industry

Cement and Steel

Transportation

Power generation

Thermal electricity

Non-energetic products

Petrochemical

Products that require inputs from the petrochemical industry

- Batteries
- Fertilizers
- Tires
- Electronic devices
- Personal hygiene products
- Solar panels
- Wind turbines
- Textiles
- Packaging
- Luggage
- Medicines

The drop in O&G production and exports from developing countries could have adverse effects:

- **An imbalance in supply and demand structures**
- **An increase in oil barrel prices**
- **Energy insecurity**

SOME OF THE COUNTRIES WITH O&G RESERVES, WHICH ARE AMONGST THE MOST VULNERABLE IN THE CONTEXT OF THE ENERGY TRANSITION, ARE ALSO ~~AMONG~~ THE LEAST RESPONSIBLE FOR GLOBAL GHG EMISSIONS

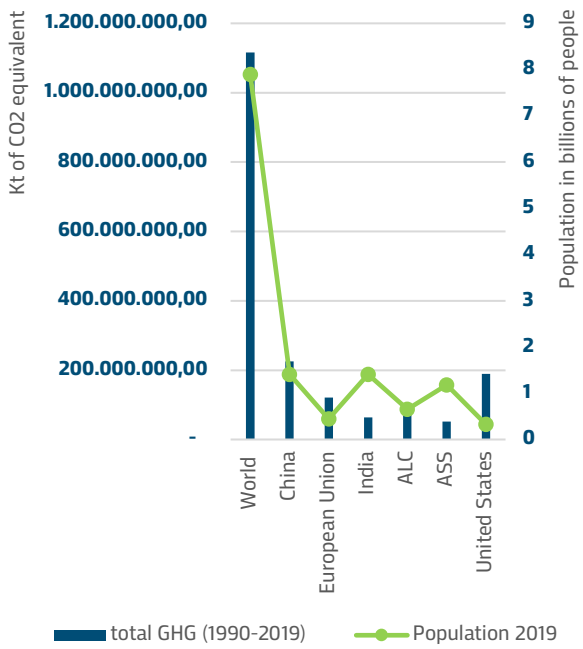
Amongst O&G-producing countries, the impact on global GHG emissions can be analyzed by considering the scope of their activities:

Countries that have significant O&G reserves but have not yet begun to monetize these resources; or are just starting these activities.

Countries whose production is predominantly of natural gas

Countries whose production is predominantly of oil

GHG emissions over the period 1990-2019 in selected countries and regions

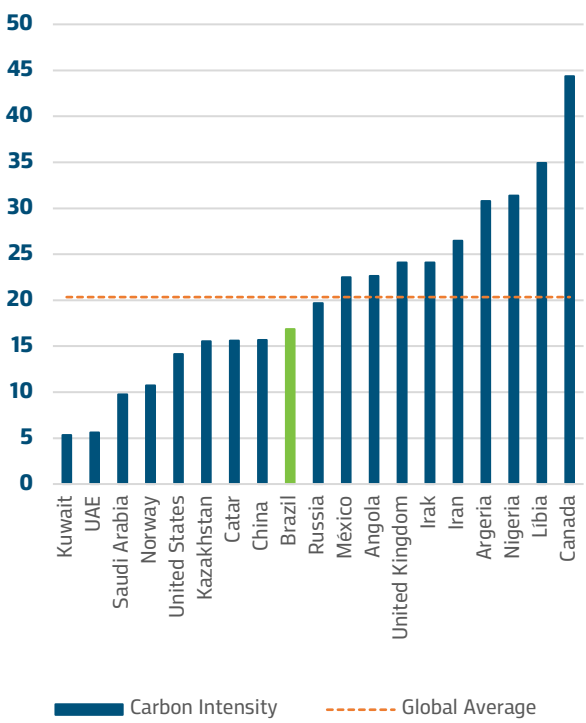


* Latin America and the Caribbean.
** Subsaharian Africa.
Source: designed by IBP using data from the World Bank, 2019.

THE SHARE OF GHG EMISSIONS LINKED TO OIL PRODUCTION ACTIVITIES VARIES ACCORDING TO THE VOLUME AND QUALITY OF THE RESOURCE EXTRACTED

Carbon intensity of oil production in selected countries

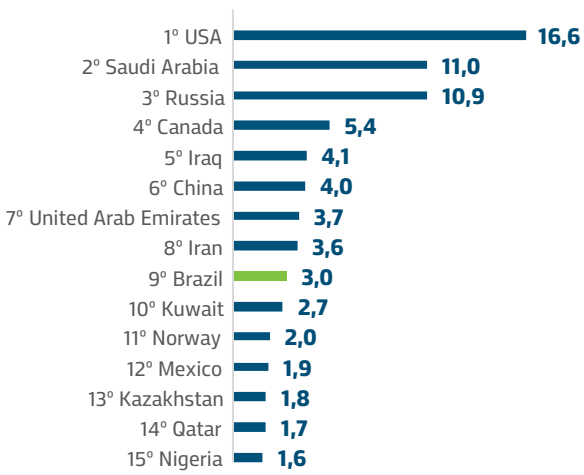
kgCO2/obe, (2019)



Source: designed by IBP using BP data, 2022.

World's largest oil producers

Millions of barrels per day, 2021



Source: designed by IBP using BP data, 2022.

The monetization of O&G resources could be an alternative for financing climate action plans in developing countries

The production and export of O&G can be a source of funds for developing countries to fund their climate action plans.

BUT WHAT DOES JUST MEAN?

The literature on just energy transition establishes some criteria for identifying which countries could have priority in monetizing their O&G reserves:

Criteria raised by the literature on just energy transition:

Accountability
The country's share of global GHG emissions

Necessity
Ability to finance their climate action plans

Equality
Population size and income level

Sovereignity
Energy supply security guarantees

Cost-effectiveness
Production costs, effectiveness in reducing GHG emissions, and institutional capacity

WHAT DOES THE PARIS AGREEMENT SAY?

Article 2 of the 2015 Paris Agreement states that its implementation will be done *"in a manner that reflects equity and the principle of common but differentiated responsibilities and respective capabilities in the light of diverse national circumstances".*

ALTERNATIVES FOR O&G-PRODUCING COUNTRIES

O&G-producing countries need to move forward in implementing plans to mitigate the socio-economic impact of the low-carbon energy transition. These plans could include the following measures:

- Implementing strategies to extend the longevity of the industry by reducing GHG emissions (CCUS, natural gas, and production of less carbon-intensive oils)
- Adopting plans for economic diversification beyond fossil fuel-intensive production activities and investments in RD&I
- Supporting workers in the sector in reformulating their professional career plans
- Carrying out climate change mitigation and adaptation plans

THE IMPORTANCE OF INTERNATIONAL COOPERATION TO MITIGATE THE IMPACTS OF THIS PHENOMENON IN MORE FRAGILE O&G-PRODUCING COUNTRIES

Industrialized countries, which have a greater share in global GHG emissions, can coordinate planned actions to fulfill their demand for fossil fuels by purchasing these resources from developing countries.

COOPERATION PLANS MAY INCLUDE:

- Diversification of O&G supply sources from reliable producing countries
- Institutional strengthening programs for the implementation of public policies focused on energy and climate
- Compensation programs to developing countries for the decision not to monetize their O&G reserves

BIOFUELS AND THEIR IMPORTANCE FOR THE BRAZILIAN ENERGY TRANSITION

WHAT ARE THEY?

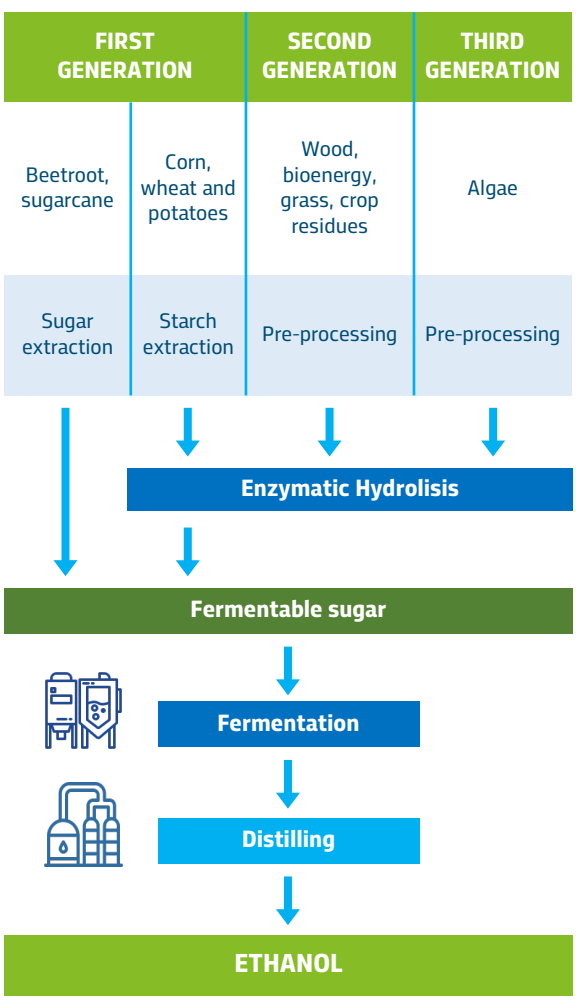
They are a category of fuels derived from organic raw materials, usually crops or agricultural products, which can be used to power vehicles, machinery and power plants, partially or totally replacing fossil fuels (MME, 2023).

LIQUID BIOFUELS

They represent a category of fuels derived from plant or animal sources that remain in a liquid state under standard temperature and pressure.

Ethanol is a chemical substance produced mainly by the fermentation of sugars. It is used in internal combustion engines with spark ignition (known as the Otto cycle) and is an alternative to gasoline (exhibit 1). Among the types of ethanol are anhydrous, hydrated and 2nd generation.

Exhibit 1. **Schematic pathways for the production of first, second and third-generation ethanol**



Source: UF-IFAS, 2023.

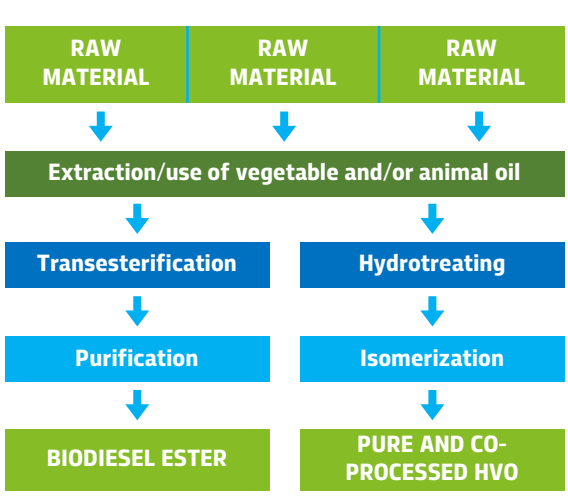
Anhydrous ethanol is a type of ethanol that has undergone a dehydration process, resulting in an extremely low water content, usually less than 1%. This process is carried out to make ethanol suitable for blending with gasoline.

Hydrous ethanol is a type of ethanol that holds a water content of around 5% to 7% of its weight. This category of ethanol is used directly as fuel in flex-fuel vehicles.

2ª-Generation ethanol is produced from the fermentation of sugars contained in the pomace and straw of sugarcane or other agroforestry residues, with a significant gain in productivity in the same planted area, compared to 1G ethanol.

Biodiesel is a type of biofuel derived from renewable biomass, intended for use in internal combustion engines (diesel cycle) that use compression ignition or, in accordance with current regulations, can be used in the production of other forms of energy, with the capacity to replace, in part or completely, fuels derived from fossil resources (exhibit 2).

Exhibit 2. **Schematic pathways to produce biofuels for the diesel cycle**



Source: UF-IFAS, 2023.

There are different technological means to priduce biofuels for diesel engines (biodiesel as provided by Act no. 9478/97):

Biodiesel ester is a biofuel produced from the transesterification and/or esterification of fatty materials and fats of vegetable or animal origin. It is a methyl ester that is transformed into biodiesel after undergoing purification processes.

HVO or Green Diesel is a 100% bio-based liquid fuel with the same characteristics as fossil diesel. It is fungible with fossil diesel and can be mixed in any proportion. Produced by hydrotreating biogenic material, it can use the same raw materials as biodiesel ester and other sources such as organic waste.

The **renewable portion of co-processed diesel (HVO)** is the result of an advanced production method that involves the simultaneous use of vegetable oils or animal fats and mineral oil fractions in a chemical co-reaction process. This process is carried out in oil refineries and uses hydrotreating units, adapted to include vegetable oils or animal fats in the process.

Another important type of biofuel is the **Sustainable Aviation Fuel (SAF).** It is obtained from renewable sources, from various technological routes previously approved by ASTM, under sustainability standards.

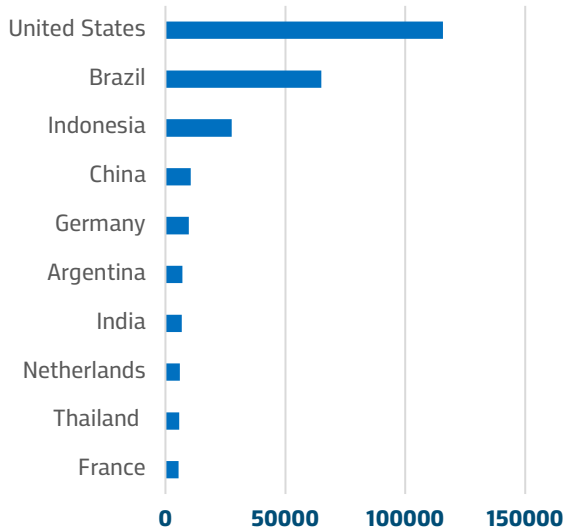
HVO and SAF are drop-in biofuels and can be incorporated directly into existing supply systems without the need for adaptations. Although they can be produced separately, both types of biofuels should be encouraged, as joint production leads to greater efficiency and consequently lower costs.

GLOBAL BIOFUELS LANDSCAPE

Global biofuel production has grown steadily over the last decade, exceeding 308,435 cubic meters per day (m³/d) by 2022 (IEA, 2022).

The United States is the world's largest producer of biofuels, responsible for 115,743 m³/d (38%), followed by Brazil with 65,026 m³/d (21.5%) and Indonesia with 27,664 m³/d (9.15%) (BP, 2023) (Chart 1).

Chart 1. **Main biofuel-producing countries in 2022**
Thousands of cubic meters (m³) per day



Source: BP Statistical Review, 2023.

IMPORTANCE OF BIOFUELS IN THE ENERGY TRANSITION

Biofuels are an important alternative to help decarbonize the transportation sector, due to its characteristics that enables a cleaner combustion and can emit up to 80% less greenhouse gases (GHG) than fossil fuels throughout their life cycle (ÚNICA, 2020).

According to the International Energy Agency (IEA, 2022), global demand for liquid biofuels is expected to increase in the following decades. In the optimistic scenario, called Net Zero Emissions (NZE), the agency estimates that this demand could reach 906,229 m³/d by 2030.

However, there are still challenges to be overcome in order to make the development and competitive diffusion of these technological options environmentally efficient, scalable and affordable compared to fossil fuels:

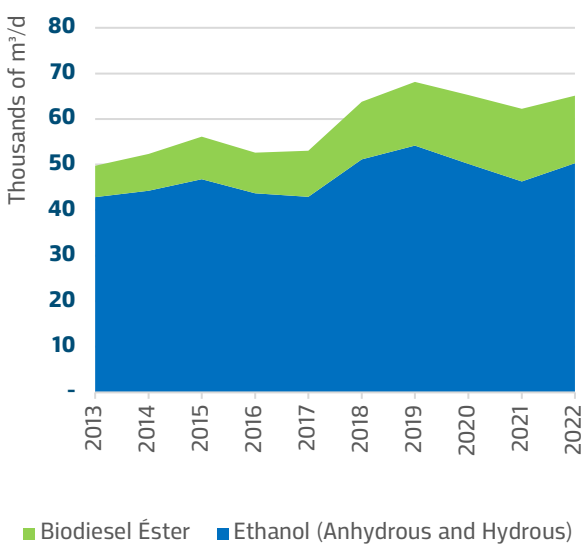
- Regulatory stability to encourage long-term investment in expanding production.
- Incentives for RD&I projects aimed at developing competitive technological solutions.
- Sufficient availability of sustainable raw materials.

THE BIOFUELS INDUSTRY IN BRAZIL

Brazil has a long tradition of implementing public policies and working with the private sector to boost the development of biofuels.

Currently, the country has a consolidated biofuel industry with a wide variety of players operating along the production chain. The Brazilian production profile is concentrated on anhydrous and hydrous ethanol and biodiesel, with 360 and 59 production units, respectively (Chart 2).

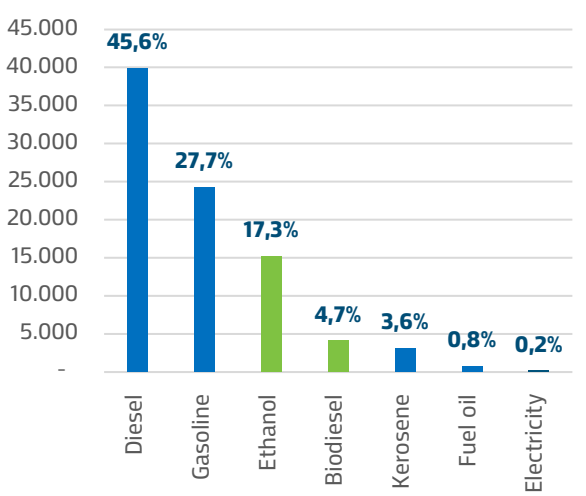
Chart 2. **Evolution of ethanol and biodiesel production in Brazil** (2013-2022)



Source: BP Statistical Review, 2023.

In 2022, ethanol and biodiesel accounted for 22% of the energy demand in the transportation sector (Chart 3).

Chart 3. **Final energy consumption in the transportation sector** (2022, thousand tons of oil equivalent)



Source: EPE.

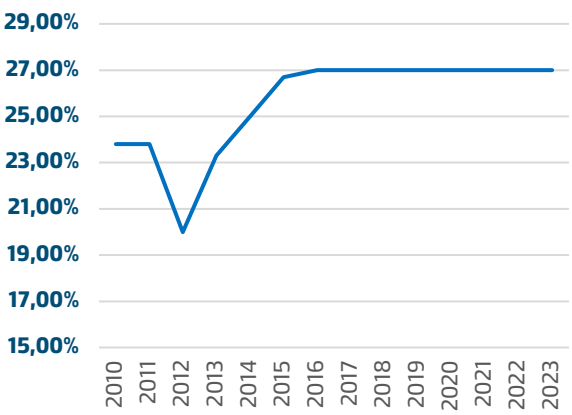
PILLARS OF BRAZIL'S BIOFUELS PUBLIC POLICY

Public policies to encourage the production and use of biofuels in Brazil can be segmented into three areas: compulsory mandate, RenovaBio and differentiated tax rates between fossil fuels and biofuels.

The **compulsory mandates** aims to encourage an increase in the share of biofuels in the transportation grid since the 20th century.

The blending of anhydrous ethanol into A gasoline has been carried out since the last century, evolving over time and, since 2015, stipulated at 27% (Chart 4)

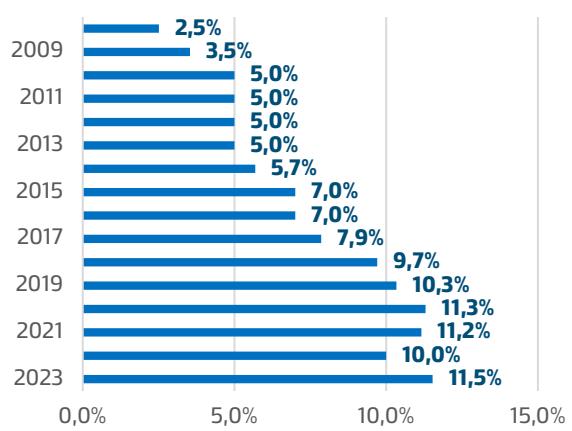
Chart 4. **Average percentage of anhydrous ethanol in gasoline** (2000-2023)



Source: Designed by IBP using ANP data.

In the case of diesel, the mandatory and gradual addition of biodiesel ester to diesel A began in 2008. Since then, the blending mandates have increased from 2% to the current 12% (Chart 5).

Chart 5. **Average annual biodiesel blend** (2008-2023)



Source: Designed by IBP using data from EPE and CNPE.
(*) 2023 Estimated amounts.

The definition of biodiesel established in Act 9478/97 is broader than the ANP regulation (focused only on the transesterification route).

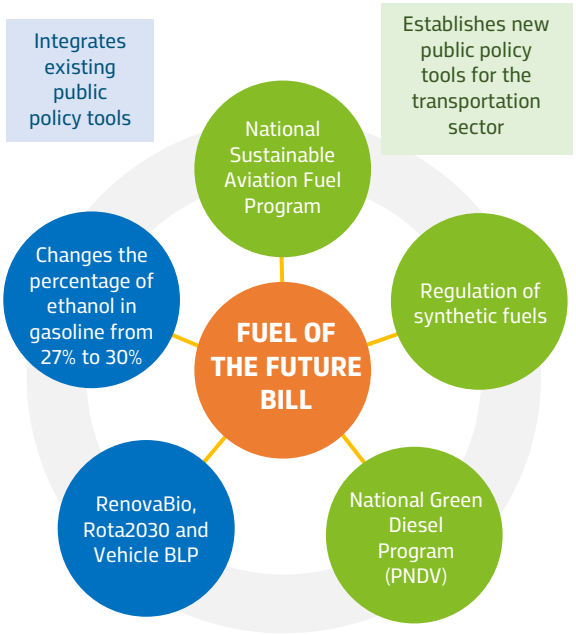
IBP is in favor of harmonizing the definitions of biodiesel, as set out in the legislation, which says *"biofuel derived from renewable biomass for use in internal combustion engines with compression ignition".*

Therefore, a broader concept is ensured, and it is not exclusive to the transesterification route, as per RANP 45/2014 (Brasil, 1997; ANP, 2014)

THE FUEL OF THE FUTURE PROGRAM

As a result of discussions with society, the federal government recently sent to Congress the "Fuel for the Future" bill, PL 4516/23, with the aim of advancing the decarbonization agenda for the country's transport sector (Exhibit 3).

Exhibit 3. **Pillars of the Fuel of the Future Bill**



Source: designed by IBP.

"E-fuels" are a category of synthetic fuels produced by capturing carbon dioxide (CO_2) from the atmosphere and using renewable electrical energy to carry out the chemical synthesis, usually using hydrogen.

RenovaBio, established by Act 13576 of 2017, aims to expand the production of biofuels in line with Brazil's commitments to reduce GHG emissions under the Paris Agreement.

The Program's main tool is the definition of annual carbon emission reduction targets for the fuel sector. This is intended to stimulate the production and use of biofuels in the country's transportation sector (ANP, 2023).

Finally, the **different tax rate** between biofuels and fossil fuels provides a competitive tax differential between the products.

The bill Gather RenovaBio, the Rota 2030 Program and the Brazilian Labeling Program, using the fuel's Life Cycle Assessment to estimate GHG emissions.

It establishes the National Sustainable Aviation Fuel Program, encouraging the use of Sustainable Aviation Fuel (SAF), as well as other measures to decarbonize this sector (decarbonization mandate).

It establishes the National Green Diesel Program (PNDV), which stipulates mandates for the gradual mixing of hydrotreated biodiesel, as a way of encouraging the investment necessary for its production and decarbonization of the road transportation sector.

It proposes increasing the limits for blending anhydrous ethanol into gasoline, raising the minimum level to 22% and the maximum to 30%.

It regulates the use of synthetic fuels, called "e-Fuels".

LEARN MORE ABOUT **BIOFUELS**

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.

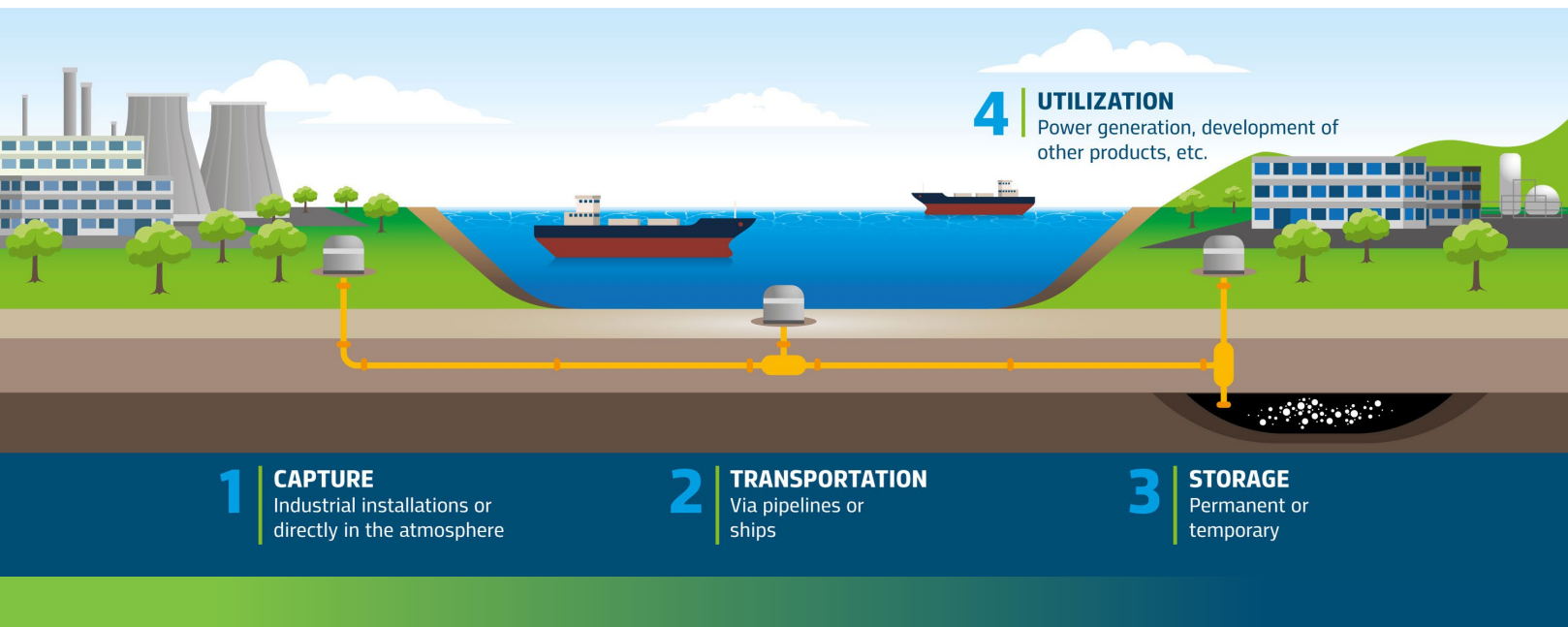
In post-combustion capture methods, CO2 is captured from the exhaust of combustion systems and absorbed in a solvent before the polluting elements are removed and compressed. CO2 can also be separated using high-pressure membrane filters or cryogenic separation processes. Finally, there is oxy-fuel combustion, 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.

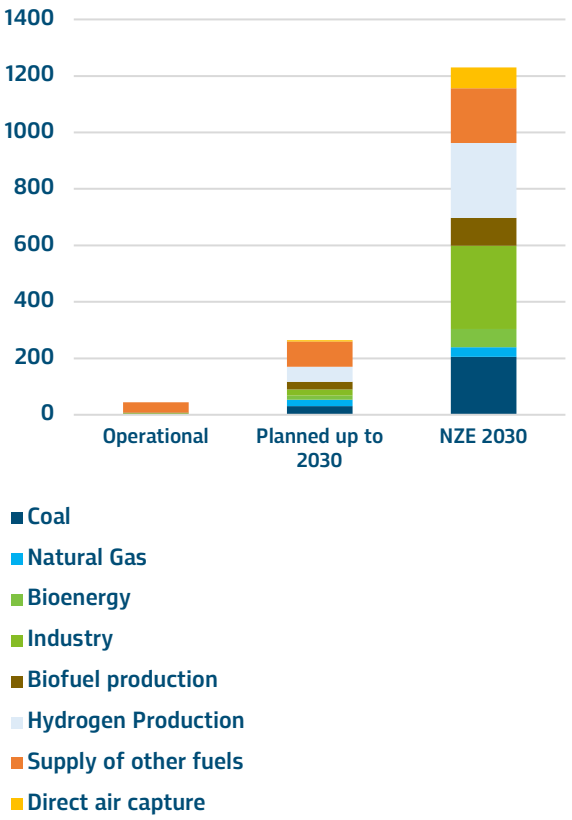
According to data from the International Energy Agency (IEA) (2022), there are currently 35 CCUS installations in operation with a capture capacity of 45 Mt CO2/year. However, in the net zero scenario (NZE) constructed by the international agency, it is estimated that capture capacity must increase to 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 35 CCUS installations in operation with a capture capacity of 45 Mt CO2/year."*

[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.

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.

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.

Acknowledging this potential, in recent years Petrobras has incorporated this technology among the options to advance its plans to reduce emissions by 2050 and to develop new businesses. Due to the features of the resources in some pre-salt fields, where the natural gas needs to be separated from the CO2, the company had to develop technological solutions to make this separation feasible and reinject the CO2 into the reservoir and avoid venting it into the atmosphere.

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].

In recent years, Brazil has also made advances in climate policy with the potential to encourage the adoption of CCUS technologies. In 2021, Brazil's GHG emission reduction targets were updated. In 2022, the federal government published decree 11.075, in which it established procedures for preparing sectoral climate change mitigation plans and establishing a national GHG emissions reduction system[4].

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] 2022. Presidência da República. http://www.planalto.gov.br/ccivil_03/_ato2019-2022/2022/decreto/D11075.htm#:~:text=DECRETO%20N%C2%BA%2011.075%2C%20DE%2019,21%20de%20mar%C3%A7o%20de%202022.

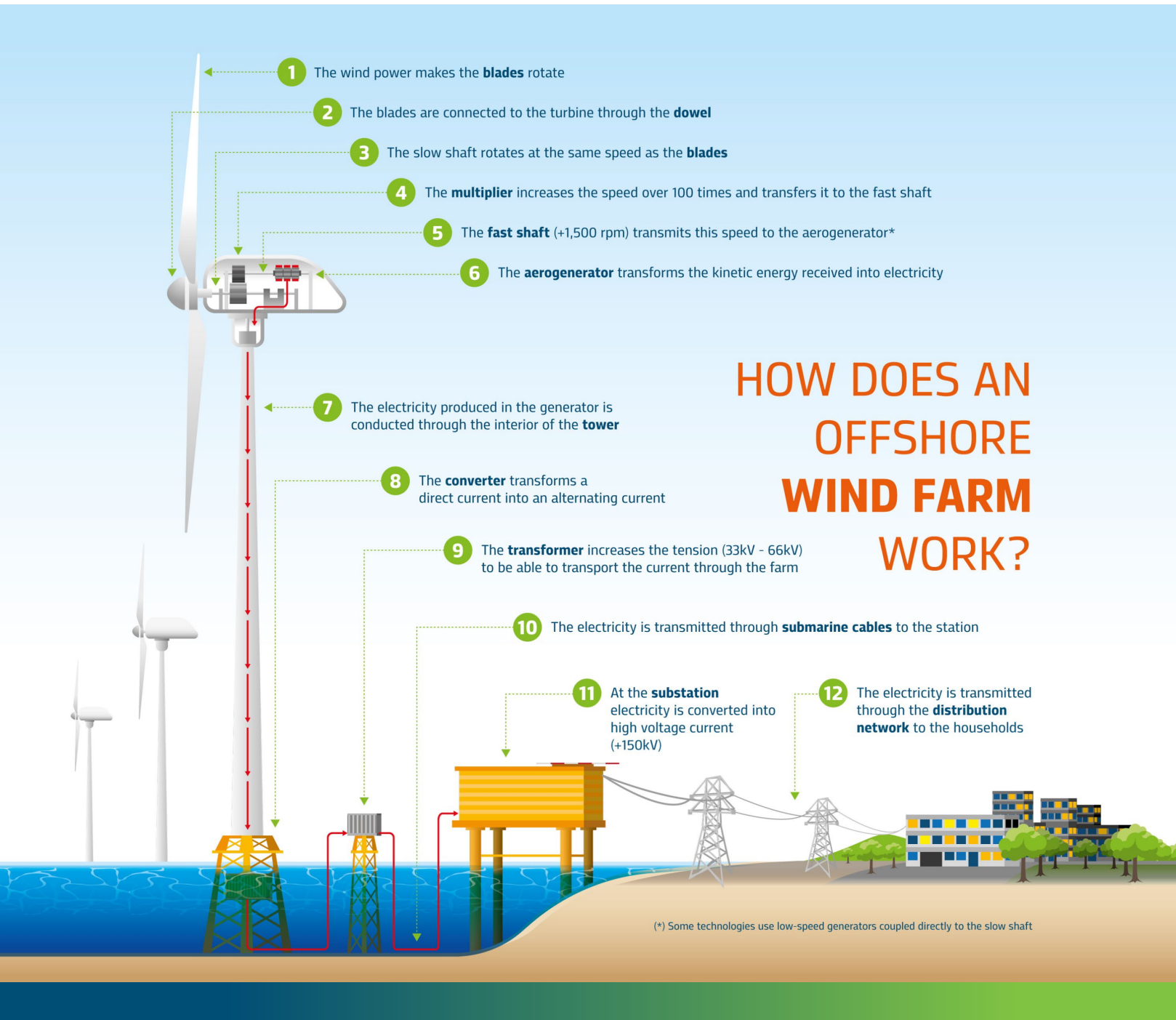
OFFSHORE WIND ENERGY AND THE OIL AND GAS SECTOR

INSTITUTO BRASILEIRO DE PETRÓLEO E GÁS

HOW DOES IT WORK?

Wind energy is well known for being a renewable energy source obtained from the power of the wind. Wind turbines are structures with blades like those of a windmill propelled by the wind, turning a rotor connected to a generator that produces electricity. In the case of offshore wind farms, the principle is the same, but with the difference that the wind turbines are located on the sea, where the winds tend to reach greater steadiness and speed since there are no obstacles such as mountains or buildings.

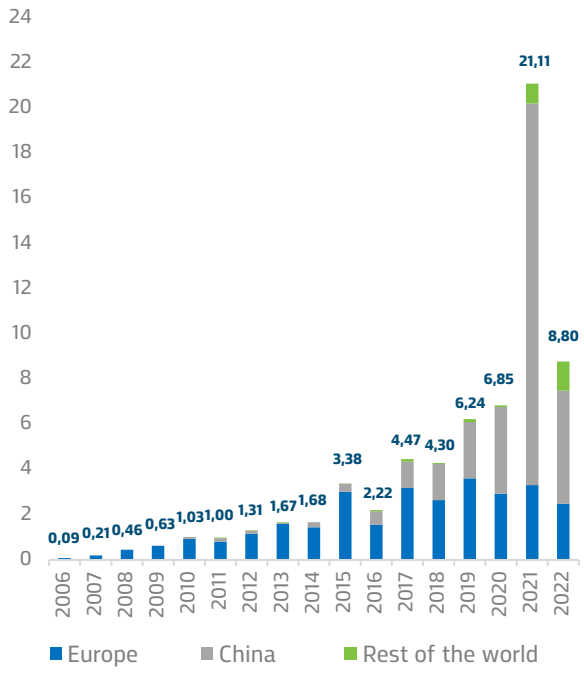
Electricity generated offshore is transmitted via submarine cables to substations and distribution centers located on land and is then sent to consumer units via distribution networks. Recent technological advances associated with the quest for decarbonization have been driving the development of this source, which has been growing rapidly worldwide and consolidating itself as an important alternative to boost the energy transition.



OFFSHORE WIND FARMS IN THE CONTEXT OF ENERGY TRANSITION

The year 2021 was particularly remarkable for offshore wind power. Data from the Global Wind Energy Council (GWEC) indicates that 8.8 GW of offshore wind power was connected to the grid worldwide in 2021. As a result, global capacity increased to 64.3 GW. China was the country that stood out the most during the year, concentrating around 57% of new installations last year (5 GW)1. Exhibit 2 shows the evolution of new offshore wind installations in recent years, with China's participation standing out.

Exhibit 2: **New offshore wind farms installed** 2012-2021, Gigawatts (GW)

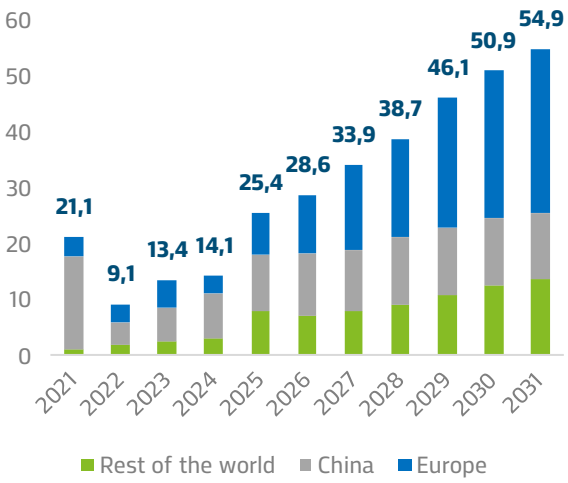


Source: Global Wind Energy Council, 2022

In addition to the sustainability goals that are being defined by an increasing number of countries, the conflict between Russia and Ukraine has given a new impetus to renewable sources due to the volatility of fossil fuel prices, as well as fears about energy security and Europe's dependence on Russia's fuels.

In Europe, the continent most affected by the conflict between Russia and Ukraine, the IEA estimates that wind power will gain prominence over the coming decades, accounting for more than 50% of total generation by 2050, considering its most optimistic scenarios for the diffusion of renewable sources[2]. This trend can also be observed specifically in the case of offshore wind. GWEC's projection for this source over the next few years indicates significant growth, with a strong emphasis on the European continent, as shown in Exhibit 3.

Exhibit 3: **Projection for new offshore wind farms** 2021-2031, Megawatt (MW)



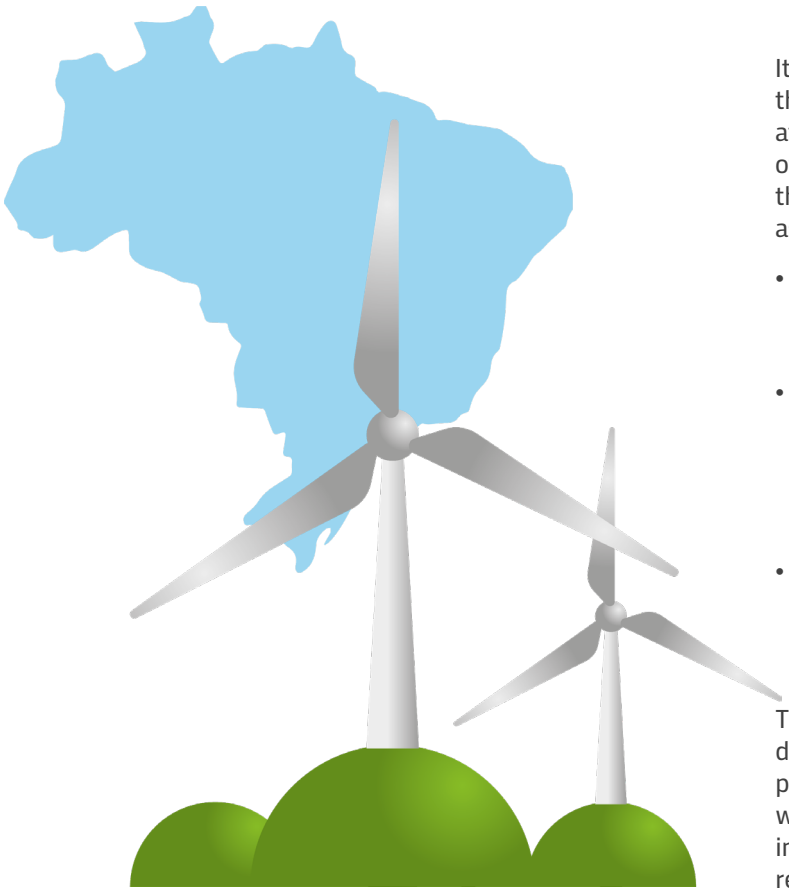
Source: Global Wind Energy Council, 2022

Projections indicate that offshore wind power will play a key role in the energy transition in the coming years. In this scenario, countries like Brazil, which have great potential for developing this source, are able to take on a strategic position in this market, especially if they take advantage of the synergies that exist between sectors such as oil and natural gas.

OFFSHORE WIND POWER IN BRAZIL

Brazil has more than 20 GW of installed capacity[3] of wind energy, which is equivalent to around 13% of its electricity mix. With 7,367 km of coastline and 3.5 million km² of maritime space, the country can be a promising player in offshore wind generation, helping consolidate its position as one of the leaders in the energy transition[4]. Brazil's potential is already attracting the attention of investors. Data from the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA) indicates that there are around 189 GW of offshore wind projects with environmental licensing processes underway at the agency[5].

[1] 2022, GWEC. Global Offshore Wind Report 2022.
[2] 2022, International Energy Agency. World Energy Outlook 2022.
[3] Installed capacity represents the maximum amount of power that a generating unit or a set of them can supply to the system when operating at full capacity.
[4] 2022, BRASIL. https://www.gov.br/pt-br/noticias/meio-ambiente-e-clima/2022/11/eolica-offshore-e-a-aposta-do-brasil-para-consolidar-a-transicao-energetica
[5] 2022, IBAMA. http://www.ibama.gov.br/phocadownload/licenciamento/2022-12-07_Usinas_eolicas_offshore_Ibama.pdf



Still regarding Brazil's particularities, another important aspect is the country's potential for producing and exporting green hydrogen, i.e., hydrogen produced from renewable sources. This is due to the privileged logistic position of its ports in relation to European countries. This increases the need for Brazil to expand its production of electricity from renewable sources. Thus, the demand for green hydrogen that is likely to gain momentum in the coming decades, could be another important vector for the development of offshore wind power in Brazil.

From a regulatory point of view, the country has made important progress. At the beginning of 2022, the Federal Government issued a decree containing the main guidelines for the operation of offshore wind projects in Brazil. Senate Bill 576/2021, which regulates the use of offshore energy potential, was also approved last year. On the environmental front, IBAMA has launched a Term of Reference for offshore wind projects, which is also an important signal.

However, there are still discussions involving the consolidation of a regulatory framework for offshore wind power. The National Electric Energy Agency (ANEEL) will be responsible for contracting offshore areas for energy generation and the agency has postponed regulation of this source until 2024. There is therefore no clear forecast for the first auctions to be held for this source, which brings uncertainties that are still damaging the business environment for investors.

It is also worth highlighting the need to increase the competitiveness of offshore wind in Brazil in attracting international investment compared to other countries that are already more advanced in their regulatory frameworks, with the following as priorities:

- The bidding process as the only model that offers legal certainty to developers for the transfer of use of the maritime area;
- The qualification of stakeholders to participate in the bidding process, ensuring that the bidder has the technical, economic and financial capacity to develop the suggested area;
- The criterion for judging the auction to award the areas, which is limited to the highest amount offered to pay for the occupation/retention of the area.

There are also other issues, such as the development of a local supply chain capable of providing the necessary goods and services, as well as logistical bottlenecks that require investment in port infrastructure and reinforcement of transmission lines, which is associated with adequate financing alternatives.

O&G SECTOR CONTRIBUTIONS

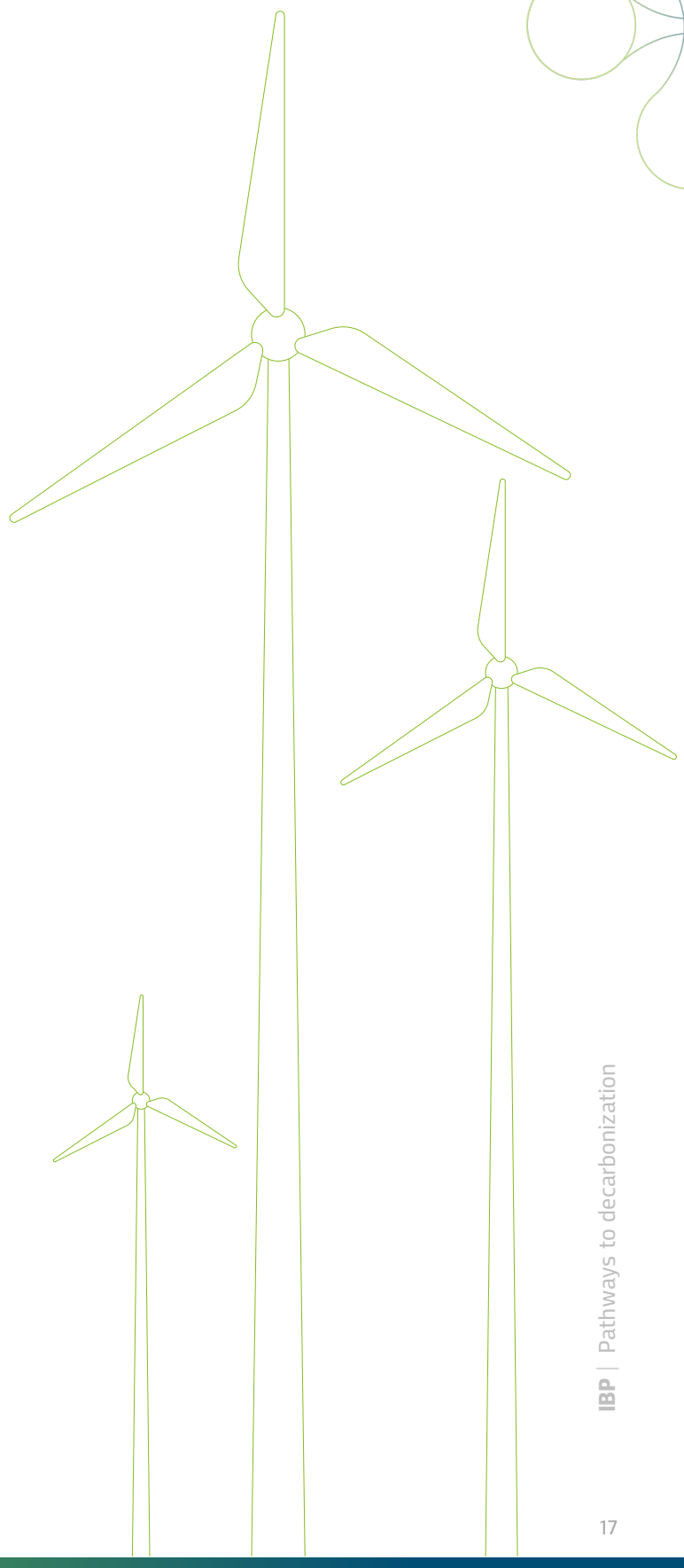
The O&G sector is proving to be an important partner for the development of offshore wind power, especially in technological and regulatory terms. The Energy Research Company's (EPE) Ten-Year Expansion Plan 2031 (PDE), for example, states that "the oil sector's expertise in the installation of structures, logistics and operations in the marine environment could benefit the development of offshore wind". This can be explained by the existence of important similarities between the challenges faced by the O&G sector and the offshore wind industry.

Knowledge of the type of environment, installations on floating bases and the suitability of materials and techniques are some examples of the synergies that exist between these two sectors. The O&G sector's extensive expertise in the maritime environment can be an important way of reducing costs and leveraging knowledge, especially when it comes to the construction and operation of assets in this environment. In addition, it is worth noting that improving technologies and reducing their costs depends on engineering resources, the management of large projects and the ability to mobilize large volumes of capital, aspects that can be associated with the O&G industry.

From the point of view of regulatory and environmental discussions, important contributions can also be identified from the O&G sector. The environmental licensing process for the oil sector is already quite mature, so the data and knowledge used can be widely reused by the offshore wind sector, including the relationship with affected communities and species. There are also important opportunities for interaction between the two sectors by improving the regulations for decommissioning oil fields, which could also include an assessment of the possible reuse of the field for offshore wind activity[6].

Cooperation between the two sectors can also bring gains for logistics, operations, and maintenance activities. It is possible, for example, to share maintenance assets, vessels and even port structures and their management[7]. Seeking to benefit from this type of synergy, large companies in the O&G sector have already been mapping and adapting existing solutions for the renewable energy segment, with a strong emphasis on offshore technologies. The existing synergies explain why several O&G companies are considering investing in offshore wind production as part of their decarbonization and portfolio diversification strategy.

Brazil has also seen initiatives involving these sectors together. This is the case, for example, with the Technical Cooperation Agreement signed in 2022 between the Brazilian Oil and Gas Institute (IBP) and the Brazilian Wind Energy Association (ABEEólica), which created a specific Working Group on offshore wind to deal with issues such as regulation, the value chain, Research & Development (R&D), funding, safety, and the environment. Thus, the diffusion of offshore wind involves a path that can be paved with an important contribution from the O&G industry.



[6] 2019. Carvalho, Lívia. A POTENCIAL SINERGIA ENTRE A EXPLORAÇÃO E PRODUÇÃO DE PETRÓLEO E GÁS NATURAL E A GERAÇÃO DE ENERGIA EÓLICA OFFSHORE: O CASO DO BRASIL. http://www.ppe.ufrj.br/images/publica%C3%A7%C3%B5es/mestrado/Livia_Paiva_de_Carvalho._MESTRADO_2019.pdf

[7] 2019. Carvalho, Lívia. A POTENCIAL SINERGIA ENTRE A EXPLORAÇÃO E PRODUÇÃO DE PETRÓLEO E GÁS NATURAL E A GERAÇÃO DE ENERGIA EÓLICA OFFSHORE: O CASO DO BRASI. http://www.ppe.ufrj.br/images/publica%C3%A7%C3%B5es/mestrado/Livia_Paiva_de_Carvalho._MESTRADO_2019.pdf

THE RD&I CLAUSE IN THE OIL AND NATURAL GAS INDUSTRY: AN INNOVATION DRIVER IN THE BRAZILIAN ECONOMY

INSTITUTO BRASILEIRO DE PETRÓLEO E GÁS

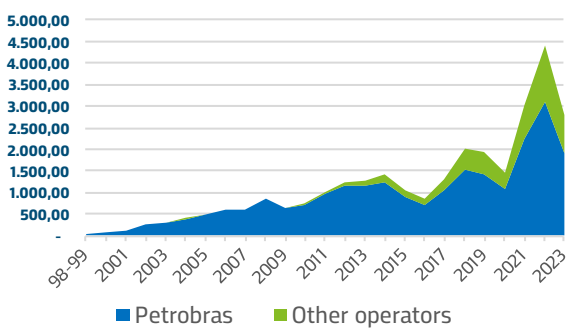
WHAT IS THE RD&I CLAUSE?

Set out in oil and natural gas exploration and production contracts, the clause determines that oil companies must make investments equivalent to 1% of their gross revenue in research, development and innovation (RD&I) activities.

The National Petroleum, Natural Gas and Biofuels Agency (ANP) is responsible for defining the criteria for distributing the funds, in accordance with the provisions of each specific contract (concession, production sharing and transfer of rights) and Resolution No. 918/2023.

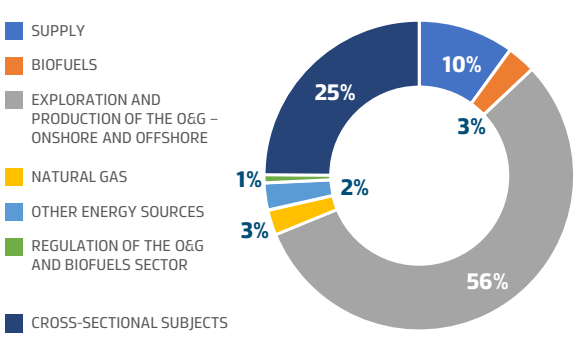
The aim of this measure is to ensure a permanent source of funds to stimulate Science, Technology and Innovation (ST&I) in the Brazilian oil and gas (O&G) sector. Since 1998, when the first regulations on RD&I obligations were established, investments of over BRL 26 billion have been channeled into the sector.

Volumes of RD&I obligations generated per year
1998-2023, in millions of BRL

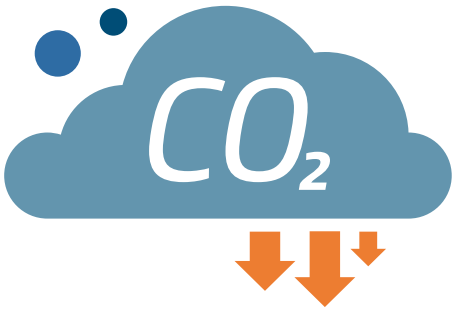


Source: ANP Investment Obligations Dymanic Panel (Total Obligations).

Distribution of RD&I projects
authorized by área (2016-2024)



Source: own elaboration based on data from the ANP (2024).



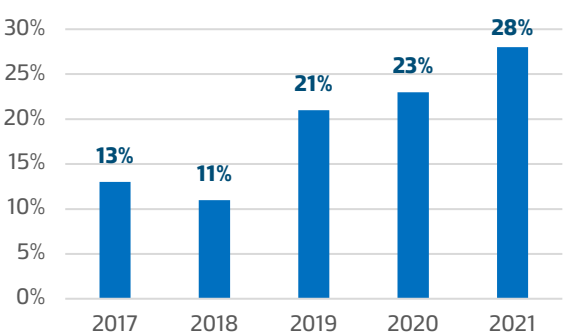
THE INCREASE IN INVESTMENTS IN DISRUPTIVE, LOW-CARBON TECHNOLOGIES

As companies in the O&G sector take on more ambitious commitments to mitigate the impact of their operations on the environment and diversify their business plans in the context of the energy transition, the amounts allocated to RD&I projects tend to be increasingly directed towards activities that converge with the energy transition..

Subjects funded with resources from the RD&I Clause associated with decarbonization technologies:

- Carbon capture, storage and utilization (CCUS).
- Negative emission technologies.
- Conversion of CO2 into hydrocarbons.
- Biofuel production technologies.
- The use of nanotechnology to recover degraded areas in the Amazon.
- Agave-based ethanol in Brazil.
- Use of remotely operated and autonomous technologies.
- Image characterization and spill removal efficiency.

Proportion of projects funded in digital transformation, renewable energies and decarbonization



Source: own elaboration based on data from the ANP (2023).

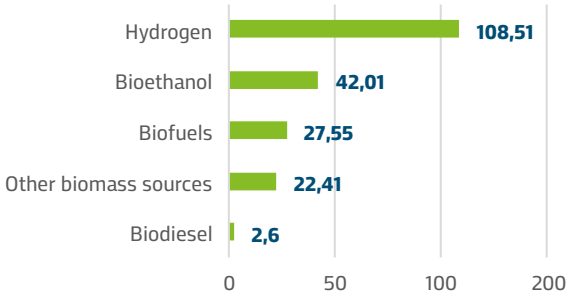
RELEVANCE OF THE RD&I CLAUSE IN THE CONTEXT OF THE ENERGY TRANSITION:

It contributes to the development of technological capacity in future-oriented sectors of the energy industries.

It is a necessary source of funds to enable the decarbonization of the sector and Brazil's energy transition.

Harnessing Brazil's renewable energy potential is the key to ensuring a fair energy transition.

RD&I Clause funds invested in selected technologies throughout 2022
(in millions of BRL)



Source: own elaboration based on data from the ANP (2023).

IMPACTS OF THE RD&I CLAUSE IN THE ST&I NATIONAL SYSTEM AND HUMAN RESOURCES TRAINING

Resources from the RD&I Clause have been vital in enabling the training of technical staff required by the O&G industry and other sectors of the national economy, as well as reducing the gap in access to educational opportunities.

Over **170** institutions accredited to receive funds and more than **1000** research units

Fonte: elaboração própria a partir de dados da ANP (2022).

OUTCOMES TO BE HIGHLIGHTED:

Improved infrastructure conditions for more sophisticated scientific and technological research projects.

University-company integration experiences with tangible results in terms of developing technological solutions for the O&G industry.

Project funding in different regions of Brazil, encouraging regional development.

PROMINP Professional Training Program (2004-2015): over **90 thousand** trained people in **175** professional categories.
Source: PROMINP (2015).

ANP Human Resources Training Program (PRH-ANP):
- From 1999 to 2015: **8,290.**
- From 2020 to October 2021: **1,147.**

Source: ANP (2021).

RD&I Clause investments aimed at human resources training (2012-2021): **BRL 215.8 million.** **Source**: ANP (2021).

Examples of laboratory infrastructure funded under the RD&I Clause:

Belém, PA	Recife, PE	Natal, RN	Salvador, BA

MAIN PROJECTS UNDER THE RD&I CLAUSE

The challenges posed by the geological, meteorological and oceanographic conditions of the areas where offshore oil and natural gas reservoirs are located in Brazil have led oil companies to develop specific technological capabilities in order to make production activities in these areas viable.

In this sense, the resources of the RD&I Clause have been allocated to the development of technological expertise in sectors beyond the traditional areas of knowledge.

BLUE AMAZON

Under the direction of the Brazilian Navy Research Center, the funds support initiatives involving research and monitoring of biodiversity and marine resources in the Blue Amazon region, a Brazilian maritime area.

PARTICLE ACCELERATOR (SIRIUS)

The project is a state-of-the-art particle accelerator, developed by the Brazilian Synchrotron Light Laboratory (LNLS), which allows materials to be analyzed at the atomic and molecular level, boosting scientific and technological research in various areas.

OCEAN FLOOR CO2 SEPARATOR (HISEP)

Developed by Petrobras, high-pressure separation technology (HISEP) is a solution that allows the gas coming out of the reservoir to be separated and reinjected from a system located on the seabed. With this technology, the field's production is increased, and it also allows for lower greenhouse gas emissions for each barrel of oil produced and lower production costs.

SUPERCOMPUTERS (CS21)

High-performance supercomputers have made it possible to carry out advanced computer simulations, contributing to the development of more accurate models in the O&G area and in other areas of research. We highlight the supercomputer at SENAI CIMATEC's Supercomputing Center for Industrial Innovation (CS21), in Salvador, Bahia..

INVESTMENT IN RD&I IN THE O&G INDUSTRY IS AN INNOVATION DRIVER FOR THE BRAZILIAN ECONOMY

The technologies developed by the O&G industry have a positive impact on other sectors of the Brazilian economy, generating innovation, competitiveness, employment and income in the country.

TECHNOLOGIES DEVELOPED BY THE O&G INDUSTRY WHICH ARE USED IN OTHER SECTORS OF THE ECONOMY

WATER SUPPLY

Treatment plant

The process of desalinating seawater for injection into reservoirs, using reverse osmosis, is used to produce drinking water for consumption.

OCEANOGRAPHY

Remotely operated submarine vehicle

This technology is used and constantly improved in the oil industry, as well as to better assess marine fauna and flora in inhospitable locations.

HEALTH

Interpretations of reservoir flow models

Tools and mathematical models made for reservoir analysis have been used to improve the interpretation of MRI scans and investigate the spread of tumors in the human body.

RENEWABLE ENERGIES

Offshore floating wind farms

Based on the model developed for platforms, the structure of wind farms can be assembled close to the coast, to be later moved and anchored in deeper waters, where the wind is stronger and less variable.

CCUS

Geological storage of CO_2

The injection of CO2 and other gases is an activity often used by O&G companies as part of advanced oil recovery techniques.

LEGAL UNCERTAINTY AFTER THE COMPETITIVE BIDDING:

Changing the conditions in the middle of the process would tarnish the entire bidding process, as well as violate the perfected legal act of the contract.

Even if some kind of change is made to the legislation, the contractual clause does not allow for any deviation of purpose. Such a provision would only be valid for new contracts if they so provided.

IBP'S PERSPECTIVE:

Any change in the regulation of the RD&I Clause must be carefully assessed and discussed, considering the impacts both for companies in the sector and for the country's technological and economic development. It is essential to ensure that the proposed changes do not undermine the Brazilian O&G sector's capacity for innovation and technological progress, avoiding any deviation of purpose that could jeopardize the benefits achieved so far.

TAKEAWAYS

Over the two decades of its implementation, the RD&I Clause has become a key source of funds for strengthening the national ST&I system, generating benefits for the O&G sector and society in general.

The funds directed through the RD&I Clause have been vital in enabling technological development in the O&G sector, with positive repercussions in other sectors of the economy.

The RD&I Clause has been a vital source of funds to finance the training of technical staff required by the O&G industry and other sectors of the Brazilian economy.

Funds secured under the RD&I Clause are essential to enable the development of the technological solutions needed to ensure that Brazil can meet its emissions reduction targets, as well as seize the opportunities that are opening up as the transition to a low-carbon economy progresses.

Changes to the established model must be carefully evaluated and discussed, considering the impacts both for companies in the sector and for the country's technological and economic development.

CARBON MARKET IN BRAZIL

WHAT IS CARBON PRICING?

The concept of pricing is based on the principles of the financial market, as an economic instrument, where those who emit greenhouse gases (GHG) must internalize the cost they are generating for society.

WHAT ARE CARBON MARKETS?

Carbon markets can be **voluntary** or **mandatory (regulated)**

VOLUNTARY

It is the voluntary demand to meet an individual, corporate or national target for a certain period of time, through carbon credit compensations

Voluntary supply of credits generated through projects or initiatives that reduce or remove GHG emissions

MANDATORY (REGULATED)

A government or regulatory authority sets GHG emission reduction targets for a particular sector, region or country

Agents who manage to reduce their GHG emissions below the targets can sell their surplus credits

Those who are unable to comply buy these credits to offset their GHG emissions

THE REGULATED MARKETS' MAIN MECHANISMS

The **cap-and-trade** system defines the maximum amount of aggregate GHG emissions that regulated agents can emit (cap) and emission rights (allowances) are generated in an equivalent amount. Regulated agents evaluate trading opportunities according to the market price (trade).

The **taxation** system sets a rate to be paid per ton of CO2 equivalent emitted. Economic agents are free to define how much they will emit and must bear its costs. In this case, the government also sets a cap on emissions.

Through the **performance certificate trading systems** agents have a legal obligation to achieve a certain level of efficiency, i.e., it involves performance certificates rather than permits.

CARBON CREDITS?

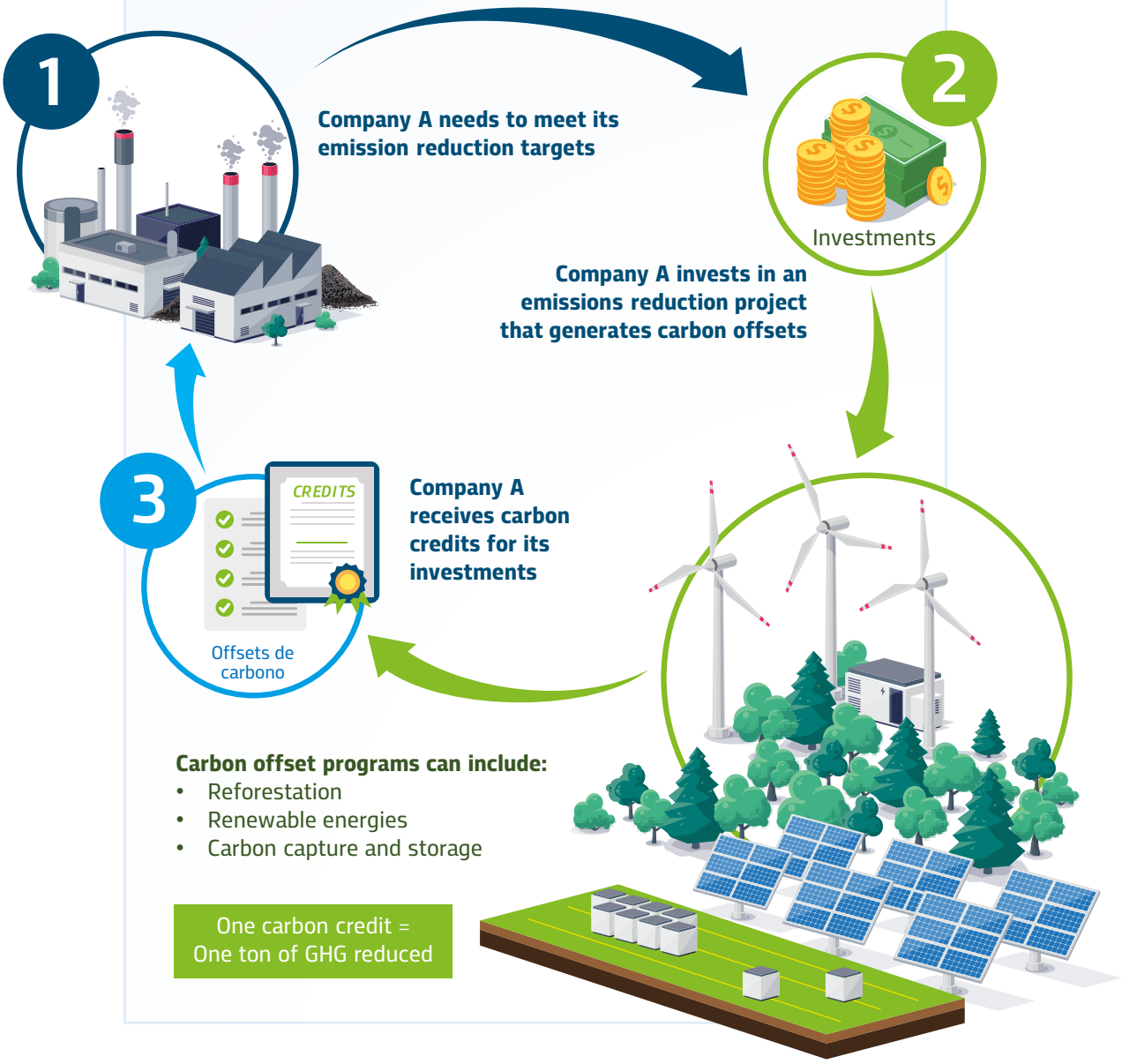
Stakeholders develop projects to mitigate or cut out GHG emissions and can issue credits that are verified by a third party.

Credits are sold to offset their emissions, either by a voluntary target or in a system with regulatory obligations.

For hard-to-abate industries, carbon credits are an alternative for compensation or neutralization.

WHAT ARE **OFFSETS?**

Offsets in carbon markets refer to emission reduction units that are generated by projects that contribute to the reduction or removal of GHGs from the atmosphere.



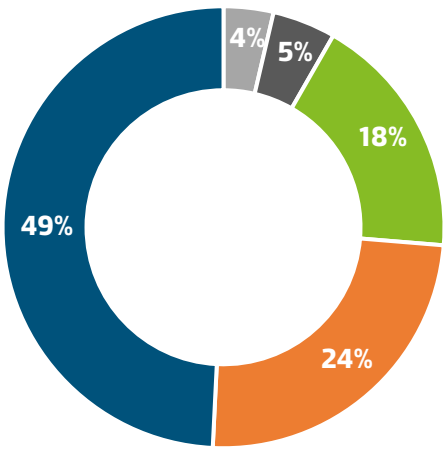
Carbon offset programs can include:

- Reforestation
- Renewable energies
- Carbon capture and storage

One carbon credit =
One ton of GHG reduced

TOTAL EMISSIONS OF GREENHOUSE GASES IN BRAZIL

2021, CO2e(t) GWP-AR6



- Waste
- Industrial Processes
- Energy
- Farming
- Land use change and forests

Unlike the profile of most countries, the energy sector is not primarily responsible for greenhouse gas emissions in Brazil.

Source: Designed by IBP using SEEG data

EMISSION REDUCTION TARGETS IN BRAZIL*

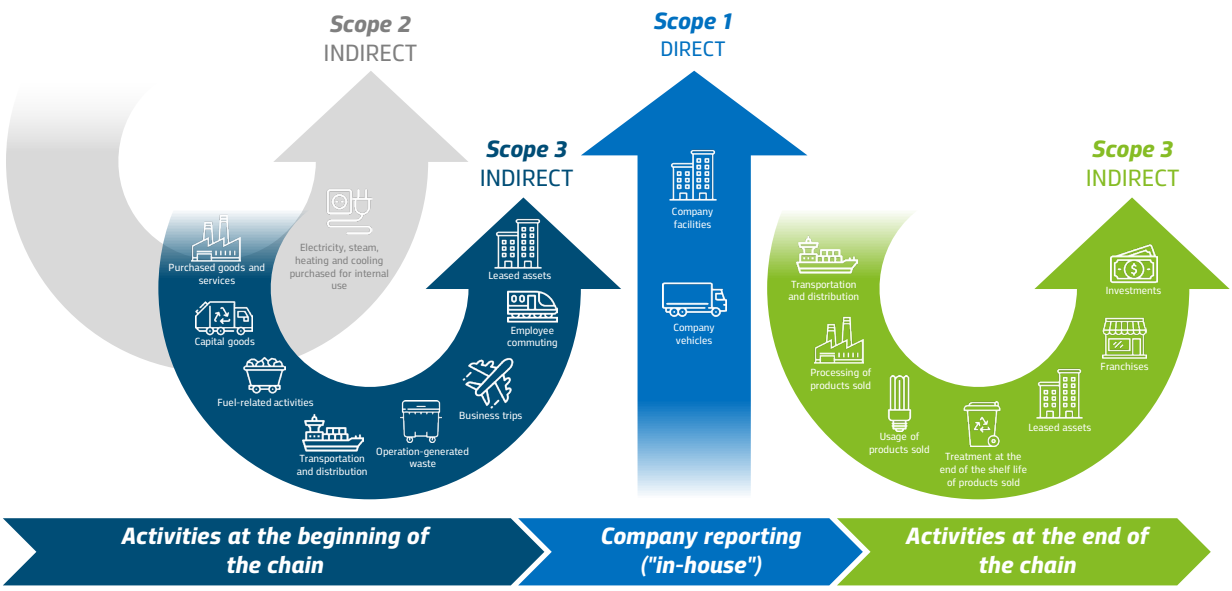
The implementation of a regulated carbon market on a national scale, with clear rules and in line with other GHG pricing initiatives, is an alternative to encourage the increase in investments needed to achieve national emission reduction targets.

2025	2030	2050
48%	53%	Net-zero

* Data provided by the Ministry of the Environment in September 2023.

EMISSION SCOPES (GHG PROTOCOL)

- **SCOPE 1:** Direct GHG emissions (under the control of the organization/country/system)
- **SCOPE 2:** Indirect GHG emissions related to electricity/steam consumption
- **SCOPE 3:** Indirect GHG emissions present in the value chain (i.e., suppliers, customers, business trips)



Source: GHG Protocol, 2022.

IBP SUPPORTS

Even though the energy sector is not the main GHG emitter in the country, IBP understands the importance of implementing a carbon market in Brazil, which is why IBP supports:

- A broad carbon market policy that operates economy-wide and is aligned with Brazil's Nationally Determined Contribution (NDC).
- The gradual, flexible and non-retroactive implementation of a command-and-control instrument to the extent that it does not compromise the country's economy or the cost-effectiveness of the project to the detriment of other more viable alternatives.
- A robust policy of Monitoring, Reporting and Verification (MRV) of Greenhouse Gas (GHG) emissions to be established prior to the implementation of carbon markets.
- Adoption of a single carbon pricing policy for the sector, considering the existence of Renovabio (regulated market).

Check out our opinion in full

INSTITUTO BRASILEIRO DE PETRÓLEO E GÁS

CONNECTING THE INDUSTRY TO GO BEYOND. **THIS IS ENERGY.**

Expedient:

President/CEO of IBP:
Roberto Furian Ardenghy

Corporate Executive Director
Claudia Rabello

E&P Executive Director
Julio Moreira

Natural Gas Executive Director
Sylvie D´Apote

Downstream Executive Director
Valéria Amoroso Lima

O&G Technical Analysis Management

Isabella Costa
William Vitto
Vinicius Daudt

Communications and Associates Relationship Management

Flavia da Justa
Tatiana Campos
Vanessa Rangel
Demy Gonçalves
Alexandre Romão
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