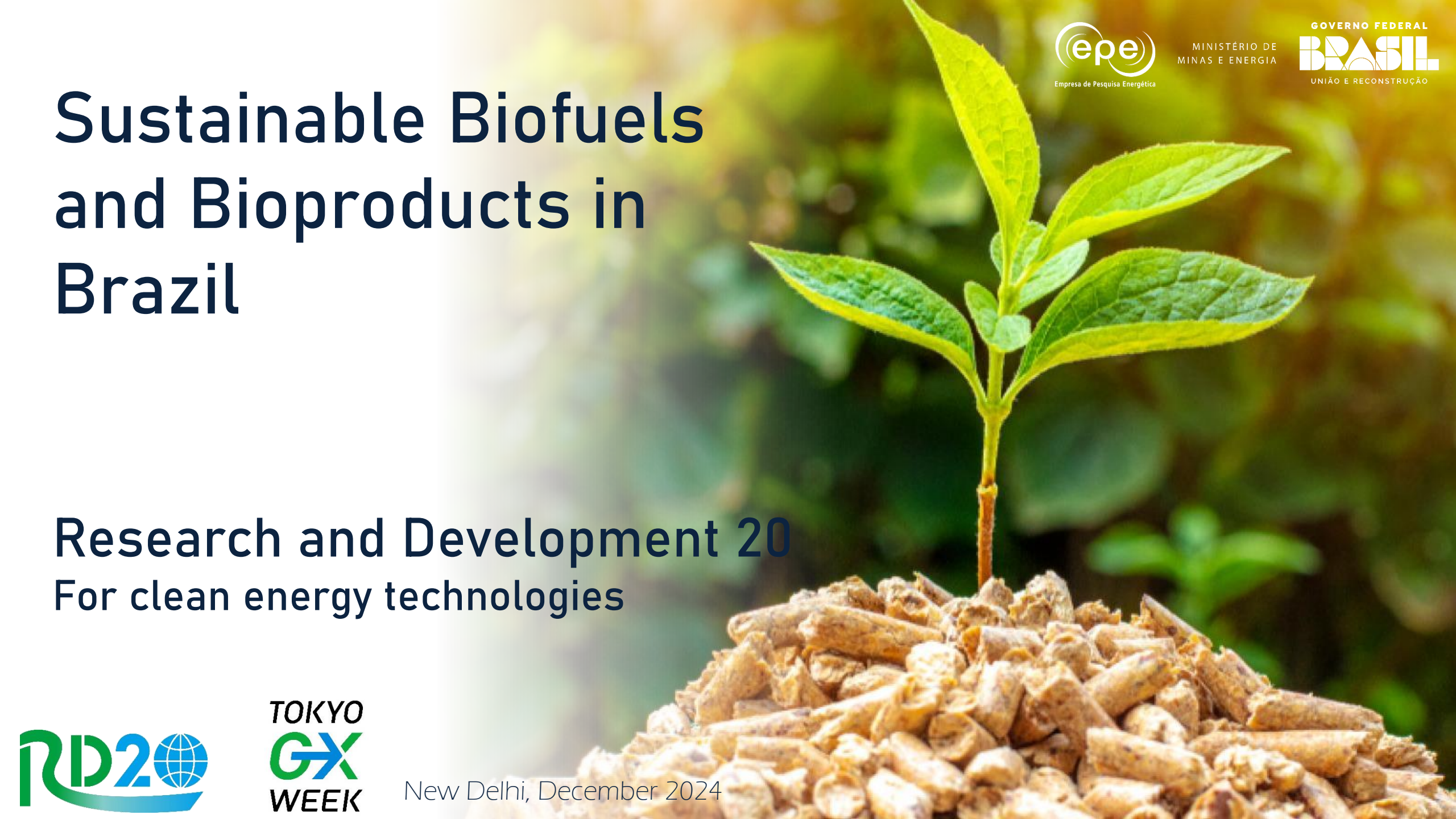
Sustainable Biofuels and Bioproducts in Brazil



Research and Development 20

For clean energy technologies

New Delhi, December 2024

Sustainable Biofuels and Bioproducts in Brazil

Research and Development 20

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Rachel Henriques

Technical Consultant

Oil, Gas and Biofuels Studies Division
Oil Products and Biofuels Department

New Delhi, December, 2024

MINISTÉRIO DE MINAS E ENERGIA

GOVERNO FEDERAL BRASIL UNIÃO E RECONSTRUÇÃO

About Energy Research Office - EPE

Empresa de Pesquisa Energética

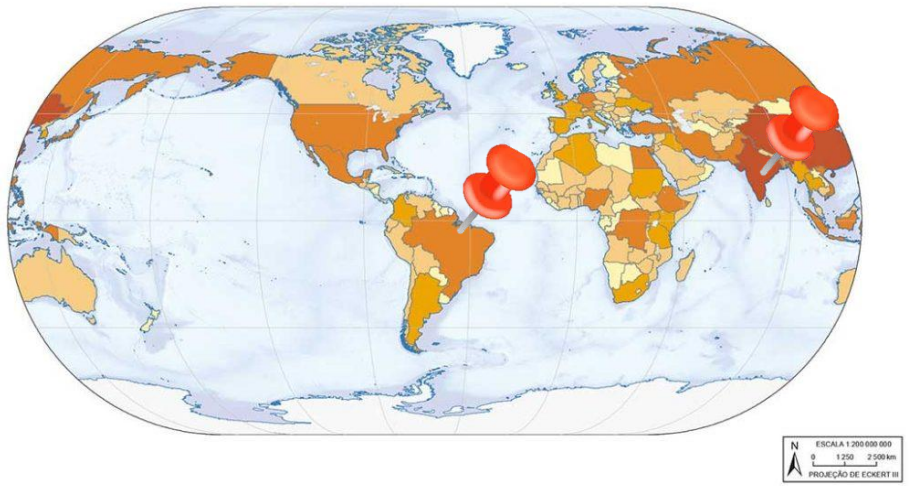
www.epe.gov.br/en

Federal policy institute, **attached to the Ministry of Mines and Energy**.

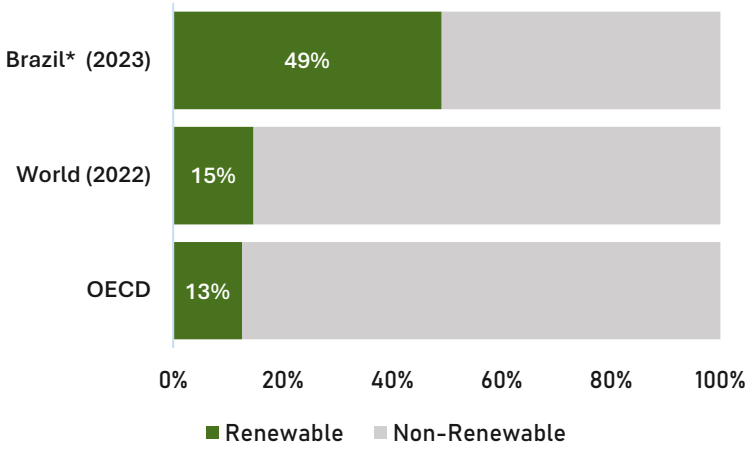
The purpose of **EPE** is to provide energy **information**, **studies and research** that support the **national energy planning**.

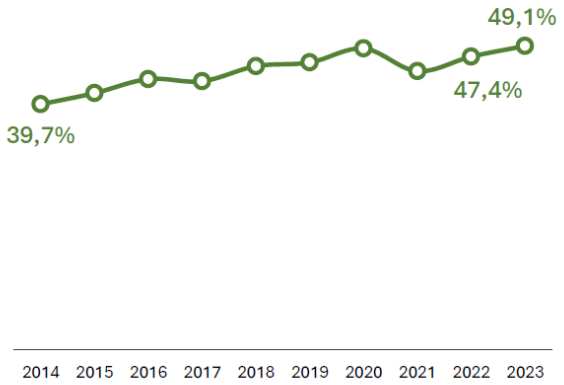
EPE's expertise areas cover **electricity, oil, natural gas, coal, nuclear, renewables and energy efficiency.**

Brazil in the world map

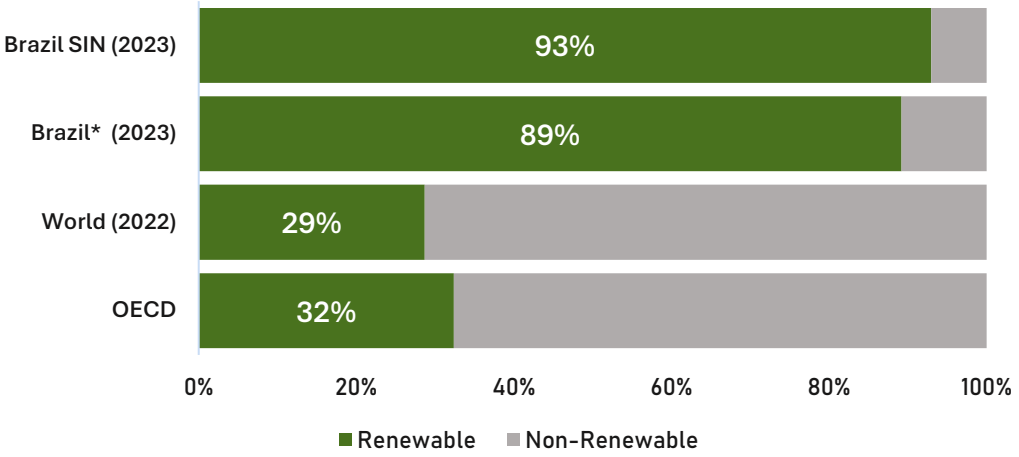


Total Primary Energy Supply

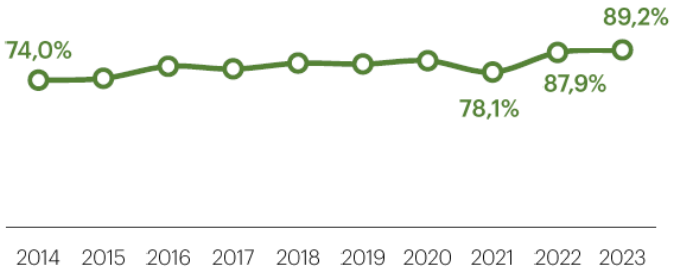




Electricity Mix



The renewability of the National Interconnected System (SIN) calculation excludes Isolated Systems, Electricity Imports, Self-production not injected into the grid and MMDG.



Source: IBGE, EPE

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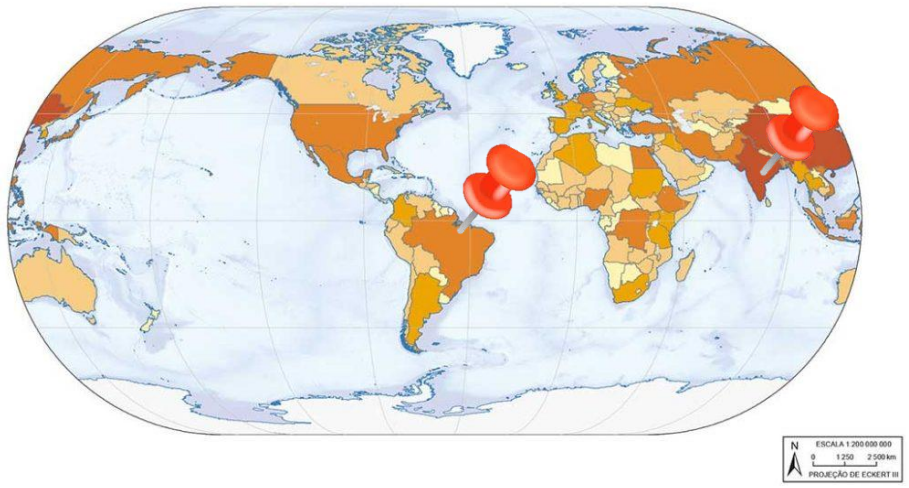
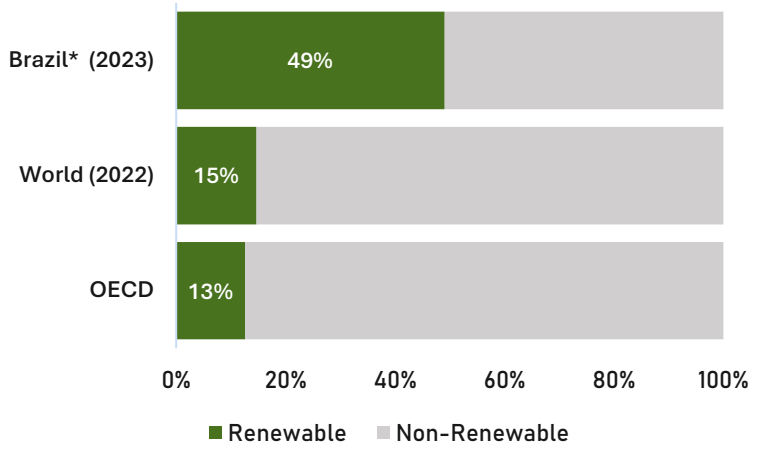
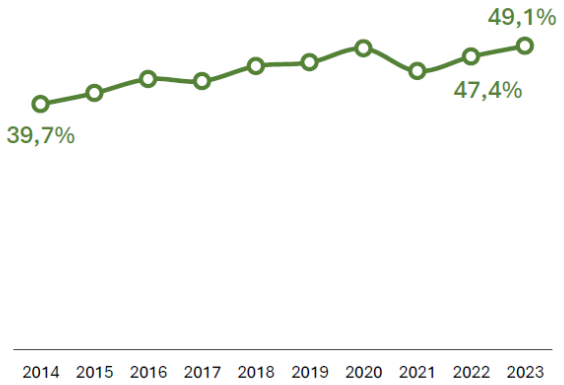
Brazil in the world map



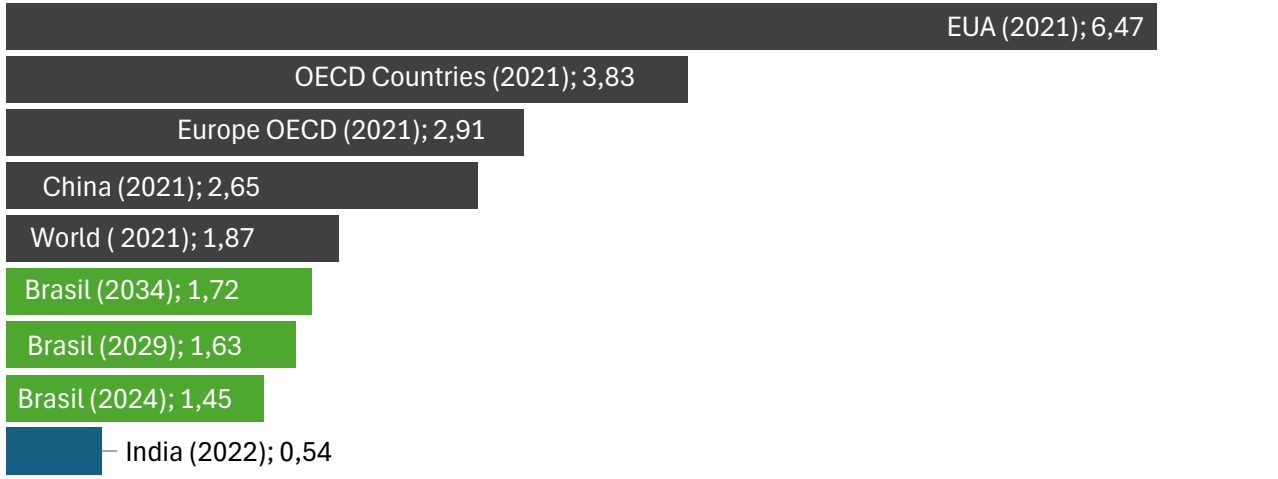
Total Primary Energy Supply



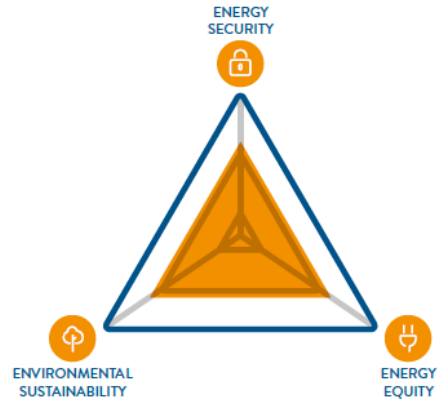


Total Primary Energy Supply per capita

toe/hab



Energy trilemma is the main driver



Source: IBGE, EPE

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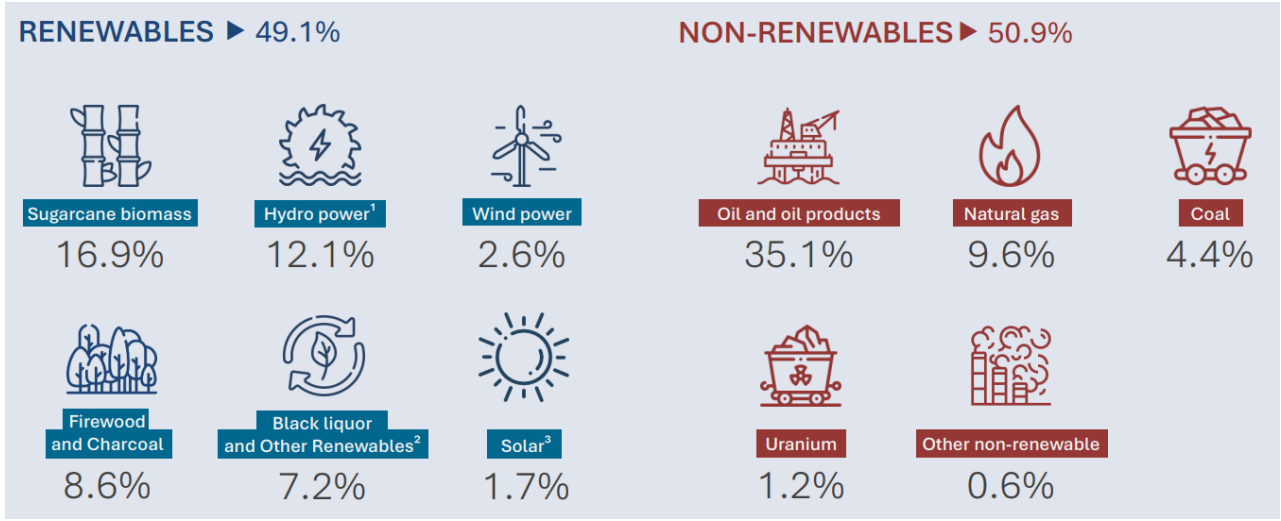
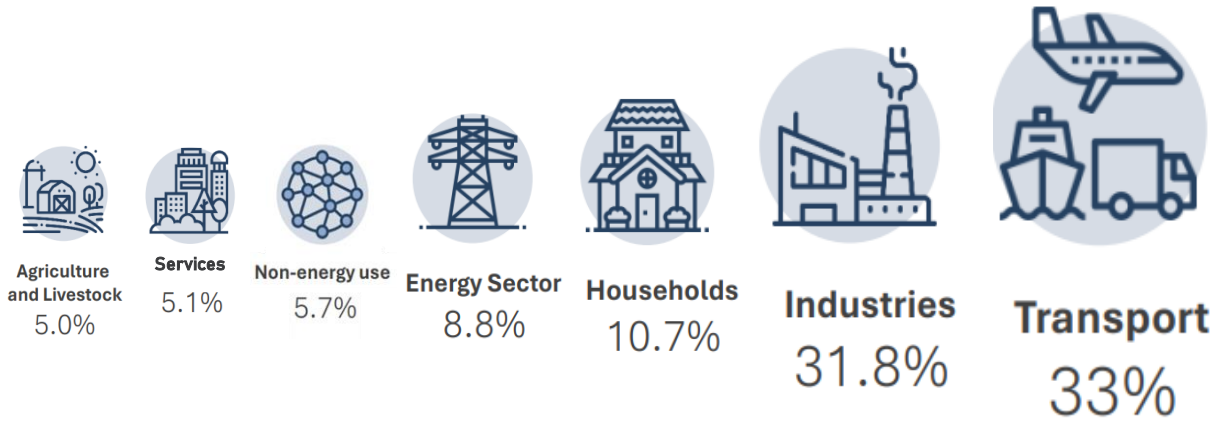
Transport sector: the leader in terms of energy consumption in Brazil

Breakdowns of total energy supply in Brazil (2023)

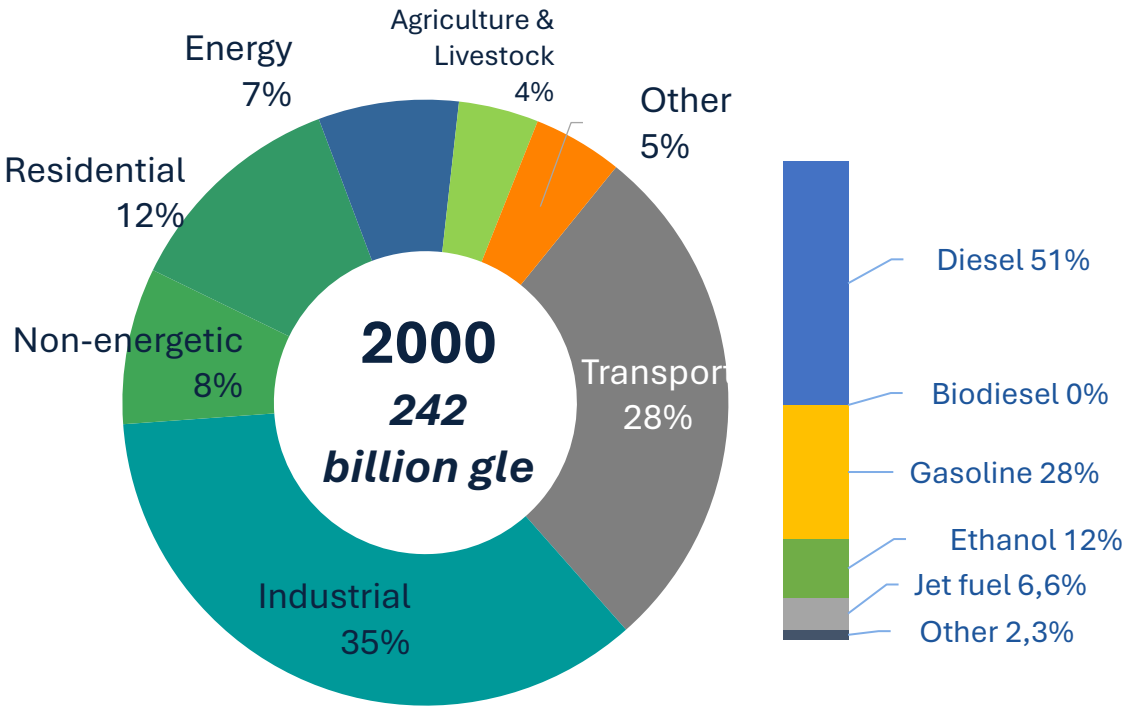


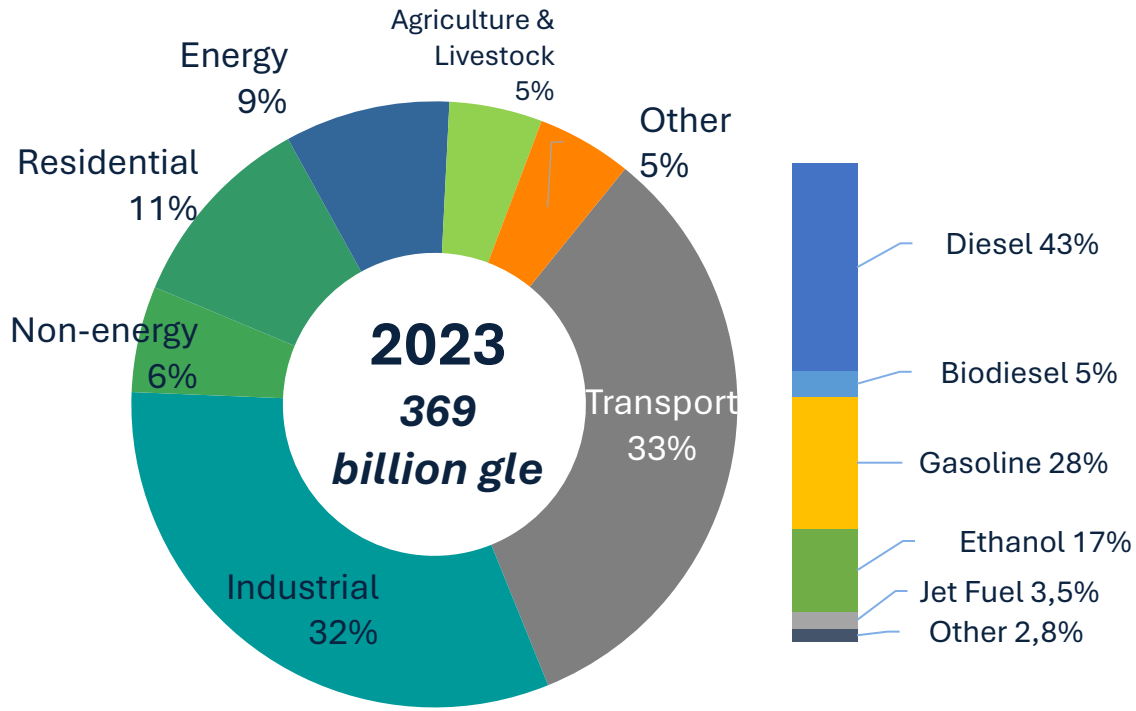


Source: EPE

Transport sector is one of the largest energy consumers in Brazil

Evolution of final energy consumption and the transport sector in Brazil (billion lge, %)



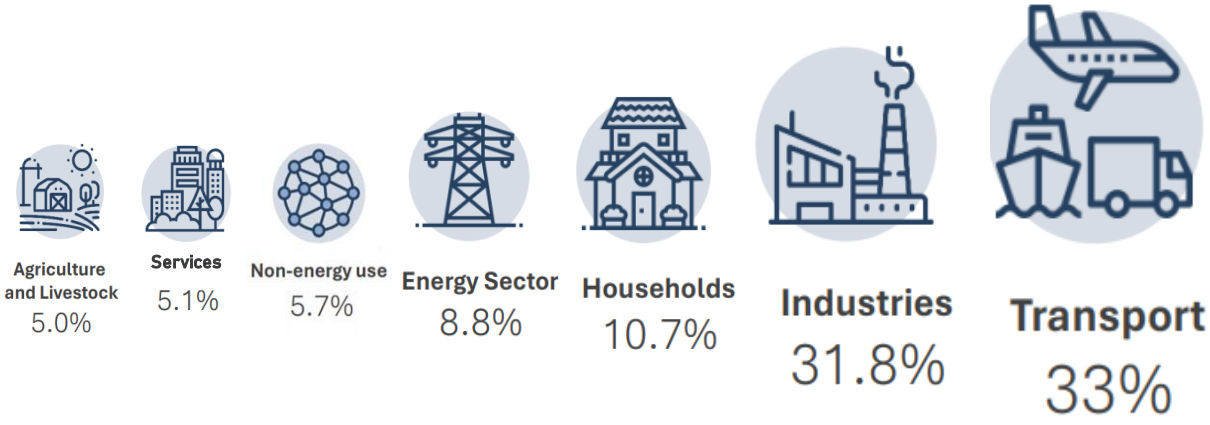


- National **energy consumption** grew by **1.9% p.a.** between 2000 and 2023, in line with GDP growth. In the same period, the energy consumption of **the transport sector** grew **2.6% p.a.**.
- Growth of **5.1% p.a. of renewable sources in transport**, especially due to incentives for **biofuels**, and the dissemination of ***flex-fuel*** vehicles.

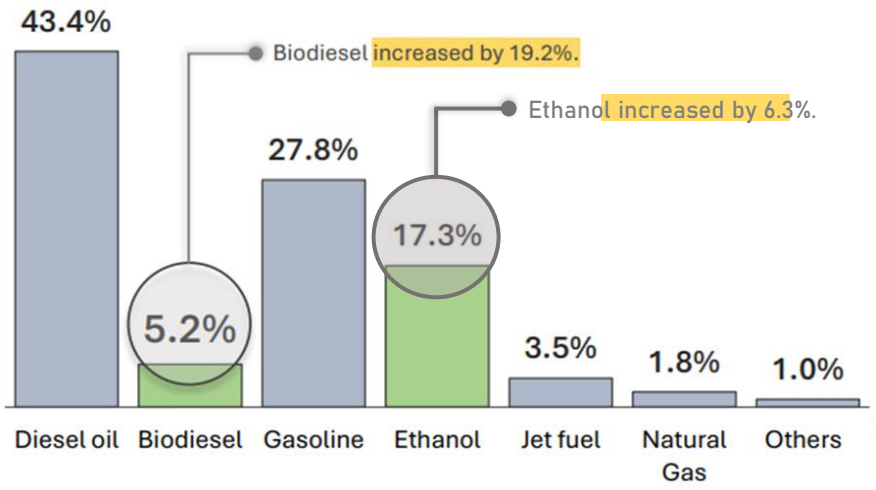
gle - gasoline liters equivalent

Source: EPE

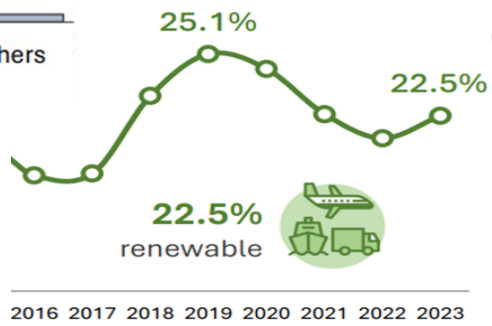
Transport sector: the leader in terms of energy consumption in Brazil



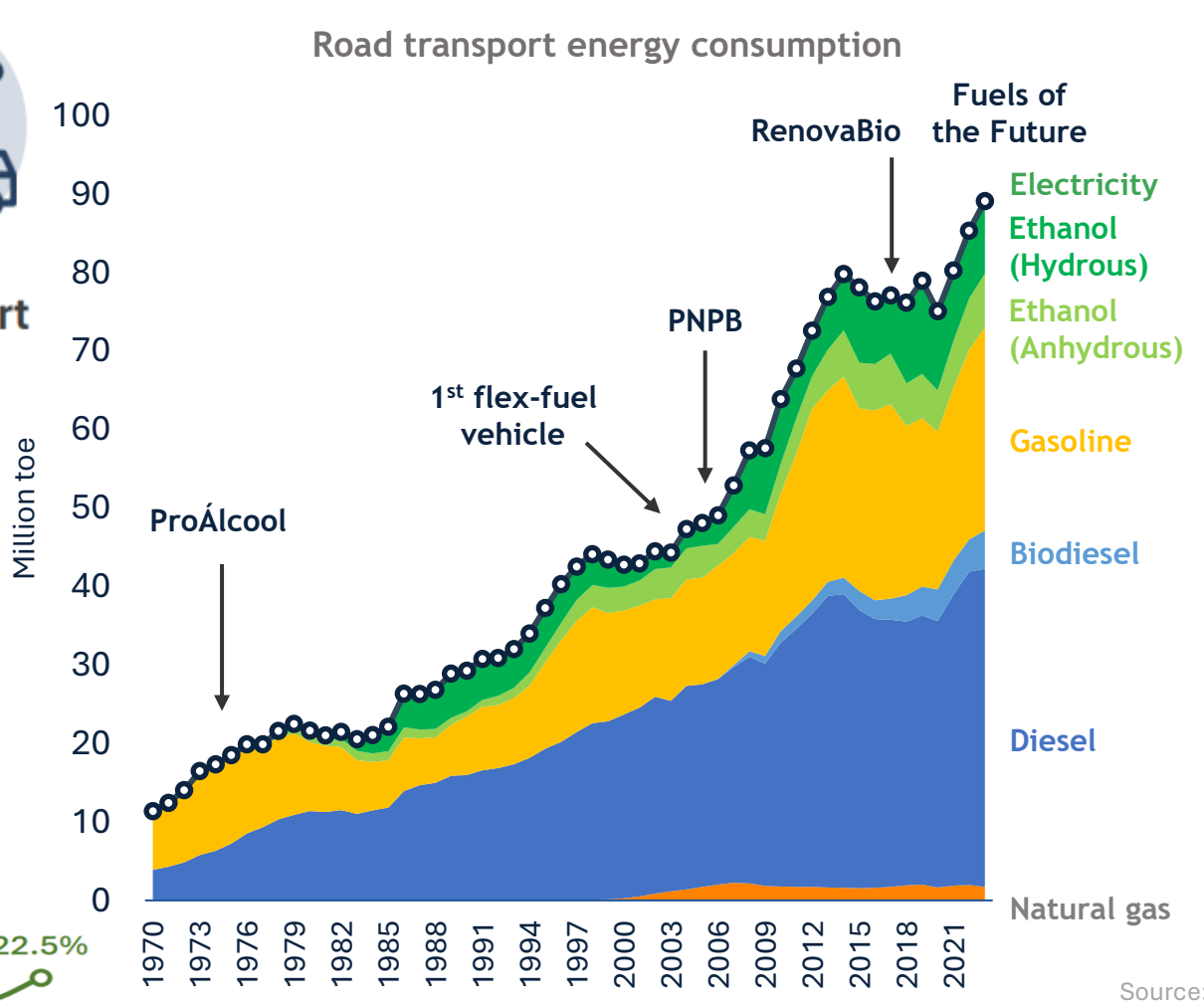
Energy consumption in the transport sector (2023)



Source: EPE



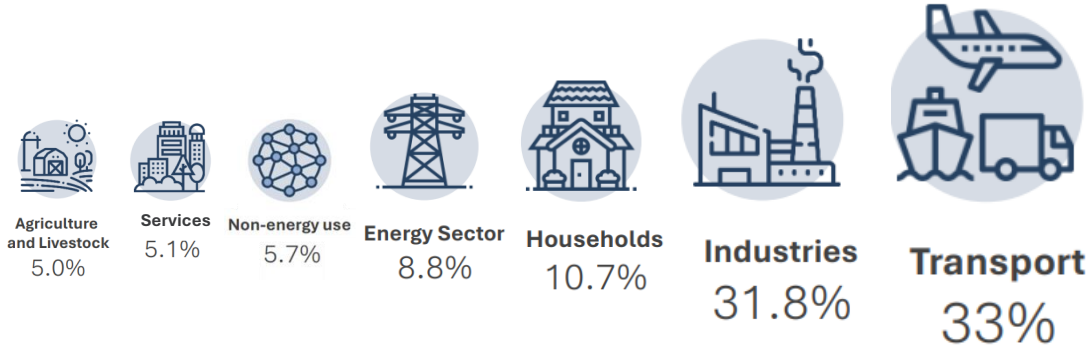
Road transport energy consumption

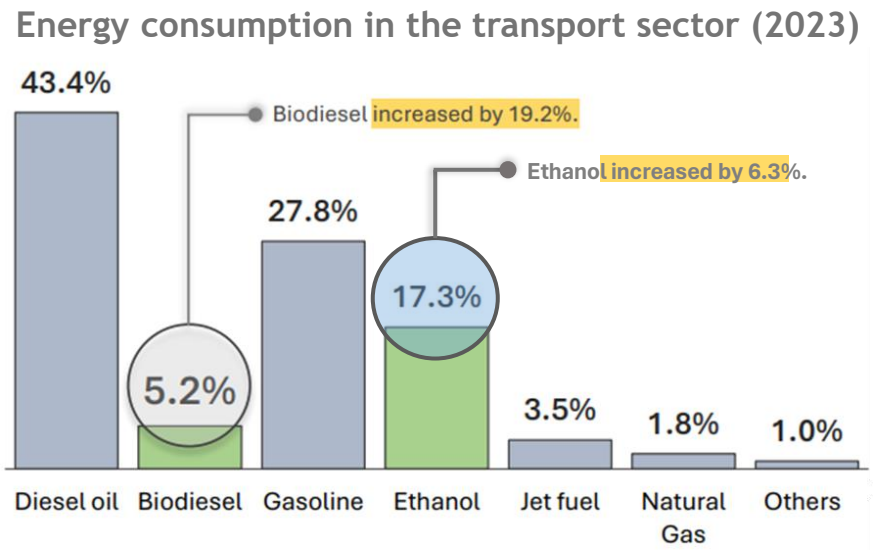


Source: EPE

Source: EPE

Transport sector: the leader in terms of energy consumption in Brazil





Source: E

Brazilian Alcohol Program (ProÁlcool)

1931

Mandatory addition of anhydrous ethanol to gasoline C

- 5%

-27%/ 25%

Tax differentiation between fuels

2003 -Flex fuel vehicles

1975

Strategic policy of the Brazilian government to replace petroleum-based fuels with ethanol after the 1973 oil crisis. This made Brazil a leader in sugar and ethanol productions worldwide.

Brazil's Biodiesel Program (PNPB)

2005

Stimulates the production and use of biodiesel in a sustainable way with a focus on productive inclusion and sustainable rural development through employment and income generation.

RenovaBio

2017

Incentives to reduce the carbon intensity of Brazil's transportation matrix by expanding the use of biofuels and creating a carbon market to offset emissions of greenhouse gases by fossil fuels.

Additional fuel and public policies enforcing the clean energy transition

2016

Promoting carbon neutral growth from 2020. It uses some market-based environmental policy instruments to offset CO_2 emissions. Brazil will adopt this rule from 2027 onwards (mandatory phase).

2021

Fundamental aspect for the construction of the Brazilian hydrogen strategy was laid out by EPE in 2021. Brazil considers the low-emission hydrogen production routes.

2023

Enhanced common ambition to reach net-zero GHG emissions from international shipping by or around 2050 and a commitment to ensure an uptake of alternative zero and near-zero GHG fuels by 2030.

2024

Specific goals set by 2033 for infrastructure, mobility, bioeconomy and energy transition. Relevant goals are increase the share of biofuels and e-mobility and progressive nationalization for batteries supply chain.

2024

Reduce carbon emissions by 50% by 2030 and promote the expansion of investments in energy efficiency, include minimum recycling limits in vehicle manufacturing and charge less tax to those who pollute less.

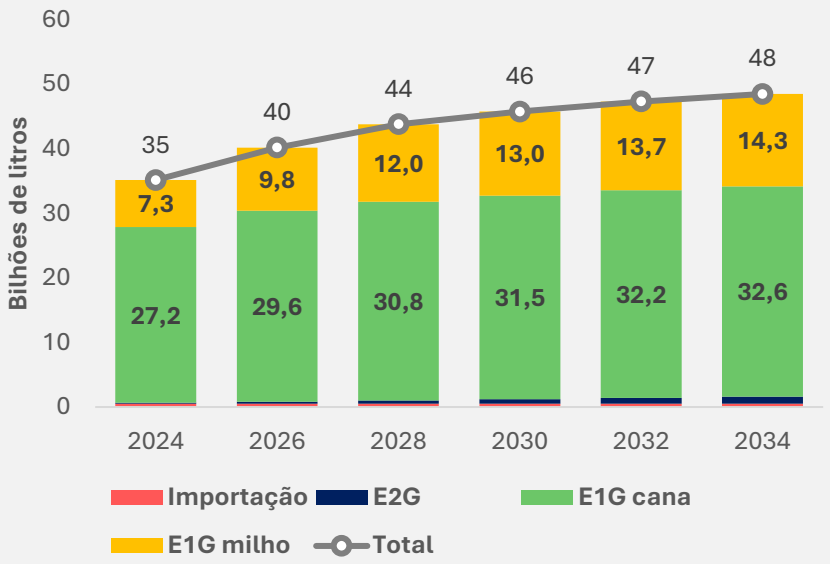
2024

Increase of the use of sustainable fuels and low carbon intensity, as well as the application of national vehicle technology, with biofuels.

Biofuels Supply | The share of biofuels tends to remain relevant...

Total ethanol supply (billion liters)

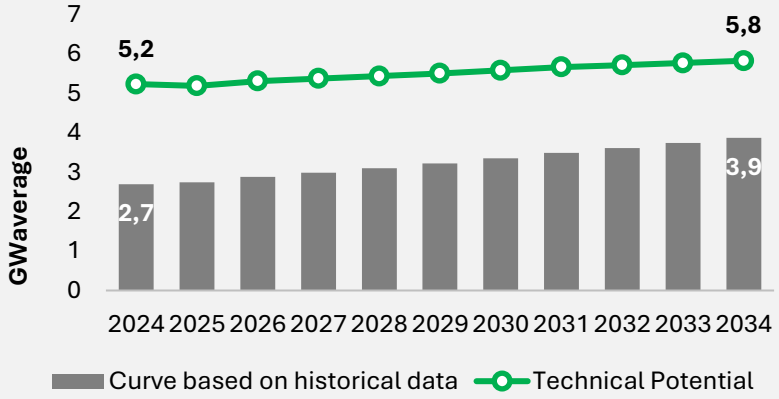
Source: EPE



- Sugarcane ethanol maintains its importance;
- Corn ethanol will represent 30% of total supply in 2034;
- E2G production also exhibits growth;
- For the future, there is a potential demand for ethanol for the national **SAF** production or as an input for its production in other markets, which could change demand or encourage ethanol production.

Potential bioelectricity from bagasse to the grid (GW average)

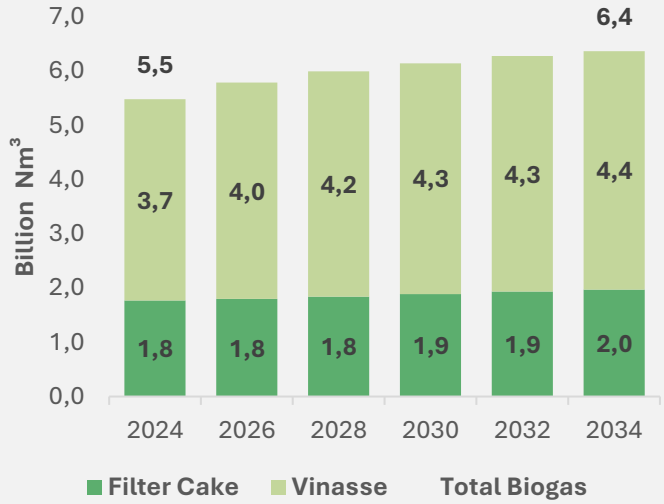
Source: EPE



- The free contracting environment (ACL) and energy settlement in the spot market (PLD) are configured as majority markets;
- In addition to bagasse, the technical potential for energy export from straws and sugarcane tops can vary between 6.5 GW average and 10.2 GW average at the end of the ten-year period;

Potential for biogas production with residual sugarcane biomass (billion Nm³)

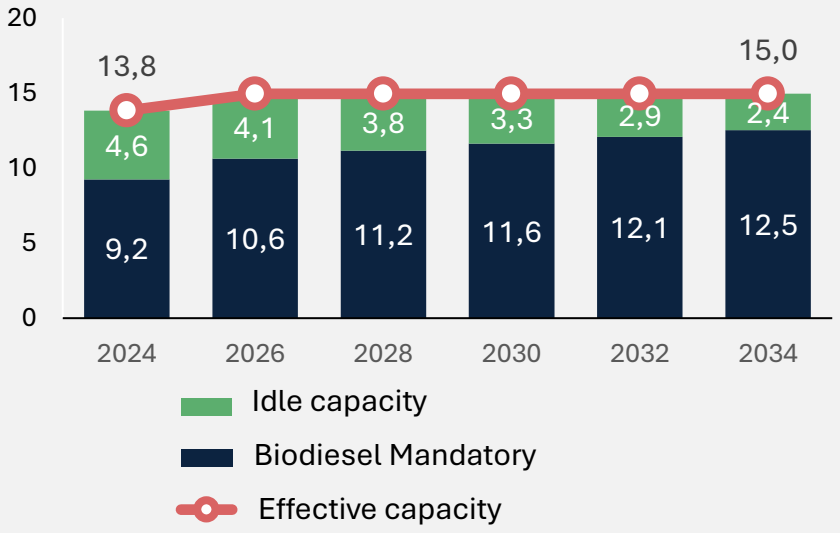
Source: EPE



- Biogas will have a greater insertion in the energy matrix, being able to be used for electrical generation and, with purification for biomethane, it can replace diesel and mixed with fossil natural gas, in gas pipeline networks..

... contributing to Brazil maintaining its importance in the use of renewable energy and in leading a fair and inclusive energy transition.

Biodiesel demand (billion of liters)

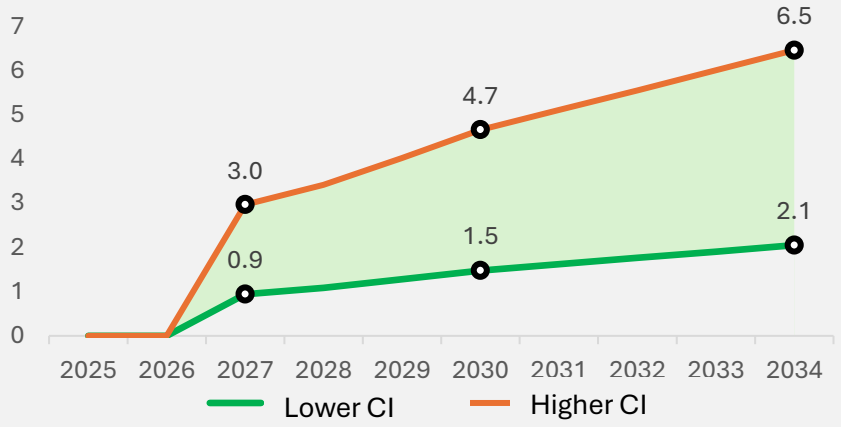


- B15 from 2025;

Source: EPE

- Soybean oil is expected to maintain its historical leadership position;
- Production capacity will have surpluses over the ten-year period, which can be used to meet demands from other sectors, such as maritime transport sector;
- The **mandatory** percentages result in a demand of **12.5 billion liters** in 2034. With the **addition of as maritime transport sector, it totals 13.6 billion liters in 2034**.

National demand for SAF (billion of liters)



Source: EPE

- The volumetric demand for SAF will vary according to the carbon intensity (CI) of the fuel produced, as CORSIA and ProBioQAV establish emission reduction targets;
- The announced projects represent 12% of estimated jet fuel demand between 2030 and 2033, but the share declines as demand grows. Between 2027 and 2034, on average 41% of emissions reduction targets are met by these projects;
- The diversification of raw materials for biofuel production still requires investment to achieve scale.

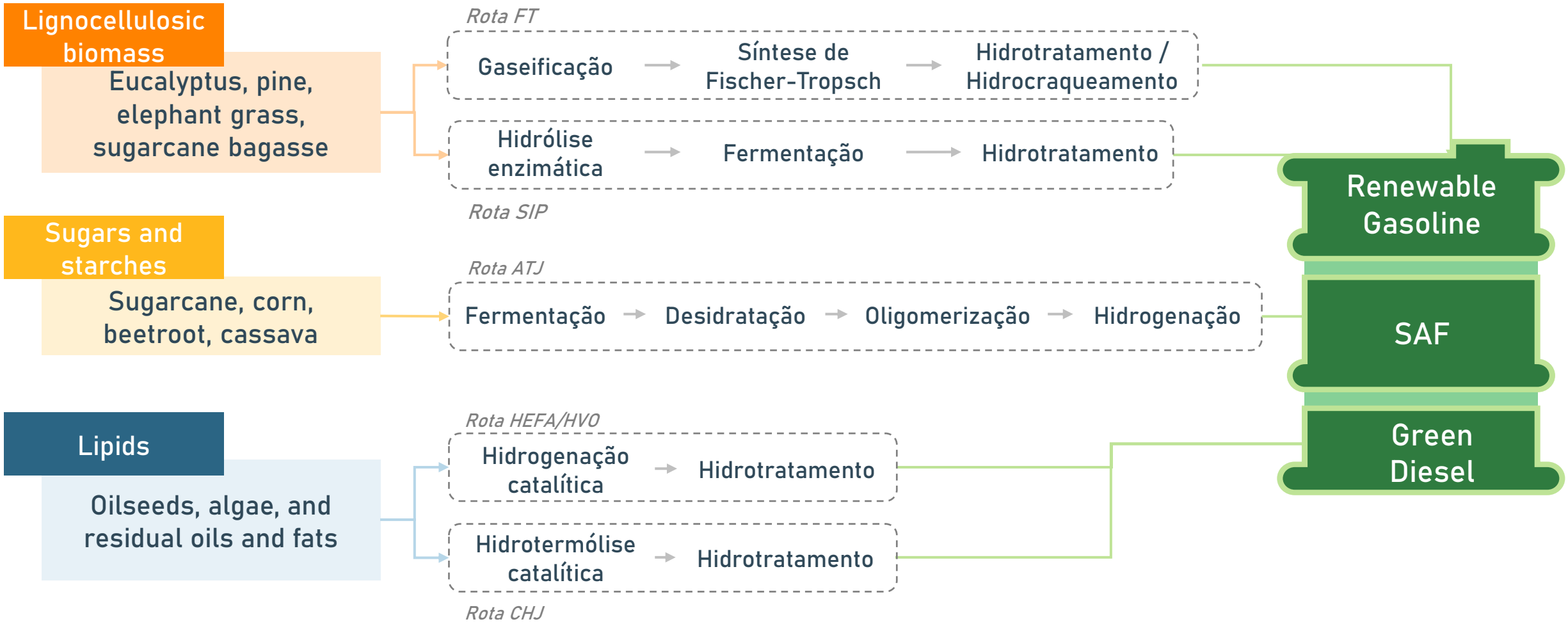
Innovations and emerging perspectives

Biogenic carbon capture and storage (Bio-CCS or **BECCS**)
Brazilian bioenergy can capture CO_2 at competitive costs and, when stored in geological reservoirs, can characterize "negative emissions"

Low-carbon hydrogen
Production routes from biomass can contribute to the development of the country's low-carbon H_2 chain, complementing and diversifying the supply based on its particularities.

Synthetic Fuels
Two main sets of routes: Biomass conversion and Electrofuels (e-fuels)
Brazil has the resources to develop both routes, as its bioenergy is a competitive advantage, as it generates CO_2 under conditions favorable to capture and use.

Technological Routes

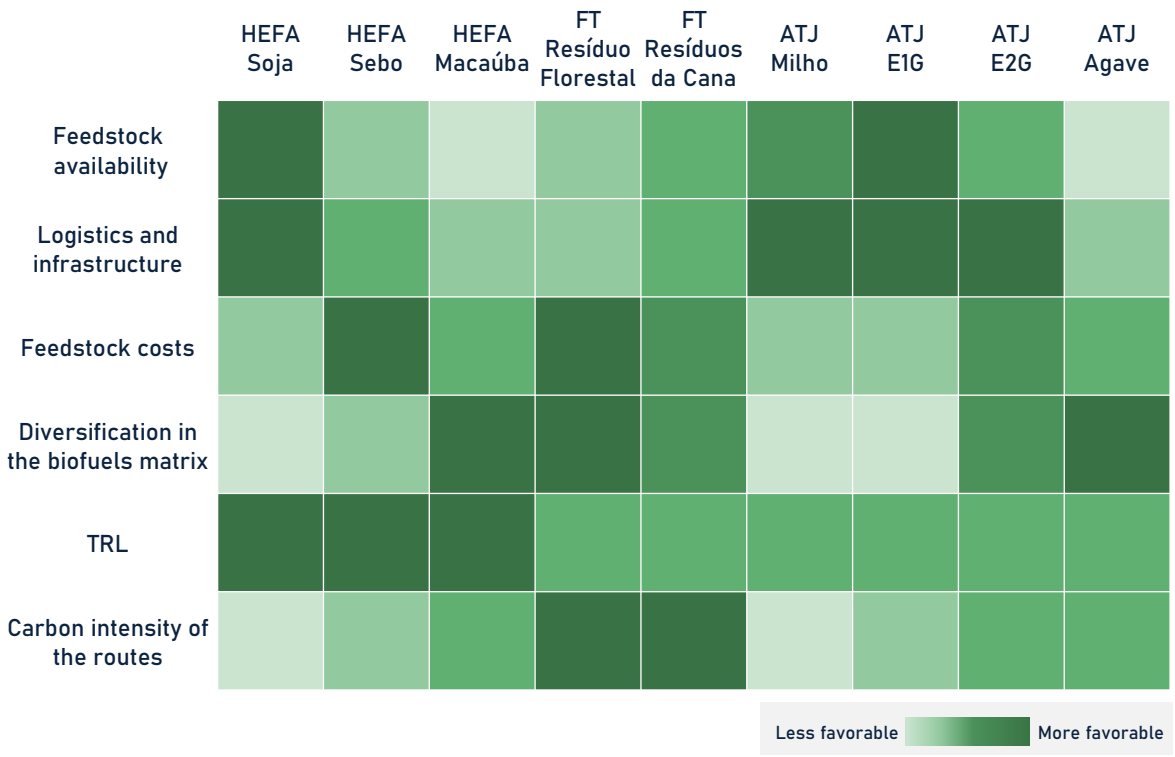


[1] Mistura máxima: percentual máximo permitido de mistura ao querosene de aviação em resolução ANP.
Fonte: 9, 10

Multi-criteria analysis

The combination of conversion processes and feedstocks will depend on the assessment of various factors and constraints

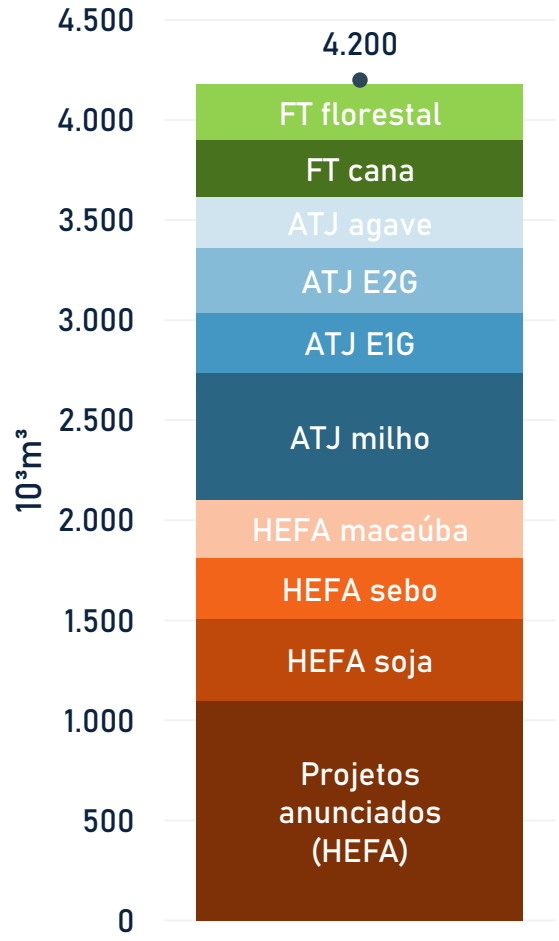
- The combination of conversion processes and feedstocks will depend on the evaluation of various factors and constraints, such as:



- Other factors may also influence the composition of the mix, such as financing, geopolitical aspects, national strategy, etc.

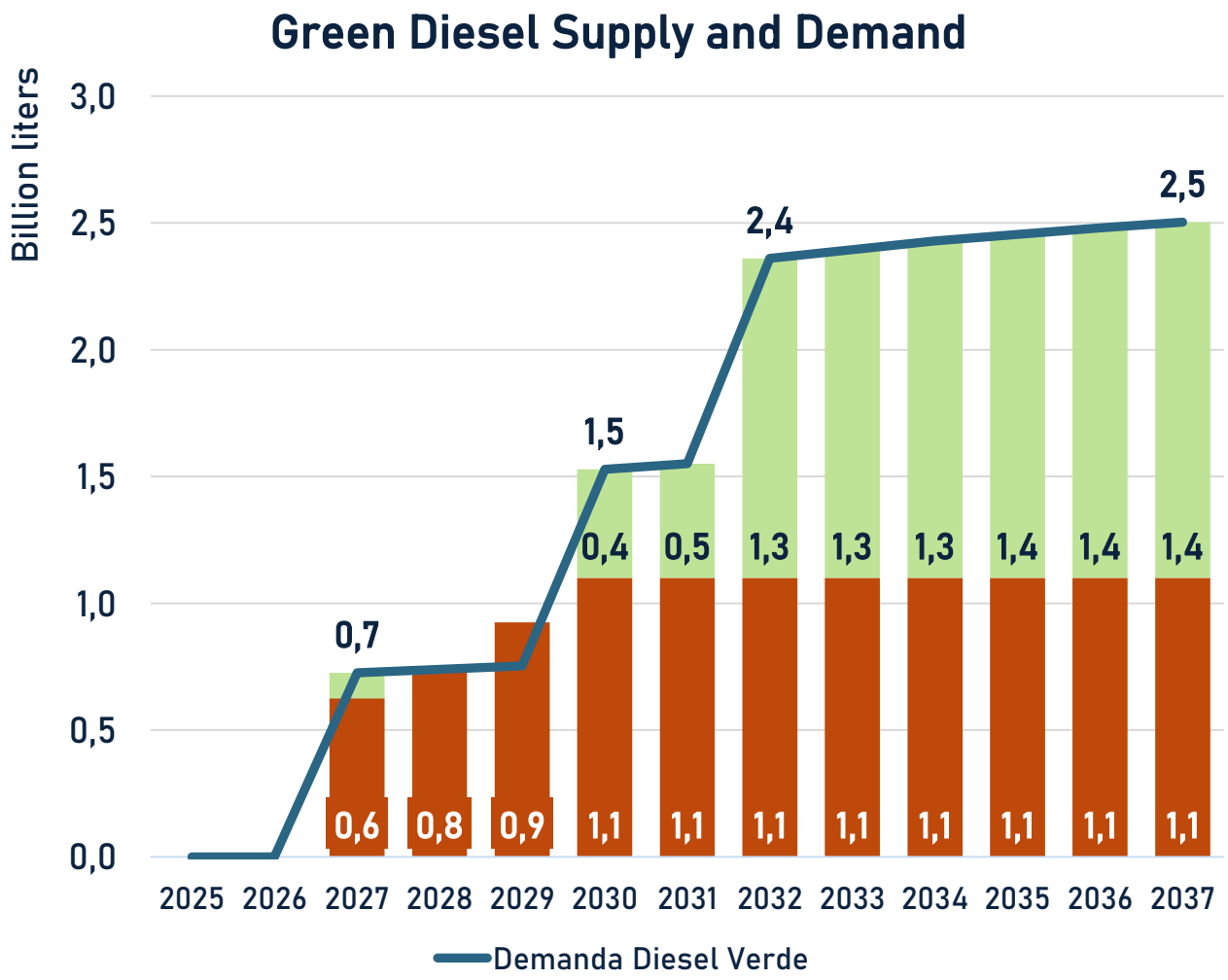
- The weighting of different criteria suggests a **possible SAF production** route composition aimed at meeting sector emission reduction targets and diversifying feedstocks.
  - Diversifying feedstocks for biofuel production still requires investments to achieve scale
  - However, this could be a key driver for regional development, pasture recovery, and job creation.

SAF production by conversion process 2037



Source: EPE,based on 2, 8, 16, 20, 25, 34

Green diesel volumetric goal



Aumento gradual

1% since 2027
2% since 2030
3% since 2032

Green diesel demand to be met by new projects

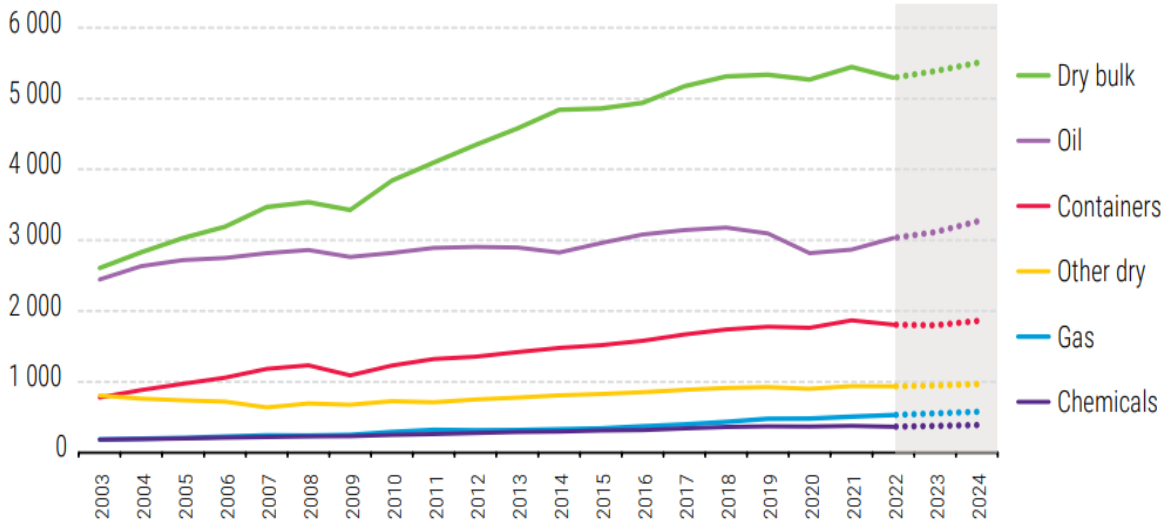
Green diesel supply from announced SAF projects

Fonte: elaboração própria

International maritime trade and GHG emissions

International trade

(milions of tons, 2003-2024)



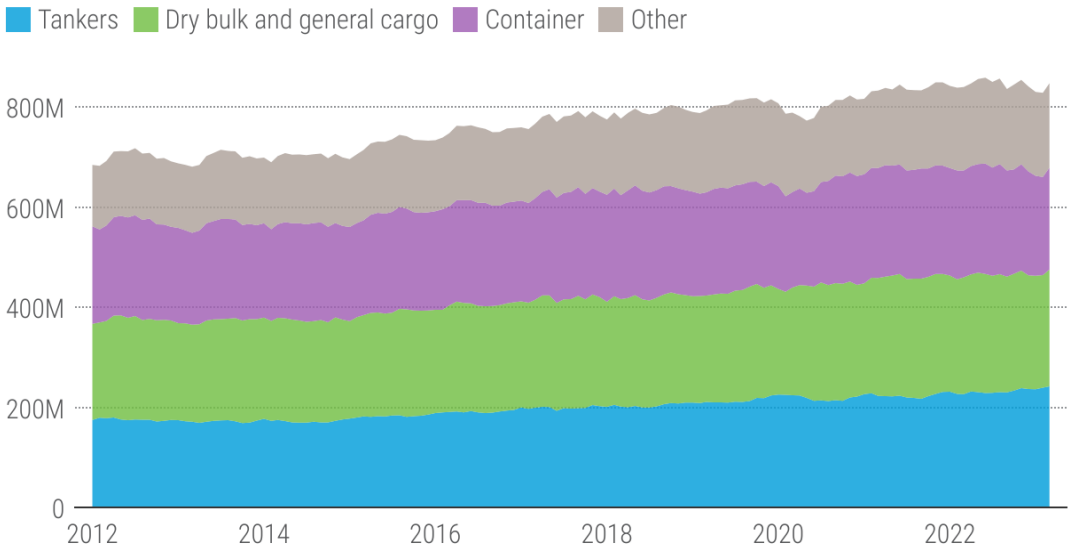
Source: UNCTAD secretariat, based on Clarksons Research, Shipping Intelligence Network time series (July 2023).

Notes: 2023 and 2024 are forecast. "Dry bulk" includes major bulks (iron ore, coal and grain) and minor bulks (metals, minerals, agribulks and softs); "Oil" encompasses crude oil and refined oil products; "Other dry" is an estimation of all other dry trade that is not included in major/minor bulks, for instance, cars and other vehicles, roro and project cargoes, as well as reefer cargoes that don't go in containers and breakbulk cargoes that are not in the minor bulk category; "gas" includes LPG, LNG and ammonia.

- **Maritime transport** plays a crucial role in the economy, accounting for **approximately 90% of world trade**.

CO_2 emissions by vessel type

(in tons, 2012-2023)



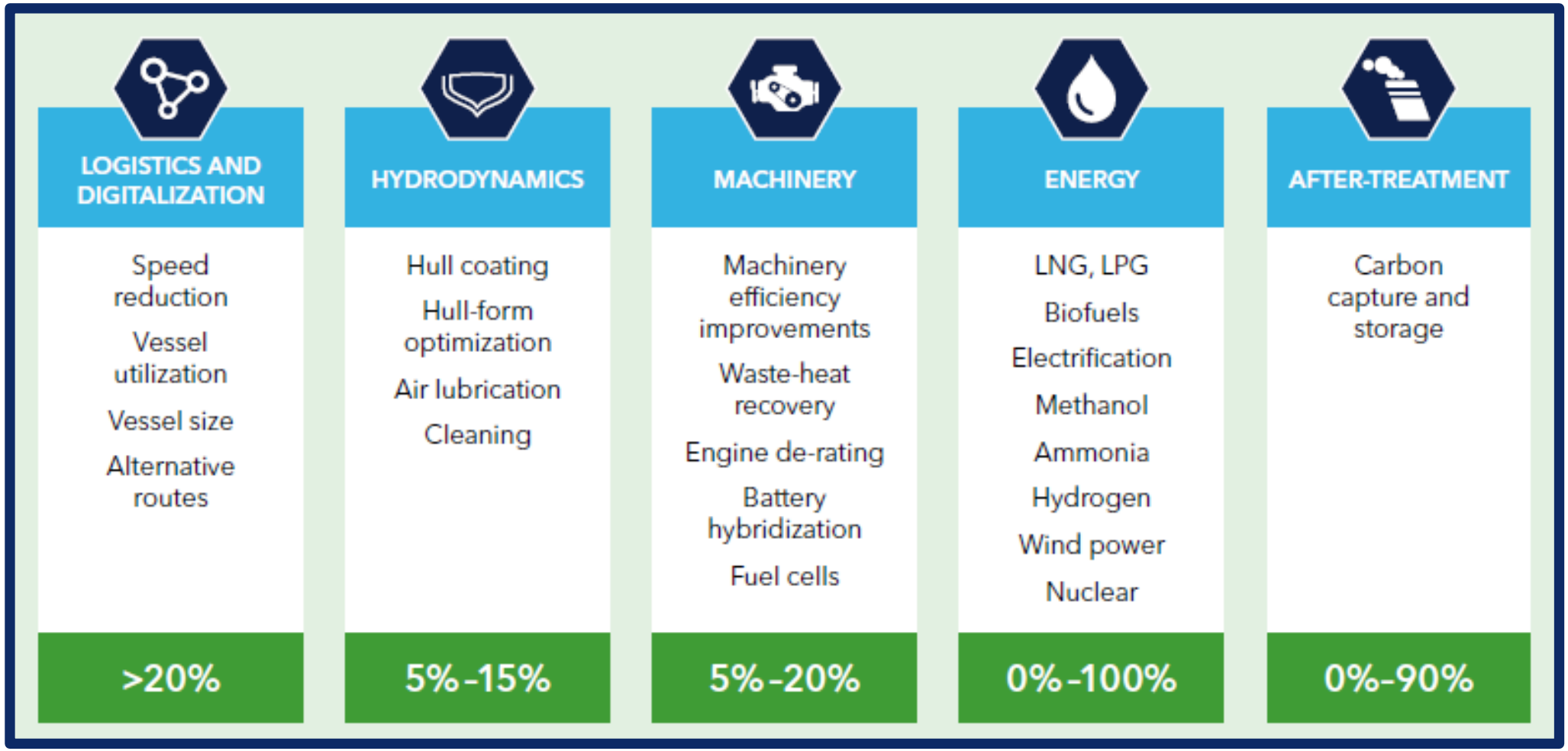
Note: The group "other" includes vehicles and roll-on/roll-off ships, passenger ships, offshore ships and service and miscellaneous ships.

Source: UNCTAD based on data provided by Marine Benchmark, June 2023.

- **International shipping** is responsible for **3% of GHG emissions** and essential for world trade.

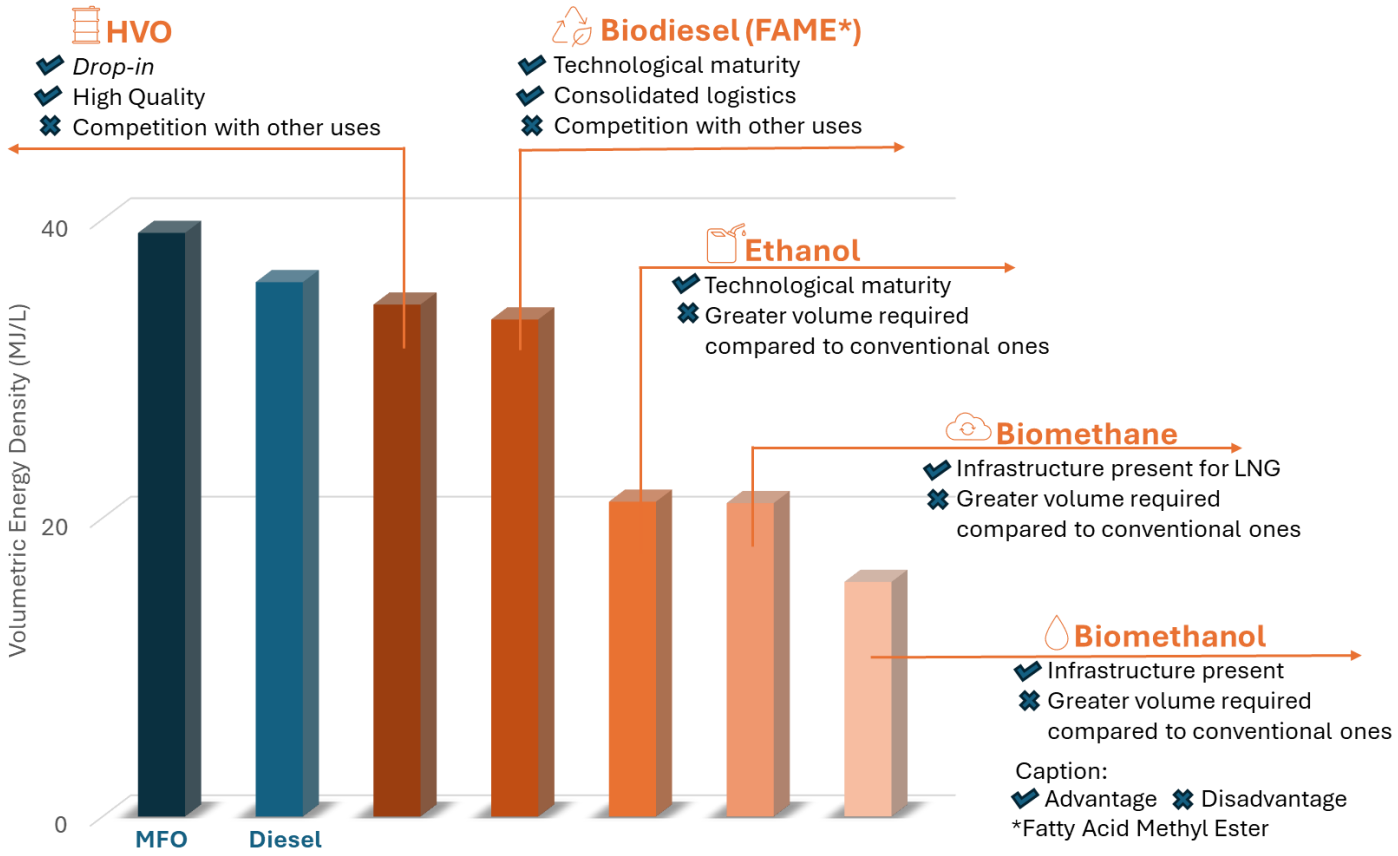
Solutions to decarbonize maritime transport

Potential (%) for reducing GHG emissions



* In particular, with the use of Small Modular Reactors (SMR) technology.

Possible actions to decarbonize waterborne transportation in Brazil



Biofuels can be an alternative to contribute to the reduction of GHG emissions in maritime transport:

- Have a lower carbon intensity than fossil fuels.
- Potential to meet the IMO target of adopting zero or near-zero emission technologies, fuels and/or energy sources, corresponding to at least 5% by 2030.

Preliminary Long-Term Studies – Building Trajectories

Trajectory Base — Emissions reduction techniques

Trajectory 2 — No fossil fuels in 2050

Trajectory 3 — No fossil fuels in 2050, prioritizing methanol and ammonia

Trajectory 4 — No fossil fuels in 2050, prioritizing biofuels

4a — *+ best agricultural practices combined with BECCS*

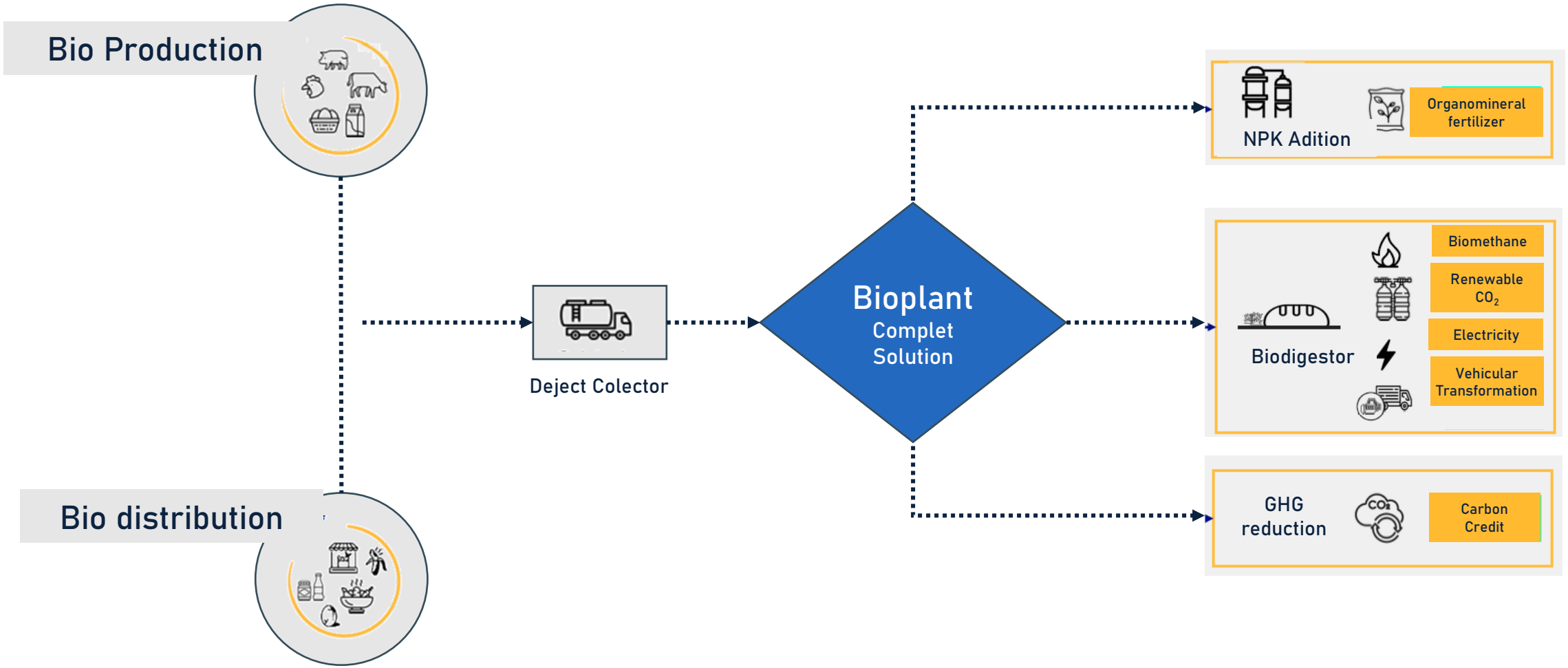
Note: Energy efficiency gains (22%) in all trajectories (2025-2050)

Trajectories resume

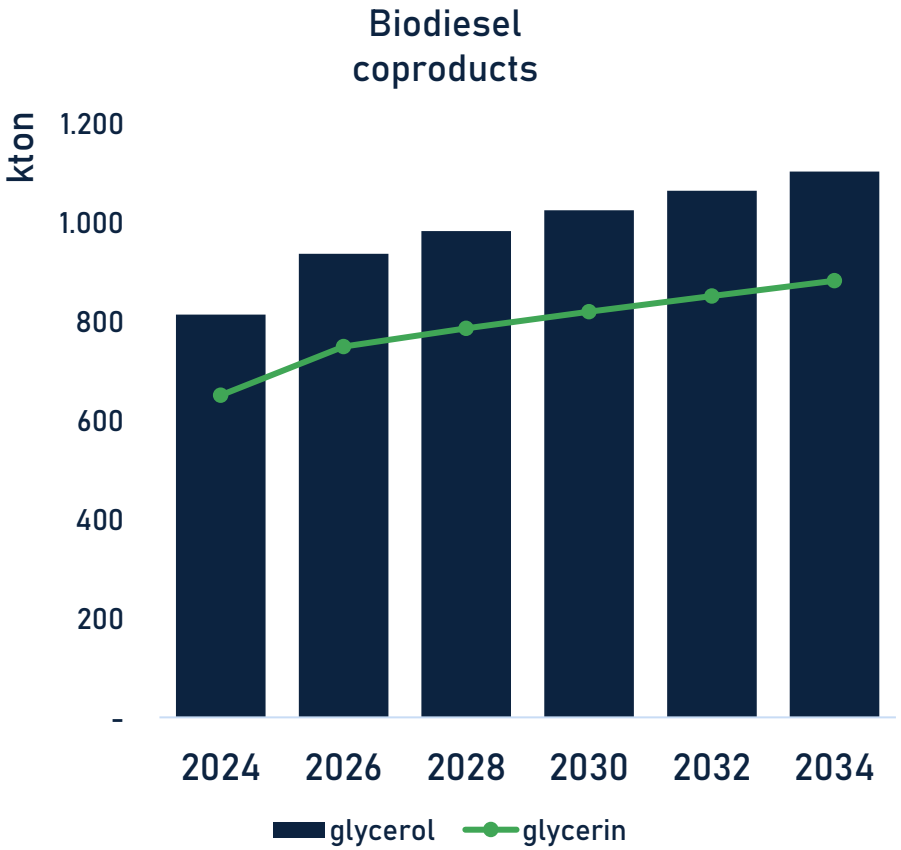
Trajectory	Fuels use	Inland navigation	Cabotage	International maritime transport	GHG Emmisions reduction
Base	**Emissions reduction techniques**	gradual replacement of **marine diesel** by **biodiesel**, reaching **100%** by 2050	blending **biodiesel** in the **bunker fuel** starts in 2026, reaching 30% mix in 2038. New large vessels, delivered from 2034/2035, will use other fuels such as **ethanol, methanol, ammonia, and hydrogen**	use of **biodiesel** in short term. **GNL** in medium term. New large vessels, delivered from 2034/2035, will use other fuels such as **ethanol, methanol, ammonia, and hydrogen**	**61%**
2	**No fossil fuels in 2050**	gradual replacement of **marine diesel** by **biodiesel and ethanol**, reaching **90% and 10%** by 2050	blending **biodiesel** in the **bunker fuel** starts in 2026, reaching 30% mix in 2038. New large vessels, delivered from 2034/2035, will use other fuels such as **ethanol, methanol, ammonia, and hydrogen**	use of **biodiesel** in short term. **GNL** in medium term. New large vessels, delivered from 2034/2035, will use other fuels such as **ethanol, methanol, ammonia, and hydrogen**	**91%**
3	**No fossil fuels in 2050, prioritizing methanol and ammonia**	gradual replacement of **marine diesel** by **biodiesel and ethanol**, reaching **90% and 10%** by 2050	blending **biodiesel** in the **bunker fuel** starts in 2026, reaching 30% mix in 2038. New large vessels, delivered from 2034/2035, will use other fuels such as **ethanol and methanol**	use of **biodiesel** in short term. **GNL** in medium term. New large vessels, delivered from 2034/2035, will use other fuels such as **ethanol, methanol, and ammonia**	**90%**
4	**No fossil fuels in 2050, prioritizing biofuels**	gradual replacement of **marine diesel and bunker fuel** by **biodiesel and ethanol**, reaching **80% and 20%** by 2050	gradual replacement of **marine diesel and bunker fuel** by **biodiesel and ethanol**, reaching 80% and 20% by 2050	**no fossil fuels**, using **biodiesel (30%),ammonia (22%), methanol (22%), ethanol (20%), and hydrogen (6%)** in 2050	**81%**
4a	**No fossil fuels in 2050, prioritizing biofuels + best agricultural practices combined with BECCS**	gradual replacement of marine diesel and bunker fuel by biodiesel and ethanol, reaching 80% and 20% by 2050	gradual replacement of **marine diesel and bunker fuel** by **biodiesel and ethanol**, reaching 80% and 20% by 2050	**no fossil fuels**, using **biodiesel (30%),ammonia (22%), methanol (22%), ethanol (20%), and hydrogen (6%)** in 2050	**102%**

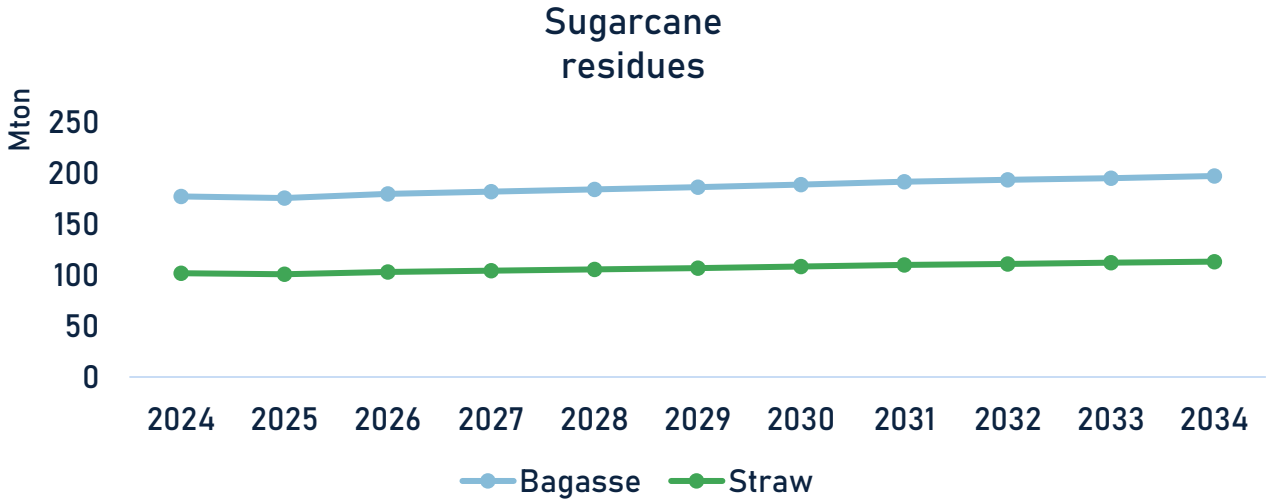
Note: Energy efficiency gains (22%) in all trajectories (2025-2050)

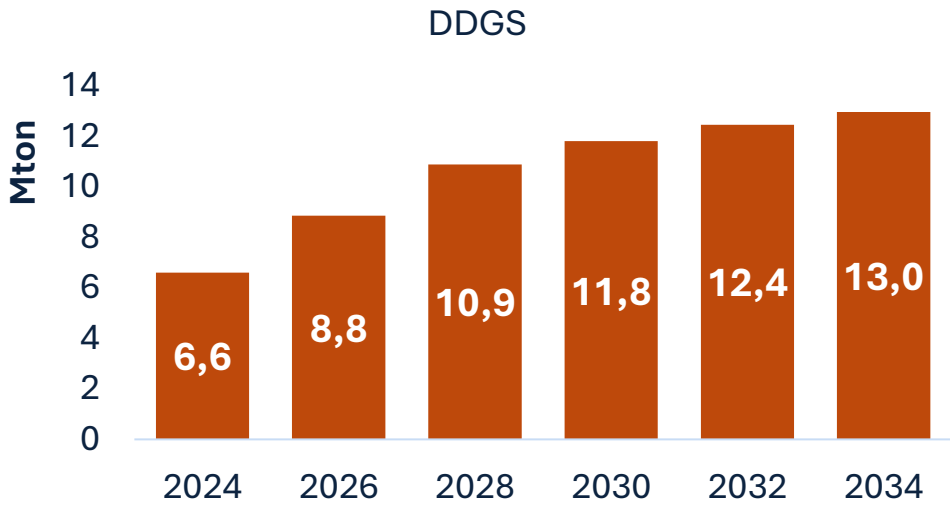
Bioplant sources and bioproduct flow



Main coproducts from the biofuels industry







epe 20 anos

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Brazil is one of the leading biofuel producers in the world

2nd biggest ethanol producer globally

- US: 59.1 Bl
- Brazil: 35.3 Bl
- India: 5.4 Bl
- China: 4.0 Bl

2nd biggest biodiesel producer globally

- Indonesia: 14.0 Bl
- Brazil: 7.5 Bl
- US: 6.4 Bl
- Germany: 3.5 Bl

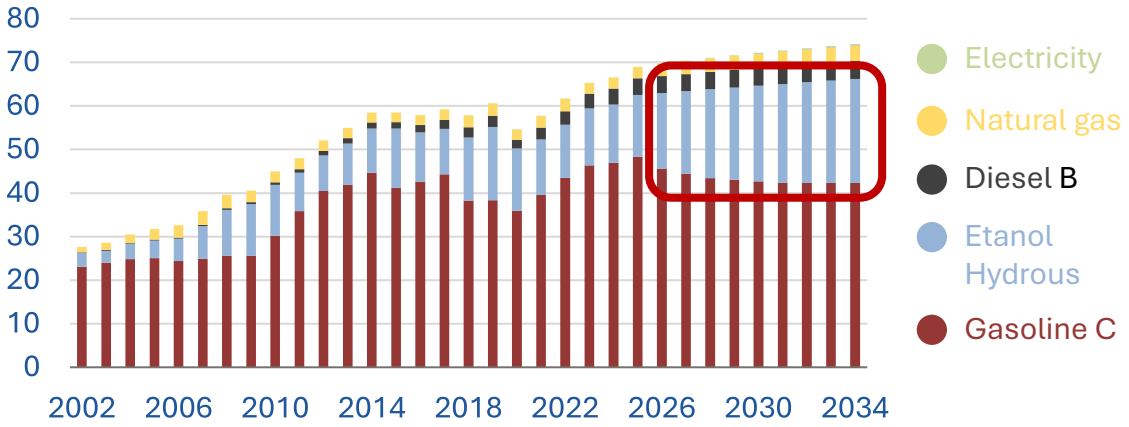
Brazil fuel supply chain

18	Refineries
387	Ethanol plants
61	Biodiesel producers
183	Fuel distributors
44,224	Fuel stations

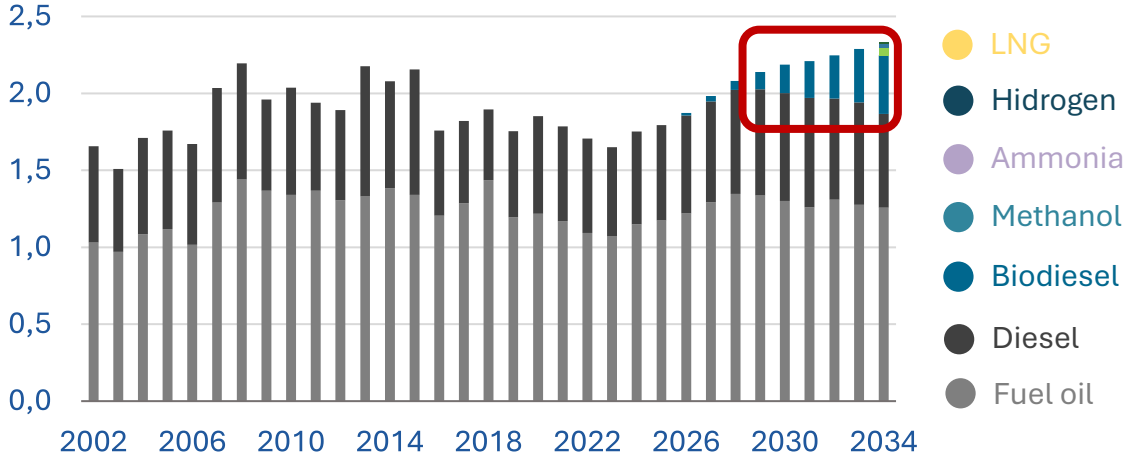
Source: DOE, USA; https://afdc.energy.gov/data
EPE, 2023 Análise de Conjuntura dos Biocombustíveis – Ano 2022

The role of biofuels in the transport decarbonization in Brazil | PDE 2034

Energy demand of individual road passenger transport (billion gle)



Energy demand of waterway transport (billion gle)



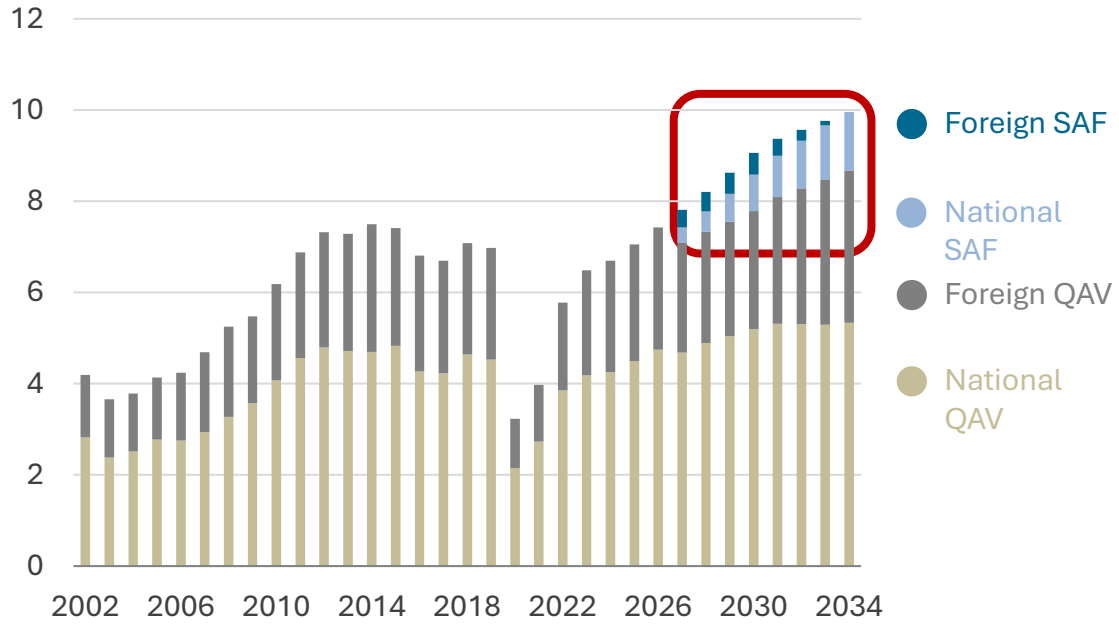
- The **MOVER Program**, phase L8 of Proconve (equivalent to Euro VI), in addition to the **scrapping of the old fleet**, stimulate **efficiency gains in individual road passenger** transport.
- Compliance with **IMO regulations** will imply the adoption **of low-carbon fuels in waterway transport**.
- The demand for fuel oil will be complemented with **biodiesel blends** (BX), which will contribute to the reduction of emissions.
- The insertion of **alternative fuels**, such as methanol, ammonia, hydrogen and LNG, will **incorporate the energy demand** on the path to energy transition.

gle - gasoline liters equivalent

Source: EPE

The role of biofuels in the transport decarbonization in Brazil | PDE 2034

Energy demand of domestic aviation transport (billion gle)



Source: EPE

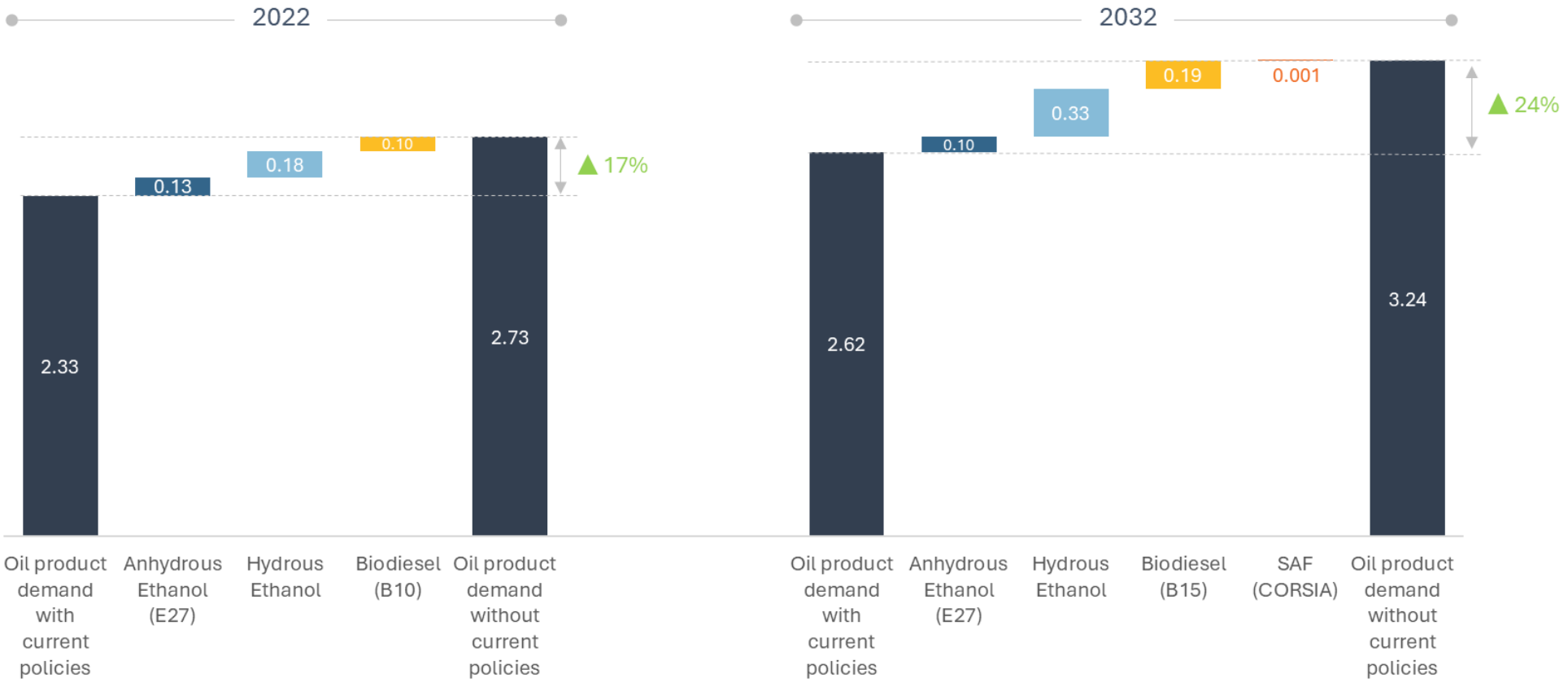
- The gradual **modernization of the fleet**, with the entry of more efficient aircraft, **increases the efficiency**.

- The **aircraft** will predominantly have conventional propulsion technology and will be **powered by fossil QAV and Sustainable Aviation Fuel (SAF).** Especially SAF, under the influence of decarbonization commitments of the civil aviation sector such as ProBioQAV (Combustível do Futuro) for domestic flights and CORSIA for international flights.

gle - gasoline liters equivalent

The role of biofuels in the transport decarbonization in Brazil

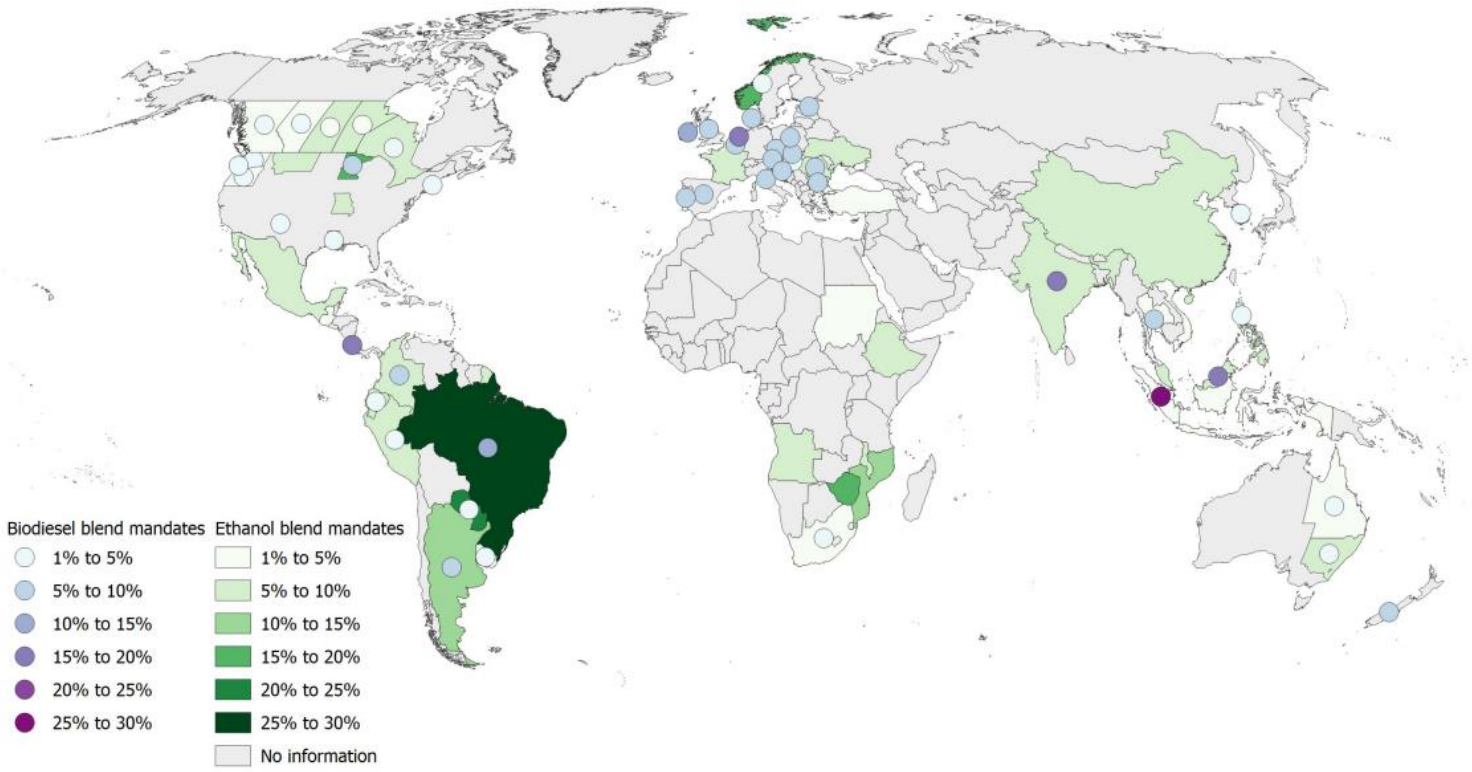
Potential increase in the use of biofuels to replace oil products (million boe/d)



Source: EPE

The role of biofuels in the transport decarbonization

Biofuel blending mandates worldwide, by blend level (2020)



Source: SLOCAT

Access to the webmap EPE: Biofuel blending mandates

- **Climate and land availability** favor the production of biofuels.
- Availability of **sugarcane crops,** installed capacity of mills, and idle capacity in **production of biodiesel** allow for an expedited increase in renewables.
- Disseminated **flex-fuel technology** allows Brazil to expand ethanol use.
- **Shared infrastructure** minimizes costs of increasing ethanol and biodiesel use.
- Country can better **manage the pace of decarbonization while reducing emissions**, and without needing to commit to a specific route.

Final Remarks

- Sustainable biofuels are of great importance in mitigating global and local pollutant emissions, as well as contributing to energy security

- Biofuels: environmental and socioeconomic advantages, contribute to job and income generation

- Public policies were important for the entrance and increase of its participation in the Brazilian Energy Matrix

- Brazil, India and other countries can cooperate to build a global market for biofuels

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