BOSTON CONSULTING GROUP

Seizing Brazil's potential for low-emission marine fuels

UNLOCKING OPPORTUNITIES IN BIOFUELS UNDER THE IMO NET ZERO FRAMEWORK

BRAZIL CLIMATE SUMMIT NEW YORK
September 2025

Brazil Climate Summit.

Brazil is a global forerunner towards a low-carbon future – its innate advantages could unlock $2-3T in investments until 2050

A global biofuels leader, the second-largest producer of ethanol and biodiesel worldwide[1]

Protagonist in Wind and Solar: LCOE: $33/MWh and $15B+/yr in investments[2]

Green H_2 Hub positioning to capture 10-15% of global exports +2030

Worldwide hub for low-carbon industrial products

#1 CO_2-offset supplier: mitigate up to 1 Gt CO_2e/yr[5]

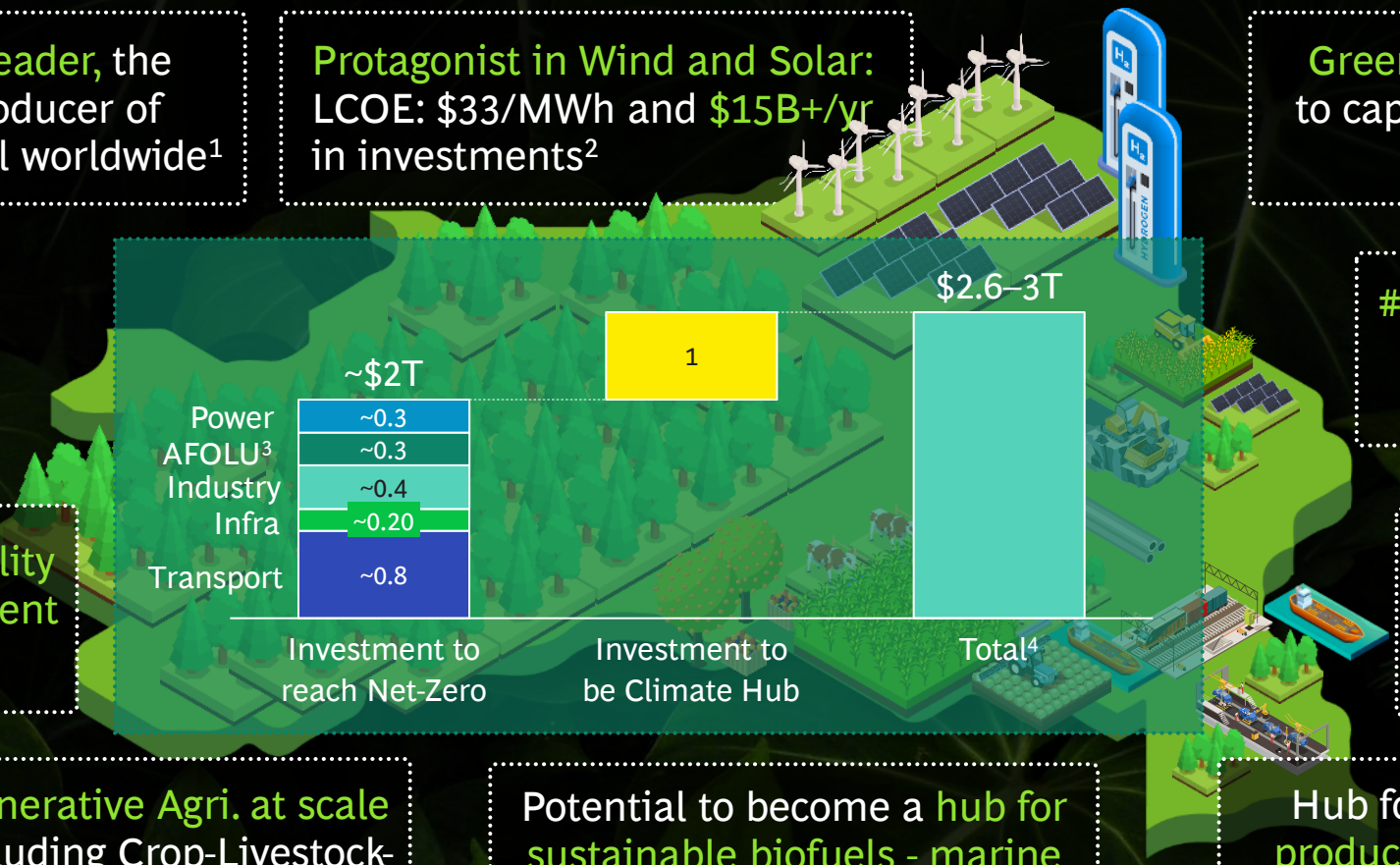
Increased Sustainability in wastewater treatment and water supply[6]

Zero illegal deforestation through command and control[7]

#1 country in Regenerative Agri. at scale (up to 100 Mha including Crop-Livestock-Forest Integration and non-till-farming)

Potential to become a hub for sustainable biofuels - marine fuels as a lighthouse

Hub for green industrial products and minerals for energy transition



1. Brazil: Biofuels Annual (USDA/FAS), 31 ago 2024; 2. Average Levelized Cost of Energy for wind & Solar plants, considering experts inputs, capacity expansion as disclosed by ONS in 2023, and average renewable energy investments in Brazil between 2015-2022 as reported by UNCTAD in 2023 3. AFOLU: Agriculture, Forestry and Other Land Use; 4. Bloomberg NEF (2025). World Energy Transition Investment; 5. Gibbs, H. K., Rausch, N. F. (2015). Brazil's Soy Moratorium. Science, 347(6220), 377–378; 6. Path toward Sustainability in Wastewater Management in Brazil", International Journal of Environmental Research and Public Health, vol. 20, n.º 16, 2023; 7. Brasil (MMA). PPCDAm – 5ª fase (2023–2027): meta de desmatamento zero até 2030, com foco no combate ao desmatamento ilegal (Portuguese).

BCS Reports highlight the "how to" make opportunities material - today we present the case for sustainable marine fuels

A global biofuels leader, the second-largest producer of ethanol and biodiesel worldwide[1]

BCS NY Sept. 2024

Green H_2 Hub positioning to capture 10-15% of global exports +2030

BCS Paris May 2025

Worldwide hub for low-carbon industrial products

BCS Sept. 2023

BCS EU May 2024

#1 country in Regenerative Agri. at scale (up to 100 Mha including Crop-Livestock-Forest Integration and non-till-farming)

Today's focus:

Potential to become a hub for sustainable biofuels - marine fuels as a lighthouse

BCS EU May 2024

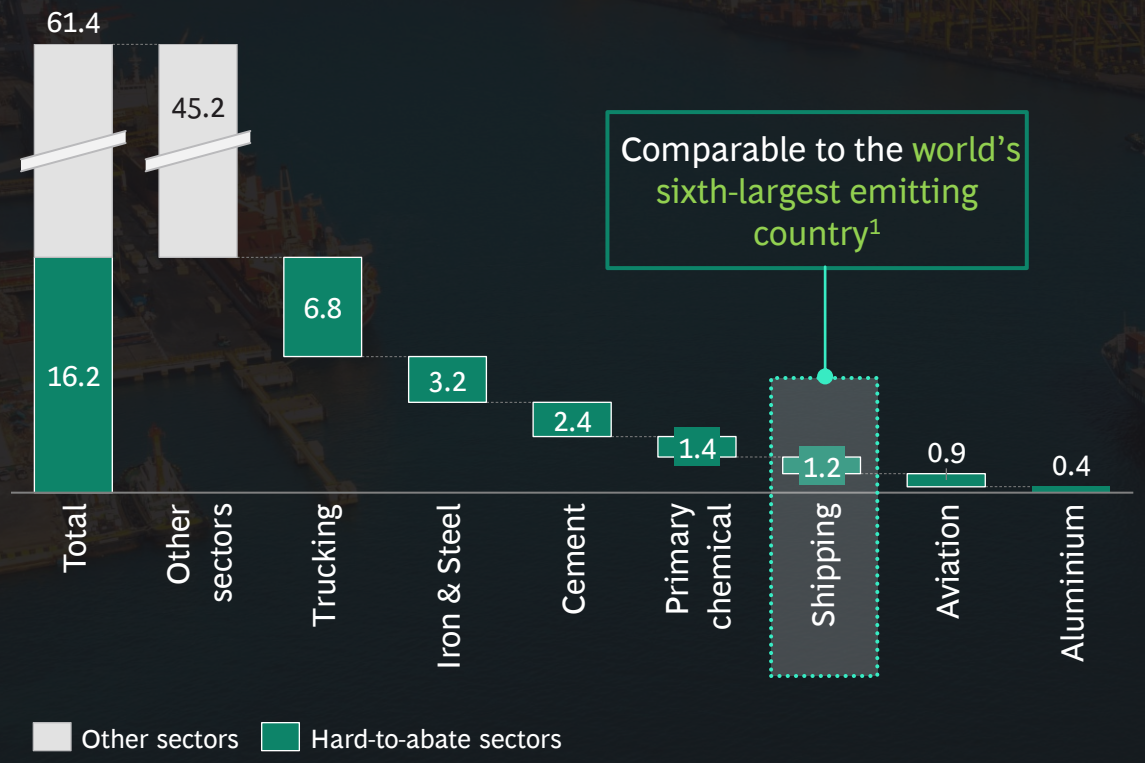
Hub for green industrial products and minerals for energy transition

1. Assume potential of NBS in a price-competitive scenario with carbon price at $70/ton CO2;
Source: BCG Analysis

Shipping represents ~1.2 Gt CO_2e of hard-to-abate emissions – IMO NZ Framework offers a pathway to sector decarbonization

Global GHG emissions

Gt CO_2e, 2024



IMO Net Zero Framework (IMO NZF) key aspects[2]

Presented on 11 April 2025

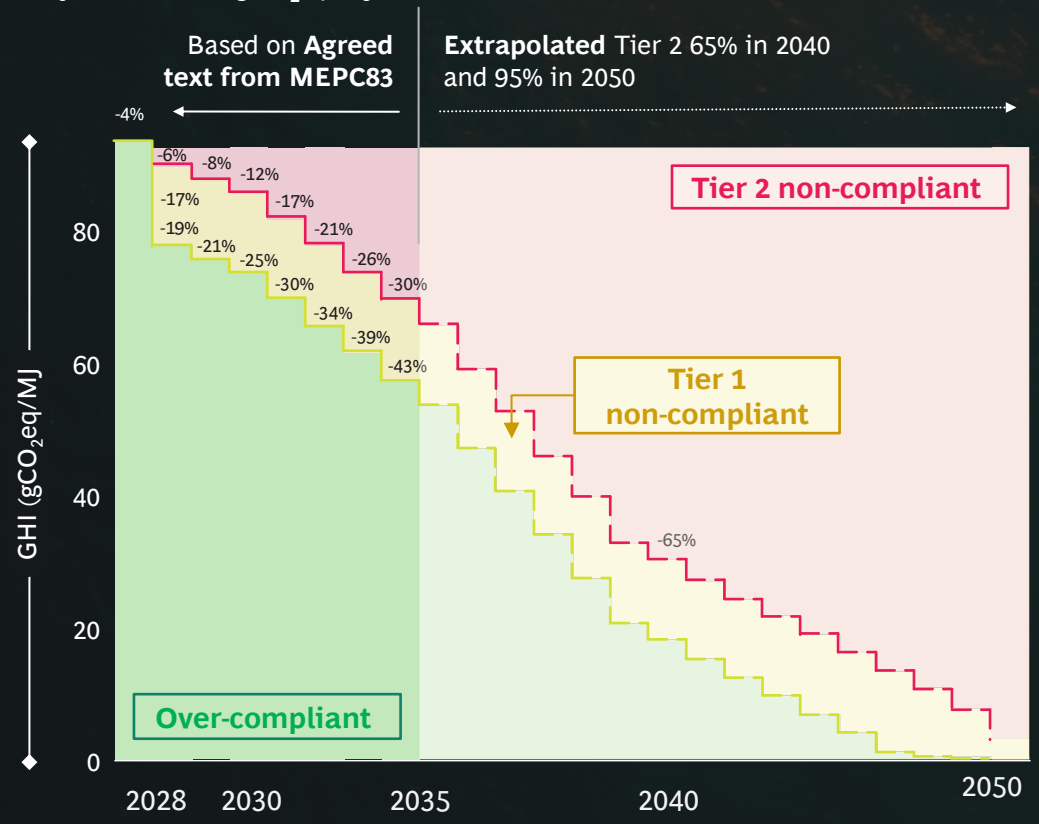
- GHG-intensity decarbonization pathway with defined 2028–35 targets and a sector-wide market mechanism, agreed at Marine Environment Protection Committee 83rd session (MEPC 83)
- Global scope reflecting shipping's international jurisdiction and the large share of emissions governed by the IMO
- Proven track record by the IMO in implementing the 2020 global 0.50% m/m Sulphur cap, with robust enforcement and high compliance[3]
- Next step: Formal adoption at IMO's extraordinary MEPC session, MEPC/ES.2, mid October 2025
- COP30 could serve as a strong platform for advancement on shipping decarbonization, aligned with the Action Agenda (Key Objective #2)

1. Source: B3. Inventário de emissões de gases de efeito estufa 2024: Apresentação de Resultados [Greenhouse Gas Emissions Inventory 2024: Results Presentation]. 2025. (Portuguese) 2. Presented on 11 April 2025, at the close of IMO's MEPC 83 (7–11 Apr, London); 3. Under MARPOL Annex VI Reg. 14, "IMO 2020" lowered the global sulphur limit in marine fuels to 0.50% m/m from 1 Jan 2020 (with 0.10% in ECAs) and introduced a carriage ban for non-compliant fuel from 1 Mar 2020; EU THETIS-EU inspections report >95% compliance. Note: IMO NZF = IMO Net-Zero Framework. Source: EDGAR 7.0; IEA; BCG Analysis

Considering IMO NZF, from 2028, vessels need to reduce emission intensity, face penalties of $100–380/tCO₂e, or acquire surplus units

GHG intensity (GHI) reduction factors and pricing mechanism agreed on MEPC83[1]

Reference: 93.3 gCO₂eq/MJ



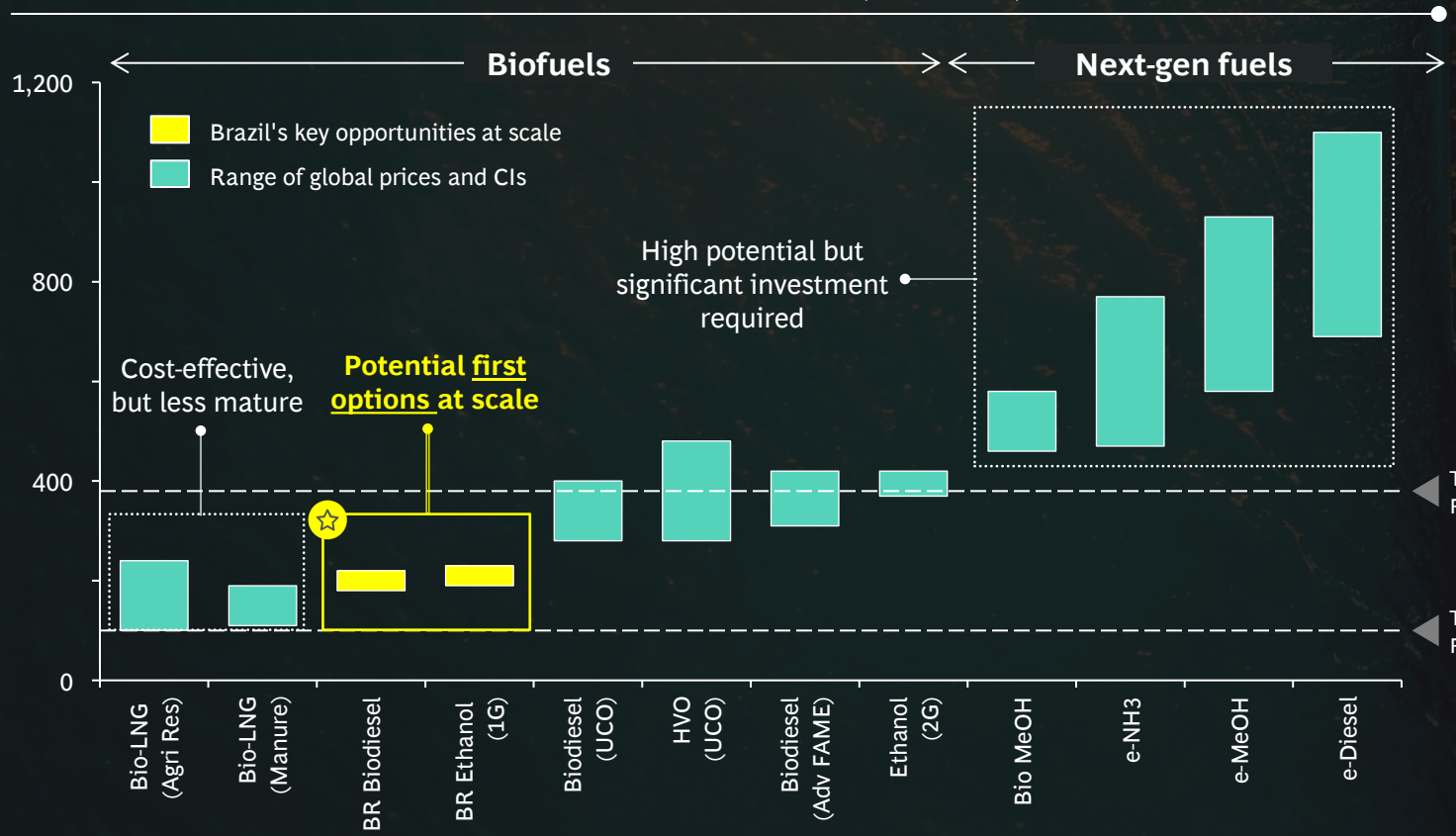
Possible actions	Over-compliant	Tier 1 non-compliant	Tier 2 non-compliant
Sell Surplus Units[2] (optional)	✓	-	-
Reduce GHG intensity to reach compliance	-	✓	✓
Pay 100$ /tCO₂e[3] (Tier 1)	-	✓	-
Pay 100$ /tCO₂e (Tier 1) + buy Surplus Units[2]	-	-	✓
Pay 100$ /tCO₂e (Tier 1) +pay 380$ /tCO₂e (Tier 2)	-	-	✓

Penallties collected to future **IMO fund**
Rewards for near zero fuels (**ZNZ**) to be defined
Price of Surplus Units will depend on market development

1. Formal adoption at IMO's extraordinary MEPC session (MEPC/ES.2), 13–17 Oct 2025; 2. SU (Surplus Units) — MEPC 83: If a ship's annual GHG Fuel Intensity is below the Direct Compliance target, it earns SUs, which can be banked for up to two years or transferred once to offset another ship's Tier-2 deficit. 3. At Tier 1, credit purchases are not permitted; the only option is to pay the USD 100/tCO₂e penalty
Source: Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping; IMO - MEPC 83; GCMD; FuelEU Maritime; Argus; IEA; BCG analysis

Brazil can deliver near-term cost-competitive biofuels for marine decarbonization…

Fuel carbon abatement costs 2025-2030 ($/tCO2)[1,2]



Brazil key opportunities

Short-medium term

Biodiesel and ethanol offer fast turnaround, cost-competitive, scalable alternatives, supported by degraded-land restoration

Deep dive ahead

Medium-long term

Bio-LNG **potential in Brazil is significant**, but will require more materiality of demand and development of distribution and liquefaction infrastructure

Long term

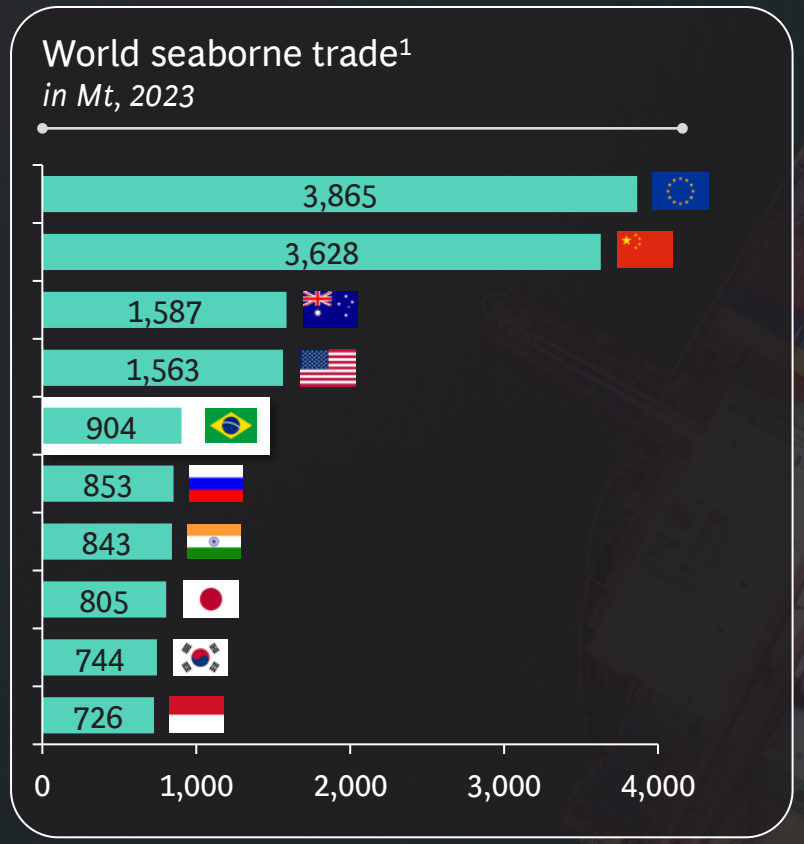
Brazil **has strong next-gen fuel potential** — realization hinges on capital, tech readiness, and engine scaling

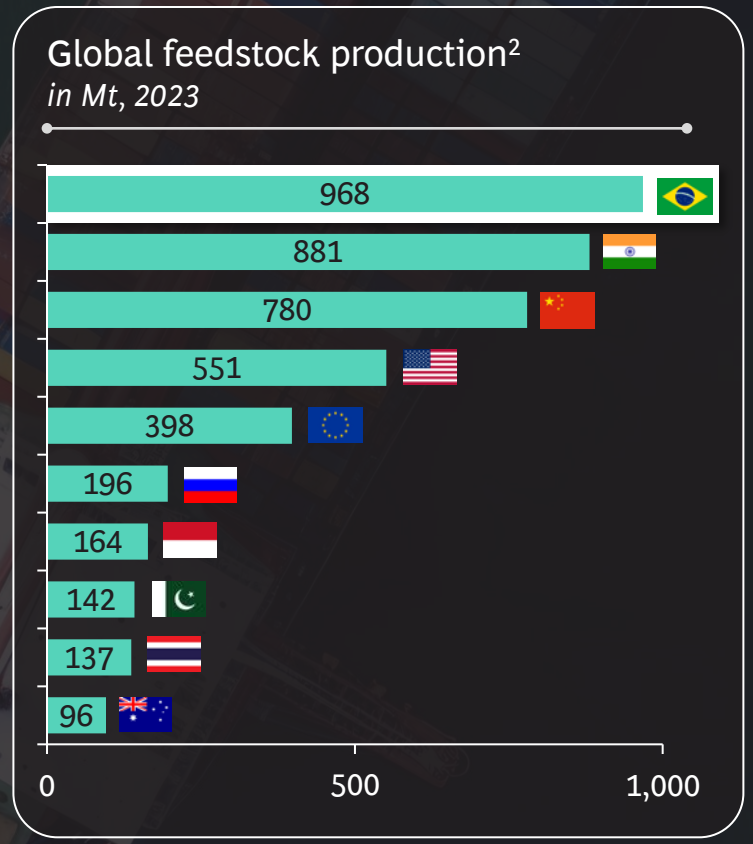
1. Carbon abatement cost of fuels; excludes infrastructure, vessel operation, penalties, etc; Note: (a) The fuels shown are not exhaustive - emerging fuels (e.g.. e-LNG. HTL. pyrolysis oil) have been excluded for clarity; (b) Biofuel costs assume minor changes in 2025-2030 period and don't account for potential supply constraints / scarcity due to competition induced by additional demand from IMO policies for shipping, that may lead to volatility / increase of fuel price; (c) In this study only fuel costs were analyzed: most biofuels are drop-in solutions requiring no changes to existing HFO or LNG fueled vessels and infrastructure thereof; next-gen fuels require additional CAPEX, but according to DNV and MMMCZCS, this has negligible impact on TCO compared to next-gen fuel costs; Fuel expenditures represent ~25-40% of TCO today - for next-gen fuels TCO share may rise to 60% during financing period and 80-90% after financing period
Source: Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping; IMO - MEPC 83; GCMD; FuelEU Maritime; Argus; IEA; BCG analysis

… leveraging its strategic position to supply at scale

#5 worldwide in maritime traffic (~3% of global volume)

#1 worldwide producer of feedstock used for biofuels





#Key possibilities to unlock scale

Green corridors
Ongoing initiatives

Proposed Declaration of Intents for Green Shipping Corridor with countries such as France and Norway

Pastureland recovery
Scale potential

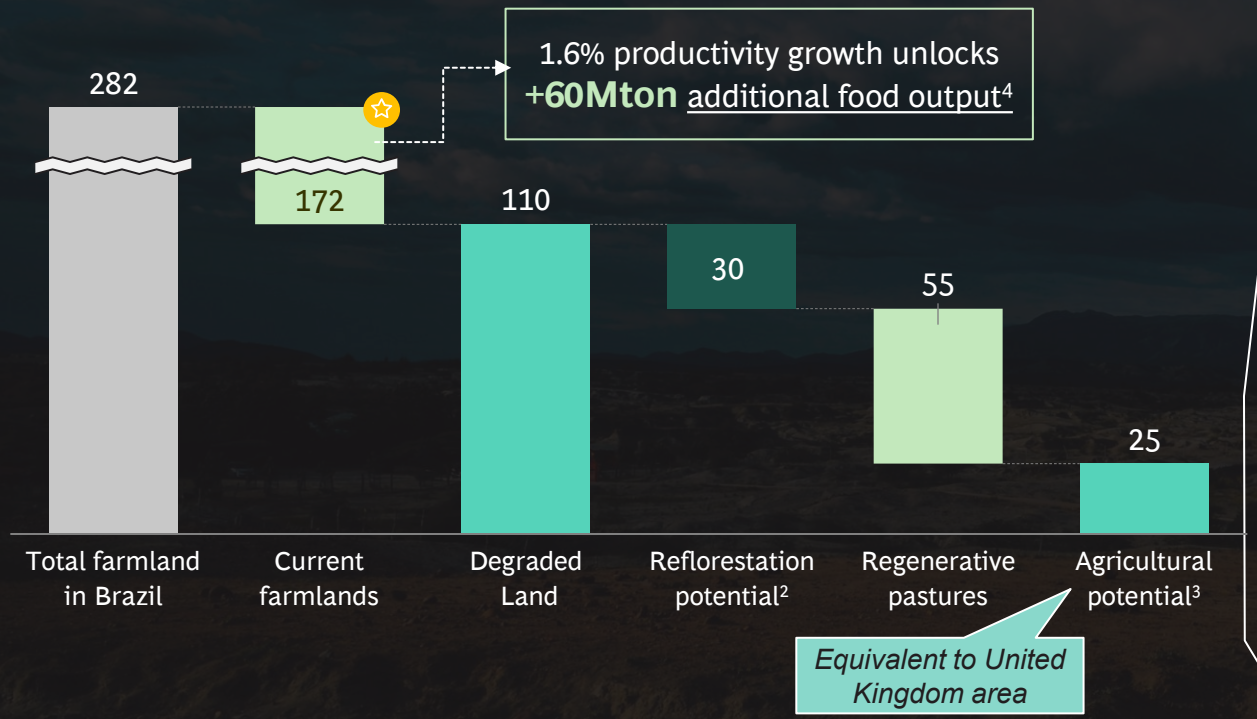
Restoring degraded pastureland in Brazil to increase the area available for biofuel production

Deep dive ahead

1. Considers both total goods loaded and discharged; 2. Considers cereals, oilcrops, sugar crops, and treenuts
Source: FAO – Crops and livestock products (QCL) 2023; UNCTADstat - World seaborne trade by type of cargo, annual; Brazil Climate Summit (BCS); Brazilian Government

Biofuel production can restore 25Mha of degraded land, while promoting reforestation and increasing food production

Potential uses for recovered pasturelands *(in Mha)*



Final products generated

Plantation[1]	Biofuels	Food	Other
2 Mha[3] +Food crops	-	-	-
4 Mha Sugarcane	**20 BL** Ethanol (sugarcane)	-	**4.4 GWm** Bioelectricity[5] **4.9Mm³/day** Biomethane[6]
8 Mha Corn	**23 BL** Ethanol (corn)	**15Mton** DDGS	-
20 Mha Soy	**16 BL** Biodiesel	**65 Mton** Bran	-

Food · Degraded land restored · Energy generated · Productivity expected to increase by 1.6% a.a.[2]

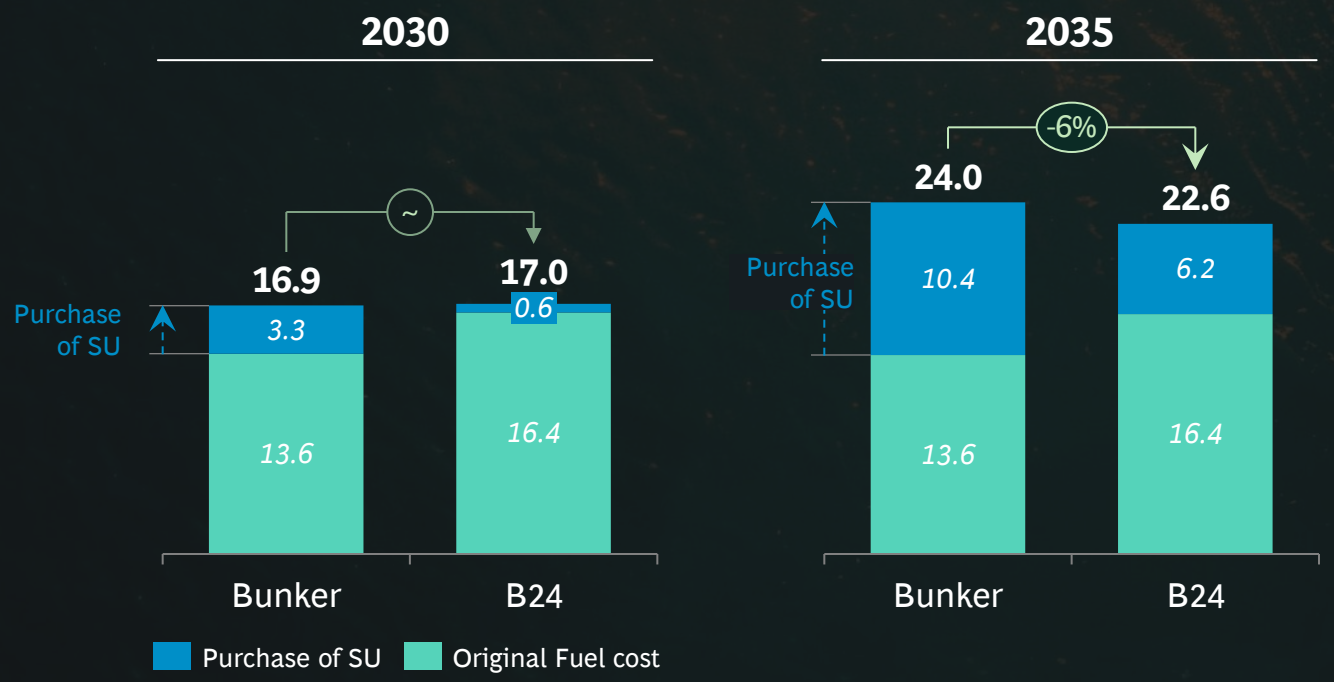
1. There is overlapping planting (use of the same lands) for corn and soybeans; 2. Estimated based on Griscom, 2020 & Roe 2021, according to BCG Forestry NZE 2050 projections in Brazil; 3. The calculation considers only the difference between food-demand growth (1.85% p.a.) and productivity growth (1.6% p.a.); 4: Considering the current supply (only considered grains) of food of 312 Mton - Daniel Rittner, "Brasil virou 'celeiro do mundo' e já lidera exportações mundiais de sete alimentos, diz BTG," CNN Brasil, March 4, 2024; 5. Based on residual bagasse from ethanol production and 25% efficiency in electricity generation; 6. Generated from vinasse, a byproduct of ethanol production
Source: Embrapa; Conab; MapBiomas; Brazil Climate Summit (BCS); BCG analysis

Biodiesel blends offers a near-term and cost-competitive decarbonization lever

Cost competitiveness of B24[1] compared with bunker[2]

In U$ per GJ, assuming 38 gCO2eq/MJ for biodiesel (B100) and 91.7gCO2e/MJ for bunker

Assuming Surplus Unit price of 350 $ /tCO_2e[3]



Biodiesel blends are **compatible with conventional engines**, covering ~90% of the current fleet[4]

Brazilian B100 differentials

35-38 gCO2e/MJ

Brazilian soybean biodiesel's WtW[5] carbon intensity

220-230 $/tCO2e

Abatement cost at BR ports, smaller than IMO $380/tCO2e

280-300 $/tCO2e

Abatement cost at Rotterdam and Singapore ports, smaller than IMO $380/tCO2e[6]

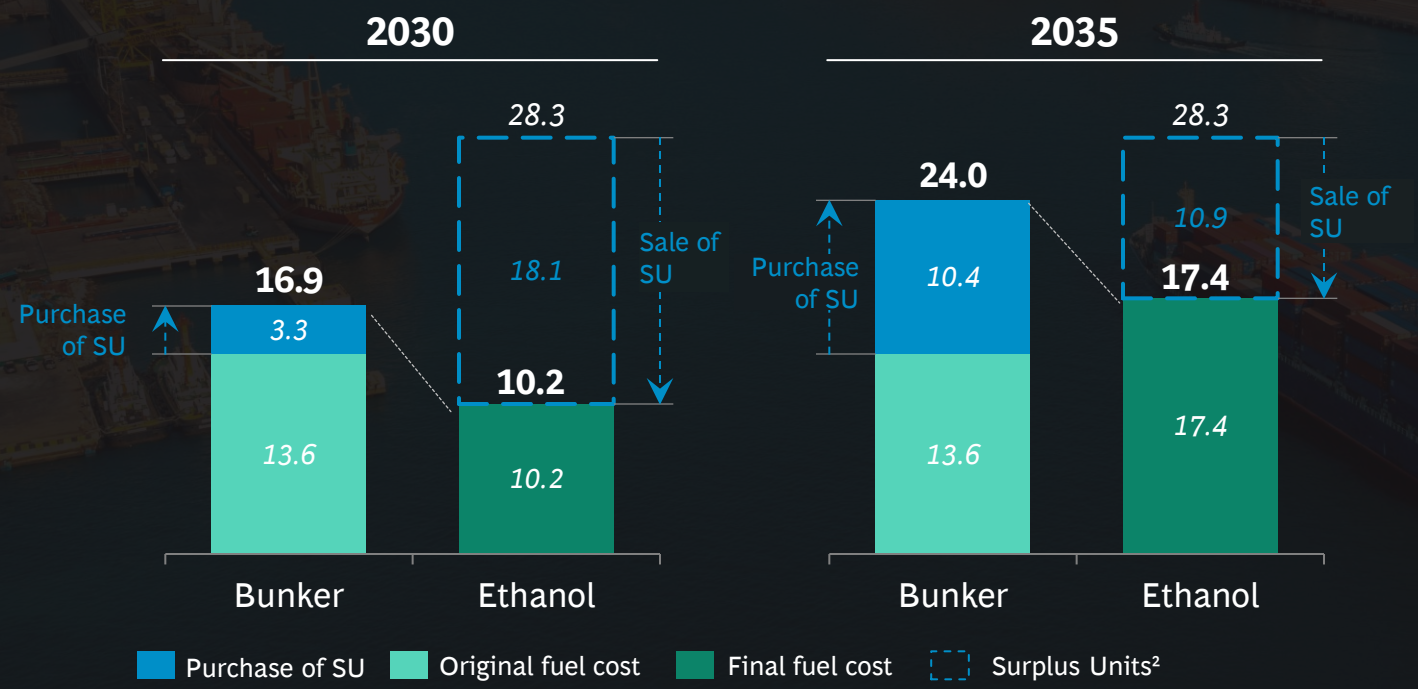
1.'BX' designates biodiesel blend levels—B24 contains 24% biodiesel 2. Assuming penalties being paid, delivered at BR port; 3. Surplus units value will be defined by the market, consider value slightly lower than IMO carbon penalty
4. B24 blends are already in the market and are blended at the Rio Grande Terminal (TERIG) in Rio Grande, Rio Grande do Sul; 5. Well to Wake ; 6. Considering the mixing conducted at the country's port
Note: Considering bunker prices at $0.53/L and biodiesel prices at $0.91/L; The number of Surplus Units is determined by the difference between the submitted fuel's carbon intensity and the IMO compliance targets
Source: Agência Nacional do Petróleo; Gás Natural e Biocombustíveis (ANP); IMO; General Index; BCG Analysis

As engine technology evolves, ethanol offers scalable mid-term growth alternative, with surplus units ensuring cost-effectiveness

Cost competitiveness of ethanol compared with bunker[1]

In U$ per GJ, assuming 22 gCO2e/MJ for ethanol and 91.7gCOe/MJ for bunker

Assuming Surplus Unit price of 350 $ /tCO_2e[3]



Studies show **compatibility of ethanol with methanol engines**

Brazilian ethanol differentials

20-22 gCO2e/MJ

Brazilian ethanol's WtW[3] carbon intensity, corn ethanol with low CI given production in "safrinha"[4]

205-210 $/tCO2e

Abatement cost at BR ports, smaller than IMO $380/tCO2e

265-275 $/tCO2e

Abatement cost at Rotterdam and Singapore ports, smaller than IMO $380/tCO2e

1.Assuming penalties being paid, delivered at BR port; 2. Surplus units value will be defined by the market, consider value slightly lower than IMO carbon penalty; 3. Well to Wake; 4. Refers to Brazil's secondary crop cycle, where corn is grown after soybeans using the same planted area
Note: Considering bunker prices at $0.53/L and ethanol prices at $0.62/L; The number of Surplus Units is determined by the difference between the submitted fuel's carbon intensity and the IMO compliance targets
Source: Agência Nacional do Petróleo; Gás Natural e Biocombustíveis (ANP); IMO; General Index ;BCG Analysis

Unlocking the potential of biofuels for shipping requires consolidation of regulatory framework and technology evolution

Regulatory final approval

Final MEPC 83 vote scheduled for the extraordinary session in mid October 2025

Carbon Intensity standards

Carbon intensity under discussion — important evolution towards product level standards and set up of default values

Incentive mechanisms definition

Rewards definition by IMO to be concluded by March 2027

Credibility of compliance

MEPC 83’s success requires planning, execution and rigorous enforcement

Short term technology advancements

Methanol-capable engines available at scale to allow ethanol adoption

Source: International Maritime Organization; BCG analysis

Brazil has a unique position to supply biofuels to reduce shipping emission footprint

Land restoration

~25M
hectares

Emission reduction

~170
Mt CO_2e /year

Investment opportunity[1,2]

~90
USD Billion

Shipping 2050 energy demand

15%

1. Considering $53B investment required to recover degraded pasturelands and $32B investment in CAPEX to scale production; 2. CAPEX estimates reflect only the biofuel production stage, without allocation to distribution or other value chain segments
Source: Agência Nacional do Petróleo, Gás Natural e Biocombustível (ANP); Embrapa; IMO; EPE; Conab; Abiove; Raízen; Única; Unem; BCG Analysis