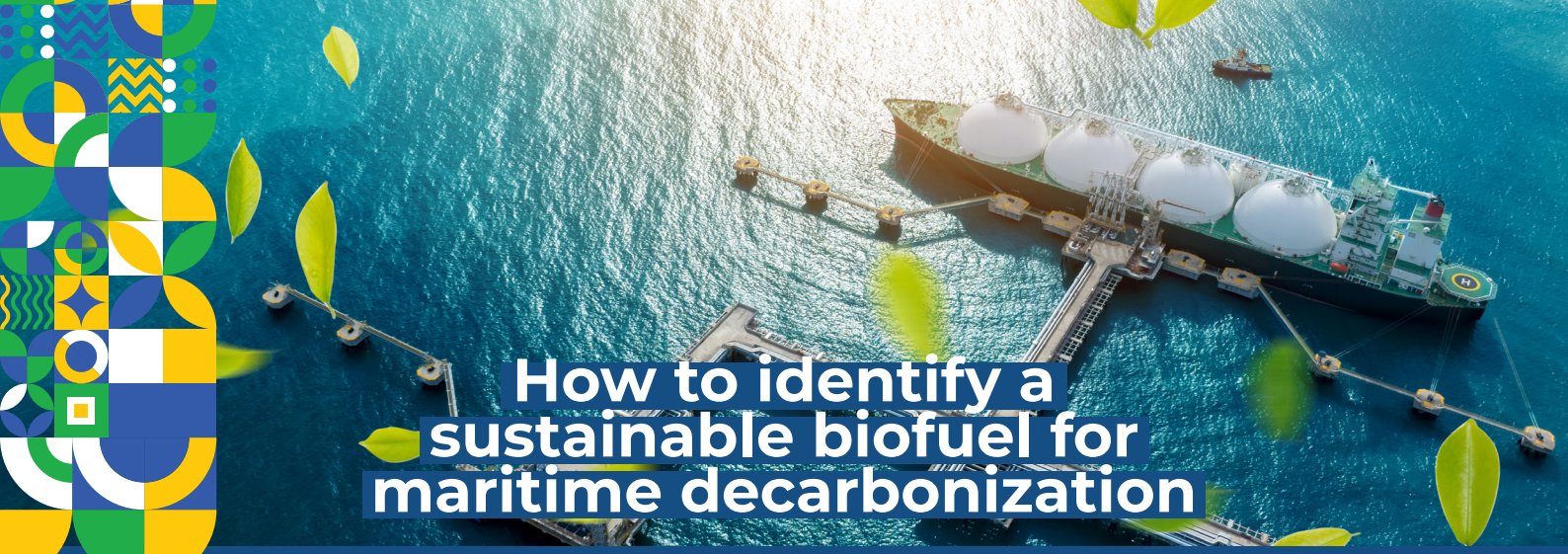

How to identify a sustainable biofuel for maritime decarbonization

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Objective of this study

Biofuels as an immediate and effective solution for the decarbonization of transportation

- Inform and clarify about the potential and sustainability of biofuels.
- Focus is on biofuels that can be produced in a sustainable manner, with sufficient capacity to be relevant to the decarbonization of the maritime sector.
- To discuss the model Brazilian of agriculture and your developments technological.
- Show how bioenergy is generating socioeconomic benefits and reducing emissions without the need of large tracts of land.
- To discuss the potential for the production of biofuels in the global south.

BIOMASS
Capacity of production, sustainability, supply/demand

PRODUCTION OF BIOFUELS
Technological routes, scale, technological maturity, economic feasibility

GHG EMISSIONS
Carbon accounting, LCA, certification, ILUC

LAND USE
Potential use of degraded areas and pastures, the model of tropical agriculture production, food security and feedstock traceability

IMPLANTATION
Policy frameworks, implementation agenda

The substitution of fossil fuels with biofuels is important to keep global temperatures from rising (IPCC, 2022)

Bioenergy is the "Overlooked giant in renewable resources ". Bioenergy share in the global renewable resources is 50%, as much as hydro, wind and solar combined (Fatih Birol, IEA, 2018).

Bioenergy contributes to energy security, food security, environmental security and sustainable development (SCOPE, 2015)

To achieve carbon neutrality, biofuel use needs to grow 2.5 times between now and 2030 (IEA, 2023)

In shipping and aviation, bioenergy, hydrogen, and hydrogen-based fuels need to increase from less than 1% of energy consumption today to almost 15% in 2030 and 80% by 2050 (IEA, 2023)

The pathway to carbon neutrality includes biofuels replacing almost 800 Mt of fossil CO_2, or 10% of current global transport emissions (IEA, 2023)

BIOEN FAPESP

Brazilian contribution to the decarbonization of transportation

1. Domestic energy supply widely is largelyrenewable (49.1%), with **16,9% coming from sugarcane and 15.8% from other sources of biomass.** Electricity is 86.1% renewable (BEN, 2024)

2. Transportation is 22.5% renewable, with 37.3 billion L/year of ethanol and 9.1 billions of billion L/year year of biodiesel, produced by 436 plants of biofuels. From 1975 to 2024, **Brazil consumed 888 billion liters of ethanol, displacing 1.4 billion tons of CO2eq.**

3. **The "Fuel of the Future" legislation** current target is 705 Mt CO2 eq of avoided emissions by 2037. E30 and B20 by 2030.

4. Biofuels grew at the same time that **became the largest exporter of food commodities.** The intensification of pastures freed up land. The second harvest was introduced.

5. In Brazil, the expansion of energetic cultures was predominantly linked to conversion of degraded lands and pastures, with the added benefit of recovery of soil and capture of carbon in the soil. (Guareghi et al., 2023).

6. **Brazil preserves 66% of its territory with native vegetation.** Agriculture uses 8%, pastures use 21% and urban areas 4%. (Embrapa, 2021).

The G20 in 2024 advanced a set of principles for a fair and inclusive energy transition with the following recommendations:

"We underscore the crucial role of technologically neutral, integrated, and inclusive approaches to develop and deploy a variety of low-emitting energies, sustainable fuels and technologies, including for abatement and removal, carbon management, and emission reduction, with a view to creating scale and global markets to accelerate energy transitions, particularly in hard-to-abate sectors.
We encourage, as appropriate, the use of mutually recognized methodologies and standards for assessing greenhouse gas emissions."
(G20, OCTOBER 2024)

Policies should be technology neutral and feedstock agnostic". ILUC numbers cannot be used to negate the effectiveness of biofuels to decarbonize transportation (International Energy Agency Carbon Accounting for Sustainable Biofuels Report, 2024).

The effects of bioenergy from edible versus non-edible feedstocks

Food availability
2/3 of the articles reported positive effects or no effects on food availability. Bioenergy has positive effects on the household scale.

Food prices
Negative effects of bioenergy on food price were concentrated on countries with High Social Development Index (SDI) (3/4).

Food production
Bioenergy has positive effects on food production in low SDI countries and at the household scale.

Bioenergy on low SDI countries has no effect on food security. Studies that report negative effects are most commonly based on modeling. When observed data was used the reporting of negative impacts was lower.

224 papers
There is no correlation between the type of bioenergy feedstock (edible, inedible, or both edible and inedible) and food security

Ahmed, S., Warne, T., Smith, E., Goemann, H., Linse, G., Greenwood, M., Kedziora, J., Sapp, M., Kraner, D., Roemer, K., Haggerty, J. H., Jarchow, M., Swanson, D., Poulter, B. and Stoy, P. C. (2021). Systematic review on effects of bioenergy from edible versus inedible feedstocks on food security. Science of Food (2021) 5:9

Observed changes brought about by bioenergy that contribute to food security:

Purchasing power

Improvement of the socioeconomic indicators:

- Years of literacy and schooling
- Income improvement: The diversification of revenue sources in the field (with corn after soybeans) and the increase in added value with ethanol and byproducts (such as DDGS for animal feed) boosted the income of rural and industrial workers*
- Formalization of work and working conditions
- Perspectives for future generations (daughters and sons of workers)
- GDP per capita in municipalities that house bioethanol companies
- A new plant increased the municipalities' GDP per capita by US$1,098 (first year) and US$1,029 (10 years)

70.000
small sugarcane producers

75.000
small soybean producers

Job opportunities (↑biodiesel = 1.1 million new jobs added in the soybean industry in the last decade)

*RICCI, Patrícia F.; GURGEL, Angelo C.; DELGADO, Guilherme C.; FERRAZ, Samuel; CONANT, Richard T.; PALMER, Charles. Socio-environmental and land-use impacts of double cropped maize ethanol in Brazil. Nature Sustainability, [SI], v. 3, p. 420–427, 2020. DOI: 10.1038/s41893-020-0480-1. Available at: https://www.nature.com/articles/ s41893-020-0480-1. Accessed on: June 13, 2025.

Observed changes brought about by bioenergy that contribute to food security

Increased access to energy

750 million
people in the world do not have electricity (80% in rural areas)

- Energy use has a direct correlation with the Human Development Index.
- Food security increases with access to energy.
- Sugarcane bioelectricity can supply 10.8 million homes, increasing access to energy in rural areas.

Observed changes brought about by bioenergy that contribute to food security: Added value to agriculture, increased productivity and production with better management practices using very little land

Modernization of agriculture

The three main energy crops (soybean, corn and sugarcane) have not yet reached their theoretical productivity limits!

Crop rotation
Planting in flowerbeds
Straw layer
Soil amendments
Waste utilization
Fertigation with vinasse
New varieties
2nd harvest

Cherubin, MR; Carvalho, JLN; Cerri, CEP; Nogueira, LAH; Souza, GM; Cantarella, H. (2021). Land Use and Management Effects on Sustainable Sugarcane-Derived Bioenergy. Land, 10.72.; Potential in Land Saving Techniques production in Brazil, EPE, 2024; Waclawovsky, AJ, Sato, PM, Lembke, CG, Moore, PH, Souza, GM (2010). Sugarcane for bioenergy production: an assessment of yield and regulation of sucrose content. Plant Biotechnology Journal 8(3), 263-276.

Observed changes brought about by bioenergy that contribute to food security: Recovery of degraded lands and increase in soil carbon

Soil quality

98% of sugarcane expansion has occurred primarily over degraded pastures and agricultural lands over the past 20 years

MM Guarenghi, DFT Garofalo, JEA Seabra, MMR Moreira, RML Novaes, NP Ramos, SF Nogueira, CA de Andrade. Land Use Change Net Removals Associated with Sugarcane in Brazil. Land 2023, 12(3), 584

Efficient land use: Second-crop corn production takes advantage of areas already cleared for soybeans, without the need for additional areas, which reduces environmental risks and expands sustainable land use: 95% of corn in Brazil for ethanol production is second-crop corn.

Biofuels produced in Brazil have very low emissions, one of the reasons is that we save on fertilizers, a major contributor to emissions.

Sugarcane production alternates with peanut and soybean cultivation in sugarcane reform areas. Corn is the intermediate crop planted after the main soybean crop.

This double-cropping system takes advantage of the nitrogen-fixing capacity of legume species (such as soybeans and peanuts), which brings nitrogen to the soil, reducing the need for fertilization.

Gurgel et al. (2024). Contribution of double-cropped maize ethanol in Brazil to sustainable development. Nature Sustainability, 1-12.; Silva et al., (2025).Meta-analysis of biofuels in emerging markets of Africa and Asia: green house gas savings and economic feasibility. Renewable and Sustainable Energy Reviews 213: 115465

Biofuels can reduce emissions by up to 84% when replacing gasoline and diesel.

For corn ethanol from Brazil, carbon intensity could be close to zero or negative

Observed changes brought about by bioenergy that contribute to food security

Agricultural infrastructure

Biofuels are integrated into food production

In 2024, Brazilian food fed the equivalent of
900 million people
(11% of the world population)

Brazil is the world's largest producer of
Soy
Coffee
Orange juice
Sugar

Brazil is the second largest producer
Chicken meat
Beef

Brazil is the world's largest exporter of
Soy
Coffee
Orange juice
Sugar
Chicken meat
Beef
Corn

Soybeans and corn produced in Brazil are the basis for the production of animal products, such as meat, milk, eggs, in different countries.

- Food
- Portion
- Fuels
- Energy

produced in parallel

The production of ethanol from sugarcane and corn in Brazil uses less than 1% of the national territory

Brazil preserves the world's largest area of native vegetation

Forest Code

Brazilian territory occupied 852 million 66% preserved with forests: 33% on rural properties + 33% preserved with integral conservation units, indigenous units, and others. Rural producers must maintain at least 20% of their own land with preserved or recovering native vegetation.
In the Amazon, the minimum preservation is 80%.

RENOVABIO

Life cycle analysis of the m roda crib + Eligibility criteria: Traceability of raw materials, prohibition of conversion of native vegetation, compliance with environmental legislation and compliance with agroecological zoning.

Agroicone, based on LAPIG (2022) for pasture; Mapbiomas (2023) 9th collection; Mapbiomas (2022) for protected areas (8th collection); Forest Code Observatory (2024) for vegetation on farms. Note*: Calculations for all categories are considered the best in 2024 since the Brazilian government does not provide official data.
*Includes undesignated public areas, public forests, settlements and quilombola areas; **Includes forestry, mosaics, etc.

Biofuel blending mandates in the global south

How can emerging markets contribute to the effort to increase biofuels 2.5-fold from today by 2030, displacing almost 800 Mt of fossil CO_2, or 10% of today's global transport emissions?

Potential and sustainability of biofuels in emerging markets

Additional biofuel production

45,7 billion
liters of biodiesel

64,7 billion
liters of ethanol

Required pasture conversion: 0.1% to 10.7%
GHG savings potential > 300 Mt CO2e per year

Developing countries with large populations and potential for high energy demand

Argentina, Brazil, China, Colombia, Ethiopia, Guatemala, India, Indonesia, Malaysia, South Africa, Thailand

47.0% of the world's population
27.0% of CO2 emissions from the transport sector

If this group of emerging economies achieved the same per capita carbon intensity from the transport sector as the OECD average, global emissions from the transport sector would more than double.

Souza et al., 2023. Biofuels in Emerging Markets. Potential for sustainable production and consumption. IEA Bioenergy Task 39.; Silva et al., (2024). Biofuels in Emerging Markets of Africa and Asia. IEA Bioenergy, 2024

Global Biofuels Alliance (GBA) Founding Document
"Recognize that biofuels are proven renewable, low carbon fuels that reduce greenhouse gas emissions, mitigate the effects of climate change, can be produced at scale, are commercially available and can spur domestic growth and develop trade opportunities"

- 29 countries are members of the Global Biofuels Alliance (GBA).
- 14 recognized international organizations are also part of the AGB, such as IEA, IRENA, World Economic Forum, World Bank, American Agricultural Bank (ADB), World Biogas Association, UNIDO, ICAO, International Energy Forum, Biofuture Platform and others.