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FEEDSTOCK AVAILABILITY FOR SUSTAINABLE AVIATION FUELS IN BRAZIL

CHALLENGES AND OPPORTUNITIES

2021 REPORT

OVERVIEW

The aviation industry can play a leading role in tackling the threat of climate change. Sustainable Aviation Fuels (SAF) can stimulate economic growth, develop rural livelihoods, and protect and enhance ecosystems — but the availability and location of the required feedstocks in Brazil are not yet well understood.

In this study, Roundtable on Sustainable Biomaterials (RSB) worked with Agroicone to map the availability and potential of bio-based residues for producing SAF in Brazil. The results presented here are intended to support decision-making processes — whether in industry or in the political sphere — towards embedding sustainable strategies in the aviation sector.

This study was developed as part of the Fuelling the Sustainable Bioeconomy (FTSB) project, powered by Boeing's Global Engagement Portfolio and led by RSB.

By providing guidance on the sustainability of alternative fuels, bringing together relevant stakeholders, and integrating the bioeconomy as a critical part of the just energy transition, Fuelling the Sustainable Bioeconomy will help to direct investment, policy, market development and further research in supporting the emergence of a truly sustainable bioeconomy.

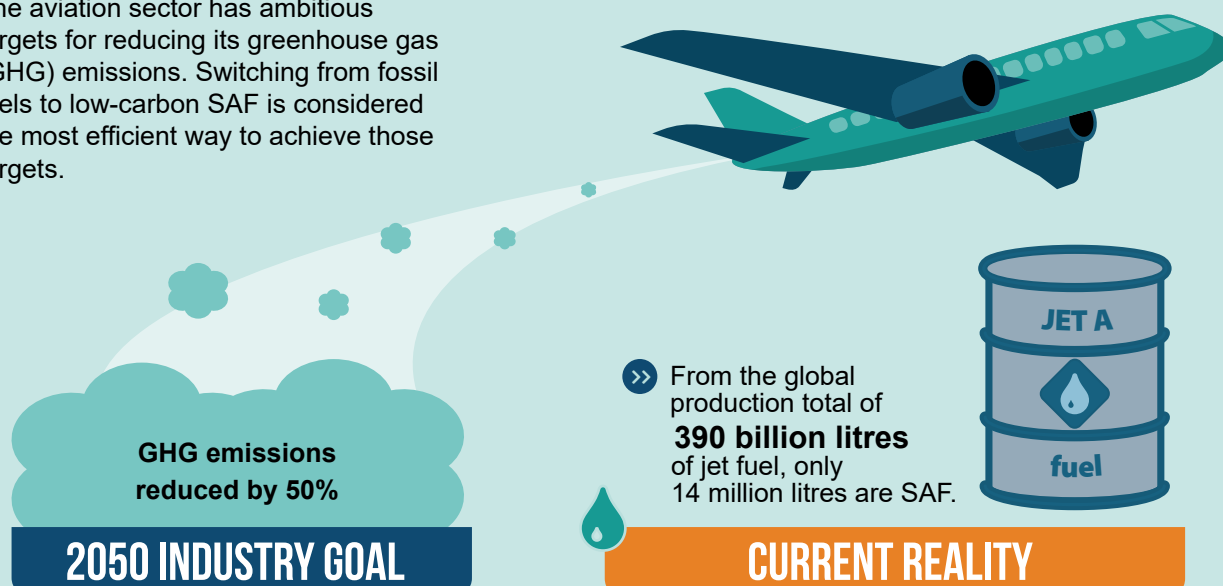
As this project progresses, further results will be published, including information on greenhouse gas (GHG) emissions and techno-economic assessments of different SAF production pathways.

For additional information about the FTSB project and RSB's work to support the aviation sector, visit www.rsb.org and explore our aviation pages.



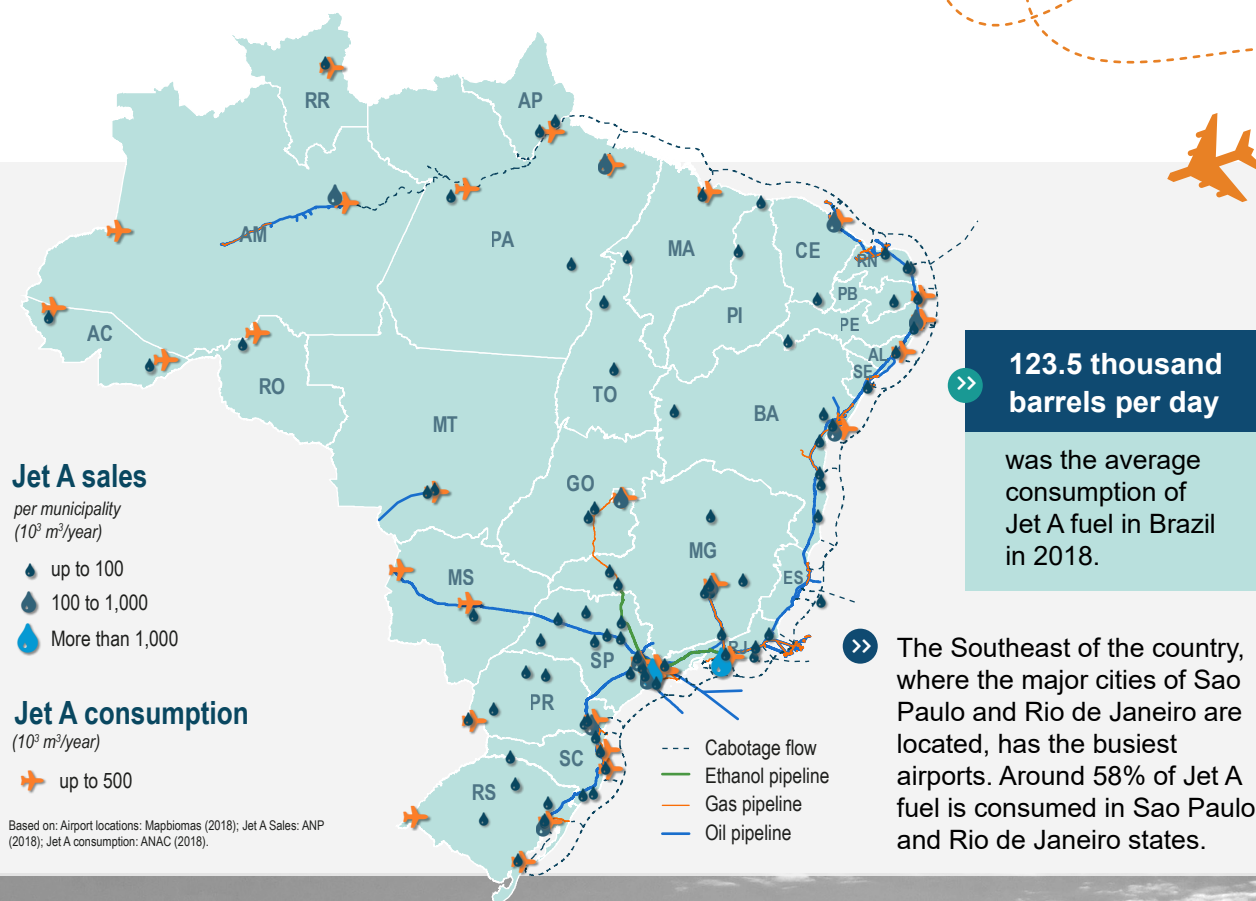
SAF: A PATH FORWARD FOR THE AVIATION SECTOR

- >> The aviation sector has ambitious targets for reducing its greenhouse gas (GHG) emissions. Switching from fossil fuels to low-carbon SAF is considered the most efficient way to achieve those targets.



JET A FUEL IN BRAZIL

» Brazil is extremely large, with a land mass covering 8.5 million km².



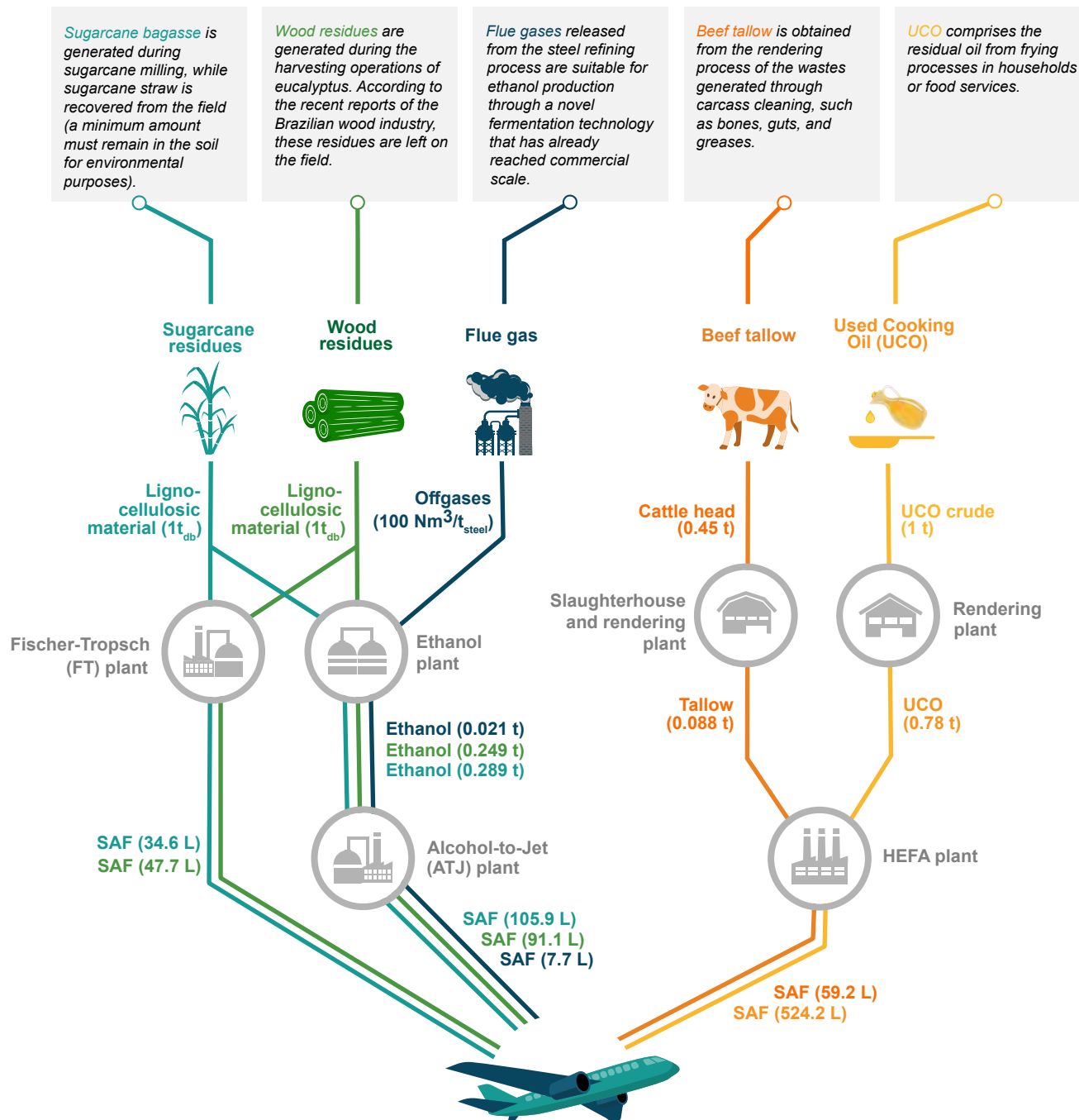
» SAF evaluation in Brazil

The SAF industry faces economic and environmental concerns, including about its economic feasibility when compared to fossil fuels and the impacts of land use change — which may result in significant GHG emissions. SAF obtained from residues may circumvent such challenges, since their cost and environmental impacts at the collection point could be close to zero.

This report presents the availability of residues and strategic locations for SAF production and consumption in Brazil.

Five residual feedstocks were combined in **seven different pathways** for SAF production, as presented below. All pathways comprise ASTM-approved drop-in fuels to be used with fossil kerosene (Jet A) in a maximum 50% blend volume basis.

FEEDSTOCKS AND PATHWAYS



» Methodology

Each pathway was evaluated by: i) mapping the feedstock's availability, ii) identifying key locations (i.e., conversion industries, oil refineries, airports, gas pipelines and harbours), iii) matching the feedstock supply with the processing industries, and iv) estimating the potential SAF production. Official databases were used to identify the location and potential of each feedstock. Production ratios for residual feedstocks and overall yields of the processing plants were collected from official reports, modelling data, and literature. When necessary, data validation was carried out with experts.

PATHWAYS OF INDUSTRIAL PLANTS



FT PLANT

For the FT pathway, the material is collected and sent to the industrial plant, where it is gasified into syngas. After the clean-up process, syngas goes to the Fischer-Tropsch reactor, where it is catalytically converted into liquid hydrocarbons, which are fractioned into SAF and liquid fuels.

Power surplus can be obtained as a co-product of the process. FT plants are, in general, self-supplied and do not depend on large volumes of other inputs such as hydrogen, meaning that they can conveniently remain near the feedstock source. Eventually, they could be constructed close to sugarcane mills to improve logistics.



ATJ PLANT

For the ATJ pathway, the residues are sent to second-generation ethanol (2G technology) plants based on enzymatic hydrolysis. Then, ethanol is sent to an ATJ plant, where alcohol molecules are dehydrated, oligomerised, and finally hydrogenated into suitable hydrocarbon chains for use as drop-in fuels.

In order to achieve low logistics costs and better infrastructure utilisation, 2G plants could be conveniently placed close to sugarcane mills. Due to the level of hydrogen consumption of the ATJ plants, it would be best to place them near oil refineries as well.



HEFA PLANT

Currently, the best-known process for SAF production is the hydroprocessed esters and fatty acids (HEFA) pathway, which has undergone large-scale testing.

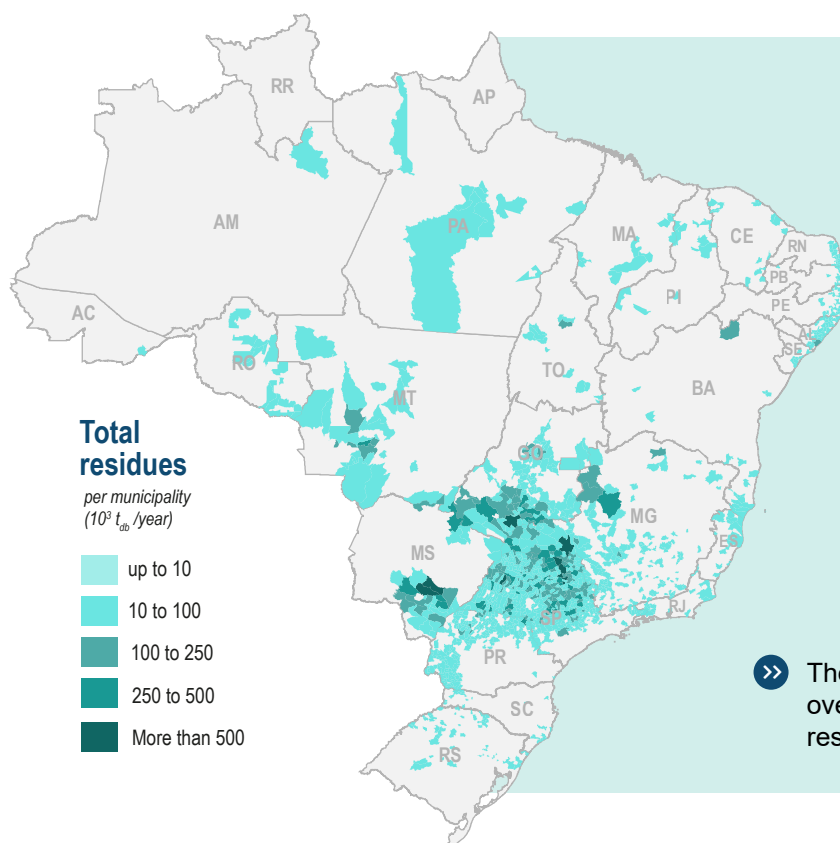
During the process, the oleaginous feedstock undergoes hydrotreatment with hydrogen in the presence of a catalyst. Unsaturated carbon bonds are saturated, and oxygen is removed. Subsequently, the hydrocarbon chains are hydrocracked in different ranges, isomerised, and fractioned — producing SAF as well as other products, such as diesel, naphtha, and propane.

Finally, the SAF is distributed to airports, where it is blended with fossil kerosene (Jet A).

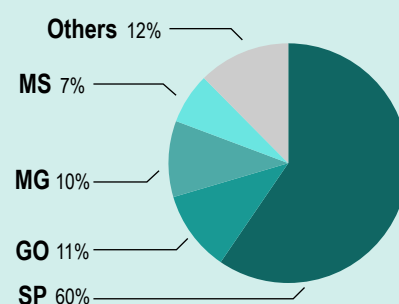


SUGARCANE RESIDUES

- » The most abundant sugarcane residues are bagasse and straw.



61 million tonnes_{db}
per year



- » The South-Central region accounts for over 90% of the currently available residues.

- » The sugarcane enters the sugarcane/ethanol mill, where it is crushed in order to separate the juice from the bagasse.

- » The juice is used to produce 1G ethanol, sugar, and other products and co-products. The bagasse (rich in lignocellulosic material) is typically burned in boilers to generate heat and power, and its availability is directly related to the plant's efficiency.

The availability of sugarcane residues, after removing those already in use for heat and power. Part of the straw (7.5 t_{db}/ha sugarcane) is left in the field for agronomic purposes.



Bagasse
31.4
million tonnes



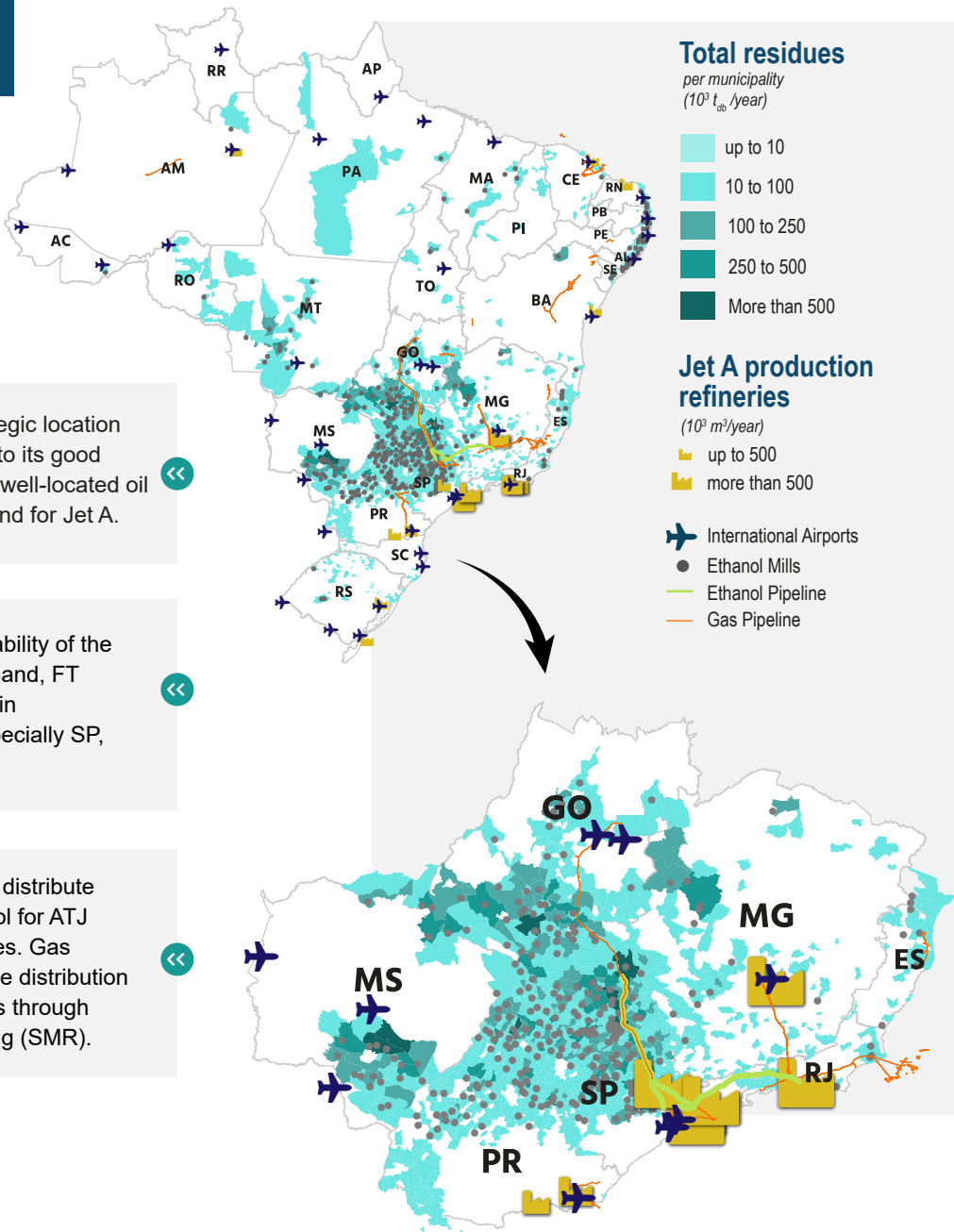
Straw
29.9
million tonnes

Selecting smart locations for SAF production

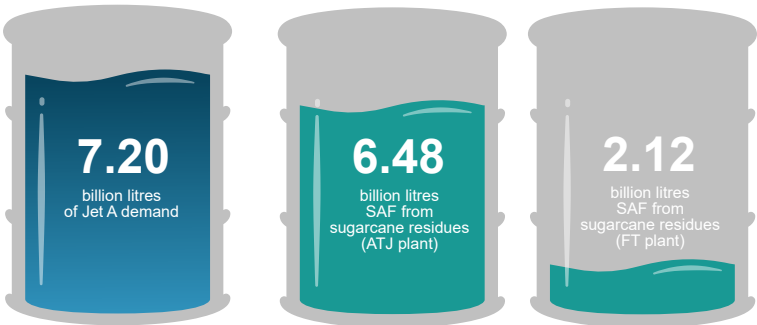
São Paulo state is a strategic location for the ATJ pathway, due to its good availability of feedstocks, well-located oil refineries, and high demand for Jet A.

Combining the high availability of the feedstocks and Jet A demand, FT pathway could be placed in South-Central region, especially SP, GO, or MS States.

An ethanol pipeline could distribute second-generation ethanol for ATJ plants close to oil refineries. Gas pipelines could support the distribution of hydrogen for ATJ plants through Steam Methane Reforming (SMR).



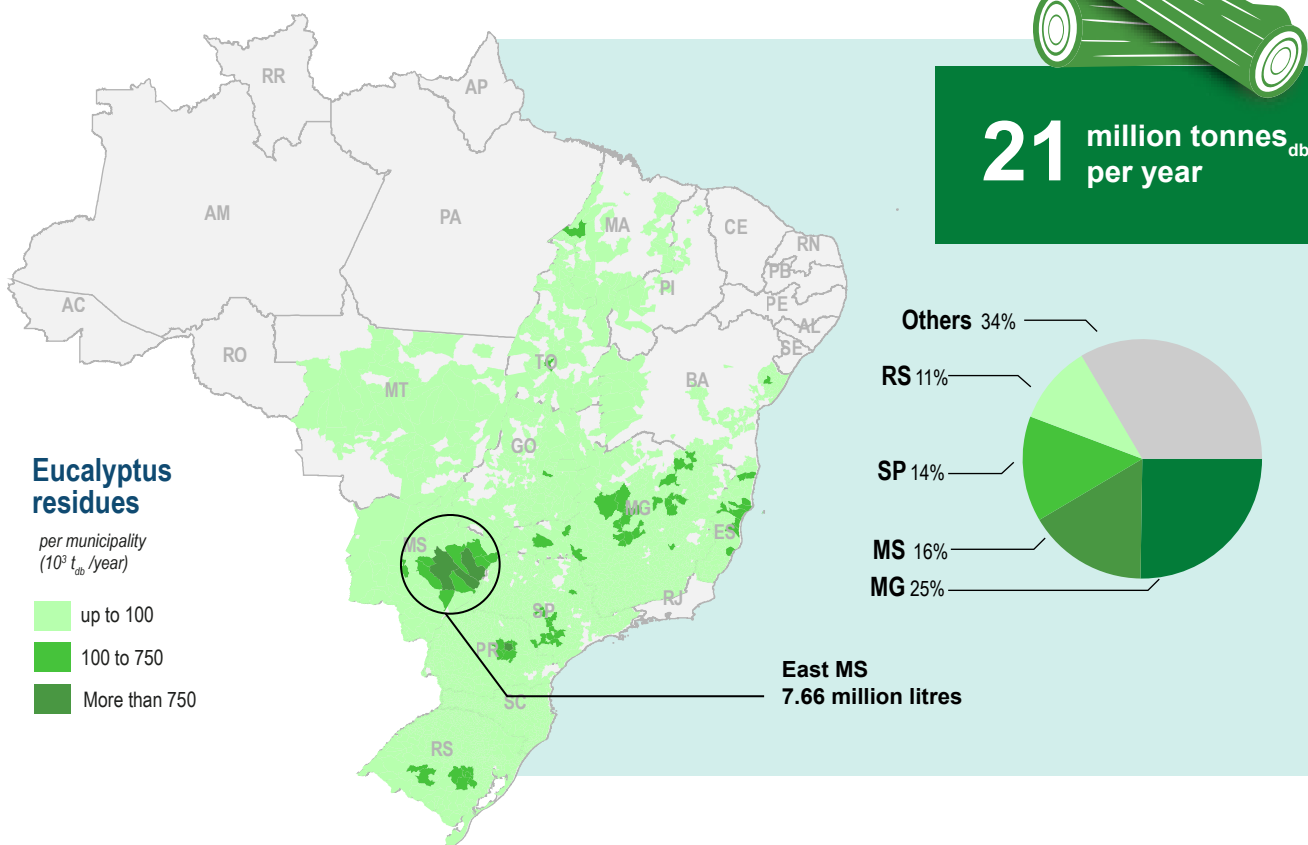
Potential Jet A production



The surplus bagasse and straw could supply 90% of the total demand for Jet A produced through the ATJ pathway, while through the FT path, sugarcane residues could supply approximately 30% of the total demand. Both paths present strong potential that could be significant in the Brazilian market.

WOOD RESIDUES

- » The most abundant wood residues come from eucalyptus plantations. This study worked on a base recovery rate of 50%.

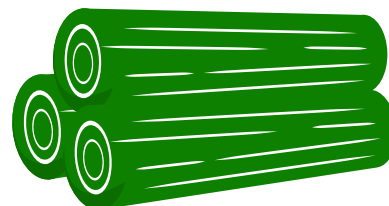


- » Wood residues are generated during harvesting of eucalyptus crops. The residues are collected, chopped, and transported to a stand-alone second-generation ethanol plant. In this plant, ethanol is obtained through steam explosion, followed by enzymatic hydrolysis.

- » Energy demand for 2G ethanol plant is supplied by processing residues burned in a cogeneration system, which also generates surplus electricity. The ethanol is then sent to an ATJ plant, where the molecules are converted into SAF.

Only residues from eucalyptus crops — which represent around 70% of the planted forest areas in Brazil (IBA, 2019) — are considered.

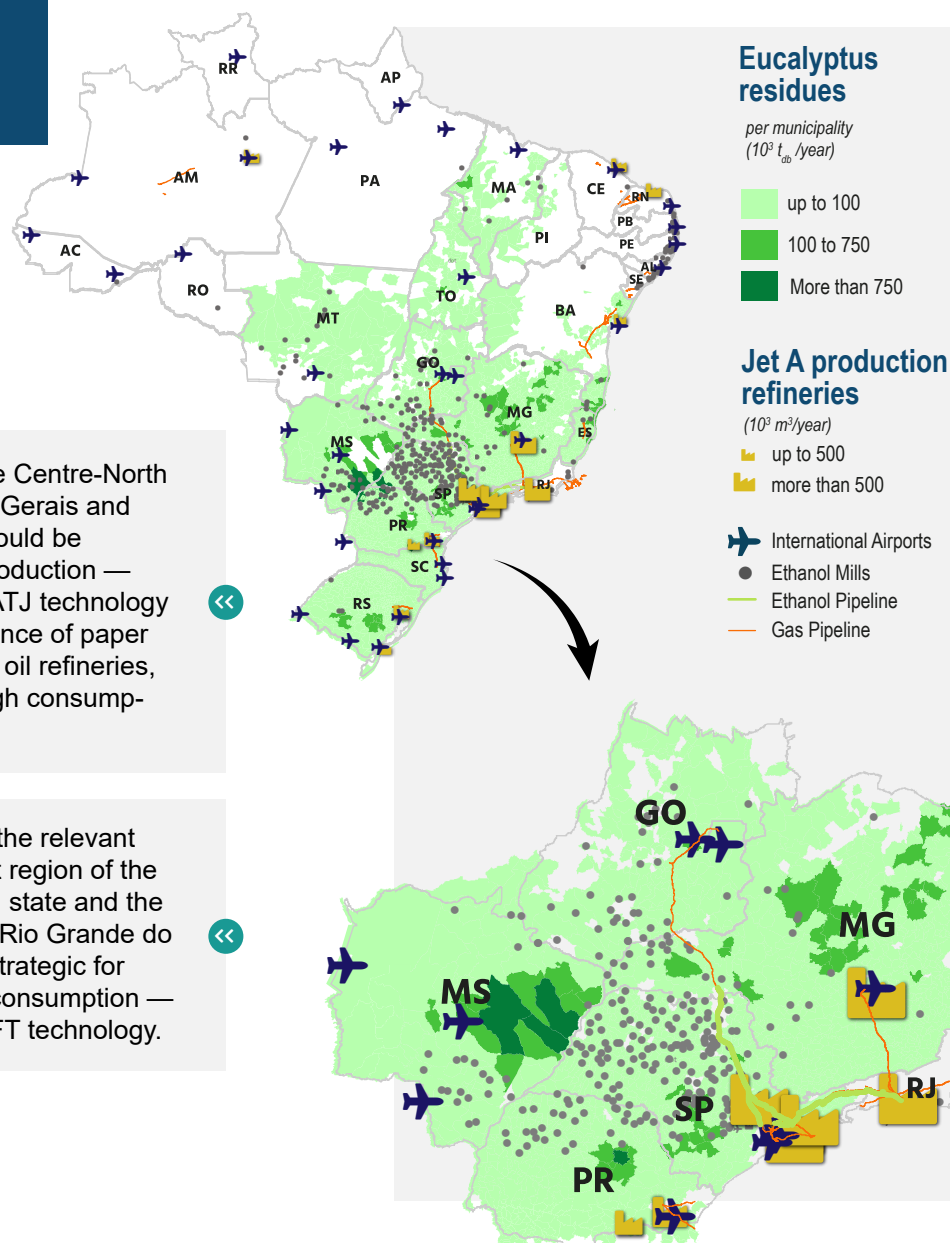
Eucalyptus generates around 0.167 tonnes of residues (dry basis) per cubic metre during the harvesting cycle.



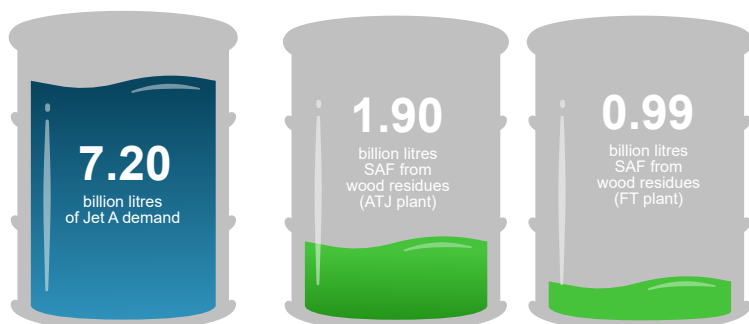
Selecting smart locations for SAF production

The feedstock in the Centre-North region of the Minas Gerais and São Paulo states would be strategic for SAF production — especially through ATJ technology — due to the presence of paper and pulp industries, oil refineries, and airports with high consumption levels.

On the other hand, the relevant potential of the East region of the Mato Grosso do Sul state and the South region of the Rio Grande do Sul state could be strategic for supplying regional consumption — especially through FT technology.



Potential Jet A production

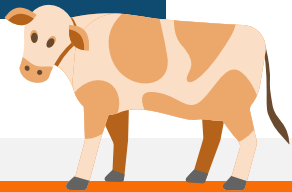


Through ATJ and FT technologies, total potential wood residues could supply, respectively, 26% and 14% of the total Jet A consumed in Brazil in each year.

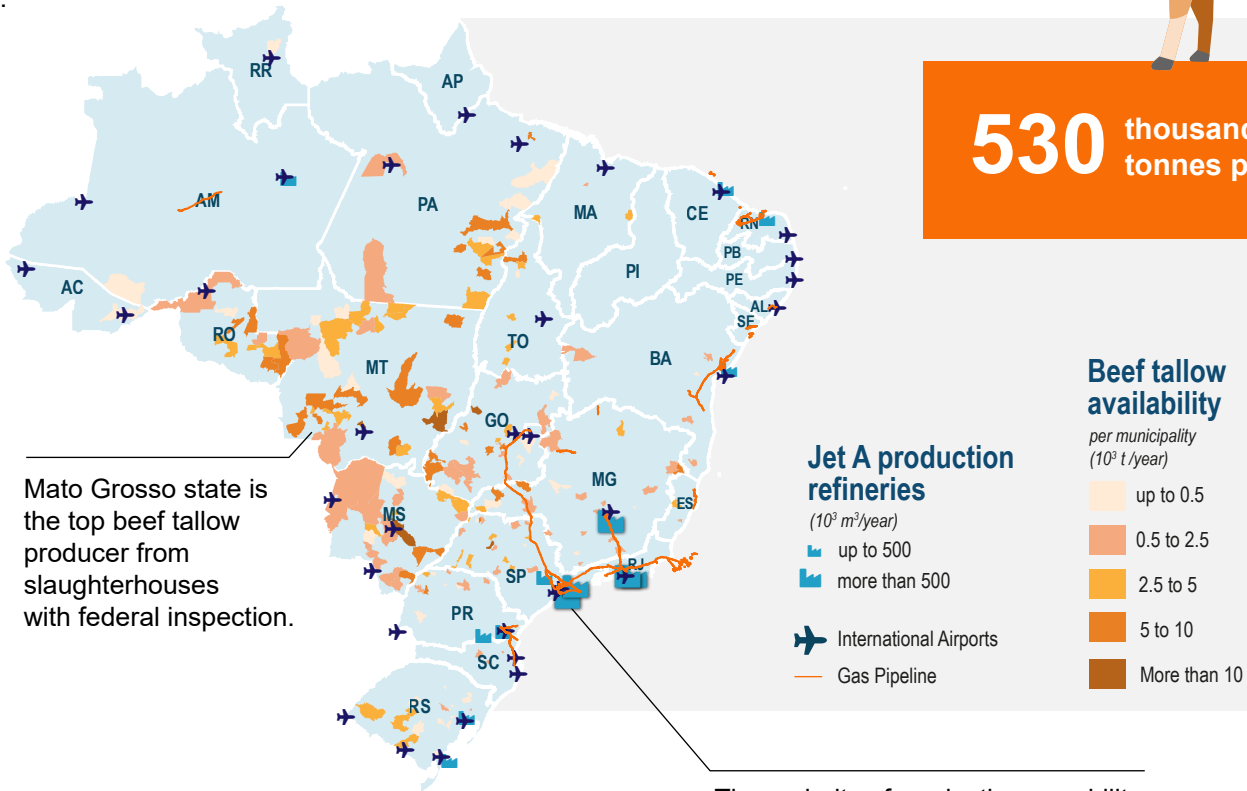
Wood residues could easily supply the fossil kerosene consumption from the states of Minas Gerais (in 1.5-fold) and Mato Grosso do Sul (in 9.6-fold) or provide fuel volumes equal to those consumed in Rio Grande do Sul and Santa Catarina.

BEEF TALLOW

>> Beef tallow is mostly used in Brazil for biodiesel production (around 700 thousands per year).

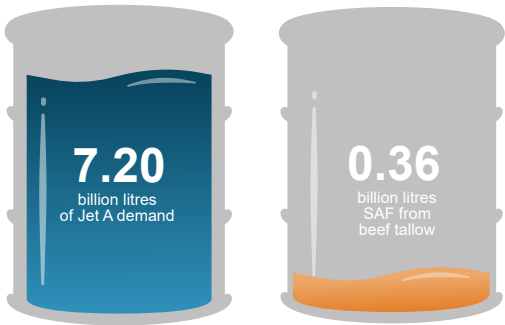


530 thousand tonnes per year

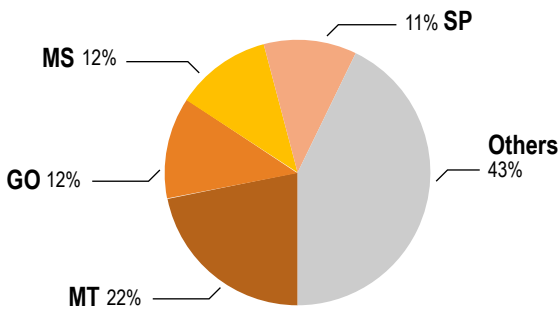


The majority of production capability and Jet A consumption is located on the coastlines in the Southern region of Brazil.

Potential Jet A production



>> Beef tallow from slaughterhouses with international quality standards could supply around 5% of the total demand of Jet A in Brazil.



>> Beef tallow is processed in HEFA plants, which require large volumes of hydrogen and should be located close to oil refineries.

>> Building HEFA plants close to gas pipelines, for hydrogen production, could supply regional consumers — including international airports — near areas with high feedstock availability, such as Mato Grosso do Sul.

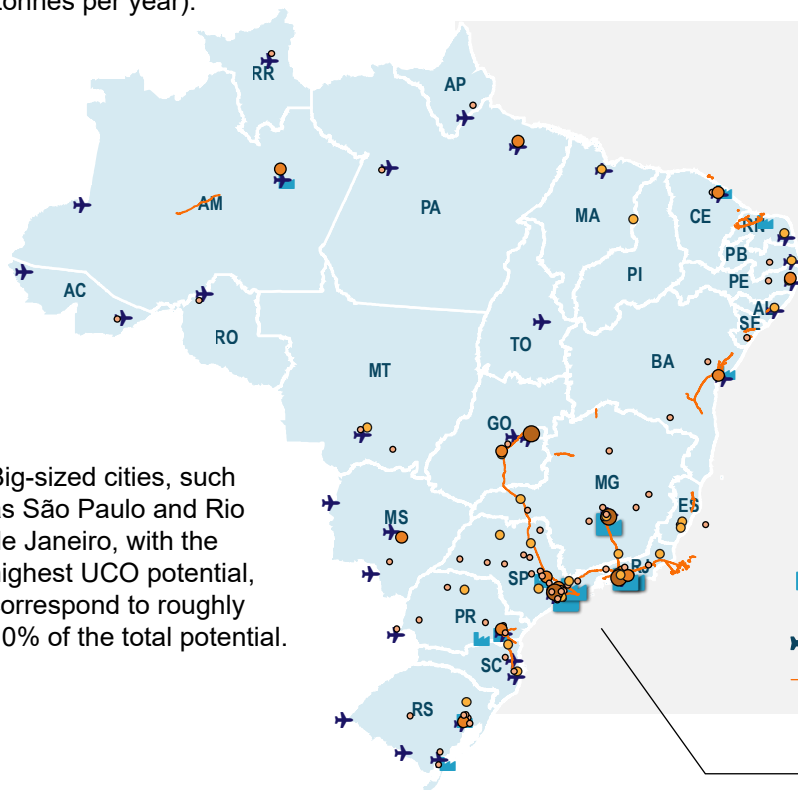
USED COOKING OIL

- » Used cooking oil (UCO) that is vegetable oil-based can be recovered from both households (35 thousand tonnes per year) and food services (177 thousand tonnes per year).



213 thousand tonnes per year

- » Big-sized cities, such as São Paulo and Rio de Janeiro, with the highest UCO potential, correspond to roughly 10% of the total potential.



Jet A production refineries

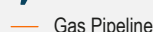
(10³ m³/year)

■ up to 500

■ more than 500



International Airports



Gas Pipeline

Used cooking oil (UCO)

per municipality
(10³ t/year)

○ 200 to 500

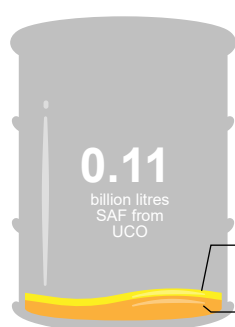
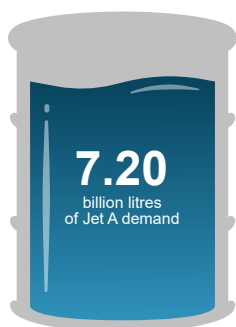
○ 500 to 1,000

○ 1,000 to 2,500

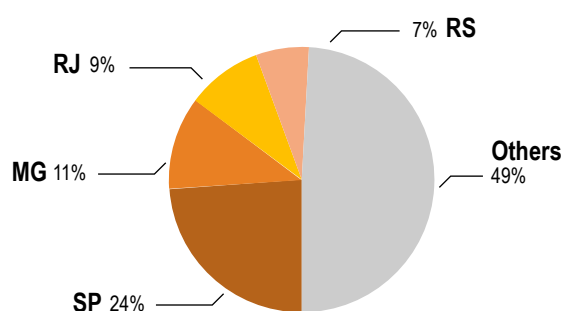
○ More than 2,500

The Southeast region (SP, RJ, MG and ES states) represent approximately 55% of the total availability of UCO.

Potential Jet A production



0.02 billion litres from households
0.09 billion litres from food services



» A total of between 35 and 211 thousand tonnes of UCO could be used to supply between 0.3% and 1.5% of the total Jet A consumed in Brazil.

» More than 3 billion litres of oil are consumed in Brazil for frying processes and less than 10% is recycled.

» Brazil does not have a well-developed supply chain for collecting UCO, but the number of initiatives to develop collections and take advantage of the low cost of procurement and potential environmental benefits is increasing.

FLUE GAS

- >> This mapping considers a novel technology of CO-rich gas fermentation to produce ethanol, which has already reached commercial scale.



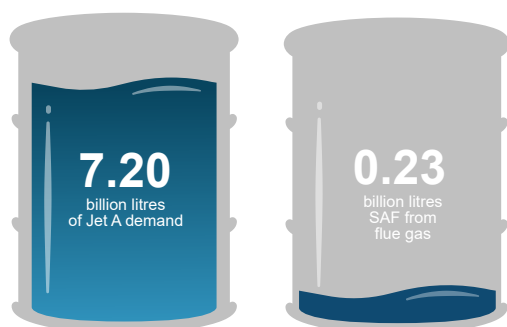
2823 millions
Nm³ per year*

*in standard pressure and temperature

- >> Steel-refining processes through Basic Oxygen Furnace (BOF) technology would be suitable for the novel fermentation process (such as that of LanzaTech).

- >> In Brazil, around 85% of crude steel is produced by 12 steel mills employing BOF technology.

Potential Jet A production



- >> The total use of flue gases for SAF production could supply roughly 3% of the total demand for kerosene in Brazil.

Jet A production refineries

(10³ m³/year)

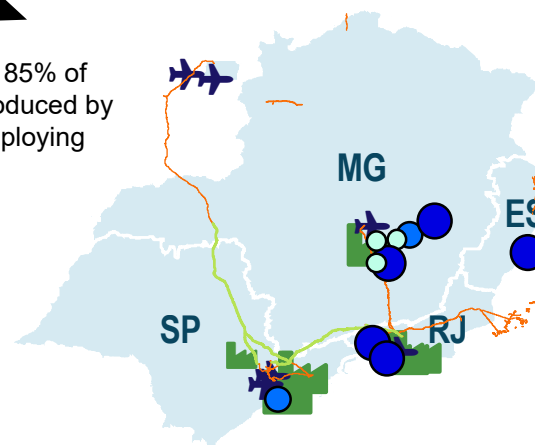
- up to 500
- more than 500

- International Airports
- Ethanol Pipeline
- Gas Pipeline

Offgases

per municipality
(10⁶ Nm³/year)

- up to 75
- 75 to 250
- More than 250

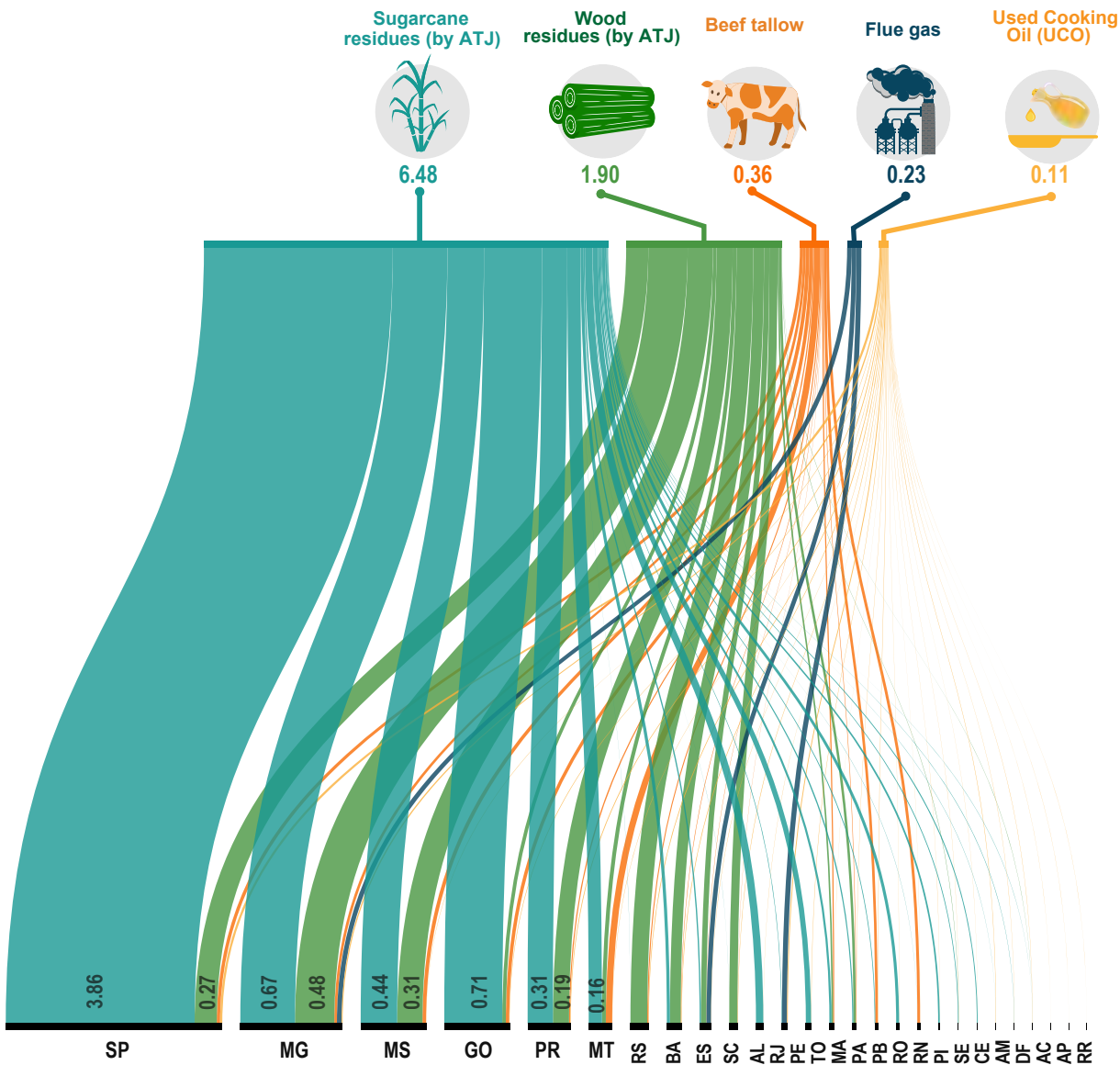


- >> Considering the availability of flue gases, Minas Gerais, Rio de Janeiro, and Espírito Santo states could be responsible for 35%, 27%, and 24% (respectively) of potential total SAF production from this pathway.

- >> Around 60% of the flue gases from the steel refining process are currently being used in Brazil for supplying the energy demand of steel mills. Switching to ethanol production could be a strategic option for the steel industry but would require an analysis of opportunity costs.

SAF PRODUCTION POTENTIAL

» Potential production of SAF in Brazilian states from each feedstock (in billions of litres).



» Feedstock Potential: Sugarcane and Wood Residues

Sugarcane and wood residues could respectively supply 90% and 30% of the total demand for Jet A through an ATJ pathway; or 30% and 14% respectively through FT technology. Considering the effective availability of these feedstocks, and the approved maximum blends with Jet A (50% in volume basis), the SAF produced from these residues in Brazil could supply the current demand, and support an export market.

» Regional Potential: Southeast Brazil

São Paulo state combines high feedstock availability and demand for Jet A with the existence of oil refineries to supply the hydrogen for the ATJ path. However, it would depend on the optimisation of the sugarcane mills to provide a surplus generation of residues, since they are currently used for supplying their own energy. Wood residues could also be explored in FT technology in the states of Mato Grosso and Rio Grande do Sul for local consumption.

ABOUT RSB

The Roundtable on Sustainable Biomaterials (RSB) is a global, multi-stakeholder, independent organisation that drives the development of a bio-based and circular economy on a global scale through sustainability solutions, certification, and collaborative partnerships.



With credible solutions, global expertise, partners across the spectrum from government to industry, academia, and NGOs, and an extremely robust approach to sustainability, RSB is the partner of choice for the aviation industry as it seeks to fulfil its global commitments to greenhouse gas reduction while also ensuring social development and environmental protection.



RSB is a member-led organisation which represents a worldwide movement of businesses, NGOs, academics, governments, and UN organisations that have demonstrated their commitment to the development of the sustainable bioeconomy by working together to create our most-trusted Standard.



The RSB Standard is the strongest and most trusted of its kind, recognised as such by the World Wildlife Fund (WWF), International Union for Conservation of Nature (IUCN) and Natural Resources Defense Council (NRDC). RSB certification for SAF has been endorsed by aviation groups such as the Aviation Transport Action Group (ATAG) and the International Coalition for Sustainable Aviation (ICSA).

ABOUT AGROICONE

Agroicone is a leading Brazilian agricultural analysis firm that produces studies and economic assessments for the agribusiness sector, governments, private companies and NGOs in Brazil and abroad. Agroicone is well known for its ability to conduct dialogues and complex arrangements, always grounded on strong technical content.

Agroicone provides analysis regarding food security, climate change, land use, energy, territorial intelligence, international trade negotiations, public policies, certifications, environmental compliance, remote and satellite sensing technology, scenario-building, and using tools for sustainability evaluation and ecosystem regulation, as well as development of quantitative instruments to design long-term scenarios.

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