SUSTAINABLE AVIATION FUELS IN BRAZIL

Future Perspectives

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

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MINISTÉRIO DE MINAS E ENERGIA

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Disclaimers

This publication provides information on the sustainable aviation fuel (SAF) supply from different technological routes, based on studies by the Energy Research Office (EPE).

The document is for informational purposes and aims to support the planning of the national energy sector. It is important to note that any decisions regarding direction, such as the formulation of public policies, strategic guidelines, investment decisions, or business strategies, must be made by other public and private institutions.

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Public Values

EPE conducts studies and research to support the formulation, implementation, and evaluation of Brazil's energy policy and planning.

With this study, EPE enhances transparency and reduces information asymmetry by presenting data and facts that can support discussions about the efforts towards energy transition in Brazil.

In this report, EPE analyzes market conditions, public policies, and international agreements related to sustainable aviation fuels, creating projections for the evolution of demand for this biofuel, thereby supporting the decision-making process of interested stakeholders.

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Context

Climate change calls for global actions to mitigate greenhouse gas emissions (GHG).
The challenge is even greater for hard-to-abate sectors, such as aviation, which accounted for 2% of global emissions in 2022

It is estimated that the demand for aviation kerosene will continue to grow, and consequently, GHG emissions, even with improvements in aircraft efficiency and systemic gains

Sustainable Aviation Fuels (SAF) constitute one of the primary measures to mitigate emissions from the sector

Brazil, with its experience in biofuel production and availability of renewable feedstocks, can assume a leadership role in the renewable fuels market and accelerate the transition to a sustainable economy

The International Civil Aviation Organization (ICAO) has set emissions reduction targets for the sector and aims to achieve net-zero carbon emissions by 2050.

Brazil is also developing a program for the sector - the ProBioQAV.

EPE conducted this study to assess the possible pathways Brazil can take in pursuit of these objectives

What is SAF?

Sustainable Aviation Fuels (SAF) are derived from **renewable** resources, such as vegetable oils, animal fats, lignocellulosic biomass, sugars and starch, residual gases, among others.

Due to their properties being similar to those of aviation fossil kerosene and compatible with existing infrastructure, SAFs are considered ***drop-in*** fuels under the blending conditions established by regulatory bodies.

The use of SAF contributes to the reduction of CO_2 emissions generated by aviation, a sector that is difficult to decarbonize.

History and Legislation

History

- **2014** – Aviation is responsible for 2% of global CO_2 emissions.
- **2016** – ICAO Assembly adopts CORSIA to address aviation emissions.
- **2017** – PL Nbr. 9,321 – Bill for the creation of the "National Biojet Fuel Program".
- **2018** – Start of preparatory actions for CORSIA. Aviation responsible for 2.4% of global CO_2 emissions.
- **2019** – ANAC – Monitoring CO_2 emissions on international flights with stops in Brazil.
- **2020** – CORSIA Deadline for the collection of sector emissions data in each country.
- **2021** – Law No. 14,248/2021 – National Biojet Fuel Program. Future Fuel Program – Technical Subcommittee ProBioQAV. Start of the CORSIA pilot phase.
- **2023** – End of the CORSIA pilot phase.
- **2024** – Start of the first phase of CORSIA – Voluntary participation.
- **2026** – End of the first phase of CORSIA.
- **2027** – Start of the second phase of CORSIA. Expected start of SAF plant operations in Brazil – Mandatory phase.
- **2030** – Aviation sector emissions equal to the baseline year.

CORSIA

(Carbon Offsetting and reduction scheme for international aviation)

International Civil Aviation Organization (ICAO)

- Efforts to reduce greenhouse gas (GHG) emissions from aviation.

ASPIRATIONAL GOALS

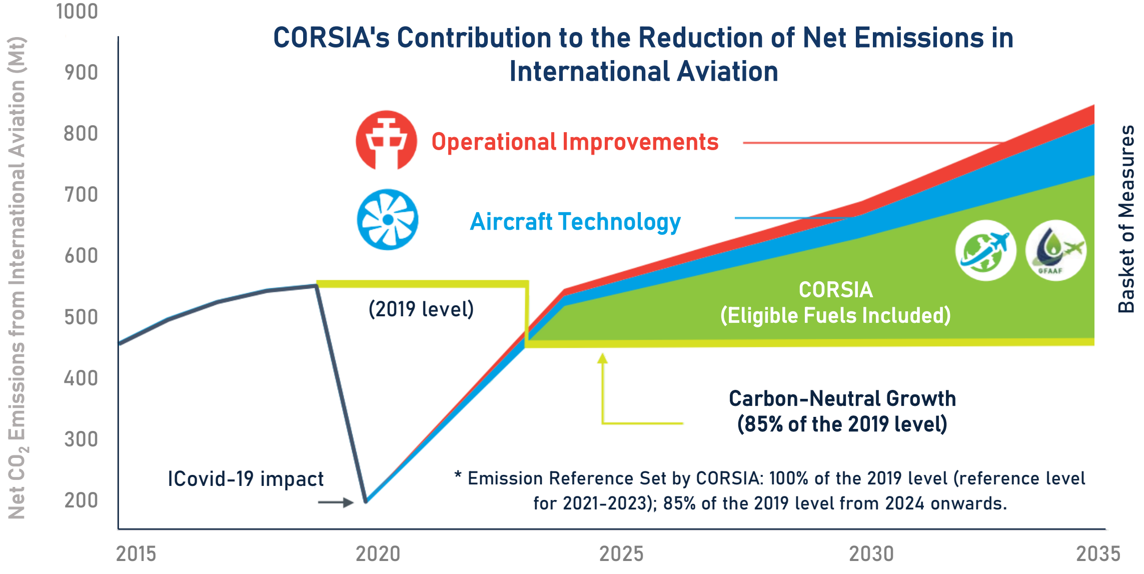
- Annual improvement of 2% in energy efficiency until 2050.
- Carbon-neutral growth starting in 2020.
- Long-term aspirational goal of net-zero carbon emissions by 2050.

MEASURES

- Technological and operational improvements.
- Use of sustainable aviation fuels.
- CORSIA

Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)

- A market-based mechanism designed to reduce and offset greenhouse gas (GHG) emissions from international aviation[1].



1 Baseline: 100% of the 2019 level for 2021-2023 and 85% of the 2019 level from 2024 onwards, due to the COVID-19 pandemic in 2020.

Source : 1, 2

CORSIA

How CORSIA works?

CORSIA has been divided into three phases – two initial voluntary phases (2021-2023 and 2024-2026) and a mandatory phase starting in 2027.

INITIAL PHASES

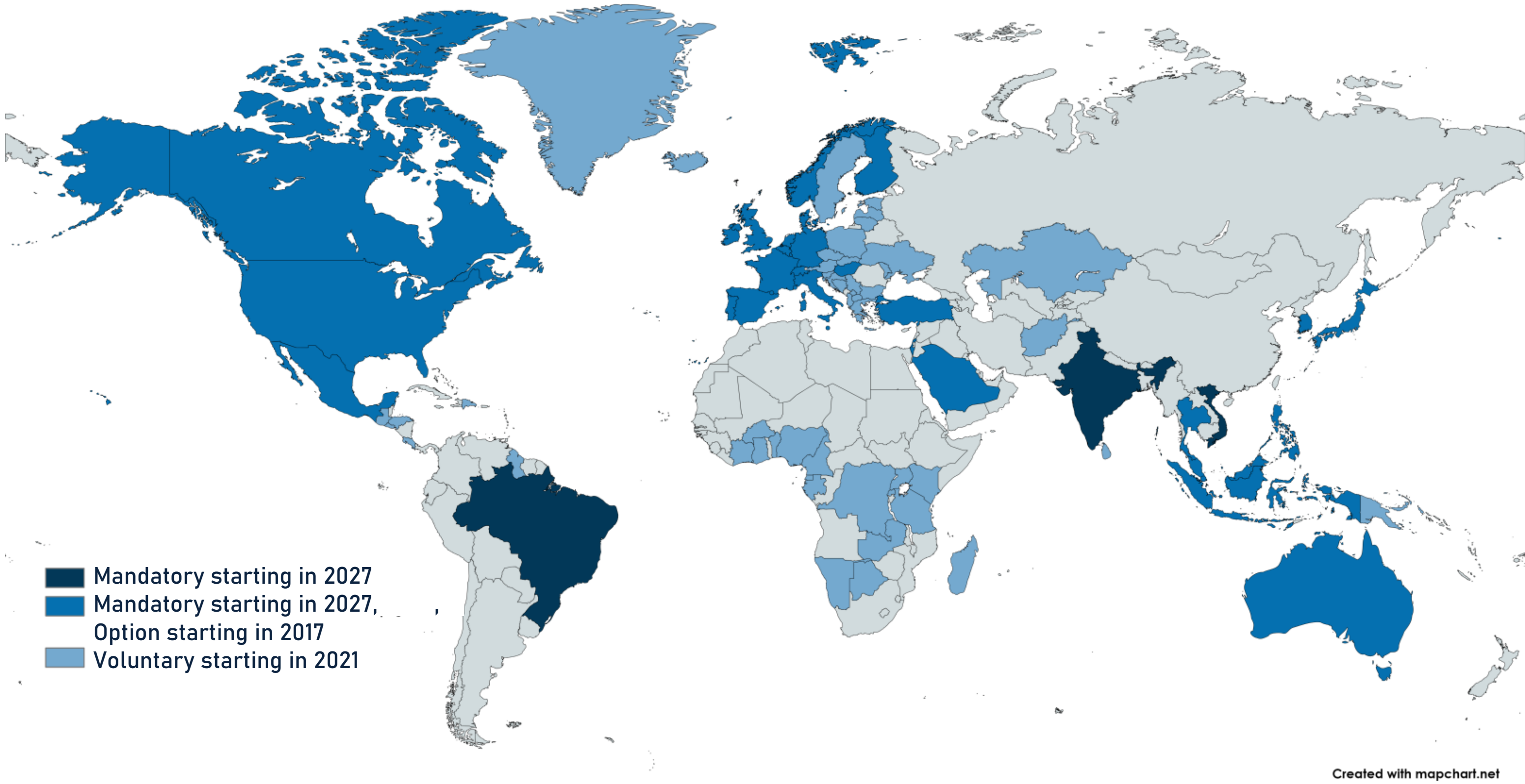
Applicable only to international flights between countries that volunteered, meaning that international flights to and from countries that did not volunteer will be exempt.

MANDATORY PHASE

It will cover all international flights (including those traveling to or from countries that did not volunteer for the initial phases). However, there will be some small exceptions:

- Least developed countries. However, these countries may volunteer if they wish.
- Countries with a very small share of international traffic.

Countries participating of CORSIA (2023)



Source : 2

Other SAF initiatives around the world*

United Kingdom
Public policy under development with the goal of introducing targets starting in 2025 and achieving at least 10% SAF usage by 2030.

United States of America
The goal is to increase SAF production by at least 3 billion liters per year by 2030.

France
It defined a SAF *roadmap* with consumption targets of 2% by 2025, 5% by 2030, and 50% by 2050.

Spain
The goal is to supply 2% SAF by 2025. New biorefineries are being planned, with a special focus on waste.

Netherlands
The SAF roadmap is under development with a mandate at the national or European Union level.

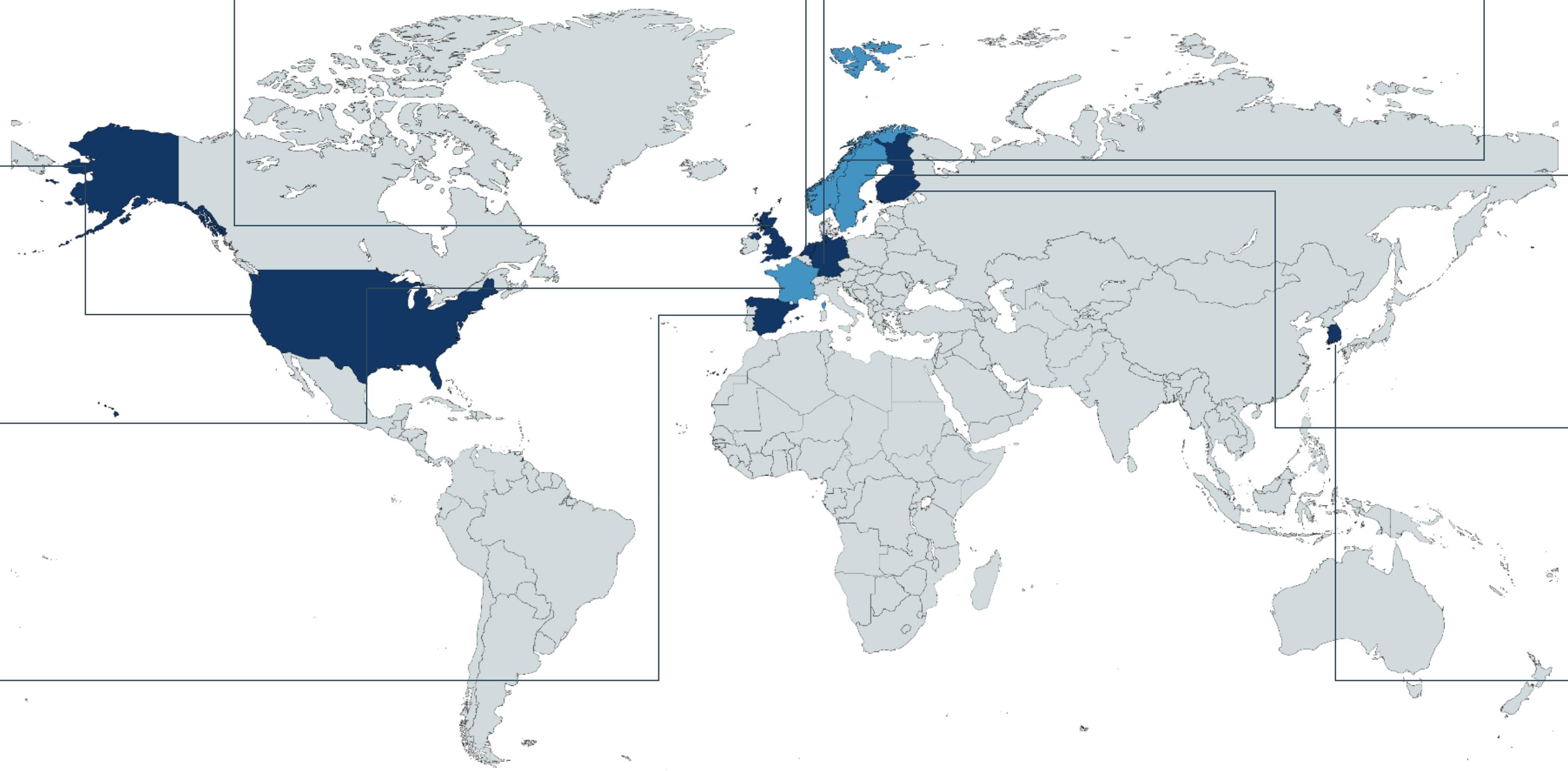
Germany
Plans to introduce SAF mandate in 2026, focusing on the Power to Liquids (PtL) route.

Norway
In 2020, Germany introduced SAF mandate of 0.5%, with the ambition to increase it to 30% by

Sweden
Implemented a volumetric SAF mandate of 1% in 2021, with the goal of reaching 30% by 2030.

Finland
Intention to implement a 30% SAF mandate by 2030.

South Korea
It will establish quality standards for SAF in 2024 and plans to begin a blending mandate in 2026.



Legend
- SAF mandate under analysis.
- SAF mandate implemented.

Created with mapchart.net

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- Illustrative and not exhaustive map.

Source : 3, 4, 5.

National panorama - Fuel of the Future Program

The Fuel of the Future Program, established in 2021 by the CNPE, was created to propose measures to increase the use of sustainable fuels across all modes of transportation, aiming at the decarbonization of the national transport energy matrix and improving the energy efficiency of vehicles.

The Technical Committee on Fuel of the Future Program was formed to develop the program through specific subcommittees for each topic.

- In 2023, the Program gave rise Bill 4516/2023[1] to which aims to:
  - Establish the National Sustainable Aviation Fuel Program – ProBioQAV.
  - Establish the Programa Nacional de Diesel Verde – PNDV (National Green Diesel Program);
  - Modify the maximum and minimum blending limits of anhydrous ethanol in gasoline C;
  - Regulate and supervise the production and commercialization of synthetic fuels;
  - Regulate and supervise Carbon Capture and Storage (CCS);
  - Integrate public policies on mobility and biofuels – RenovaBio and Rota 2030, PBEV.

[1] Still under discussion until the publication of this document.[8]. On October 8, 2024, the bill was sanctioned in Law No. 14,993/2024.

Source : 6, 7, 8

National panorama - ProBioQAV

OBJETIVE
Incentivize research, production, commercialization, and energy use of SAF in the Brazilian energy matrix.

Application
Starting in 2027, air operators will be required to reduce GHG emissions in their domestic operations using SAF.

ACCOUNTING
Life Cycle Analysis (LCA) of the well-to-wheel for each technological route of SAF production.

Minimum Annual Percentage Reduction of GHG Emissions

2027	1%
2028	1%
2029	2%
2030	3%
2031	4%
2032	5%
2033	6%
2034	7%
2035	8%
2036	9%
2037	10%

- Calculation base = volume of emissions from domestic operations carried out by the airline in the corresponding year, assuming the use of fossil fuel.
- Alternative means may be accepted to meet the target.
- CNPE may alter the percentages at any time for a justified public interest reason.

Source : 6, 7, 8

Technological Routes & Feedstocks

Approved conversion processes

Primary feedstocks	Conversion processes approved by ASTM D7566 and ANP Res. 856/2021		Blend limit[1]
Lipids: Oilseeds, algae, and residual oils and fats	**HEFA**	Hydroprocessed esters and fatty acids	**50%**
Lipids: Oilseeds, algae, and residual oils and fats	**HC-HEFA**	Hydrocarbon-Hydroprocessed Esters and Fatty Acids	**10%**
Lipids: Oilseeds, algae, and residual oils and fats	**CHJ**	Catalytic hydrothermolysis jet fuel	**50%**
Lignocellulosic biomass: Eucalyptus, pine, elephant grass, sugarcane bagasse	**FT-SPK**	Fischer- Tropsch Synthetic Paraffinic Kerosene	**50%**
Lignocellulosic biomass: Eucalyptus, pine, elephant grass, sugarcane bagasse	**SPK-A**	Synthetic Paraffinic Kerosene with Aromatics	**50%**
Lignocellulosic biomass; Sugars and starches: Sugarcane, corn, beetroot, cassava	**SIP**	Synthesized iso-paraffinic	**10%**
Lignocellulosic biomass; Sugars and starches: Sugarcane, corn, beetroot, cassava	**ATJ**	Alcohol to Jet	**50%**

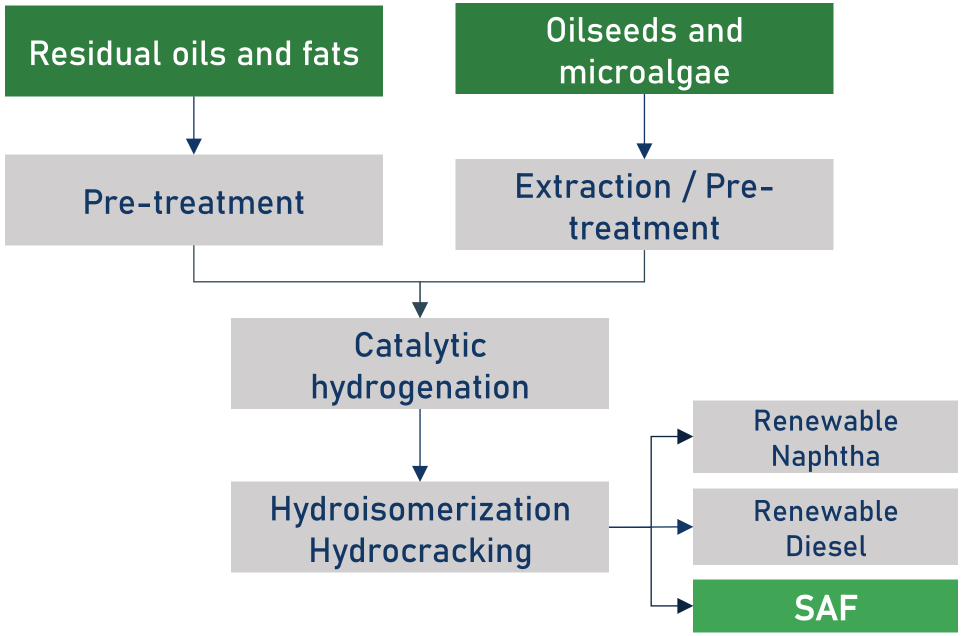
[1] Blend limit: maximum percentage allowed for blending with fossil aviation kerosene in ANP resolution

Source: 9, 10

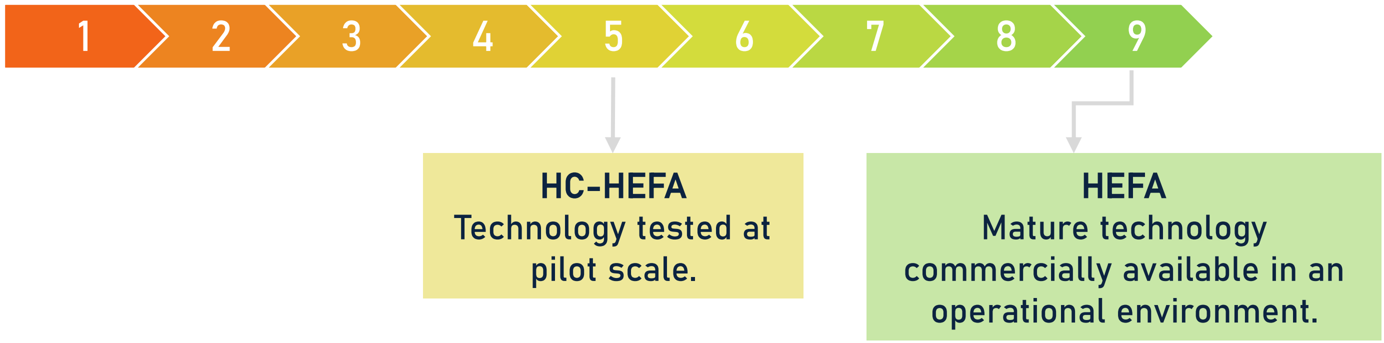
Technological Routes | HEFA and HC-HEFA

The SAF production through the HEFA and HC-HEFA routes involves the conversion of triglycerides into renewable hydrocarbon chains through reactions that use hydrogen and catalysts.

- The catalytic hydrogenation stage involves the processes of hydrodeoxygenation, decarboxylation, and decarbonylation, which aim to remove unsaturations, oxygen, and undesirable compounds from the oils to increase energy density and storage stability.
- The hydroisomerization and hydrocracking stages aim to shorten and branch the hydrocarbon chains in order to meet some of the criteria established by ASTM, such as the cloud point and cold flow properties.



Technology Readiness Level (TRL)



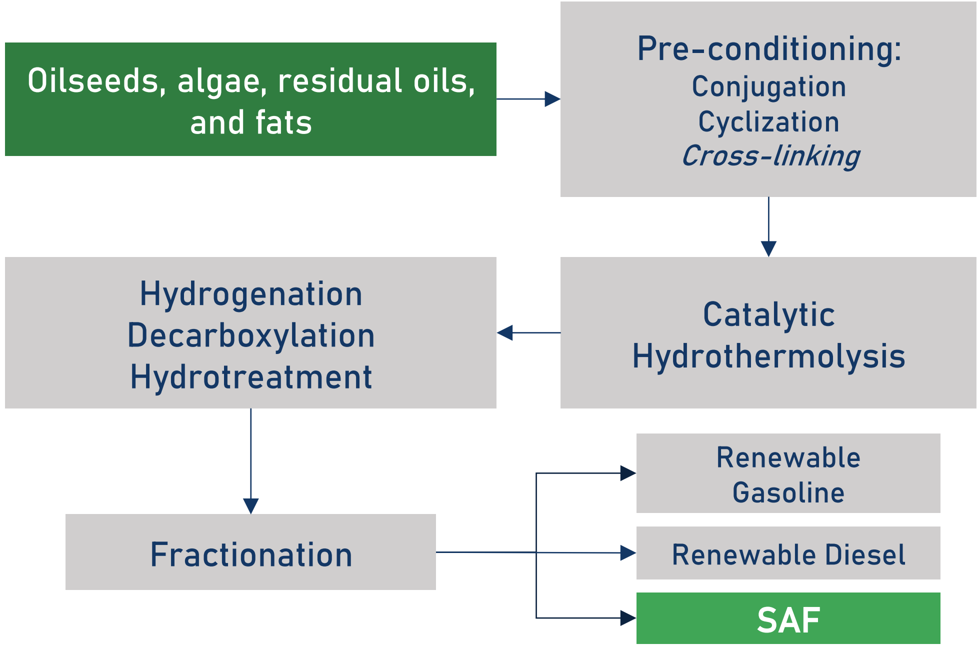
The HC-HEFA route is a variation of HEFA that uses bioderived hydrocarbons. Currently, only oil obtained from the alga *Botryococcus braunii* is recognized in this classification. The HC-HEFA route was certified by ASTM D7566 in 2020, and its maximum blending percentage is 10%.

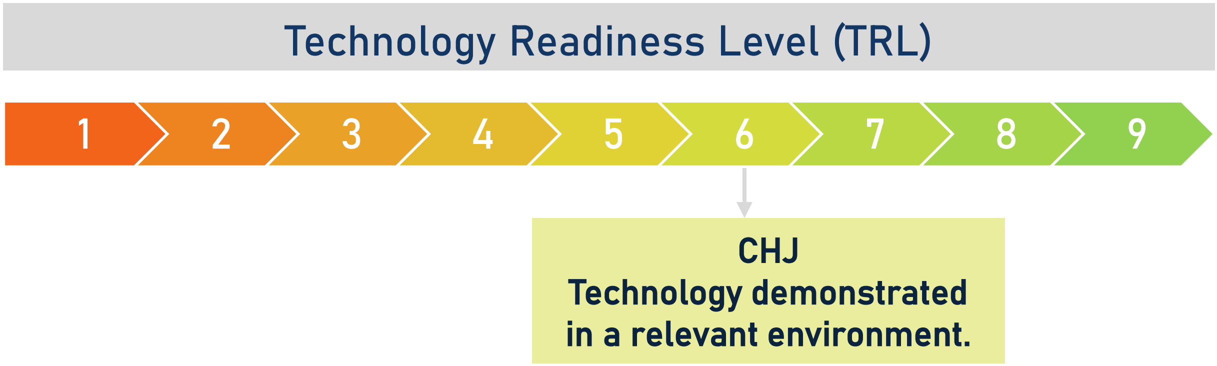
Source: 11, 12, 13, 14

Technological Routes | CHJ

In the CHJ route, the lipid feedstock undergoes a pre-conditioning stage, followed by catalytic hydrothermolysis and an additional refining stage to produce synthetic jet fuel.

- The pre-conditioning stage includes conjugation, cyclization, and cross-linking reactions to alter the fatty acid structure of triglycerides, thereby improving the efficiency of the process.
- In the hydrothermal reactor, the pre-conditioned oil reacts with water under supercritical conditions to convert triglycerides into a mix of hydrocarbons through cracking, hydrolysis, decarboxylation, dehydration, isomerization, recombination, and/or aromatization reactions.
- Finally, the oil undergoes hydrotreatment and product fractionation.





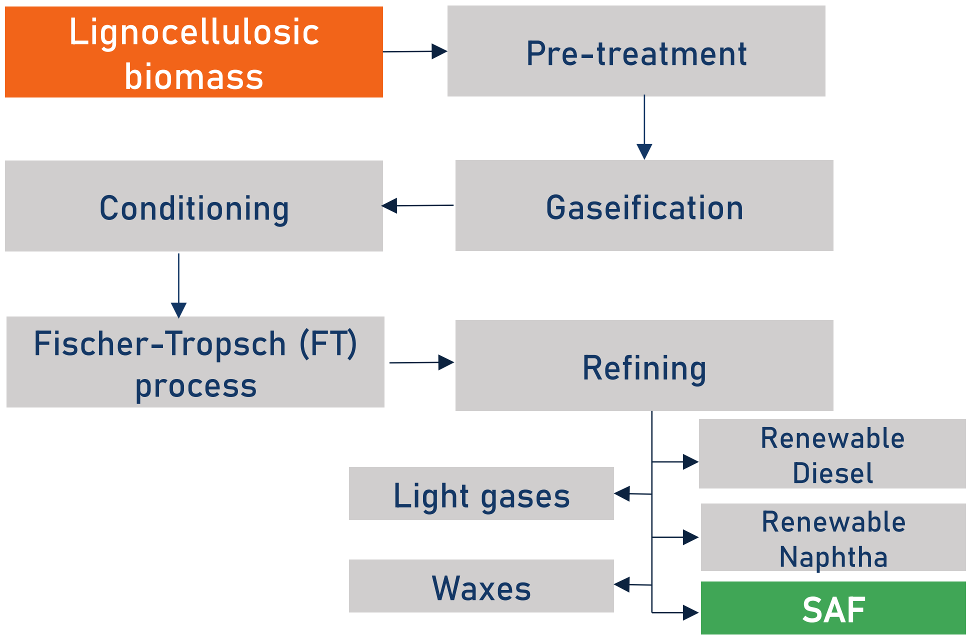
The CHJ route uses the same feedstocks as the HEFA route but applies different chemical processes to tailor them to the jet fuel range. The reactions in the CHJ route consume less hydrogen compared to HEFA but require higher pressure and temperature to operate.

Source: 13, 32

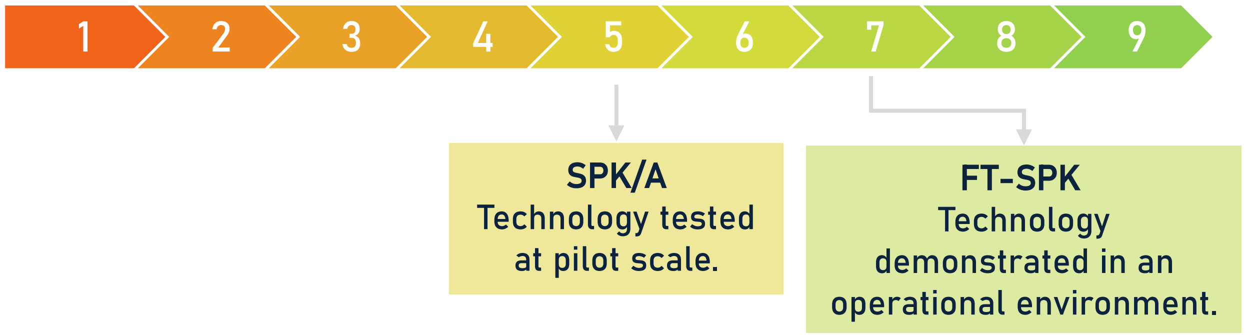
Technological Routes | SPK-FT e SPK/A

The SPK-FT and SPK/A production routes involve the conversion of plant biomass into fuels, including SAF, with Fischer-Tropsch (FT) synthesis as one of their main stages.

- After pre-treatment, the biomass undergoes the thermochemical process of gasification with the aim of converting carbonaceous materials into syngas ($CO + H_2$).
- The syngas is then applied to FT synthesis, which, through its reactions, produces a range of hydrocarbons with various carbon chain lengths.
- The additional process stage – cracking, isomerization, and fractionation – aims to increase the yield of the kerosene fraction and adjust it to meet the technical specifications of this product.



Technology Readiness Level (TRL)



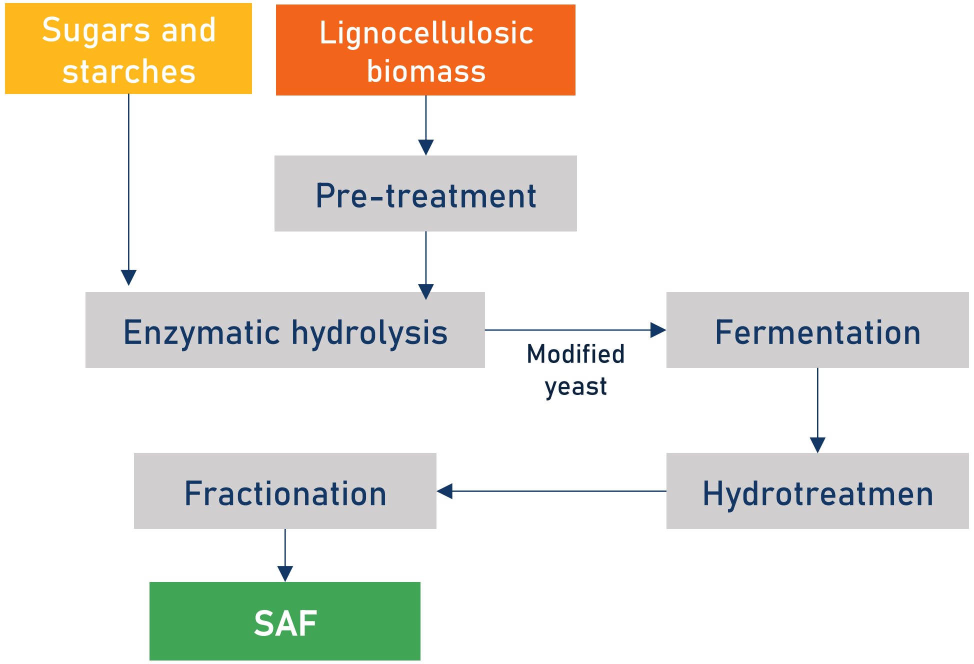
The SPK/A production route is a variation of the Fischer-Tropsch process with the addition of aromatics, which helps prevent leaks and deterioration of the rubber parts sealing the engines, helping to maintaining hydraulic pressure. Like SPK-FT, its maximum blending percentage is 50%.

Source: 11, 12, 14

Technological Routes | SIP

The SIP route occurs through the fermentation of sugars using modified yeasts.

This biochemical route converts sugars into a hydrocarbon molecule $C_{15}H_2$ called farnesene, which, after undergoing a hydrotreatment process, produces farnesane ($C_{15}H_{32}$), a fuel whose maximum blending percentage with fossil jet fuel is 10%.



Technology Readiness Level (TRL)

SIP
Technology between prototype and demonstration in an operational environment

This technology is marketed by Amyris and Total using sugarcane and a strain of S. cerevisiae in the fermentation process to produce farnesene.

Technological Routes | ATJ-SPK

The ATJ route can be divided into two stages: the production of bio-alcohol and the synthesis of medium-chain hydrocarbons.

- The production of bio-alcohols includes both established routes, such as alcoholic fermentation, and more innovative alternatives, like thermochemical pathways. Different types of bio-alcohols are being considered for the ATJ route, including methanol, ethanol, n-butanol, and isobutanol
- In the synthesis stage, short-chain alcohols are converted into longer-chain hydrocarbons (C8-C16). There are two main routes for obtaining alcohol in this process: from methanol and from higher alcohols.

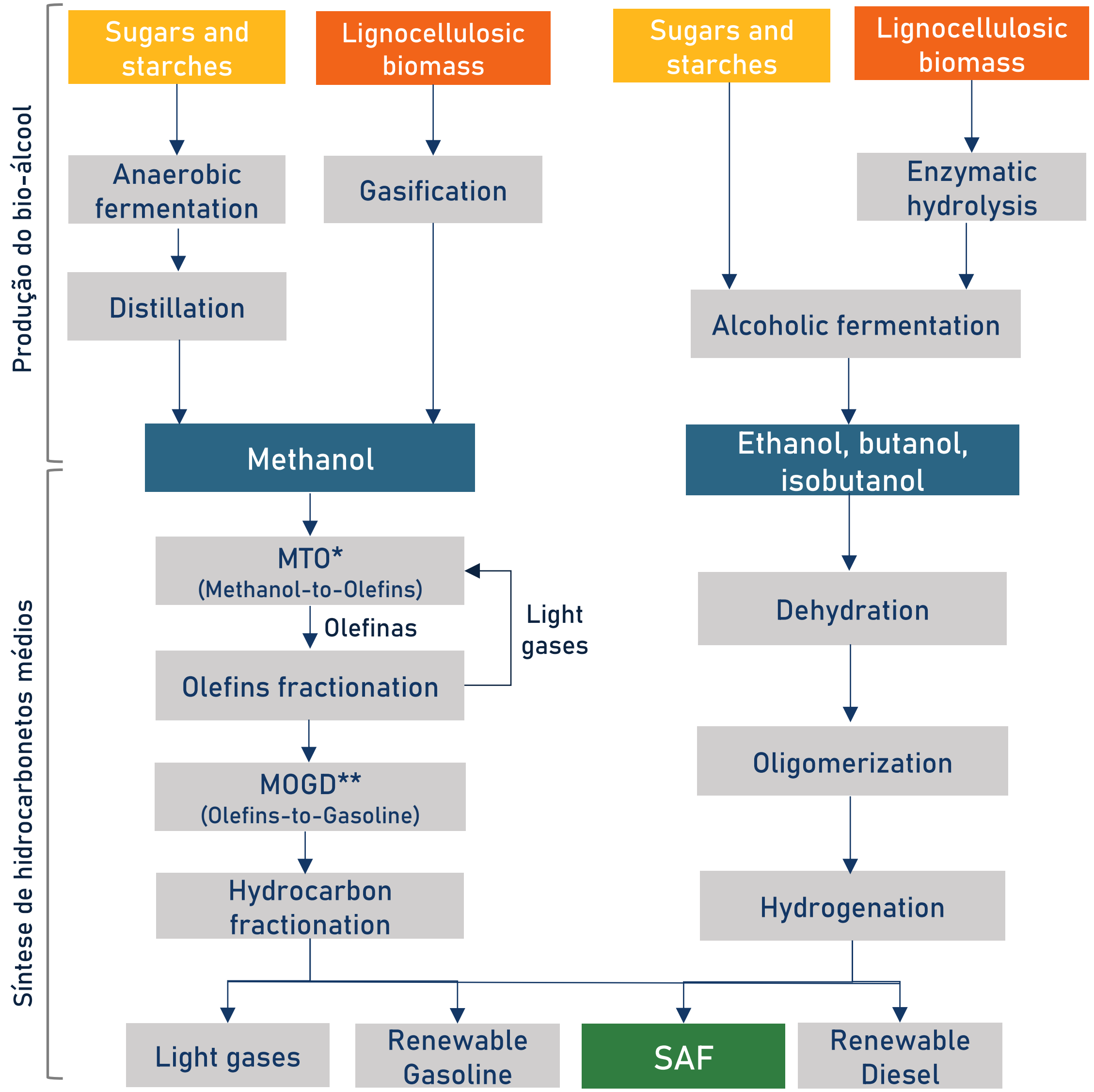
MTO (Methanol-to-Olefins): Fluidized bed reactor with a catalyst. This process produces methane, C2-C4 paraffins, C2-C4 olefins, and C5-C11 gasoline.

MOGD (Olefins-to-Gasoline): Fixed bed reactor in the presence of a catalyst.

Technology Readiness Level (TRL)

1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9

7: Technology demonstrated in an operational environment



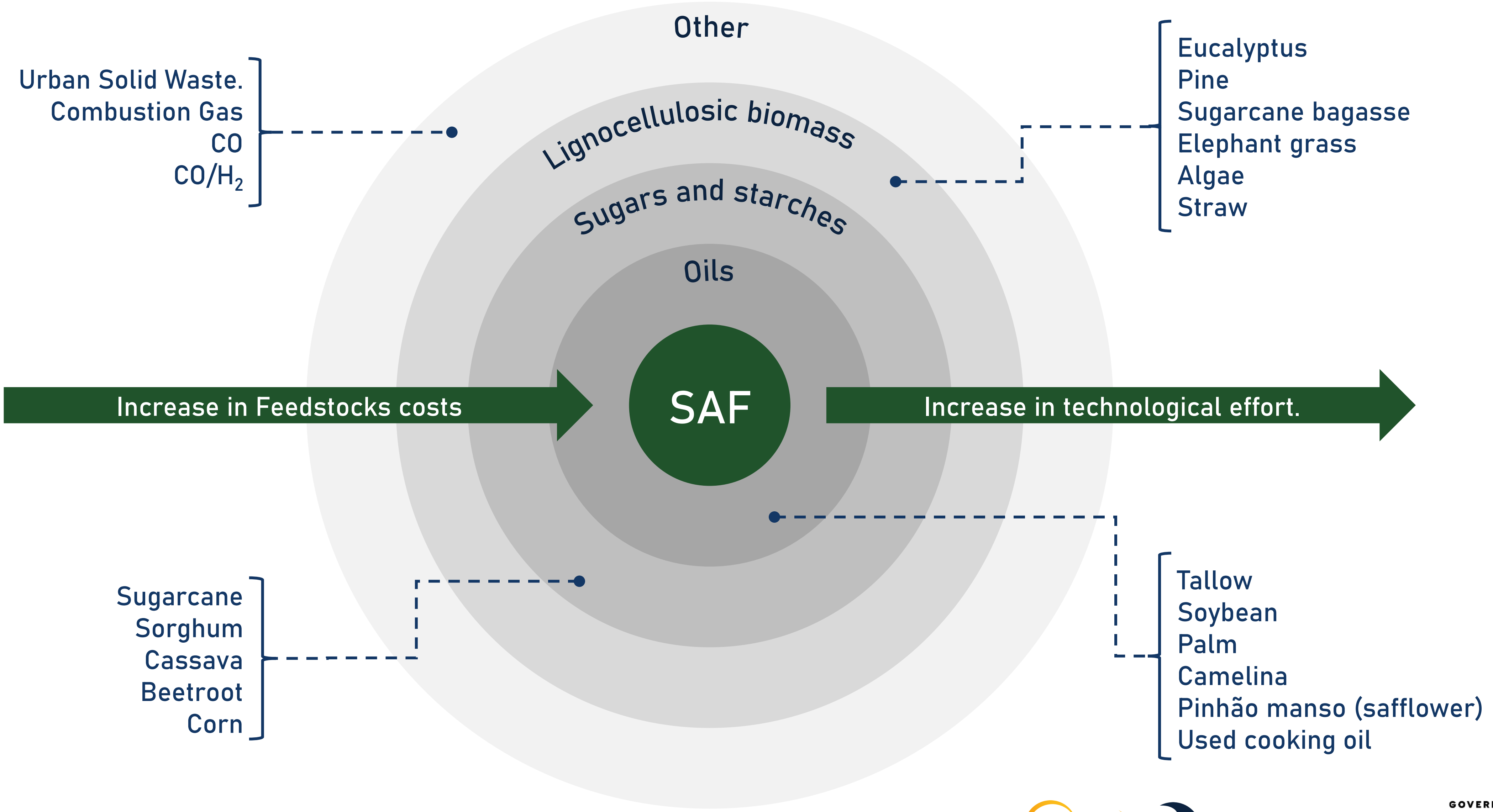
Source: 12, 13, 14, 23

Rotas Tecnológicas | Oportunidades e desafios

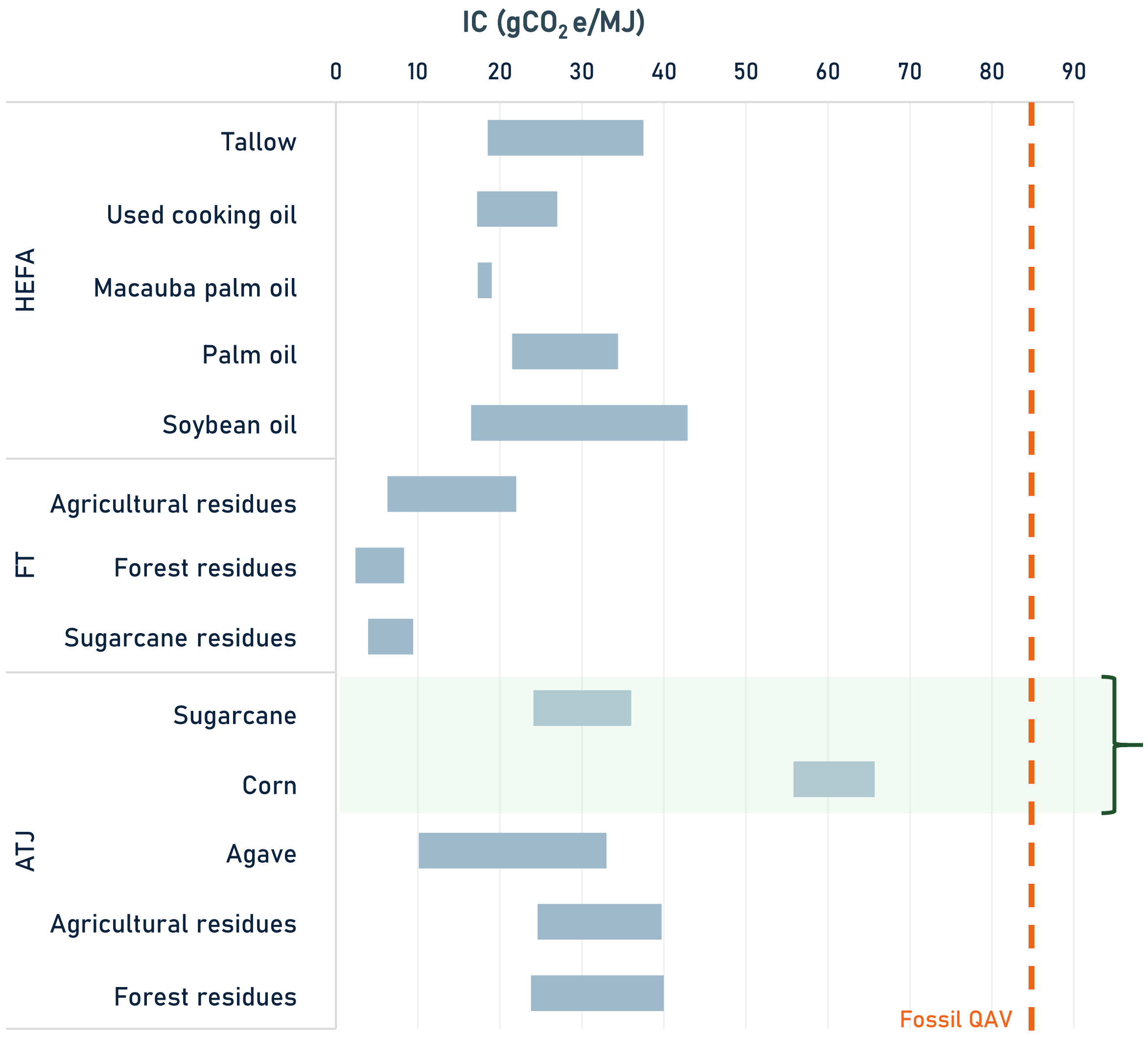
	Opportunities	Challenges
HEFA and HC-HEFA	+ Availability of raw materials on a large scale; + Low sulphur content and aromatic compounds, along with high cetane values.	- Logistical challenge in utilizing residual oils and fats; - Hydrogen-intensive process.
CHJ	+ The process can utilize wet raw materials and achieve high energy efficiency due to mild reaction conditions; + Pre-conditioning of the raw materials reduces hydrogen consumption in the final refining stage.	- High water usage in the process.
SPK-FT and SPK/A	+ Due to its sulphur-free nature, FT liquid causes less pollution to the environment.	- Low economic viability at reduced scales for the adaptation of biomass and waste utilization. - Need for the development of more suitable processes and catalysts for small-scale applications.
SIP	+ There is no need for chemical catalysts or reactions at high temperature or pressure.	- It has relatively high kinematic viscosity compared to other routes; - More suitable to produce high-value chemicals.
ATJ	+ It uses bio-alcohols as raw materials, for which the production technology is already well established. + A wide variety of resources available.	- The availability of raw materials is compromised, as biofuels have an established market in the road transport segment.

Source: 11, 21, 31

Feedstocks | Cost and technological effort



Technological Routes & Feedstocks | Carbon Intensity (CI)



Values excluding iLUC

- **Sugarcane:**

The values do not include SAF-AtJ from second-generation ethanol (E2G) derived from sugarcane residues. It is estimated that E2G from sugarcane residues has a carbon intensity (CI) 30% lower than that of first-generation ethanol*, which means that SAF-AtJ from E2G could represent an even greater decarbonization potential.

Raízen 2023

- **Corn:**

The available value refers only to SAF-AtJ from ethanol produced from corn in the USA. The literature still lacks regional values for SAF-AtJ from second-crop corn in Brazil. It is estimated that the carbon intensity (CI) of SAF-AtJ produced from second-crop corn in Brazil is significantly lower than that of SAF-AtJ from corn in the USA, primarily due to the use of bioenergy in the industry

Higher carbon intensity of SAF-AtJ when produced in non-integrated plants outside Brazil, mainly due to:

- Emissions from maritime transport of ethanol from Brazil to the SAF plant abroad;
- Fossil fuel consumption (e.g., natural gas) in the industry for SAF production.

Opportunity: The Book & Claim system as an alternative to enable SAF production in regions with competitive carbon intensity (CI), such as Brazil, accelerating the achievement of decarbonization targets at lower costs for society.

Source: 11, 15, 16, 20, 21, 25, 26

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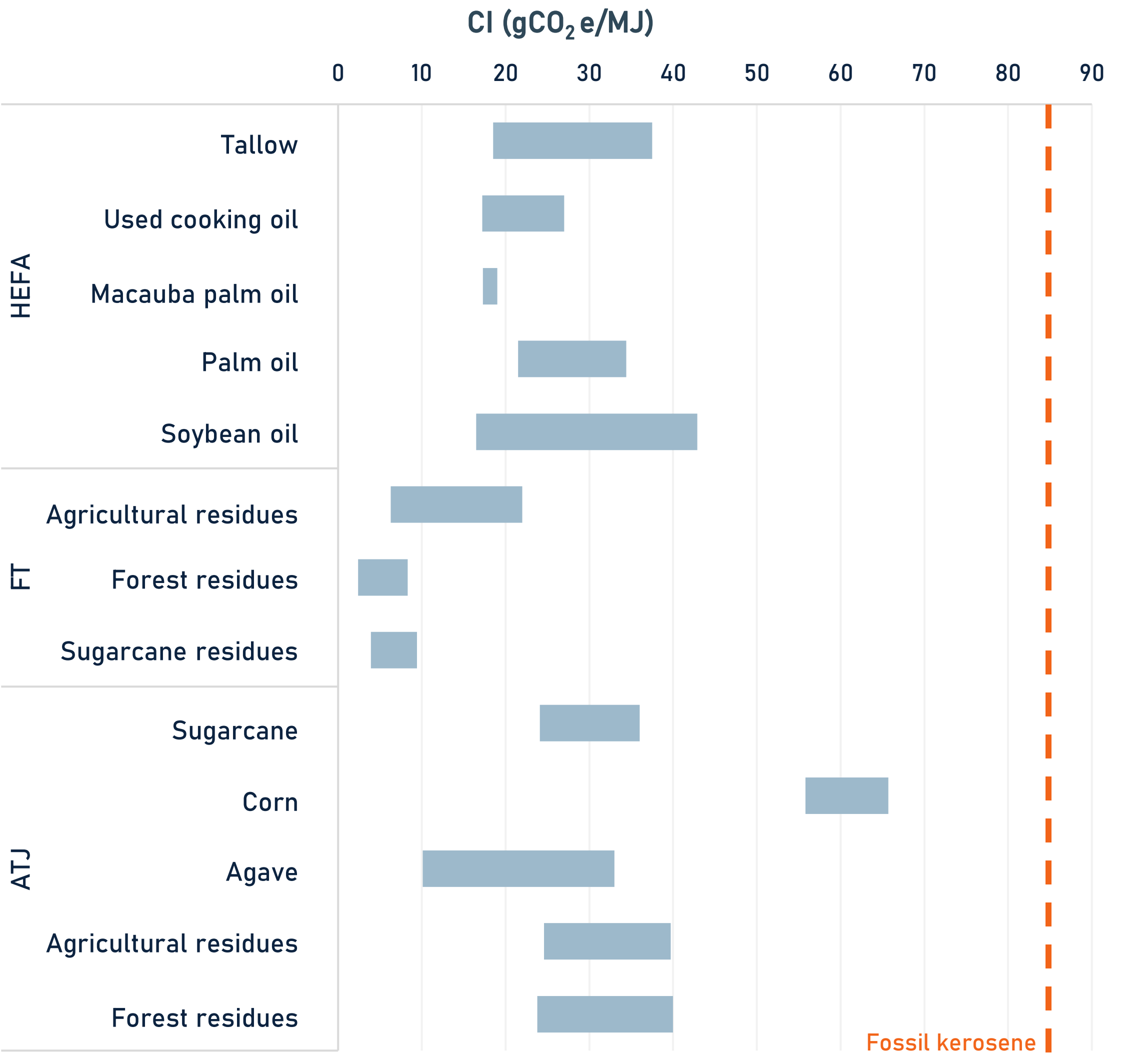
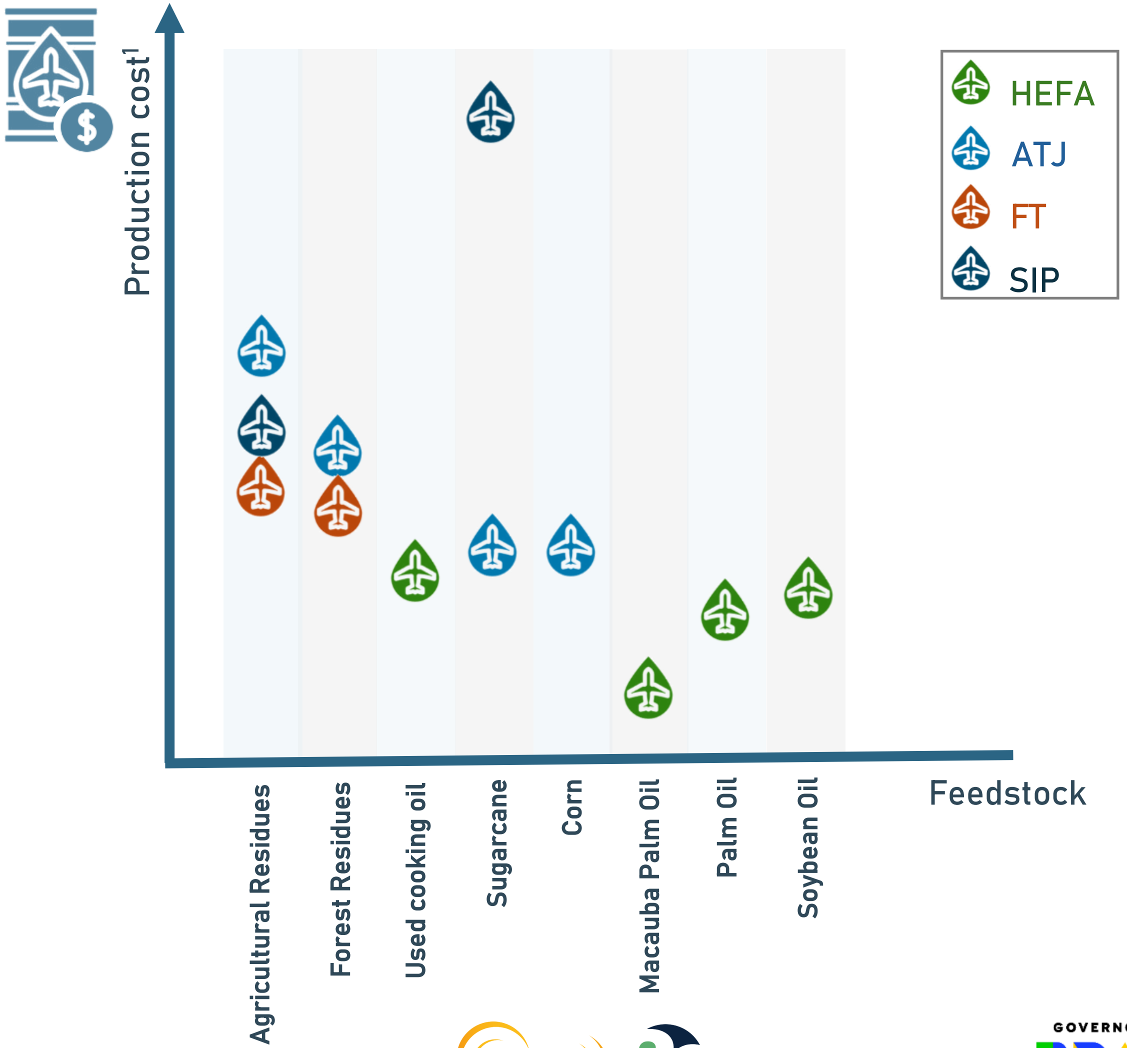
Carbon intensity (CI) and Costs



Values excluding iLUC



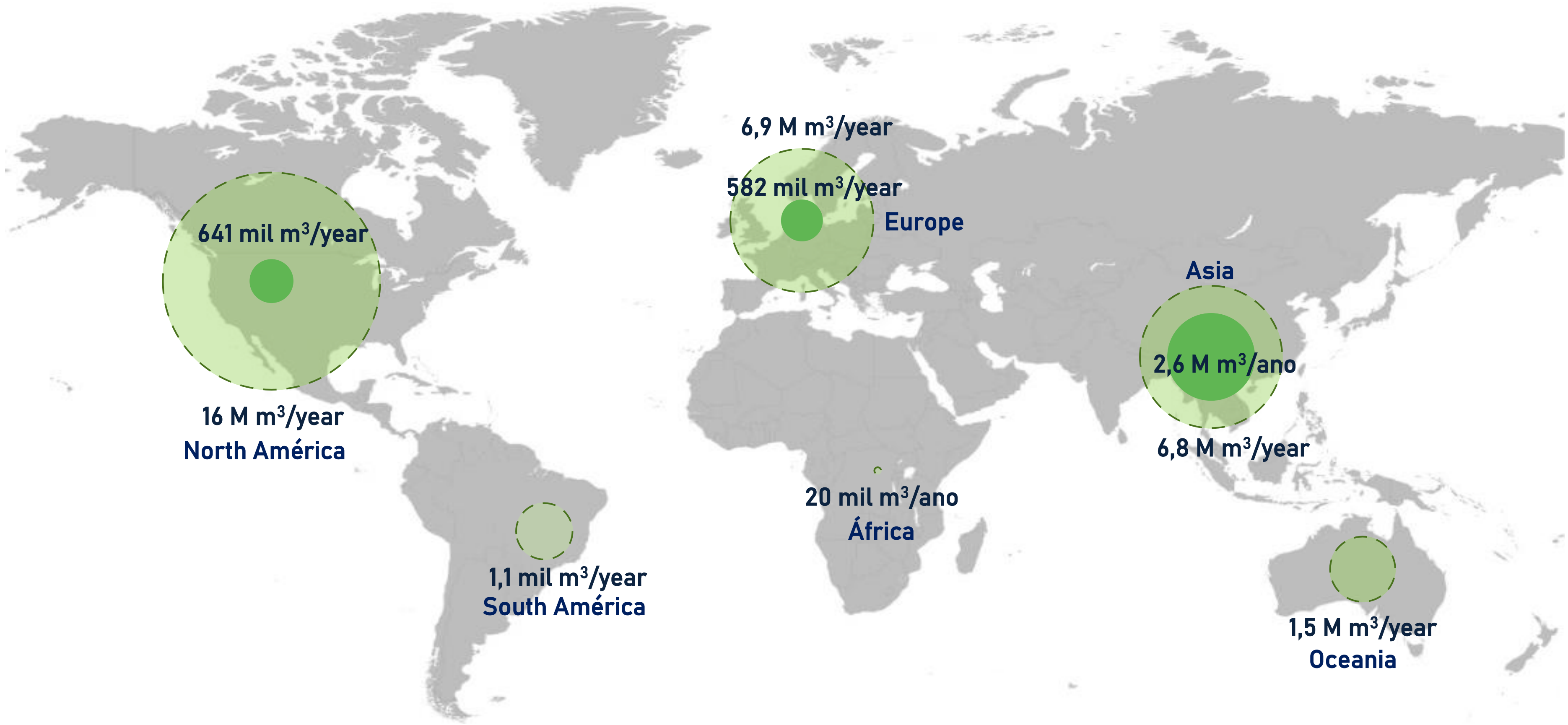
[1] The production cost per conversion process is represented by the minimum selling price of SAF

Source: 11, 15, 16, 20, 21, 25, 26

Current and future SAF production

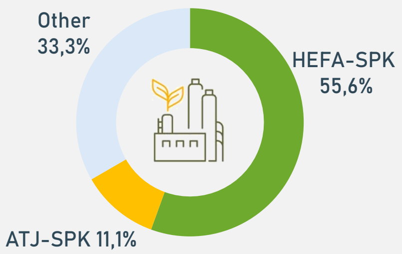
SAF Production | Around the World

Installed capacity vs Projected capacity (2030)

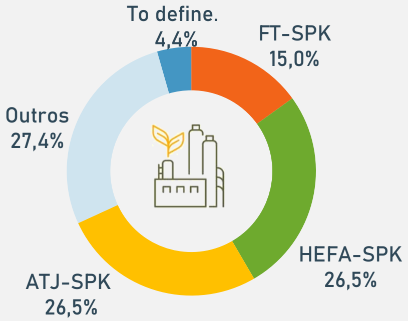


Legend

Installed Capacity



Projected Capacity



**Other: PtL, HTL,HVO, GTL*

*Data on biorefinery capacity considering maximum SAF production.

*Projected capacity data considers final investment decision with a defined and to-be-defined date.

Source: 29 (S&P Global Commodity Insights, ©2024 by S&P Global Inc)

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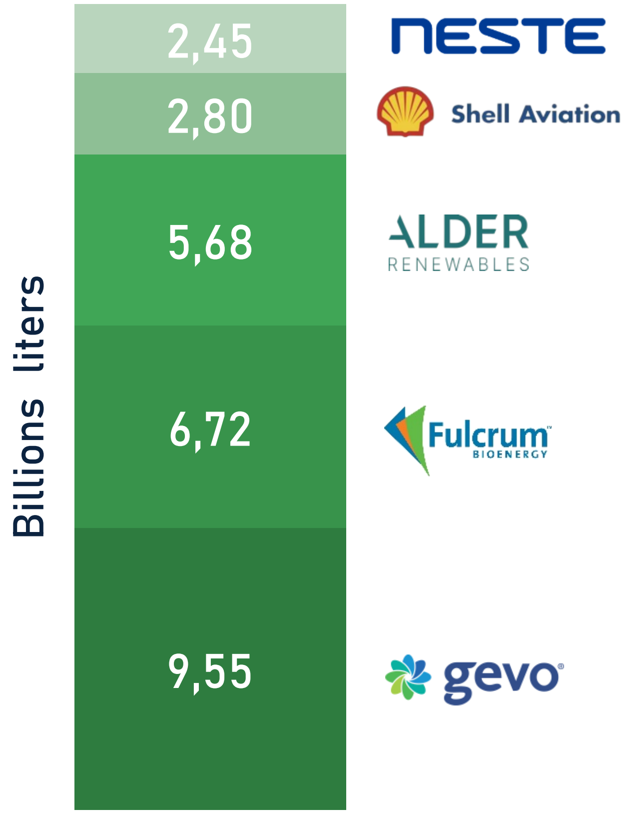
SAF Production | Experiences and consumption

Top SAF producers by total *offtake* volume[1]



Flight experiences using SAF

Commercial flights that have been operated using SAF since 2011:

736.319

Number of airports regularly supplied with SAF:

69

Airlines that have committed to SAF targets for 2030:

50

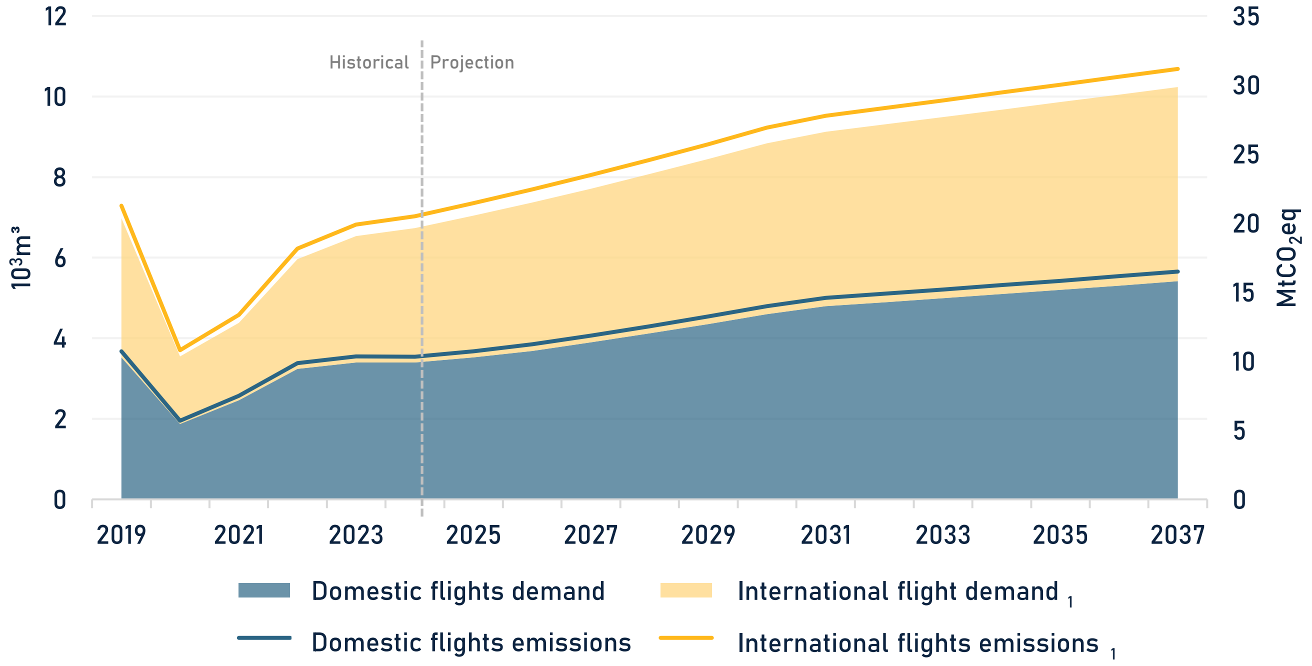
[1] Accumulated values until October 2023

Source: 30, 33

Scenarios for SAF Supply in Brazil

The demand for aviation fuel will continue to grow in the coming years

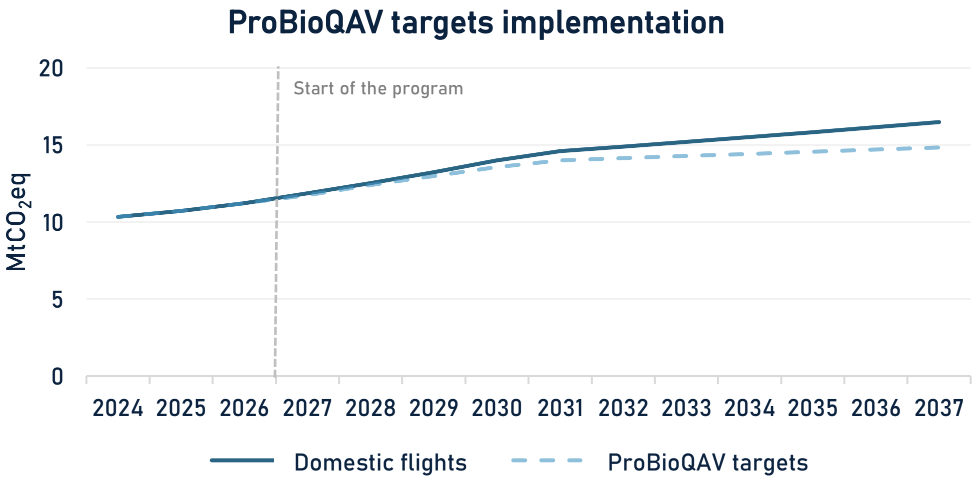
Forecast of aviation fuel demand and GHG emissions

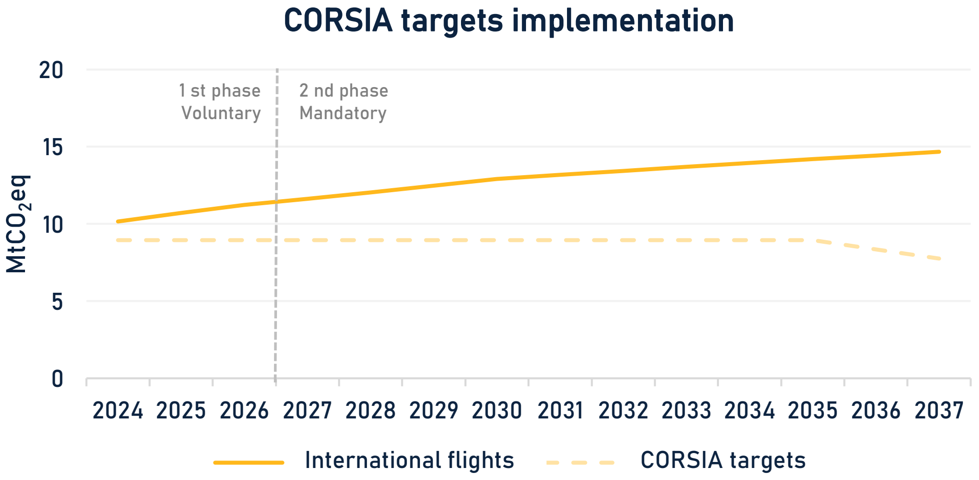


- To keep up with the sector's demand rebound post-pandemic, both domestic production and aviation fuel imports in Brazil are expected to increase.
- Despite improvements in aircraft efficiency and travel planning, emissions from the sector are also on the rise.
- In this context, SAF production must play a pivotal role in aviation decarbonization through the ProBioQAV and CORSIA programs.
- Brazil can stand out in SAF production due to its expertise in biofuels and the abundance of biomass and other renewable energy sources.

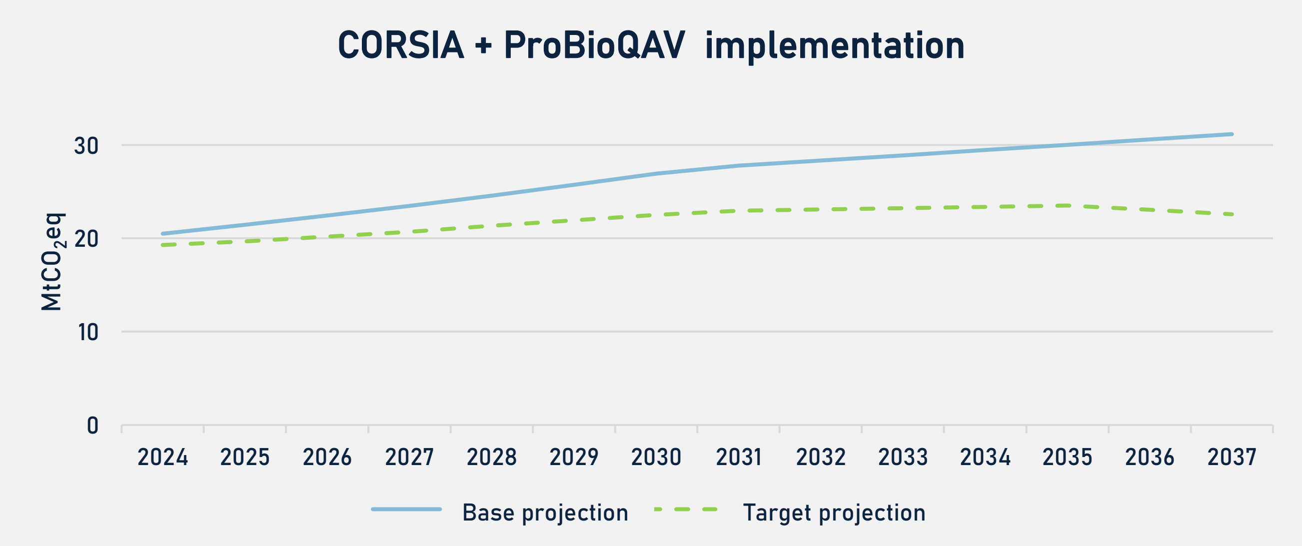
[1] Flights operated by domestic or foreign companies with origin/destination outside of Brazil.
Source: EPE, based on 34

Emissions reduction targets





- ProBioQAV and CORSIA are not based on volumetric mandates, but rather on emissions reduction targets
  - **ProBioQAV** – gradual emissions reduction percentagem Applied to domestic flights, starting at 1% in 2027 and increasing to 10% by 2037.
  - **CORSIA** – carbon-neutral growth until 2035, followed by reduction to achieve net zero emissions in international aviation by 2050.
- The implementation of both programs results in emissions reduction that can be met with SAF.



Source: EPE, based on 2, 8, 34

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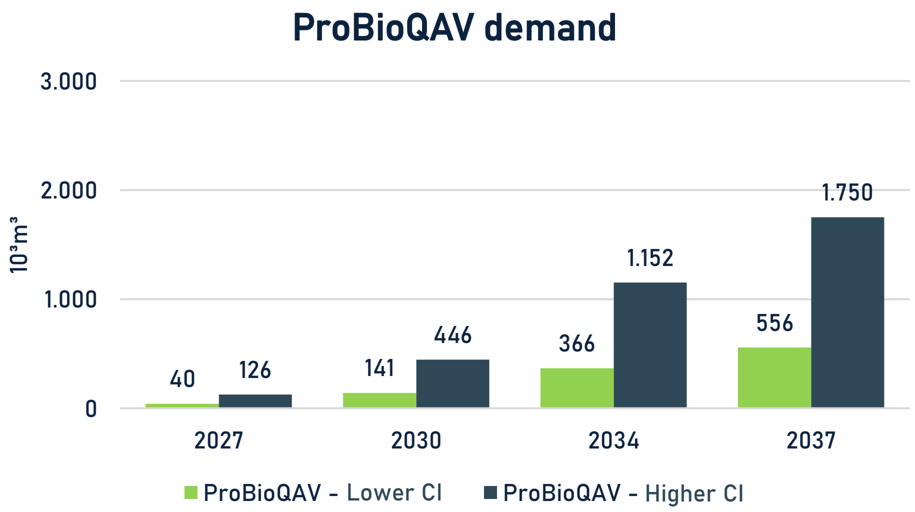
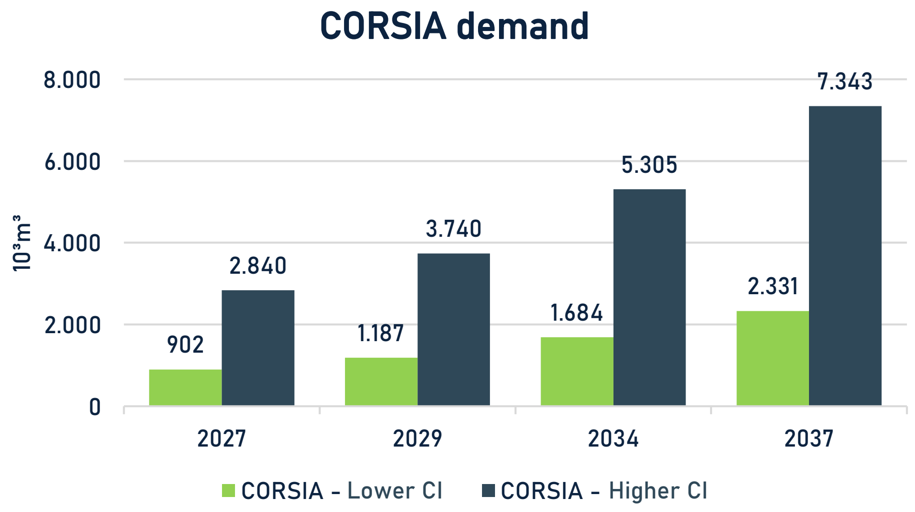
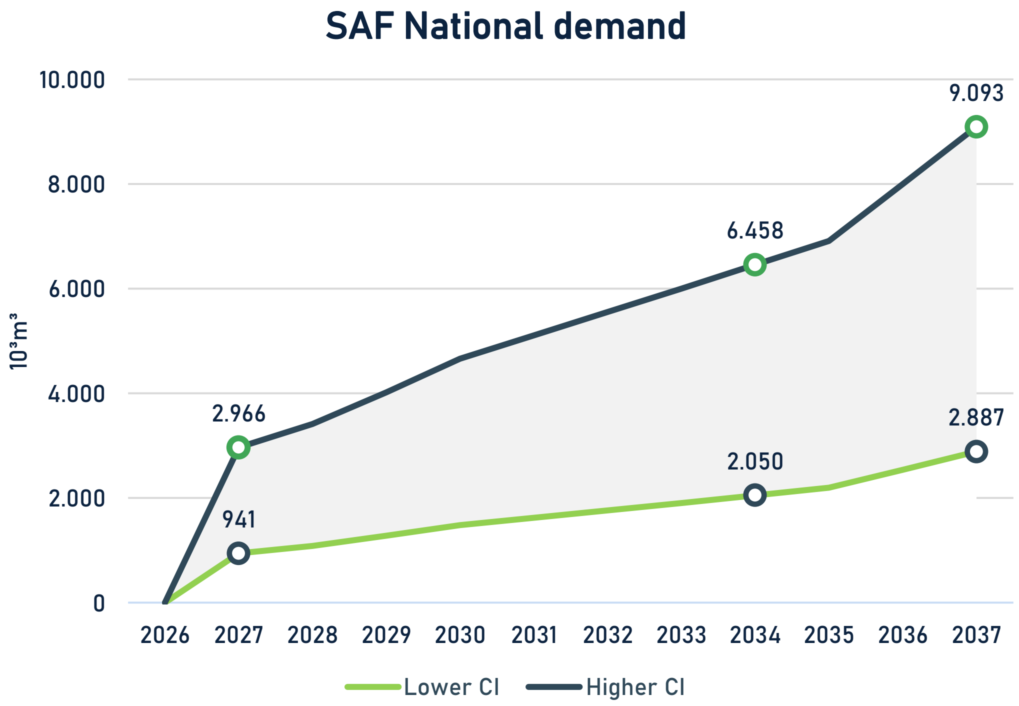
SAF demand in Brazil





- The volumetric demand for SAF will vary according to the carbon intensity (CI) of the fuel produced, as CORSIA and ProBioQAV set emission reduction targets.



Source: EPE, based on 2, 8, 34

Proposed scenarios

Announced projects

Are the announced projects sufficient to meet the emissions reduction targets?

Feedstocks

Traditional

How can soybean oil, first-generation sugarcane ethanol, and corn ethanol contribute to achieving the targets?

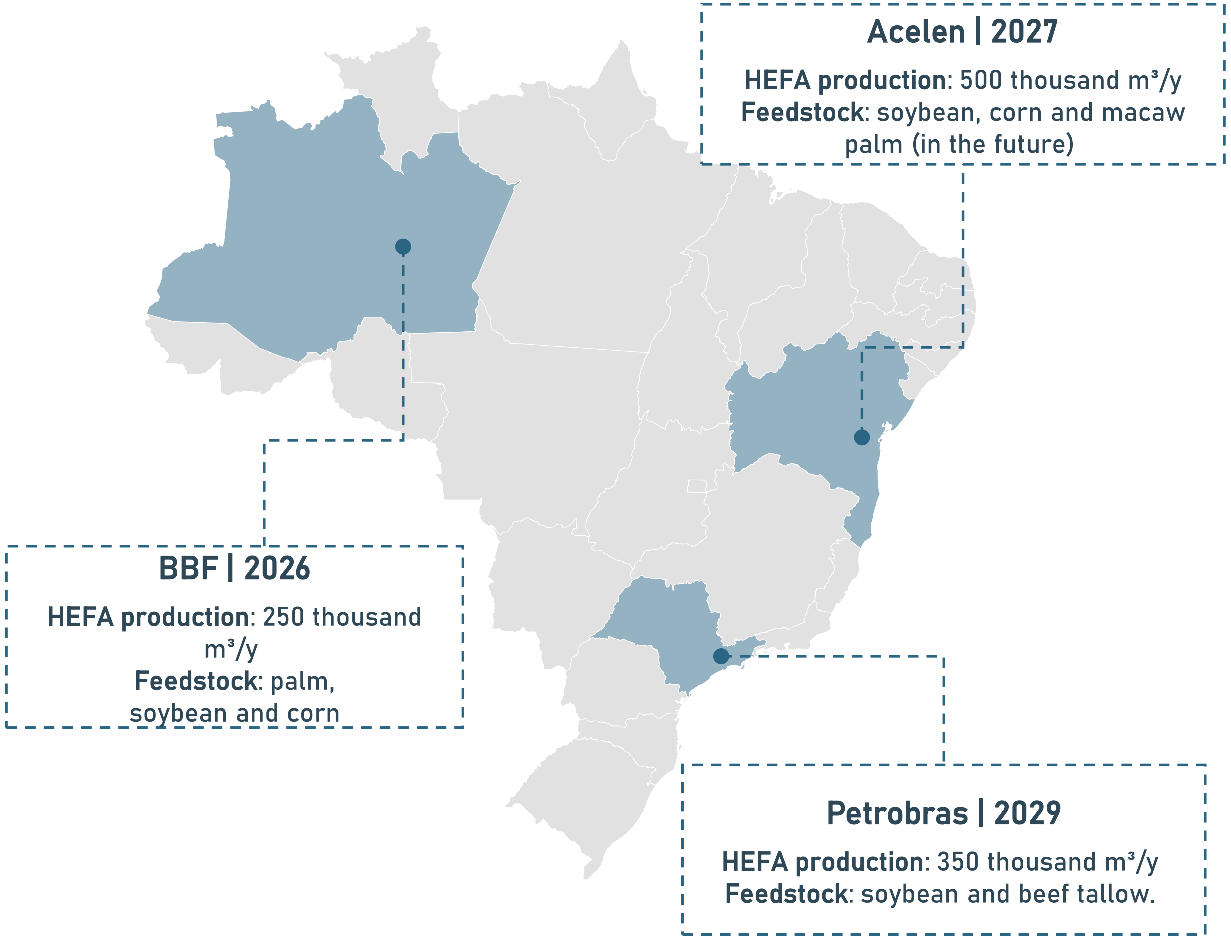
Alternatives

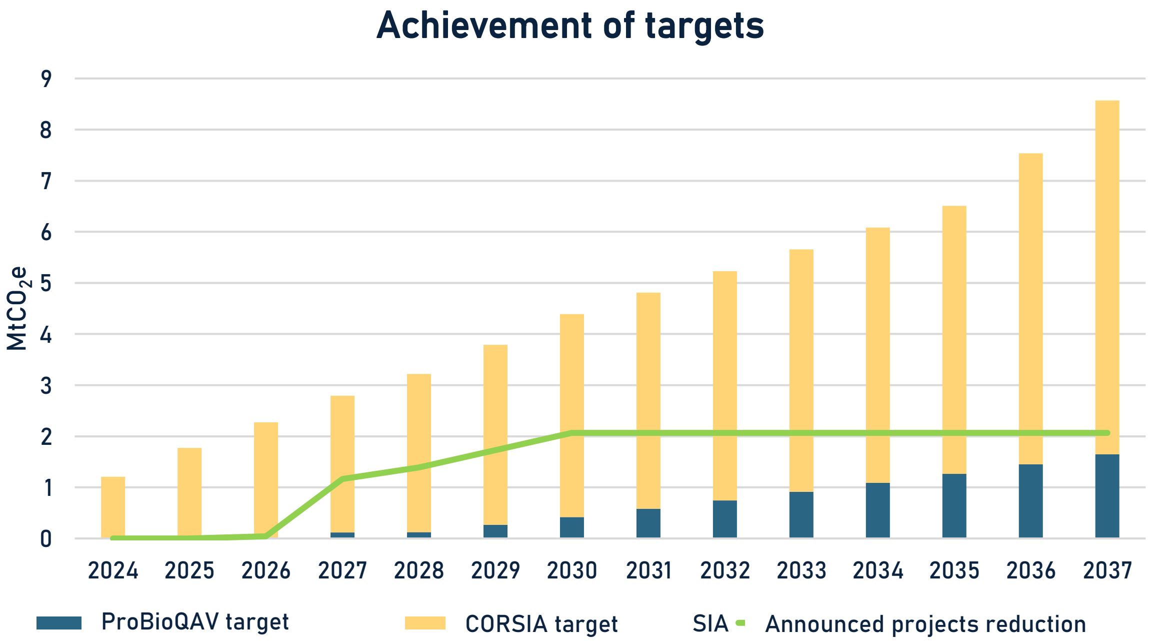
How can alternative feedstocks contribute to meeting the targets?

Residues utilization

What is the production potential of SAF from organic residues available in Brazil?

Scenario I | Announced Projects
Announced projects partially meet the emissions reduction targets



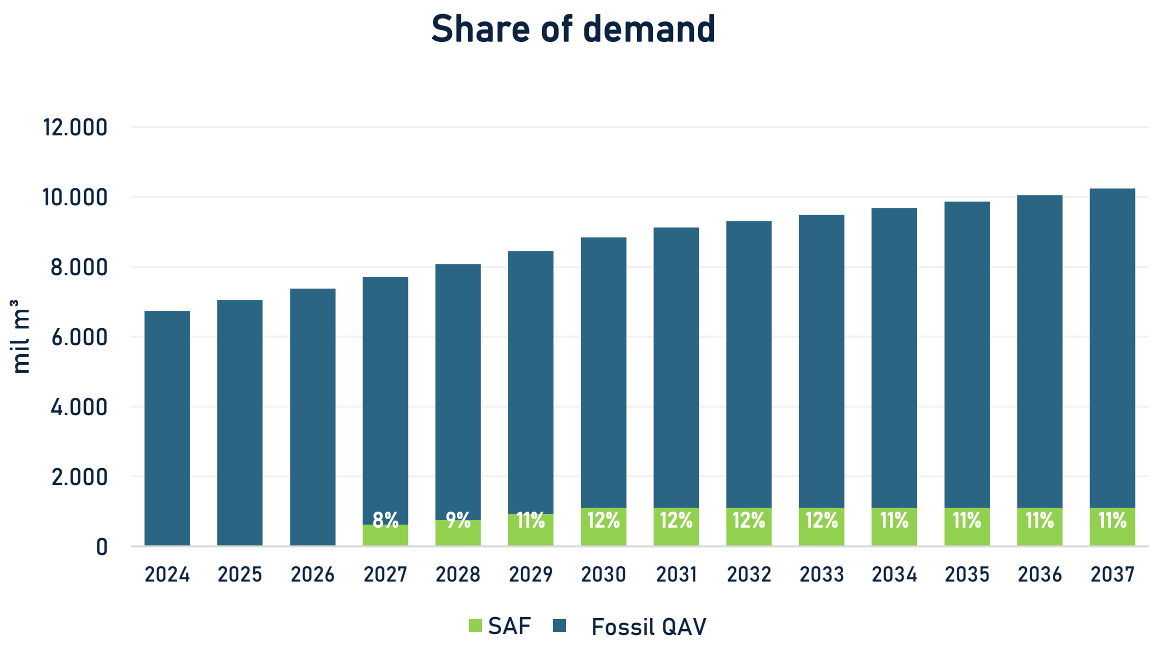


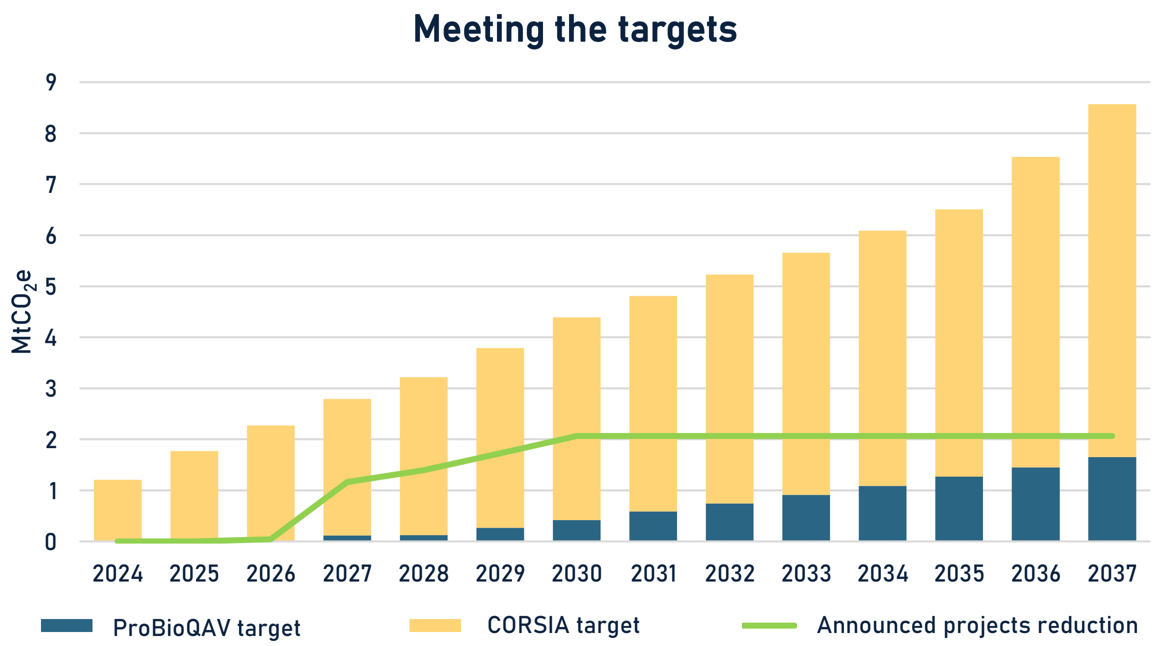
- From 2027 to 2037, projects meet na average of 38% of the emissions reduction targets set by CORSIA and ProBioQAV.
- Considering only ProBioQAV, the announced projects are sufficient to meet the established targets until 2037.

Note: There are projects to build plants that use the AtJ and HEFA routes, with a lower degree of certainty, that were not included in this study.
Source: EPE, based on 2, 8, 16, 20, 34, 35, 36,

Trajectory I | Announced projects

Partially meet emission reduction targets



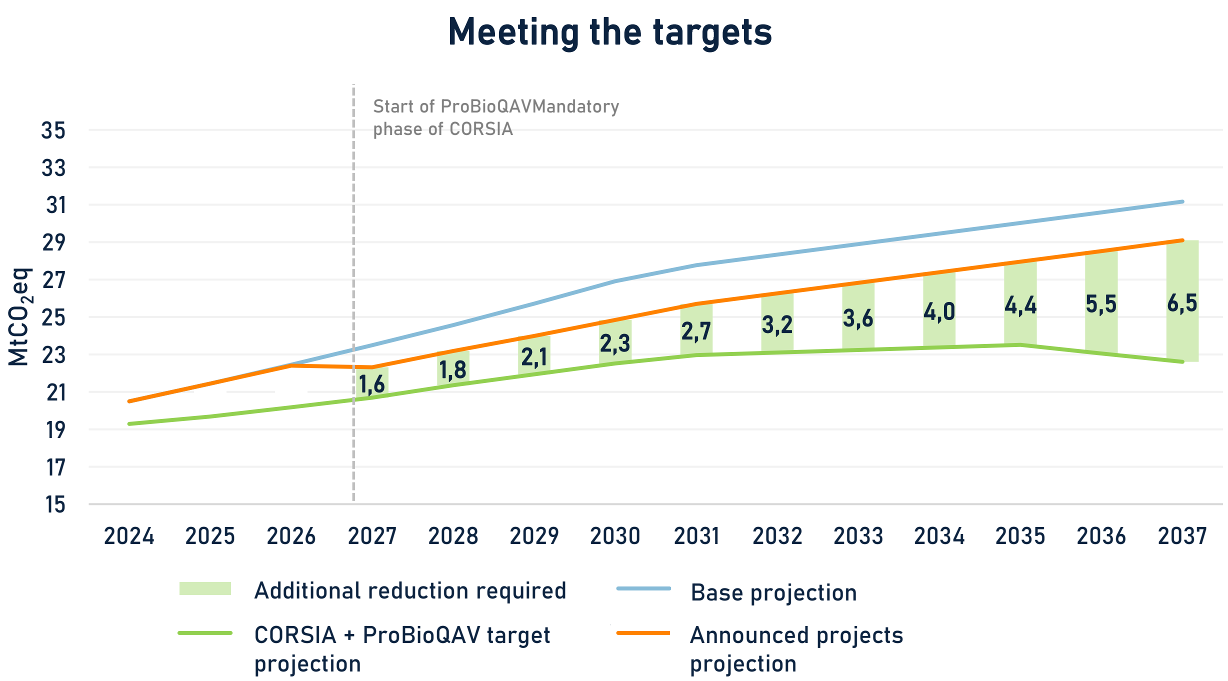


- The announced projects represent 12% of the estimated aviation fuel demand between 2030 and 2033, but the share declines as demand increases.

- Between 2027 and 2037, the projects meet, on average, 38% of the emission reduction targets set by CORSIA and ProBioQAV.
- Considering only ProBioQAV, the announced projects are sufficient to meet the targets set until 2037.

Source: EPE, based on 2, 8, 16, 20, 34, 35, 36,

Trajectory II | Consolidated and alternative feedstocks



Consolidated feedstocks			Alternative feedstocks		
HEFA	ATJ		HEFA	ATJ	
Soybean	Sugarcane	Corn	Macauba palm	Agave	E2G

- Other ventures will need to start operations by 2027, when CORSIA and ProBioQAV become mandatory.
- Consolidated feedstocks in biofuel production → scale and experience.
- Alternative feedstocks → diversification of the input basket, regional development, and integration of public policies.
- These feedstocks can "boost the **strengthening** and sustainable **development of family farming** and its organizations as a contribution to productive diversification, **reducing inequalities**, **mitigating climate impacts**, and promoting **energy security** and **food security**," aligned with the objectives of the Social Biofuel Seal.
- **This trajectory indicates the SAF volume required to meet emission reduction targets based on routes and feedstocks selected and analyzed separately.**

⚠ Note: The analyses are mutually exclusive.

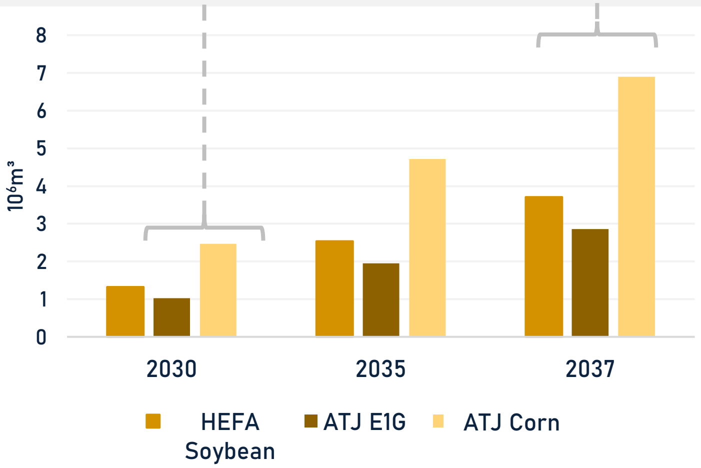
Source: EPE, based on 2, 8, 16, 20, 34, 35, 36, 44, 45

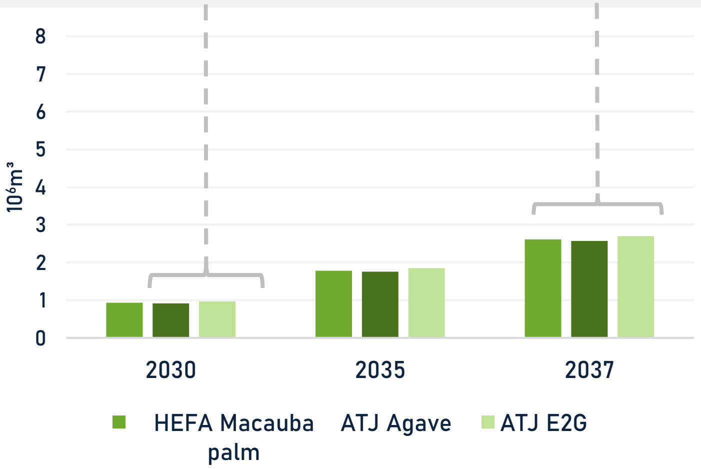
Scenario II | Traditional and alternative feedstock
Production capacity varies according to the conversion process and feedstock

	Traditional		Alternatives	
Equivalence in plants of 300 thousand m³/year [1]	**4 to 8** plants	**10 to 23** plants	**3** plants	**9** plants

Added SAF production capacity [2]

The values add up to the announced projects





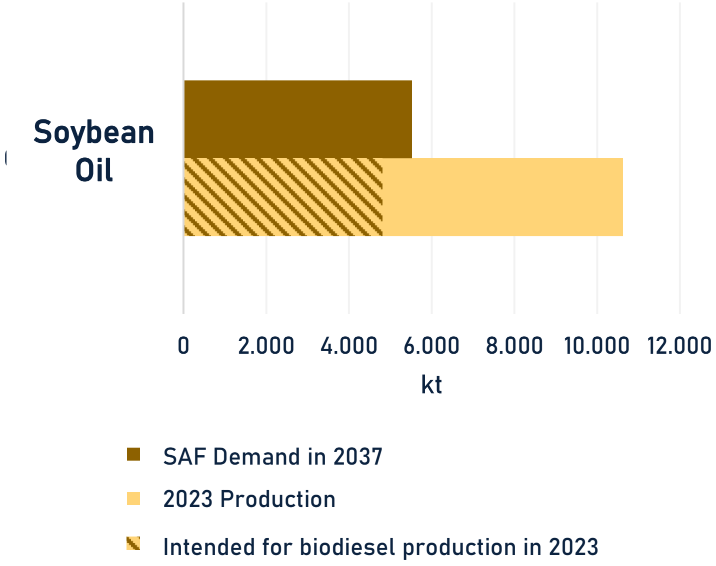
- The mix of conversion processes and feedstock will depend on the evaluation of several factors.
  - Ex: availability of feedstock, logistics, costs, environmental aspects, etc.
- In 2037, SAF production is expected to range from **3.7 to 8 million m³/year**, depending on the chosen conversion processes. This production range includes the announced projects.
- SAF could represent between 36% and 78% of the volumetric demand for QAV[3].

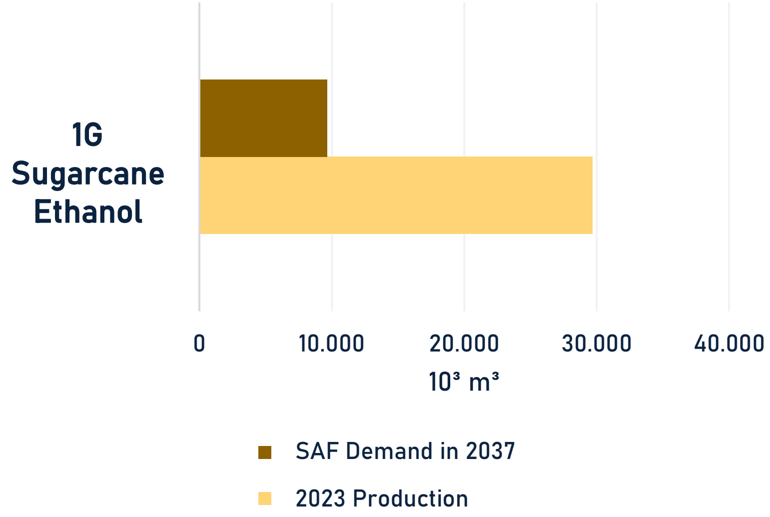
Note: The analyses are mutually exclusive.

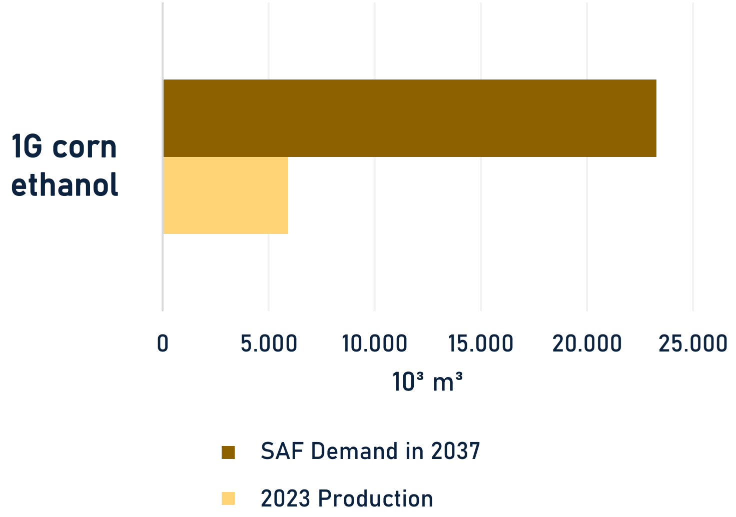
[1] Average specific capacity based on announced projects and market reports (29).
[2] The calculations used the additional emissions reduction required each year and IC values indicated on this page of the Notebook.
[3] At present, the maximum blending limit is 50%.
Source: EPE, based on 2, 8, 16, 20, 25, 34, 35, 36, 37

Trajectory II | Consolidated and alternative feedstocks

Feedstock availability is a key criterion...







- The demand for soybean oil for SAF in 2037 exceeds what was used for biodiesel production in 2023.
- Considering the soybean oil extraction capacity utilization rate in Brazil (78%), there will be a need for investments throughout the period.

- SAF production from E1G sugarcane opens a new market opportunity for this biofuel, especially due to the higher added value of SAF.
- There is an opportunity to consolidate ethanol plants as biorefineries that produce a range of products.

- The expansion of corn ethanol supply in Brazil can be further driven by the growing SAF demand in the coming years.

Source: EPE, based on 38, 39

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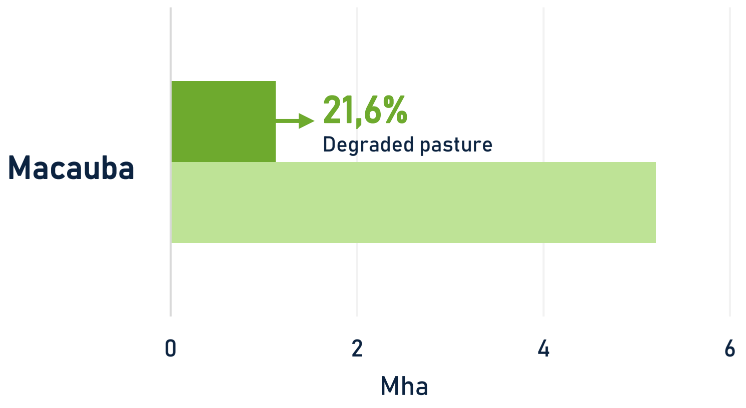
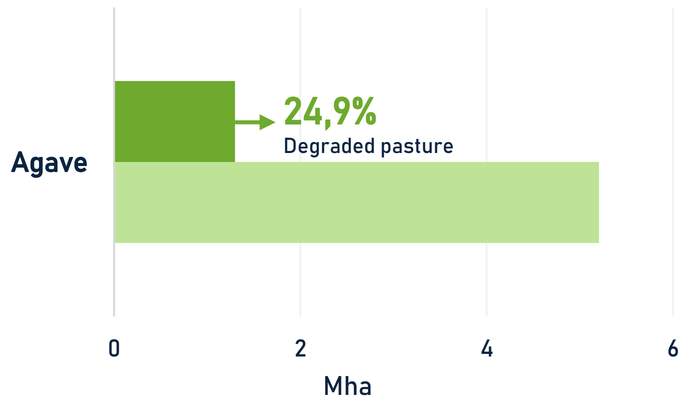
Trajectory II | Consolidated and alternative feedstocks

… and it can also be a driver of diversification in the Northeast (NE).



- Area required for cultivating feedstock for SAF in 2037.
- Degraded pasture in the semi-arid region.



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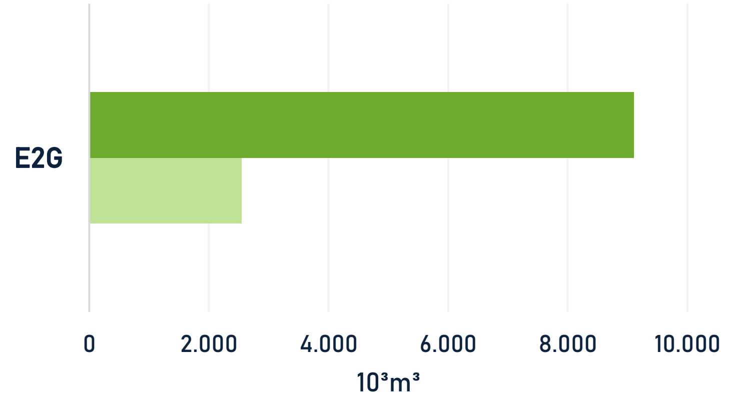


- 2037 SAF demmand
- Northeast region production potencial

- Macauba and agave are promising biomass sources for biofuel production in Brazil[1].
- Although they are not yet available at scale, these feedstocks can be vectors of:

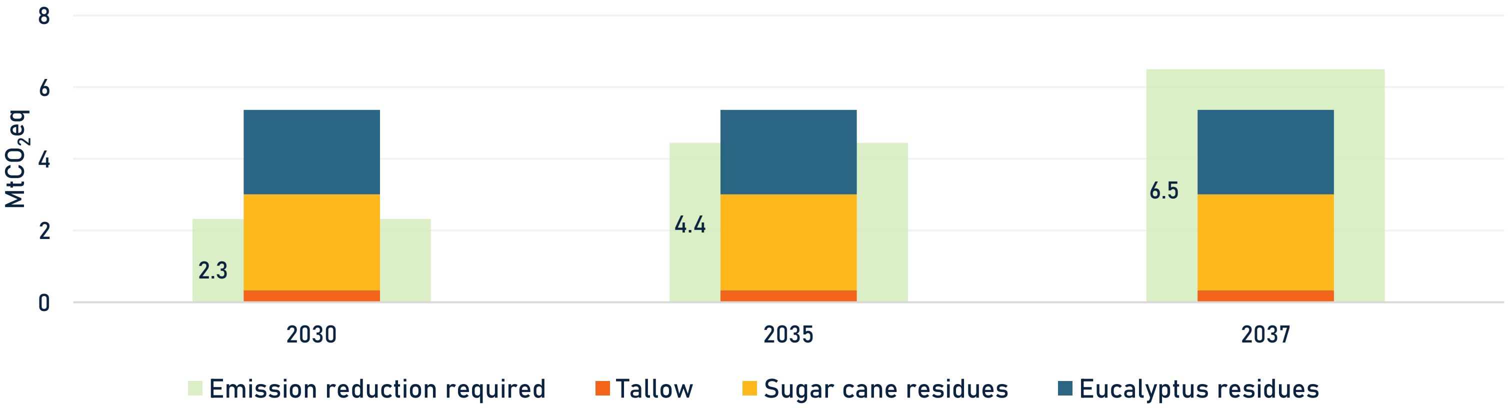
  - Integration of public policies;
  - Diversification of biomass in biofuel production;
  - Strengthening family farming;
  - Promotion of food and energy security;
  - Regional development;
  - Reduction of inequalities;
  - Recovery of degraded areas;
  - Technological development;
  - Jobs creation and income growth and distribution.

- The growing demand for SAF can stimulate the production of E2G sugarcane in the Northeast region[2].
- As a biofuel with high added value, it has the potential to drive the modernization and expansion of the product range of plants in the region, also increasing the generation of skilled jobs and income.

[1] The large-scale implementation of these plantations would require socio-environmental analyses to assess the impacts in the region.
[2] The E2G production potential in the Northeast region was defined considering the allocation of bagasse for ethanol production.
Source: EPE, based on 39, 40, 41

Scenario III – Residues utilization

	Beef tallow	Sugarcane Residues	Eucalyptus Residues
Utilization rate [1]	20%	10%	40%
Estimate of available residues	**215** thousand tons/year	**26,5** million tons/year	**16,6** million tons/year
SAF Production Potential	**~140** thousand m³/year via HEFA	**~915** thousand m³/year via FT	**~790** thousand m³/year via FT
Equivalence in plants	**1** plant of 140 thousand m³/yr	**3** plants of 300 thousand m³/yr	**3** plants of 300 thousand m³/yr



- The use of organic residues is attractive due to the low cost of feedstock acquisition and low carbon intensity.
- **This trajectory considers the level of utilization of available residues and indicates the potential for SAF production from them.**
- If the full utilization potential were realized, it would be possible to meet 82% of the emission reduction targets for 2037 using only residues biomass.

[1] The utilization rates were defined considering portions of these residues that are already used for other purposes. In the graph, the level of emission reduction from residues remains constant, as the availability in 2022/2023 was used as a reference..

Source: EPE,based on 16, 18, 38, 42, 43

Summary of 2037 scenarios

	Scenario I	Scenario II		Scenario III
	Announced projects	Traditional	Alternative	Residues utilization
Addedd capacity[1]	**1,100** thousand m³/year	**3,000 to 6,900** thousand m³/year	**~2,700** thousand m³/year	**~1,940** thousand m³/year
Equivalence in plants	**3** plants 500, 250, 350 thousand m³/year	**10 to 23** plants of 300 thousand m³/year	**9** plants of 300 thousand m³/year	**7** plants 6 of 300 + 1 of 140 thousand m³/year
Estimated investment[2]	**R$ 8.7** billion	**R$ 21 to 48** billion	**R$ 19** billion	**R$ 13.6** billion

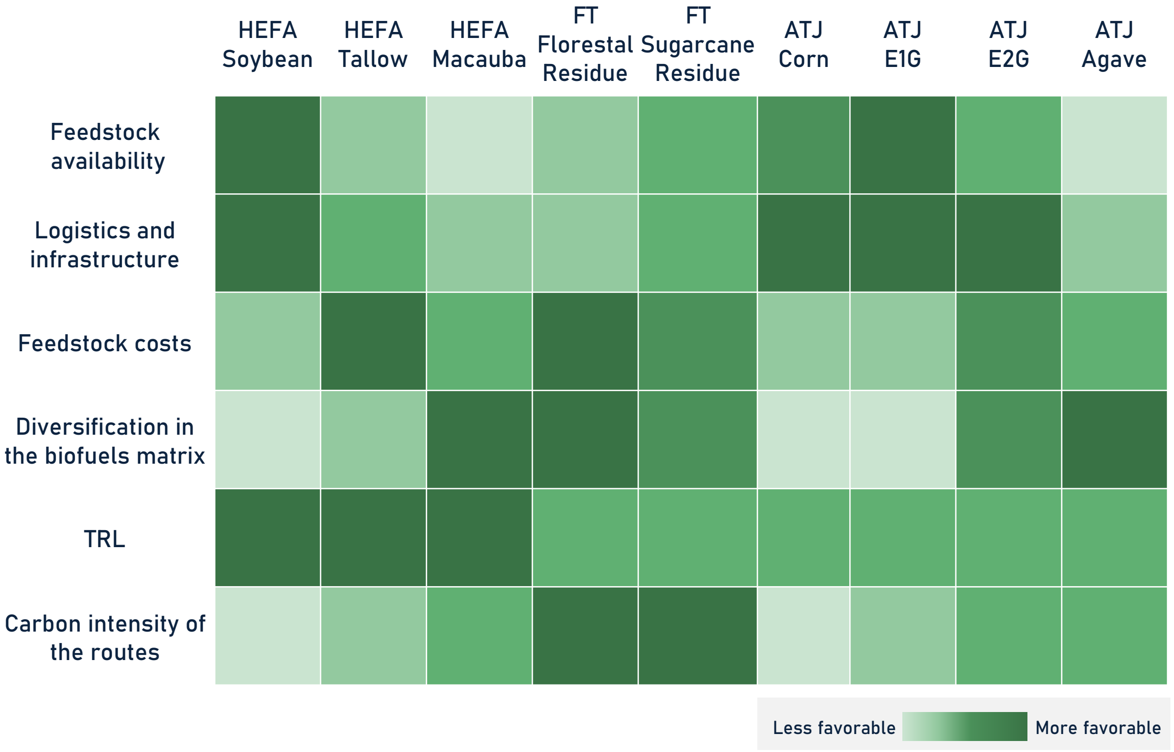
[1] The added capacity for SAF production in Scenarios II and III is based on the emission reduction targets of CORSIA and ProBioQAV, and on the IC of each conversion process/feedstock.

[2] The investment estimate was based on the average cost of announced projects in Brazil. It is noted, however, that CAPEX will vary for different conversion processes. There is also the possibility of scale and scope gains that were not considered in this calculation.

Multi-criteria analysis

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

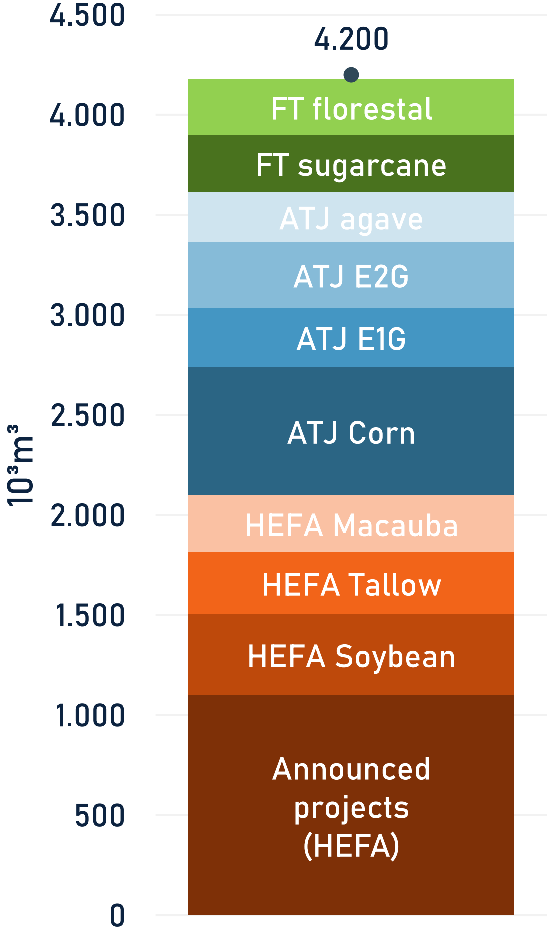
- The combination of conversion processes and feedstocks will depend on the evaluation of various factors and constraints, such as:



- 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

Key messages

Key messages

SAF production in Brazil can have a **lower carbon intensity compared to the same conversion processes in other countries** due to integrated plants.

Existing initiatives for the construction of biorefineries **can meet a portion of the emissions reduction** required by CORSIA and ProBioQAV.

But, in the long term, it is necessary to **diversify the feedstocks used in biofuels production**, which could catalyze **job creation** and **income distribution** to rural areas in Brazil.

The scenarios outlined in this study indicate a range of solutions. However, **an integrated perspective is necessary to optimize decarbonization efforts**, given the competition with other industries for resources such as land, feedstock, financing, etc.

Brazil can stand out in SAF production due to its **expertise in biofuels** and the availability of **land, biomass,** and other **renewable energy sources**.

It is important to **allocate resources towards RD&I** to establish a **strong industry** aligned with the **just energy transition towards a low-carbon economy**.

Icons from Flaticon

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