Fuel Disclosure

Sustainable. Abundant. Feasible – why SAF is unlikely to be all three at once

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About Carbon Tracker

The Carbon Tracker Initiative is a team of financial specialists making climate risk real in today's capital markets. Our research to date on unburnable carbon and stranded assets has started a new debate on how to align the financial system in the transition to a low carbon economy.

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Key Findings

- With global aviation emissions nearing pre-pandemic levels, there is an urgent need to slow and reverse this trend using all practical measures, **but most attention remains focussed on alternative jet fuels,** often referred to as sustainable aviation fuels (SAF).
- **Alternative jet fuels are unlikely to provide a near-term solution.** Even if all existing, under-development and announced projects ran at capacity, they would only be able to displace 5% of fossil jet fuel by 2030.
- **More importantly, they would not even keep up with growth in jet fuel consumption,** supplying 50% or less of increased demand for jet fuel through 2030.
- **Offtake commitments are a key signal of future demand, but they are still minimal,** covering less than 2% of potential jet fuel consumption in 2030.
- **Longer-term, these fuels must overcome some or all seven obstacles to sustainable scalability** before they can start delivering meaningful reductions in aviation emissions:
    - **Costs and price premiums** and **regulatory uncertainty** facing offtakers;
    - **Lack of long-term commitments** and **weak bankability** facing producers; and
    - **Feedstock availability, feedstock sustainability**, and **opportunity costs**.
- **Truly sustainable alternative jet fuel will play a role in decarbonising aviation, but it is likely to be smaller than currently believed.** It may power a portion of long-haul flights but is unlikely to scale sufficiently to make a significant dent in aviation emissions.
- **Greater effort is needed to scale up other solutions,** especially in short- to medium-haul flight, where zero-emission and hybrid-electric aircraft are nearing commercial viability.

Introduction

Aviation is harder to decarbonise than road transport or power and utilities. Without a clear solution like battery-electric vehicles or renewable electricity, the sector will need an assortment of solutions to decarbonise in absolute terms, if it is to meet its climate targets.

With aviation emissions recovering to pre-pandemic levels,[1] the need for a multipronged approach to tackling aviation emissions grows increasingly urgent. However, as we showed in our previous report, Awaiting take-off, most of the attention is focussed on alternative jet fuel, which is often referred to as sustainable aviation fuel or SAF. Indeed, the EU and the UK have just put in place mandates to create demand for alternative jet fuel. Plane operators, plane manufacturers, industry bodies, and even oil and gas companies are featuring the term "SAF" more prominently in their disclosures. This attention is not undeserved (see Box 1).

Box 1. Five key advantages of alternative jet fuels

Alternative jet fuel has its own merits, stemming largely from the fact that it is a "drop-in" fuel, i.e. its chemical composition is almost identical to that of fossil jet fuel. Outlined below are five key advantages of alternative jet fuel:

- It can be used in the current fleet with blends up to 50% or with only minor tweaks to engines and fuel distribution systems.
- It can be delivered to airports using existing distribution infrastructure.
- It relies on a portion of existing refinery assets for a certain portion of production.
- It can lower non-CO2 emissions, specifically soot.
- It can offer immediate reductions in carbon intensity.

Alternative jet fuels have their disadvantages

Despite its advantages, alternative jet fuel has its own, often non-trivial drawbacks. Ironically, its greatest problem stems from the very quality that has made it so appealing in the first place. **With a chemical composition nearly identical to that of fossil jet fuel, its tailpipe emissions will also be nearly identical**. Any change in the carbon footprint is a change not in absolute carbon emissions but in *carbon intensity*, occurring due to changes in emissions further upstream, in production.[2]

This major drawback is followed by a host of other constraints: costs and price premiums, limited regulatory reach, lack of revenue certainty, and weak bankability, plus trade-offs between feedstock availability and feedstock sustainability, and finally opportunity costs. We shall explore each of these in greater detail later in this report.

[1] Financial Times, European airlines' emissions on course to exceed pre-pandemic levels (27 April 2025).
[2] For a more comprehensive overview of the difference between absolute emissions and emission intensity, see Carbon Tracker, Absolute Impact, pp.15-18.

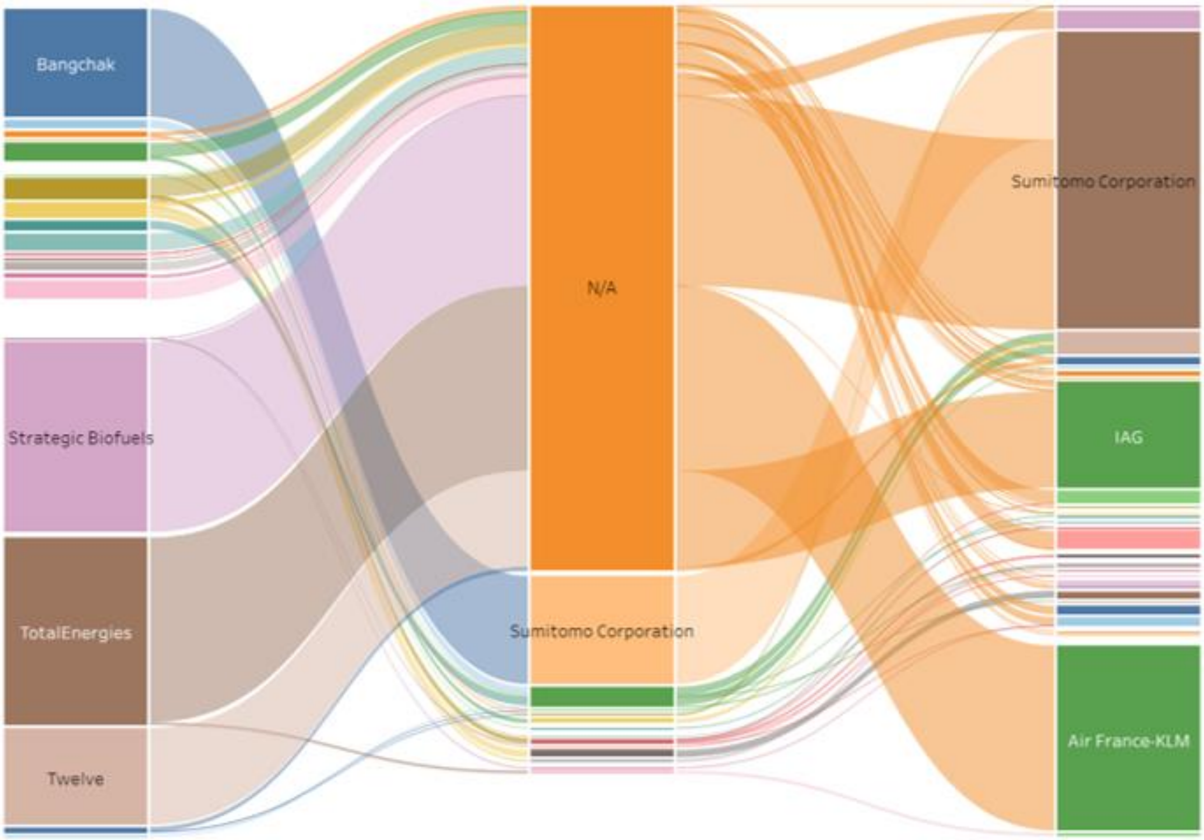
We focus on key players in the alternative jet fuel value chain to analyse recent trends

This report builds on our analysis from Awaiting take-off and explores in greater detail the challenges to scaling up truly sustainable alternative jet fuels. The report is structured as follows:

1. an overview of **Terminology** at the end of the Introduction;
2. an overview of the **State of play in the alternative jet fuel market**;
3. an overview of the **Global policy landscape**, with a focus on the EU and the UK;
4. analysis of **Seven hurdles to scaling up SAF**; and
5. **Conclusion and recommendations**, reframing alternative jet fuels as just one of a range of solutions, with a specific, limited role to play in a certain portion of commercial aviation.

A large portion of our analysis is based on the study of fuel flows through three core segments of the value chain: producers; suppliers, and aeroplane operators (see Figure 1).

FIGURE 1. ALTERNATIVE JET FUEL FLOWS FROM PRODUCERS TO SUPPLIERS TO OPERATORS



Source: Ishka SAVi, Carbon Tracker analysis

We recognise that the larger value chain includes other players: feedstock suppliers, traders, midstream infrastructure operators, airport operators, original equipment manufacturers, and passengers and courier companies. We focus on the three major segments above because these are the key players in this value chain and are, as such, the most appropriate subjects for a big-picture overview.

Terminology

Jet aircraft are powered by **jet fuel**, also known as **kerosene**. We use these terms interchangeably, regardless of the origin of the fuel. We use the term **total jet fuel consumption** to refer to the sum total of **fossil jet fuel** and **alternative jet fuel**.

Alternative jet fuels come in many varieities

There is a myriad of pathways to produce alternative jet fuels, each a product of a unique combination of specific feedstock and a specific conversion technology.

We group feedstocks into three distinct categories (see Figure 2):

1. **fossil-based** feedstocks,
2. **biogenic** feedstocks:
    a. dedicated **energy crops** such as miscanthus or switchgrass
    b. **food and feed crops** like sugarcane and corn
    c. other **lignocellulosic biomass**, including agricultural and forestry residues; and
    d. other **waste**, including lipids like used cooking oil, as well as municipal solid waste;[*]
3. **non-biogenic renewable** feedstocks.

We identify four major types of conversion technologies: **HEFA** (hydroprocessed esters and fatty acids); **ATJ**, (alcohol-to-jet); **FT** (Fischer-Tropsch); and **PTL** (power-to-liquids).[3] In this report we use the term **e-fuel** to refer to alternative jet fuel produced using PTL; other names for this type of fuel include e-kerosene, synthetic fuel, and eSAF.

Although the **Technology Readiness Level** (TRL), measured on a scale from 1 to 9, is a major distinguishing factor between the four conversion technologies, we do not focus on it in this report and assume all pathways will prove technological feasibility. Commercial viability, which decides eligibility for Technology Readiness Levels 8 and 9, is explored separately.

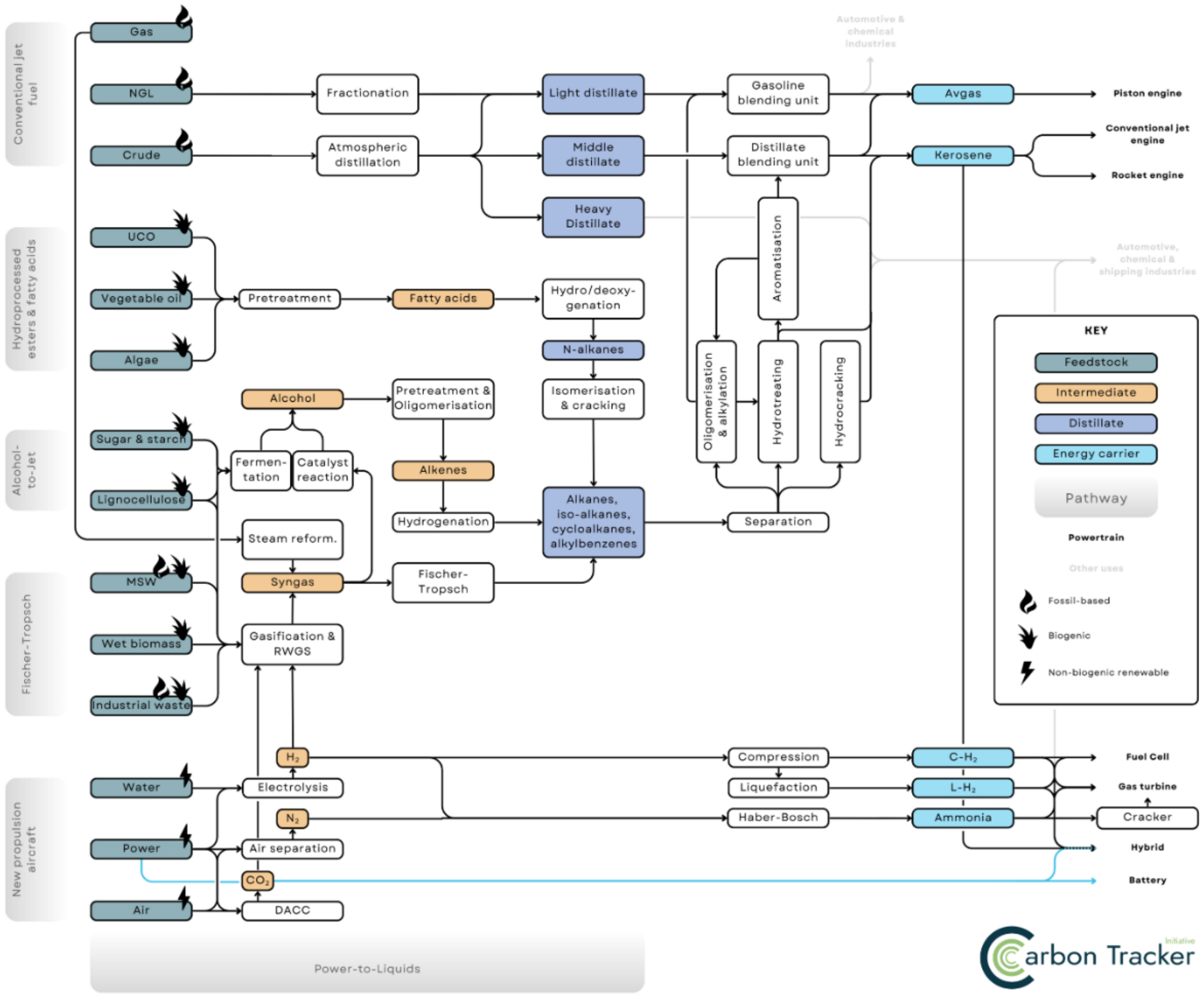
All SAF are alternative jet fuels; not all alternative jet fuels are SAF

As we shall see in the following sections, the use of alternative jet fuels does not always result in a reduction in carbon intensity. Even though most combinations of feedstock and conversion technologies – **pathways** – are indeed less carbon-intensive, there are certain pathways that produce fuels that are more carbon-intensive than fossil jet fuel.

> In this report, we use the term "alternative jet fuel" to contrast it with fossil jet fuel, and we will only use the terms "sustainable aviation fuel" and "SAF" when referring to a subset of alternative jet fuels that are likely to lead to significant reductions in carbon intensity without endangering the environment.

[*] Municipal solid waste may contains goods of fossil origin (e.g. plastic) and is therefore part-fossil-based.
[3] For a broader overview of these technologies, see Awaiting take-off.

FIGURE 2. SIMPLIFIED PROCESS FLOW DIAGRAM OF ENERGY CARRIER VALUE CHAIN IN AVIATION



Source: Carbon Tracker

State of play in the alternative jet fuel market

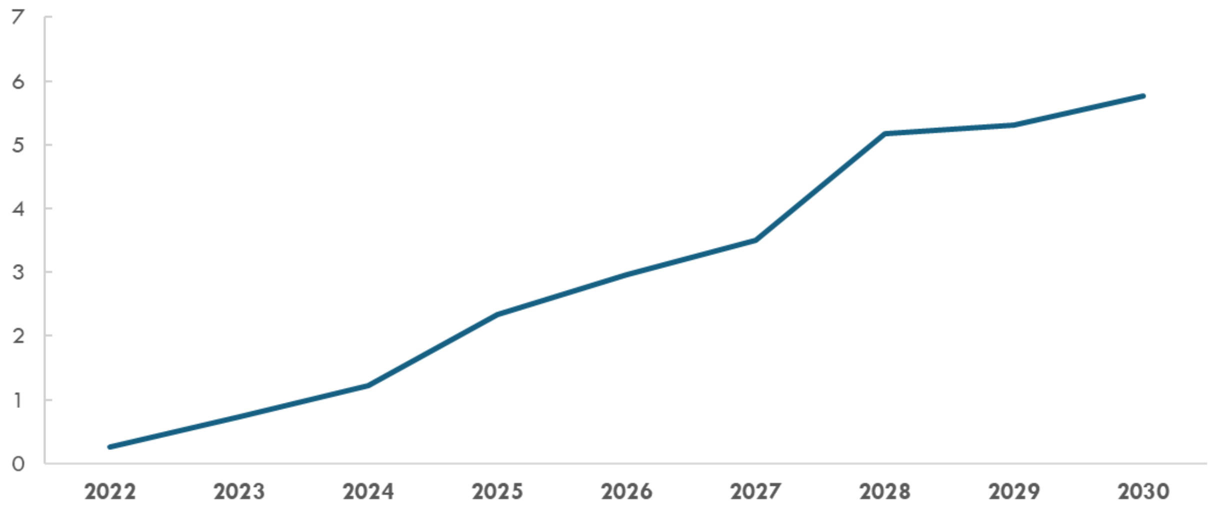
Alternative jet fuel is already in use today and reached 1 million tonnes (Mt) in production in 2024, representing 0.3% of total jet fuel consumption.[4] In this section, we explore recent trends in alternative jet fuel development and model potential supply out to 2030. Our analysis is split up into three sub-sections:

1. Analysis of alternative jet fuel volumes covered by publicly announced offtake commitments.
2. Analysis of potential future capacity based on existing and planned projects.
3. Overview of the role played by fuel suppliers.

Offtake commitments vs total jet fuel consumption

Alternative jet fuel offtake is set for significant growth through 2030. Aggregate offtake covered by commitments made so far currently stands at 2.3 Mt in 2025 and 5.8 Mt in 2030 (see Figure 3).*

FIGURE 3. ALTERNATIVE JET FUEL VOLUMES COVERED BY OFFTAKE COMMITMENTS, MT



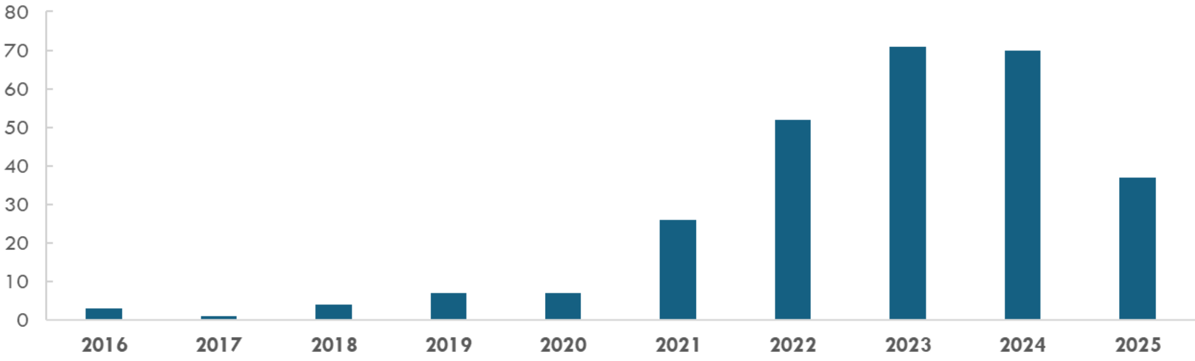
Source: Ishka SAVi, Carbon Tracker analysis

Notes: Includes binding agreements (supply, purchase, and offtake agreements, plus certificates) and non-binding agreements (letters of intent, memoranda of understanding, and options). Data as of 21 July 2025.

These figures are likely to grow over time. Firstly, more commitments have likely been made since the data was collated. A total of 37 agreements had been signed by 21 July 2025 as opposed to 71 in 2023 and 70 in 2024 (see Figure 4). The autumn months typically see a pick-up in contractual activity, which suggests that this year's total is on track to catch up with or even overtake those from 2023 and 2024.

[4] Production volumes as per IATA, Disappointingly Slow Growth in SAF Production (10 December 2024); Total jet fuel consumption as per IATA, Industry Statistics (n.d.; Accessed 30 August 2025).
* Offtake commitments mean binding and non-binding agreements to purchase fuel. Data as of 21 July 2025.

FIGURE 4. NUMBER OF SURVIVING OFFTAKE AGREEMENTS SIGNED IN 2016-2025



Source: Ishka SAVi, Carbon Tracker analysis

Notes: Surviving agreements include all agreements that have been performed or that are outstanding and have not been cancelled or superseded by follow-up agreements. Includes binding agreements (supply, purchase, and offtake agreements, plus certificates) and non-binding agreements (letters of intent, memoranda of understanding, and options). Data as of 21 July 2025.

Secondly, many more commitments are likely to be made in the coming years, especially as new blending mandates are introduced and existing ones get stricter.[5] The roll-out of mandates in the EU and the UK earlier this year have added a significant incentive for jet fuel suppliers to blend in growing shares of alternative jet fuels into kerosene deliveries at all major European airports. Assuming these remain in place, demand for alternative jet fuel should continue to rise in the region.

Offtake commitments made so far account for a fraction of total jet fuel consumption

Alternative jet fuels are still very nascent. While they have shown significant growth, offtake volumes covered by commitments made so far will still account for less than 2% of total jet fuel consumption through 2030 across a range of air travel growth scenarios (see Table 1).

TABLE 1. ALTERNATIVE JET FUEL OFFTAKE COMMITMENTS AS % OF POTENTIAL TOTAL JET FUEL USE

	2022	2023	2024	2025	2026	2027	2028	2029	2030
AJF commitments (Mt)	0.3	0.7	1.2	2.3	3.0	3.5	5.1	5.3	5.8
AJF share if total jet fuel use grows at:									
2% CAGR	0.1%	0.3%	0.4%	0.7%	0.9%	1.1%	1.6%	1.6%	1.7%
3% CAGR	0.1%	0.3%	0.4%	0.7%	0.9%	1.1%	1.5%	1.5%	1.6%
4% CAGR	0.1%	0.3%	0.4%	0.7%	0.9%	1.0%	1.5%	1.5%	1.5%

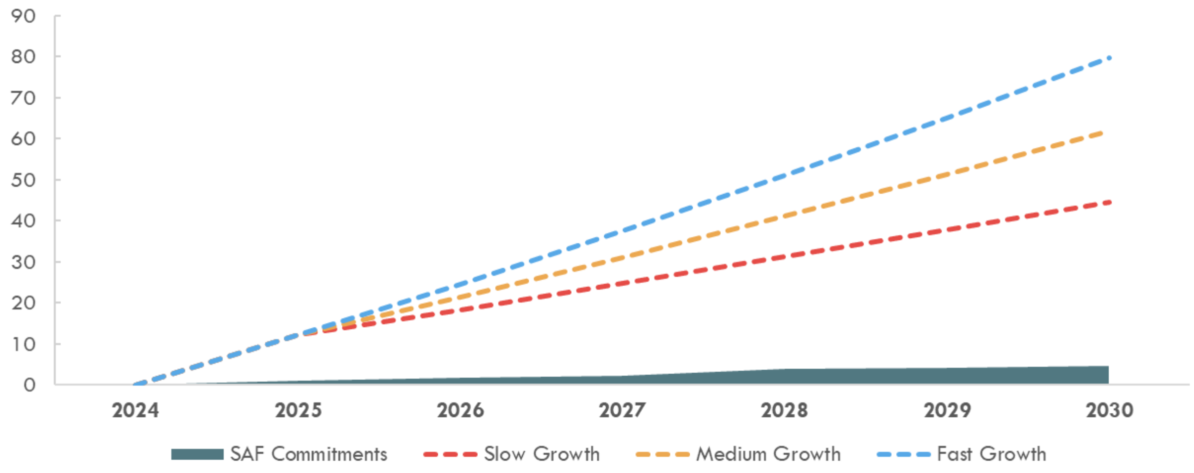
Source: IATA, Ishka SAVi, Carbon Tracker analysis

Notes: AJF means alternative jet fuel. Commitments include binding agreements (supply, purchase, and offtake agreements, plus certificates) and non-binding agreements (letters of intent, memoranda of understanding, and options). Tota jet fuel consumption growth modelled at 2%, 3%, and 4% CAGR. Data as of 21 July 2025.

[5] For an overview of mandates, see Section *Global policy landscape*.

Moreover, we see **growth in offtake volumes meeting only a small fraction of total jet fuel demand growth across a range of scenarios** (see Figure 5).

FIGURE 5. GROWTH IN ALTERNATIVE JET FUEL OFFTAKE VS GROWTH IN TOTAL JET FUEL USE, MT



Source: IATA, Ishka SAVi, Carbon Tracker analysis

Notes: Includes binding agreements (supply, purchase, and offtake agreements, plus certificates) and non-binding agreements (letters of intent, memoranda of understanding, and options). Tota jet fuel consumption growth modelled at 2%, 3%, and 4% CAGR. Data as of 21 July 2025.

Half of alternative jet fuels covered by non-binding agreements have been delivered

We should note that the analysis above is based on offtake volumes aggregated across all types of agreements, binding and non-binding alike. We give the industry the benefit of the doubt, assuming that all outstanding agreements, regardless of enforceability, will be performed in full.

However, letters of intent (LOIs), memoranda of understanding (MOUs), and option contracts are not enforceable in the same way as take-or-pay or purchase agreements. Whether the offtake volumes under those agreements materialise depends on whether the parties choose to enter into binding follow-up agreements or to exercise their option contracts.

There are reasons to believe that some volumes under non-binding agreements are likely to be offtaken. For example, a half of volumes due to be delivered in 2024 under LOIs, MOUs, and options *were* in fact delivered. Going forward, it is worth keeping track of deliveries under non-binding agreements, both to understand the effect of policy incentives and to identify the early signs of a shift to spot trading.

With near-term demand signals weak, it is worth exploring maximum supply potential

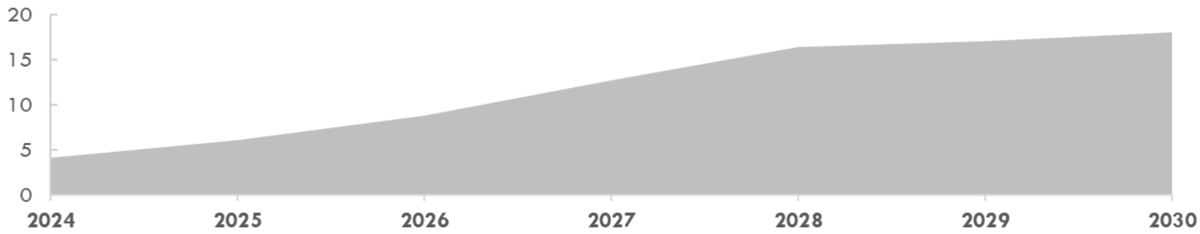
As a key demand signal, offtake commitments remain relatively weak. Our analysis shows that the volumes underpinned by binding and non-binding agreements signed so far will be able to displace less than 2% of fossil jet fuel in 2030. To understand how much further offtake volumes and consumption may grow in the near term, we conducted a separate analysis of capacity growth out to 2030 in subsection *Production capacity vs total jet fuel consumption* below.

Production capacity vs total jet fuel consumption

Offtake commitments provide insight into demand only as of 21 July 2025. As we noted above, contracted volumes out to 2030 are likely to grow as further offtake commitments are signed. This subsection explores existing and announced capacity to evaluate the maximum potential supply and, by extension, the maximum potential offtake in the near term.

The analysis below is based on the market outlook by SkyNRG, which sees capacity growing from 4.1 Mt in 2024 to 18.1 Mt in 2030 (see Figure 6)[6]

FIGURE 6. SKYNRG'S OUTLOOK FOR ALTERNATIVE JET FUEL CAPACITY IN 2024-2030

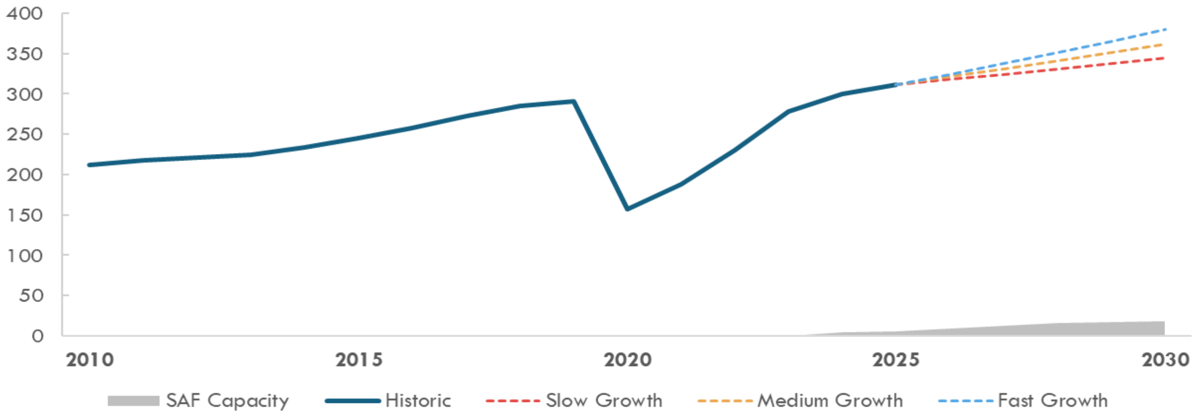


Source: SkyNRG

Potential supply will make up a fraction of total jet fuel consumption even at full capacity

Assets such as biofuel plants can take on average five years from announcement to commissioning, meaning that it is unlikely that new capacity will be added before 2030.[7] Our analysis shows that even if all existing and recently announced projects ran at full capacity, supply would still make up a sliver of total fuel consumption by 2030 (see Figure 7).

FIGURE 7. ALTERNATIVE JET FUEL CAPACITY VS TOTAL JET FUEL CONSUMPTION, MT



Source: IATA, SkyNRG, Carbon Tracker analysis

Notes: Assumes 100% utilisation rate. Total jet fuel consumption growth modelled at 2%, 3%, and 4% CAGR. Data as of 21 July 2025.

[6] SkyNRG, SkyNRG & ICF release Sustainable Aviation Fuel Market Outlook 2025 (5 June 2025).
[7] World Economic Forum, Financing Sustainable Aviation Fuels: Case Studies and Implications for Investment (2025), p.9.

Starting from around 1.4% of the total in 2024, the share of alternative jet fuel capacity would grow only threefold and just touch 5% under a medium-growth scenario (see Table 2). This appears to be in line with projections made by DNV in its latest Energy Transition Outlook.[8]

TABLE 2. ALTERNATIVE JET FUEL CAPACITY AS % OF TOTAL JET FUEL USE

Total jet fuel growth scenario	2024	2025	2026	2027	2028	2029	2030
Alternative jet fuel capacity (Mt)	4.1	6.1	8.8	12.7	16.4	17.1	18.1
Share of potential alternative jet fuel supply if total jet fuel use grows at:							
2% CAGR	1.4%	2.0%	2.8%	3.9%	5.0%	5.1%	5.3%
3% CAGR	1.4%	2.0%	2.7%	3.8%	4.8%	4.9%	5.0%
4% CAGR	1.4%	2.0%	2.7%	3.8%	4.7%	4.7%	4.8%

Source: IATA, SkyNRG, Carbon Tracker analysis

These projections are based on nameplate capacity, assuming 100% utilisation rates through the year, with no downtime for routine maintenance, outages, turnarounds, upgrades, or idling due to reduced margins. As a result, they may overstate the contribution alternative jet fuels could make. A more realistic estimate of future supply would factor in utilisation rates, which typically run at 75-90% for industrial facilities, depending on market trends in a particular industry.

In biofuels, utilisation rates have historically trended towards the lower end of that range due to feedstock supply constraints.[9] Biodiesel refineries in the US, for example, operated at 72% capacity in 2018 and 77% in 2019, *after* accounting for "normal downtime for maintenance",[10] and stayed a few percentage points below 80% through 2022.[11]

For alternative jet fuels, the rates are much lower. **Our analysis suggests that the utilisation rates of alternative jet fuel plants stood at just 24% in 2024, with 3 Mt in unused capacity.**[12] As per SkyNRG, this is "likely attributed to production ramp-ups and limited near-term demand signals."[13]

Growth in offtake volumes under current commitments will grow concurrently with capacity growth, filling around 30% of expected capacity (see Figure 8), assuming all agreements are fulfilled.

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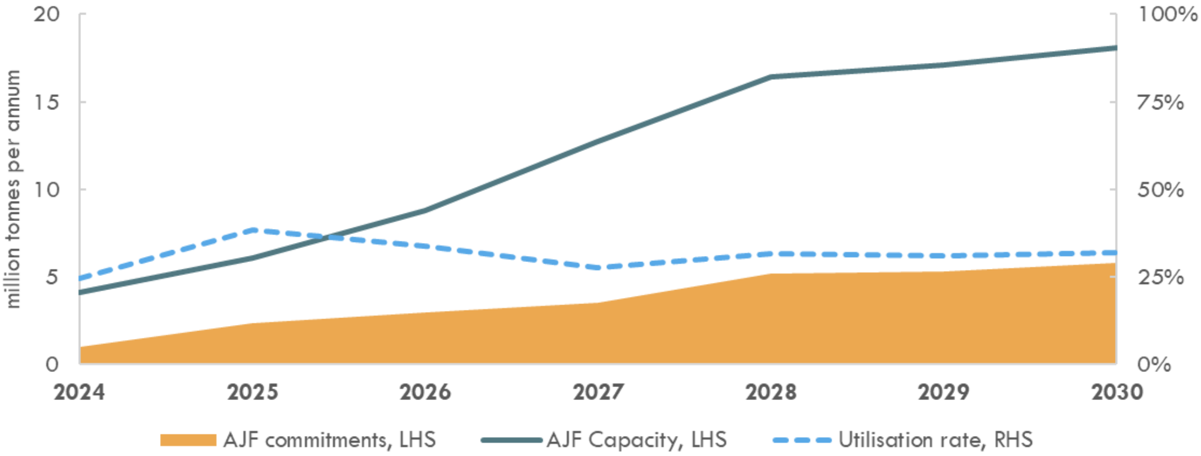
[8] DNV, Global Energy Transition Outlook 2025 (2025), p.30.
[9] LMC International, Economic Impact of Biodiesel on the United States Economy 2022: Main Report (2022), p.11.
[10] EIA, EIA releases plant-level U.S. biodiesel production capacity data (16 September 2019).
[11] NREL, 2022 Bioenergy Industry Status Report (2024), p.22.
[12] IATA reported 1 m tonnes of alternative jet fuel produced in 2024. SkyNRG's SAF Market Outlook gave 4.1 m tonnes of alternative jet fuel capacity in 2024. For more detail, see IATA, Disappointingly Slow Growth in SAF Production (10 December 2024); SkyNRG, SkyNRG & ICF release Sustainable Aviation Fuel Market Outlook 2025 (n.d.; Accessed 8 September 2025).
[13] SkyNRG & ICF, SkyNRG & ICF release Sustainable Aviation Fuel Market Outlook 2025 (n.d.; Accessed 8 September 2025).

FIGURE 8. ALTERNATIVE JET FUEL OFFTAKE AS A SHARE OF CAPACITY

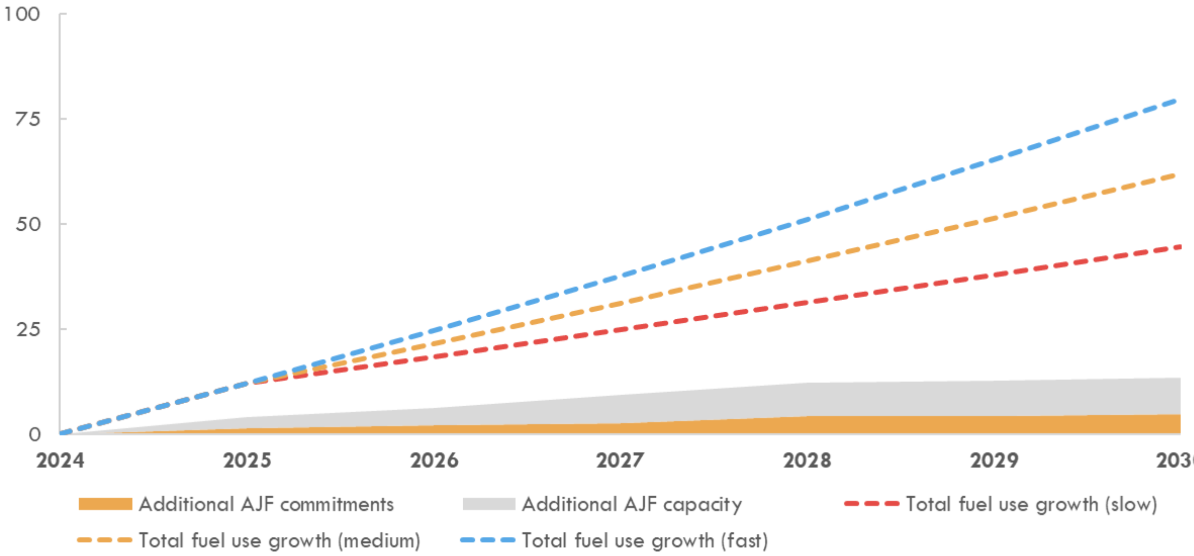


Source: Ishka SAVi, SkyNRG, IATA, Carbon Tracker analysis

Notes: AJF means alternative jet fuel; LHS denotes data series plotted on the left-hand side (volume) axis; RHS denotes data series plotted on the right-hand side (percentage) axis. 2024 offtake figure based on actual production volumes, as reported by IATA. Offtake figures from 2025 onwards based on commitment data, as supplied by Ishka SAVi. Commitments include both binding agreements (supply, purchase, and offtake agreements, plus certificates) and non-binding agreements (letters of intent, memoranda of understanding, and options). Supply data as of 21 July 2025

Clearly, the substantial growth in capacity is anticipating demand growth beyond that implied by current offtake commitments. Assuming a utilisation rate of 80%, existing and new projects would only add 13.5 Mt in potential supply by 2030, which would meet only 17-30% of additional total jet fuel consumption, modelled at 2-4% CAGR (see Figure 9).

FIGURE 9. GROWTH IN AJF CAPACITY AT 80% UTILISATION VS GROWTH IN TOTAL FUEL USE, MT



Source: Ishka SAVi, SkyNRG, IATA, Carbon Tracker analysis

Notes: AJF means alternative jet fuel. Growth calculated against 2024 baseline. Commitments include both binding agreements (supply, purchase, and offtake agreements, plus certificates) and non-binding agreements (letters of intent, memoranda of understanding, and options). Supply data as of 21 July 2025. Growth in commitments calculated against actual production data, as reported by IATA; Total jet fuel growth modelled assuming growth rates of 2%, 3%, and 4%.

In other words, **for every tonne of additional fossil jet fuel that *could* be replaced by a non-fossil alternative from an existing or announced project, there will be more than one additional tonne that won't**.

Growth in alternative jet fuel capacity beyond 2030 may face certain limitations. SkyNRG notes that HEFA, the most commercially viable pathway that accounts for 82% of total capacity, may be reaching its ceiling due to feedstock availability constraints.[14] Two other pathways, FT and ATJ, are already approaching maturity, but they may also face feedstock limitations, as we shall explore in sub-section **Hurdles 5 and 6. Feedstock availability and sustainability**.

[14] SkyNRG, SAF Market Outlook 2025 (2025), p.5.

Suppliers as intermediaries in the supply chain

In the market for fossil jet fuel, integrated oil and gas companies as well as dedicated refiners like Valero act as both producers and suppliers. However, in the market for alternative jet fuels, oil and gas companies act primarily as suppliers, sourcing their fuel from independent producers.

For offtake commitments signed in 2020-2024, the list of the top 10 suppliers, where disclosed, is dominated by oil and gas firms (see Table 3). However, from the top 10 producers, nine are specialists in alternative jet fuels and only one, Shell, is an oil and gas company, sitting in 10th place.

TABLE 3. TOP 10 FUEL PRODUCERS AND TOP 10 FUEL SUPPLIERS BY COMMITMENT VOLUMES

Rank	Producer	Volume, t	Rank	Supplier	Volume, t
-	N/A	1,751,471	-	N/A	47,611,021
1	Blue Blade Energy	8,175,600	1	Shell	1,653,248
2	Gevo	5,248,179	2	bp	1,440,000
3	DG Fuels	4,814,520	3	OMV	959,000
4	Alder Fuels	4,542,000	4	Cosmo Oil	876,000
5	Cemvita	3,028,000	5	Sumitomo Corp	876,000
6	Raven SR	2,500,000	6	World Kinect	239,110
7	Neste	2,224,204	7	Delta Air Lines	211,960
8	USA BioEnergy	2,059,040	8	Fidelis New Energy	83,573
9	ECB Group	1,800,000	9	Neste	60,000
10	Shell	1,798,632	10	Eni	30,000

Source: Ishka SAVi, Carbon Tracker analysis

Notes: N/A stands for data that has not been disclosed. Includes binding agreements (supply, purchase, and offtake agreements, plus certificates) and non-binding agreements (letters of intent, memoranda of understanding, and options). Data as of 21 July 2025.

We caveat that our assessment is based on a trammelled sight of the market, with suppliers unidentified for 88% of the 54.1 Mt agreed upon in 2020-2024. It may well be that disruptors are playing a more dominant role in the supply of alternative jet fuel than our data suggest.

Suppliers play an important role in stimulating growth in the market for alternative jet fuels, controlling fuel deliveries and thus the blending rates. But a full understanding of fuel flows through the value chain is hindered by a lack of disclosure. This is of special importance for investors with exposure to companies identified as fuel suppliers, considering the increasingly tighter regulatory environment in which they operate.

Global policy landscape

The past five years have seen an accelerating roll-out of policies to drive the production and consumption of alternative jet fuel. These mostly comprise tax credits and blending mandates or targets. In this section we provide an overview of key measures adopted or planned to be adopted in nine jurisdictions around the world, with a focus on the EU and the UK.

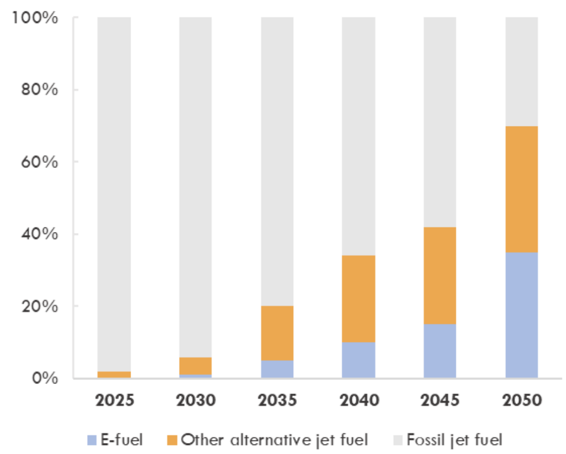
European Union

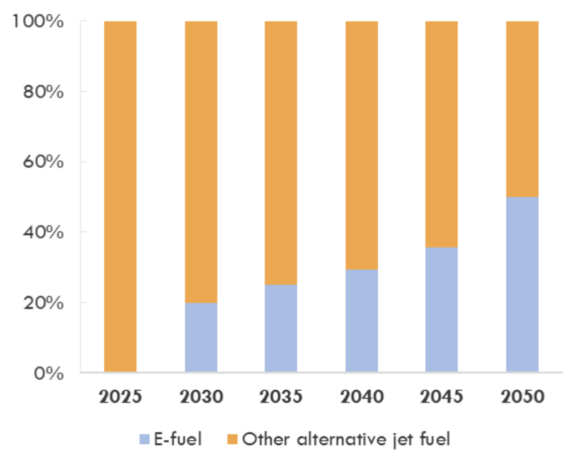
The EU's policy on alternative jet fuels is governed by ReFuelEU Aviation, adopted in 2023. Its key element is a blending mandate for jet fuel delivered to major airports, with key provisions summarised in Table 4 and targets visualised in Figure 10:

TABLE 4. SUMMARY OF KEY ELEMENTS OF EU MANDATE[15]

Status	In force
Legal force	Binding
Feedstock requirements	Strict; excludes food and feed crop-based feedstock
Emission savings threshold	• 65% for alternative jet fuels excluding e-fuel • 70% for e-fuel
Obligated parties	• Fuel suppliers to comply with mandate • Airlines to uplift at least 90% of outbound fuel from EU airports • Airports to provide infrastructure
Coverage	95% of air transport departing from EU airports
Penalty	Fuel suppliers pay 2x price differential between fossil and alternative jet fuel
Additional provisions	• Fuel suppliers to report annually on total fuel supplied, blending rates, and fuel type • Airlines to report annually on suppliers, fuel types, and lifecycle emissions

FIGURE 10. EU BLENDING REQUIREMENTS: MAIN MANDATE (LHS) AND E-FUEL SUB-MANDATE (RHS)





[15] EU, Regulation (EU) 2023/2405 (refuelEU Aviation); EU, Directive (EU) 2018/2001 (RED II).

Alternative jet fuels supplied to the EU must meet strong sustainability criteria

ReFuelEU Aviation requires that biogenic jet fuels comply with a set of strong sustainability criteria outlined in RED II, which seek to minimise the impact on climate and nature.[16] In addition to food crops, these exclude a) feedstock from biodiverse and high-carbon-stock lands, as well as lands with land-use change risk, and b) feedstock that cannot be regrown "within a reasonable time" to make up for the carbon emitted on combustion.[17]

The combination of a high emission savings threshold and strict requirements for feedstock effectively rule out a number of the less sustainable pathways, including those using corn and cereals as feedstock. **This makes it more likely that most of fuels used in EU will be true SAF**.

ReFuelEU seeks to prevent "buy-outs" by suppliers and tankering by operators

Under Article 4, fuel suppliers that fail to meet the blending requirements in a particular year will have to make up for the shortfall the following year.[18] The provision applies to alternative jet fuels in general and e-fuels specifically, although with some flexibility for the latter.[19]

The requirement to carry forward the obligation is set to **ensure that fuel suppliers don't treat the penalty as a "buy-out" clause by simply paying the penalty**. Failure to make up for the shortfall in the subsequent period will also be penalised, although the Directive does not appear to require that the obligation be carried forward into the following years.[20]

The minimum uplift requirement for airlines and cargo operators is designed to avoid tankering – the practice of uplifting more fuel than necessary at airports where prices are low or availability is higher, as a form of regulatory arbitrage. **Operators that fail to comply will be fined 2x the average annual price of jet fuel for every tonne of fuel** that falls outside of exempted volumes.[21]

ETS allowances help cut price differentials and developers access policy support

From 2024 until 2030, **aircraft operators will receive support from a fund of ETS allowances, worth €1.5-1.6 bn, to help reduce the price differential between alternative and fossil jet fuel.**[22] The highest level of support is provided for e-fuels, followed by advanced biofuels, and then others (e.g. HEFA).

In addition, alternative jet fuels are listed in the Net-Zero Industry Act as a key technology in need of support, which will include measures to expedite project permits and develop the market.[23] Further support for alternative jet fuel is expected to come from the Sustainable Transport Investment Plan, due in November 2025, which is expected to include measures to derisk capex.[24]

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[16] Article 29, EU, Directive (EU) 2018/2001.
[17] (98), EU, Directive (EU) 2018/2001.
[18] Article 4(1), EU, Regulation (EU) 2023/2405 (refuelEU aviation)
[19] IATA, ReFuelEU Aviation Handbook (2024), p.13.
[20] Article 4(7), EU, Regulation (EU) 2023/2405 (refuELEU aviation) suggests that the obligation is carried over only once, into the following period.
[21] Article 12(2), EU, Regulation (EU) 2023/2405 (refuelEU aviation). The price is likely that of fossil jet fuel.
[22] Norton Rose Fulbright, A new sustainable aviation fuel mandate (2024); Article 3c, EU, Consolidated text: Directive 2003/87/EC; EC, Reducing emissions from aviation (n.d.).
[23] See Article 3, EU, Proposal (EU) COM/2023/161; EC Net-Zero Industry Act (n.d.).
[24] European Parliament, A sustainable transport investment plan (2025).

United Kingdom

Although in some respects similar to ReFuelEU, British regulations concerning alternative jet fuels although they have their own relative strengths and weaknesses.

The UK's policy on alternative jet fuels is governed by the SAF Mandate,[25] which came into force in January 2025. Its key element is a blending mandate for jet fuel delivered to major British airports, with key provisions summarised in Table 5 and targets visualised in Figure 11:

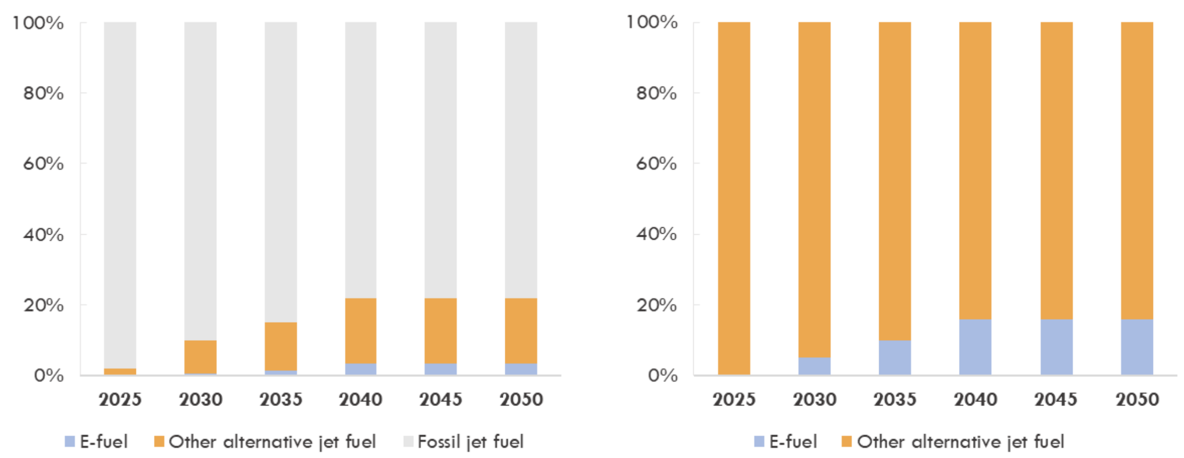
TABLE 5. SUMMARY OF KEY ELEMENTS OF UK MANDATE[26]

Status	In force
Legal force	Binding
Feedstock requirements	Strict; excludes food and energy crop-based feedstock
Min. emission savings	• 40%
Obligated parties	• Fuel suppliers to comply with mandate
Coverage	N/A
Penalty	Buy-out amount, calculated separately for biogenic and e-fuel
Additional provisions	• Suppliers eligible to trade SAF certificates • HEFA share in total supply to taper down to 2040 • Includes review mechanism to update targets • E-fuel to use low-carbon energy, meet additionality criterion

E-fuel requirements seek to avoid most opportunity costs

The two requirements for the production of e-fuels – that it use low-carbon energy and that such energy be additional to that already in use – is set to ensure that energy sources like renewables are not diverted away from other sectors. However, **e-fuel can still compete for subsidies and land, introducing the issue of opportunity costs** explored in greater detail in Subsection *Hurdle 7. Opportunity costs.*

FIGURE 11. UK BLENDING REQUIREMENTS: MAIN MANDATE (LHS) AND E-FUEL SUB-MANDATE (RHS)



[25] Department for Transport, Sustainable Aviation Fuel (SAF) Mandate (19 December 2024).
[26] The Renewable Transport Fuel Obligations (Sustainable Aviation Fuel) Order 2024.

Buy-out provision mean shortfalls in alternative jet fuel supply may not be offset

The penalty mechanism of the UK SAF Mandate is a "buy-out" payment that fuel suppliers must make at the end of the year for any shortfall in the supply of alternative jet fuel. Calculated separately for biogenic fuel and e-fuel, it applies a fixed charge for every megajoule of fuel undelivered, which translates into a constant price of around £5,900 per tonne of shortfall in all alternative jet fuels other than e-fuels and £6,250 per tonne of shortfall in e-fuel.[27]

The stated purpose of the buy-out mechanism is to protect fuel suppliers in case of fuel shortages or from fuel prices deemed to be too high, as well as to protect airlines from ticket price hikes. But given that the fuel shortfall won't need to be supplied if bought out, it is reportedly intended only as a temporary mechanism.[28]

UK SAF Mandate could theoretically serve as an emission intensity target, but unlikely to

Fuel amounts under the British mandate are calculated based on their energy content rather than their volume. In other words, the amount of fossil jet fuel that needs to be displaced and the amount of alternative jet fuel that displaces it are both measured in megajoules, not litres.

The implication is that fuel suppliers can't just discharge their obligation by replacing 1 litre of fossil jet fuel with 1 litre of whichever alternative jet fuel is eligible. The type of fuel, its calorific value, and carbon intensity will also factor into the calculation of obligation amounts. As we show in Appendix 1, all alternative jet fuels are normalised for emissions savings before they are counted towards discharging the obligation.[*]

In a hypothetical situation where all fuel suppliers would be obligated to meet the target with actual deliveries at all costs, **the mandate would effectively be a target to reduce the emission intensity of jet fuel supplied to British airports by the mandate percentage multiplied by 70%**. However, the availability of the buy-out mechanism means that intensity reduction can be lower than that if even one litre of obligated fuel is bought out rather than replaced by alternative jet fuel.

Hydrogen used as fuel can also count towards mandate obligations

The British mandate also covers hydrogen if it's used as a fuel in hydrogen-combustion engines or fuel-cell powertrains.[29] It applies the same sustainability criteria to the fuel as to alternative jet fuels.

Other types of fuel covered by the mandate include recycled carbon fuels, including those from industrial gases that can't otherwise be recycled or reused, and the portion of co-processed fuel that has been sourced from non-fossil feedstock.[30]

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[27] As per s.21(8-9), The Renewable Transport Fuel Obligations (Sustainable Aviation Fuel) Order 2024, fuel suppliers pay a fixed charge of £0.137 per MJ of alternative jet fuel other than PTL and £0.145 per MJ of PTL; As per Department for Transport, Sustainable Aviation Fuel Mandate: Compliance Guidance (2025), the conversion factor is the Lower Heating Value of 43 MJ/kg at a standard density of 1.265 l/kg. Calculations corroborated by SkyNRG, Policy nuggets: The UK SAF Mandate (29 May 2024).

[28] Norton Rose Fulbright, A new sustainable aviation fuel mandate (2024).

[*] The fuel is effectively "converted" into a baseline fuel that delivers a 70% reduction in emission intensity.

[29] Para 1.19, Department for Transport, Sustainable Aviation Fuel Mandate: Compliance Guidance (2025).

[30] Para 1.19, Department for Transport, Sustainable Aviation Fuel Mandate: Compliance Guidance (2025); Annex A, Department for Transport, RTFO Guidance for Recycled Carbon Fuels (2024), p.19.

HEFA cap is designed to encourage advanced fuels and avoid opportunity costs

The UK mandate includes a HEFA cap, requiring that the share of fuels obtained through HEFA be tapered down from 100% in 2025-2026 to 71% in 2030 and 35% in 2040.[31] The goal of the cap is to encourage the development of advanced fuels, i.e. those from the FT and ATJ pathways.[32]

This cap has been put in place seemingly in recognition of the facts that HEFA feedstock is inherently limited and that HEFA fuel is already in use in road transport.[33] We explore these issues in Subsections *Hurdles 5 and 6. Feedstock availability and sustainability* and *Hurdle 7. Opportunity costs.*

It is the only mandate to exclude energy crops as well as food and feed crops

The UK SAF Mandate is the only one in the world that explicitly excludes all types of crop-based feedstock, not only food and feed crops, but also dedicated energy crops.[34] While ReFuelEU seeks to minimise land use change from crop displacement via strong sustainability criteria, energy crops don't seem to be explicitly excluded. Annex IX of RED II appears to allow energy crops as part of "other non-food cellulosic material".[35] Even if energy crops were excluded from this category, some production would still be possible under a 3% cap for "other fuels".[36]

The reasoning behind this is that energy crops still pose a risk of food crop displacement, even if indirectly. Accepting energy crops as viable inputs, even with strong guardrails, may amplify demand signals and encourage their cultivation and later use in jurisdictions with weaker or no mandates. **A blanket ban on energy crops would reduce the risk of food displacement to zero and encourage development of advanced fuels relying on residues as well as e-fuels**.

Fuel producers can access further support via funding and revenue certainty mechanism

In addition to stimulating demand via its mandate, the British government is also considering incentivising supply domestically via the proposed revenue certainty mechanism.[37] Expected to be in place by end-2026, it will set a guaranteed "strike price" agreed with fuel producers, similar to Contracts for Difference for renewable energy projects.[38] The mechanism will be funded through levies on fuel suppliers and will prioritise non-HEFA fuel.[39]

Introduced in 2022 and still in effect as the de facto government framework for aviation decarbonisation, the Jet Zero Strategy lists alternative jet fuel as "one of the key technologies".[40] The strategy earmarked £180m of funding for alternative jet fuel and sought to have at least five plants under construction by end-2025,[41] but this seems unlikely to be achieved. Some £135m have been allocated so far for alternative jet fuel projects, with a further £63m to be awarded in 2026.[42]

[31] Department for Transport, The SAF Mandate: an essential guide.
[32] Department for Transport, The SAF Mandate: an essential guide.
[33] Department for Transport, Sustainable Aviation Fuel Mandate: Compliance Guidance (2025), p.17.
[34] Department for Transport, The SAF Mandate: an essential guide.
[35] Para (p), Annex IX, EU, Directive 2018/2001.
[36] ICCT, Considerations for the ReFuelEU aviation trilogue (2022).
[37] House of Commons Library, Sustainable Aviation Fuel Bill 2024-25 (21 August 2025).
[38] Department for Transport, Sustainable aviation fuel revenue certainty mechanism.
[39] House of Commons Library, Sustainable Aviation Fuel Bill 2024-25 (21 August 2025), pp.5-6.
[40] Department for Transport, Jet Zero Strategy (2022), p.33.
[41] Department for Transport, Jet Zero Strategy (2022), p.36; Macfarlanes, Sustainable aviation fuels (SAF): growing the UK domestic production industry (2 July 2025).
[42] Ricardo, Advanced Fuels Fund (n.d.).

Other jurisdictions

A few other jurisdictions have introduced their own policies in support of alternative jet fuels, some including mandates, others non-binding targets. Table 6 below summarises key mandates and targets, starting from the UK and the EU at the top as the two strongest policies and continuing with the weaker mandates in descending order.

TABLE 6. CURRENT ALTERNATIVE JET FUEL MANDATES AND TARGETS

Jurisdiction	Has binding force	Excludes crop-based fuels	Has emissions threshold	Includes mid-term target	Includes long-term target
UK	Yes	Yes	Yes	Yes	Yes
EU	Yes	Partial*	Yes	Yes	Yes
South Korea	Partial†	No	Yes	Yes	Yes
Brazil‡	Partial§	No	No	Yes	Yes
Japan	Partial‖	No	No	Yes	No
India	No	No	No	Yes	No
Singapore	No	No	No	Yes	No
UAE	No	No	No	Yes	No
Chile	No	No	No	No	Yes

Source: Public disclosures; Carbon Tracker analysis

*Notes: *Excludes food and feed crops but does not exclude energy crops †Mandate applies to international flights only ‡Brazil's mandate is for GHG emissions rather than fuel volumes §Mandate applies to domestic flights only ‖Mandate applies to refiners. Full table, including target and threshold specifics, available in Appendix 2. Current AJF mandates and targets.*

Brazil is unique in that its mandate applies to GHG emission intensity rather than fuel volumes.[43] While welcome for its explicit focus on emissions, such framing has one disadvantage in that without an emissions savings threshold it may incentivise the development of less sustainable fuels.

Producing these in copious amounts and pairing them up with a smaller quantity of ultra-low-carbon-intensity fuels may indeed lead to the kind of volume-weighted reduction in emission intensity that is required by the Brazilian mandate. At the same time, it may endanger biodiversity, soil health, and water availability, not to mention competing uses in road transport. This mandate could be strengthened either by shifting it to an absolute basis or introducing a high emission savings threshold.

Mandates and targets are currently being developed in China, which is reportedly planning a 2-5% blend target for 2030; Thailand, where a mandate is expected next year but has not been enacted; and Turkey.[44] Norway is reportedly planning to harmonise its regulations with ReFuelEU by 2027.[45]

[43] Art.10, Lei No.14.993, de 8 de outubro de 2024; Department of Oil Products and Biofuels, Sustainable Aviation Fuels in Brazil. Future Perspectives (2024).
[44] Reuters, China 'green' jet fuel plants push back start-up amid lack of policy (27 February 2025); Bangchak still awaiting details on Thai sustainable aviation fuel mandate, exec says (10 September 2025); Turkey to set sustainable aviation fuel mandates for airlines, suppliers (30 June 20250.
[45] SAF Investor, Norway eyes ReFuelEU implementation by 2027 (21 May 2025).

We conclude our overview of the global policy landscape by summarising other types of incentives and mandates in Table 7 below, starting from Brazil and moving westwards.

TABLE 7. GLOBAL INCENTIVES AND PENALTIES, EXCLUDING MANDATES

Brazil	• Provides tax incentives for alternative jet fuel production
US	• Has annual production goals of 3 bn gallons by 2030 and 35 bn gallons by 2050 under SAF Grand Challenge • Offers tax credit of $1/gallon for eligible fuels ending in 2029 • Offers federal support for crop-based fuels under Inflation Reduction Act and for increased use of bio-products across federal agencies • Awarded $108m of funding in 2023 under SAF Grand Challenge and $244.5m of grants in 2024 via FAST scheme • Has tax credits at state level in California, Oregon, Washington, Minnesota, Illinois, and Nebraska
Japan	• Reportedly has a 10% blend requirement for refiners • Has awarded $2.3bn of public funding to production facilities • Plans to cut GHG emissions by >5% in 2030-35 using alternative jet fuels
China	• Supports biogenic fuels rather than PTL • Launched the SAF pilot programme in 2024, with airlines blending an undisclosed proportion of alternative jet fuel • Has policies and standards in development by the SAF Technical Centre under the Civil Aviation Authority of China
South Korea	• Encourages exceeding blending quota by offering preferential access to sought-after international routes • Covers up to 20% of production facility capex and up to 40% R&D costs, with additional support for PTL fuels under consideration
Singapore	• Charges a levy to fund alternative jet fuel uptake
India	• Provides guaranteed pricing and capital support for projects • Has a national SAF Policy in planning to set standards and 2050 roadmap

CORSIA

CORSIA is an international carbon offsetting scheme aiming to limit carbon emissions from international aviation to 85% of 2019 levels. Operators can reduce their offsetting requirements under CORSIA using CORSIA-eligible fuels, which include alternative jet fuels and "lower-carbon aviation fuel". To qualify for eligibility, fuels must meet a threshold of 10% emissions savings.

The EU is planning to review CORSIA next year.[46]

[46] European Commission, Reducing emissions from aviation (n.d.; 24 October 2025).

Seven hurdles to scaling up SAF

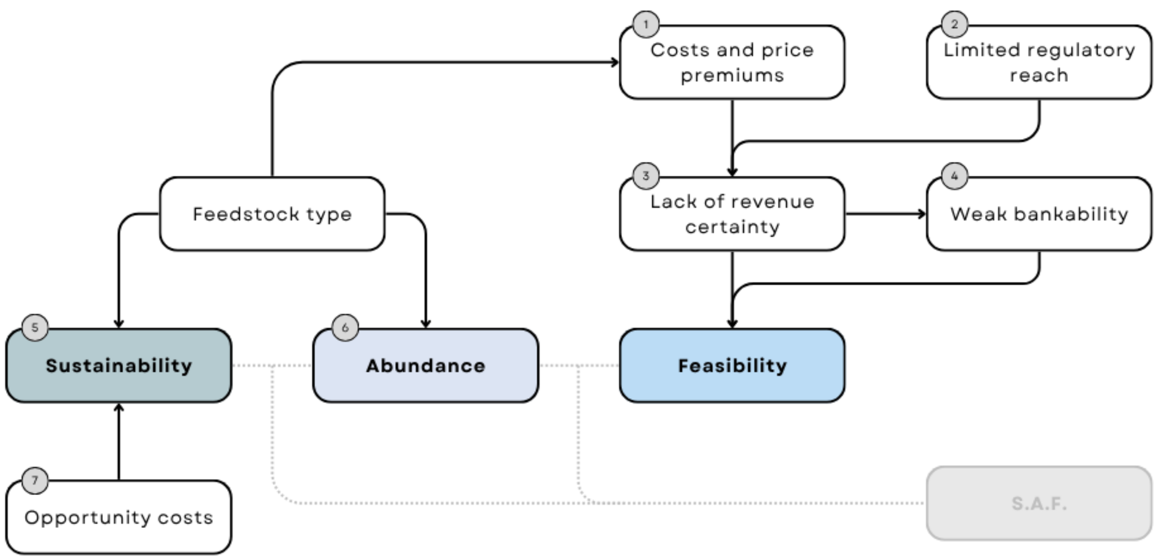
As evidenced by the state of play in the market, alternative jet fuels have yet to be sufficiently scaled up, both in terms of offtake and in terms of capacity.

The problem is that offtakers and producers are both waiting for the other side to act first: offtakers are hesitant to sign long-term agreements at this time, and producers are wary of or are simply unable to build out capacity without such agreements to back it up.

SAF adoption is impeded by seven hurdles

The underlying cause of this deadlock is the lack of a pathway that can deliver sustainable fuel in sufficient volumes and at competitive prices. We believe that these three criteria – sustainability, abundance, feasibility – are key to determining whether alternative jet fuels can act as a viable lever of decarbonisation in aviation (see Figure 12).

FIGURE 12. HURDLES TO SCALING UP SUSTAINABLE AVIATION FUELS



Source: Carbon Tracker

In this section, we'll explore the seven hurdles to scaling up SAF. The first four concern feasibility and apply to alternative jet fuels in general. The other three explore the trade-offs between feedstock availability and feedstock sustainability and apply to SAF specifically.

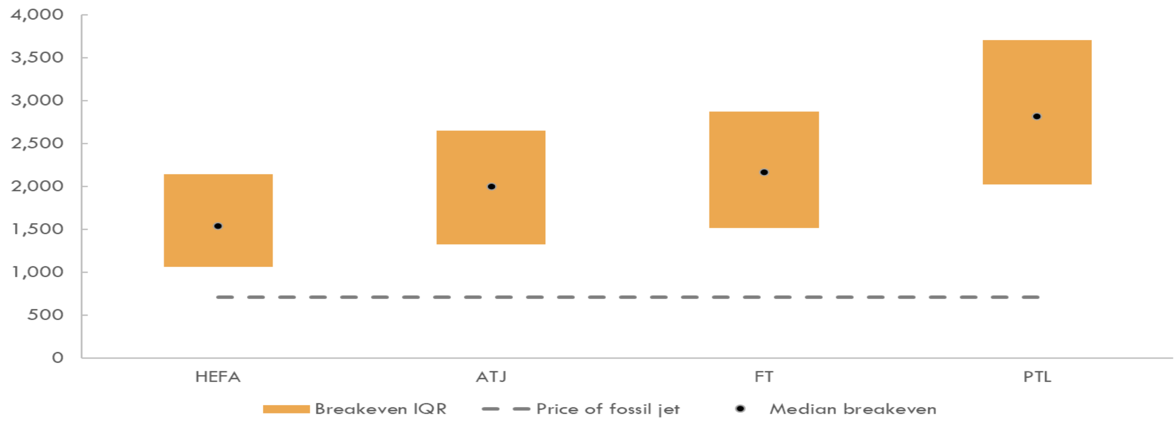
Hurdle 1. Costs and price premiums

The first hurdle is the price premium. In the 12 months to mid-September 2025, HEFA-SPK, which accounts for virtually all alternative jet fuel on the market, sold for $1,800-$2,780/tonne, according to S&P Global Commodity Insights.[47] In contrast, fossil jet fuel held close to $715/tonne.[48] This translates into **a price premium of 150%-280%**.

Alternative jet fuel price premiums stem from significantly higher costs

A substantial portion of that is due to the cost of production. On average, HEFA jet fuel breaks even at over $1,500/tonne, with significant variability based on feedstock type.[49] We note that this is the cheapest and most commercially viable of the four major pathways, with costs increasing in the following order: ATJ, FT, and PTL (see Figure 13).

FIGURE 13. COSTS OF PRODUCTION FOR MAJOR CONVERSION TECHNOLOGIES, USD/TONNE



Source: Braun et al. (2024), Carbon Tracker analysis

One of the chief cost drivers is the feedstock price

The cost difference *between* pathways is largely explained by their complexity and maturity.[50] However, the cost difference *within* pathways is influenced to a greater degree by the feedstock price.[51] Our analysis based on ICAO data shows feedstock price typically accounting for 30-90% of the breakeven price (see Figure 14). Only one feedstock-pathway pair (FT from municipal solid waste) showed the feedstock price accounting for less than 30% of the breakeven price.

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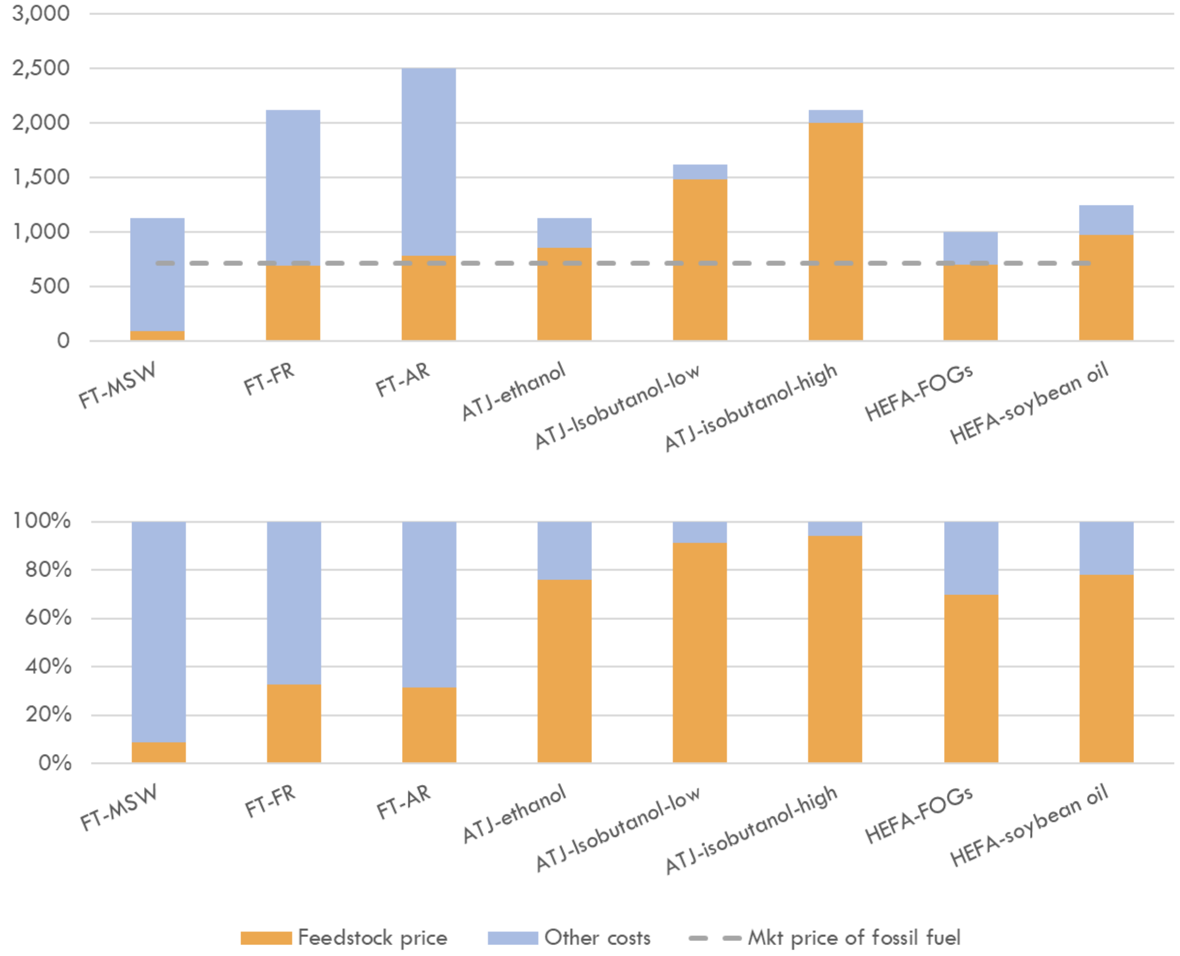
[47] Alternative jet fuel prices sourced from S&P Global, Feedstock availability not limiting factor for aviation net zero by 2050: IATA quoting HEFA-SPK CIF NWE (price per tonne of HEFA-SPK-type fuel delivered to North-West Europe under cost, insurance and freight contracts).
[48] Fossil jet fuel prices based on General Index's JET1NECC Index of Jet Fuel NEW CIF Cargoes (price per tonne of jet fuel delivered to North-West Europe under cost, insurance and freight contracts) via Bloomberg.
[49] Braun et al., Pathway to net zero: Reviewing sustainable aviation fuels, environmental impacts and pricing (2024). See also Fang & Yao, Sustainable aviation fuel pathways: Emissions, costs and uncertainty (2025); World Economic Forum, Financing Sustainable Aviation Fuels: Case Studies and Implications for Investment (2025), pp.10-12.
[50] World Economic Forum, Financing Sustainable Aviation Fuels: Case Studies and Implications for Investment (2025), p.10.
[51] IATA, Global Feedstock Assessment for SAF Production. Outlook to 2050 (2025), p.13.

FIGURE 14. FEEDSTOCK PRICE AS A SHARE OF BREAKEVEN PRICE, TOTAL PRICE AND NORMALISED



Source: ICAO, Carbon Tracker analysis

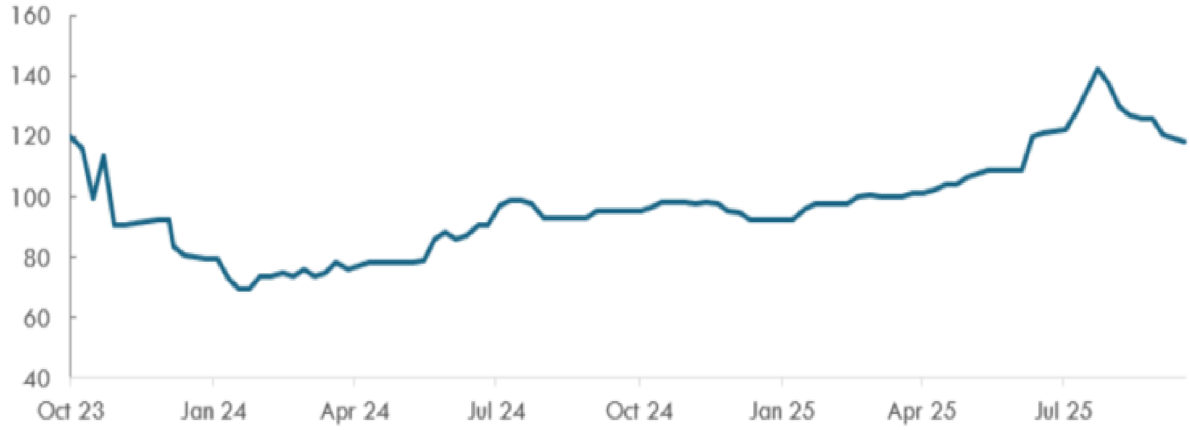
Notes: breakeven prices are indicative of production costs but may not reflect market prices

Feedstock prices are variable, volatile, and can increase with demand

While unit production costs are likely to decrease over time – as technologies mature, refineries reach economies of scale, and production is centralised in hubs linking feedstock processing plants – feedstock prices are variable, highly volatile, and can go either way.[52] For example, the price of used cooking oil ranged from ¢70/kg to ¢140/kg in the two years to end-September 2025 (see Figure 15).

[52] IATA, Global Feedstock Assessment for SAF Production. Outlook to 2050 (2025), p.13

FIGURE 15. USED COOKING OIL PRICES, OCTOBER 2023-SEPTEMBER 2025, US CENT/KG



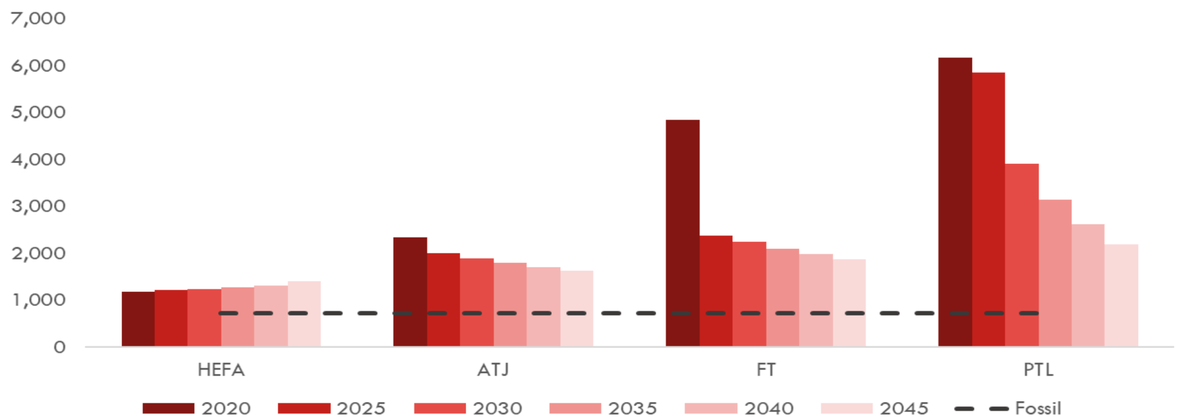
Source: Green Markets via Bloomberg

Notes: US Midwest Used Cooking Oil FFA

Breakeven prices for major pathways are likely to stay above current fossil jet fuel prices

As demand for alternative jet fuel grows due to blending mandates, feedstock prices too are likely to increase, particularly for fuels offering the highest decarbonisation impact. If upward pressure on feedstock prices were to offset reduction in production costs, breakeven prices would not decline significantly. In fact, **IATA expects the breakeven prices of all four major pathways to remain above the current fossil jet fuel price even through 2045**, with HEFA showing modest increases, likely due to feedstock constraints (see Figure 16).

FIGURE 16. IATA'S ESTIMATED AVERAGE BREAKEVENS FOR FOUR MAJOR PATHWAYS, USD/TONNE



Source: IATA[53], redesigned by Carbon Tracker

Notes: Excludes additional market costs

[53] IATA, Brief: SAF procurement. Pricing options for different strategies (11 December 2024).

We note that the breakeven price of alternative jet fuel is not its actual market price, which is likely to be much higher, especially if demand outstrips supply. The introduction of a carbon tax would help reduce the price gap between fossil and alternative jet fuel to a degree, although **since most alternative jet fuels are not carbon-neutral, they may also attract a carbon tax, albeit at lower rates**.

Airlines can pass the costs on to consumers but only where circumstances allow

At least for now, the price premium is proving to be a hurdle to securing long-term offtake, especially from airlines. Fuel accounts for nearly a quarter of their operating expenses (see Table 8), and the average industry net margin of 3.7% leaves little room to absorb higher costs.[54]

TABLE 8. FUEL COSTS AS % OF OPEX AT THREE MAJOR AIRLINES IN EUROPE

	IAG Group	Air France-KLM	Lufthansa
Fuel costs	7,116	6,907	7,785
Operating expenses	27,817	27,215	36,039
Fuel cost as a share of opex	26%	25%	22%

Sources: IAG, Annual Report 2024; Air France-KLM, URD 2024; Lufthansa, Annual Report 2024;

Notes: Lufthansa fuel costs include lubricant costs. Air France-KLM fuel costs include alternative jet fuel costs (€170mn).

Airlines may be able to pass the premiums on to consumers. Evidence suggests that airlines buying alternative jet fuel are already baking the price premium into ticket prices.[55] And customers themselves show willingness to pay the "green premium", with evidence to suggest that corporate clients can accept a premium of up to 160% over fossil jet fuel.[56]

Besides, the impact on the ticket price may not be as significant as the premiums may initially suggest; at up to 10% blending, prices would increase by single digits for fuels sourced through HEFA, ATJ, and FT (see Table 9). So, for a €740 flight from Paris to New York operating on 10% alternative jet fuel bought at the lower end of the HEFA price range, the increase would equal €30, or roughly the cost of delaying the ticket purchase from 30 days to 27 days before flight date.[57]

[54] IATA, IATA - Revenue Management: the Heartbeat of Aviation (n.d.; Accessed 2 October 2025).
[55] For example, an audit and accounting analysis of public disclosures conducted by Carbon Tracker's Capital Markets Transparency team shows that in FY2024 Air France-KLM reported offsetting €153 mn of the €170 mn expenses attributed to alternative jet fuel through surcharges and voluntary contributions. Generally, Air France-KLM reported that it did not conduct sensitivity tests to fuel prices "given the industry's tendence to pass the impact on to ticket prices."
reported "SAF expenses" of €170mn and passing a significant portion of that on to consumers via
[56] RMI, Unraveling Willingness to Pay for Sustainable Aviation Fuel (17 September 2024).
[57] Calculations based on Williams, Dynamic Airline Pricing and Seat Availability (2017).

TABLE 9. TICKET PRICE SENSITIVITY MATRIX FOR DIFFERENT BLENDS AND PRICE PREMIUMS

Price Premium	Example	Price increase at 2% blend	Price increase at 6% blend	Price increase at 10% blend	Price increase at 30% blend	Price increase at 70% blend
70%	*HEFA breakeven*	0%	1%	2%	5%	12%
180%	*ATJ breakeven or HEFA lower market price*	1%	3%	4%	14%	32%
230%	*FT breakeven or HEFA upper market price*	1%	3%	6%	17%	40%
450%	*PTL breakeven 2030*	2%	7%	11%	34%	79%
700%	*PTL breakeven 2025*	3%	11%	18%	53%	123%

Sources: IATA, Air France-KLM, Carbon Tracker analysis

Notes: Assuming that fuel currently accounts for 25% of the average ticket price and holding non-fuel components of the ticket price constant

Key considerations in airlines' ability to absorb the higher cost of alternative jet fuel are: a) price elasticity of demand for economy and premium-class passengers; b) market fragmentation across routes; and c) the relevance to consumers of alternative jet fuel use as a differentiating factor. If a flight between Points A and B is serviced by relatively few operators and caters to a higher-than-average share of First and Business class customers* who are willing to pay the "green premium", then it is likely that the airline will be able to increase the blend of alternative jet fuel beyond that mandated by the two jurisdictions.

However, where the market is fairly fragmented, business travel is light, and customers are less willing to pay the green premium, increasing purchases of alternative jet fuel may add to an airline's expenses and impact on its bottom line. For fragmented markets such as these, the level of alternative jet fuel use will largely depend on the existence and strength of policy incentives.

* Air travel demand is fairly inelastic among business passengers, who generate 20% of airline revenue, and moderate elastic among economy passengers, who account for the rest. See IATA, Air Passenger Market Analysis (17 May 2024); InterVISTAS Consulting, Estimating Air Travel Demand Elasticities (2007).

Hurdle 2. Limited regulatory reach

The second hurdle is the limited reach of the current policy and regulatory framework. Mandates have been introduced in just a handful of jurisdictions and only apply to flights *taking off* from airports within them. This means that an international roundtrip flight will be subject to two distinct regulatory regimes, and the incentive to use alternative jet fuel is likely to correlate with the strength of the mandate within each, if one has been enacted at all (see Table 10).

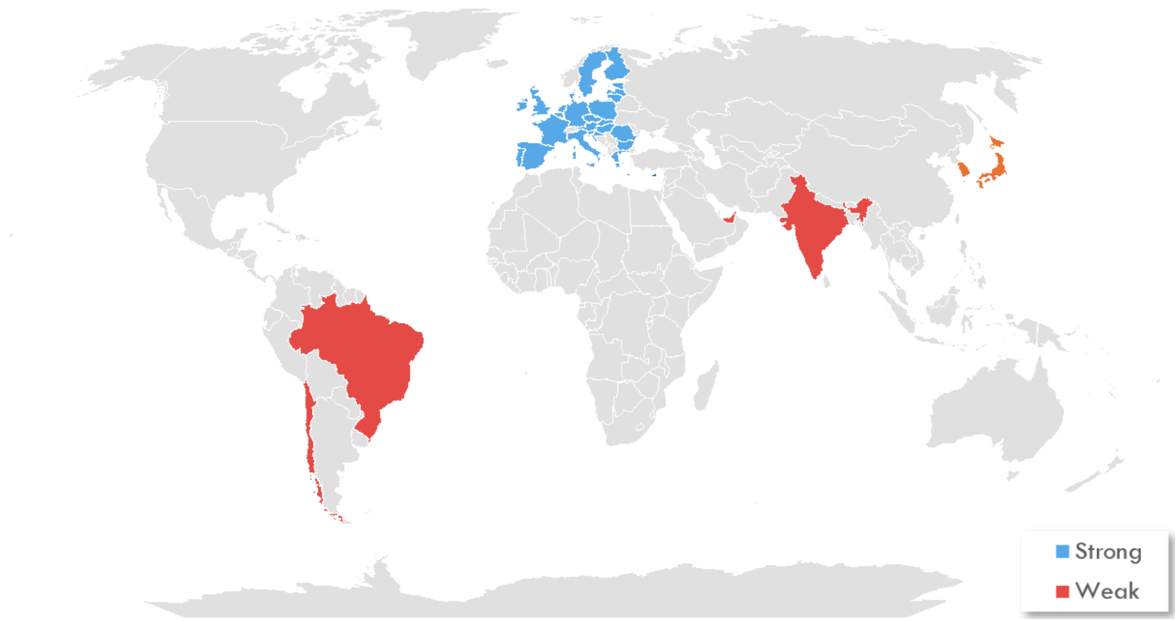
TABLE 10. EXAMPLES OF IMPACT OF MANDATES ON INCENTIVES TO USE ALTERNATIVE JET FUEL

Mandate Strength		Incentive for alternative jet fuel use
Jurisdiction X	**Jurisdiction Y**	
Strong	Strong	Strong incentive for both legs of the journey
Strong	Weak	Strong incentive for the outbound flight but weak incentive for the return flight
Strong	None	Strong incentive for the outbound flight, but none for the return flight

Only two mandates are sufficiently framed

Based on the summary of global SAF mandates and targets from Table 6, we grouped policies into two categories. We classified binding mandates with strong sustainability criteria as strong and non-binding goals or mandates with weak targets as weak. In our assessment, we found only the EU and the UK to have strong mandates (see Figure 17).

FIGURE 17. SAF MANDATE OR TARGET STRENGTH AS PER CARBON TRACKER'S ANALYSIS



Source: Carbon Tracker

Assuming that the rational operator will seek to minimise costs, it is reasonable to conclude that for each and every flight, it will choose to uptake only up to the blend mandated by the government or the blend delivered to the airport, whichever is greater.

Most mandates don't guard against tankering, risking extra fuel burn

Furthermore, the rational operator flying from a jurisdiction with a weak mandate into a jurisdiction with a strong mandate may find itself inclined towards tankering.[*] While economically beneficial, tankering leads to extra fuel burn and, thus, a greater amount of carbon emissions than would otherwise be emitted on an optimal flight.[58]

This problem could be solved by reinforcing mandates with anti-tankering provisions, as is the case with ReFuelEU or the South Korean mandate.

[*] Tankering is the practice of uplifting more fuel than necessary for the first leg of the journey to reduce fuel uptake on the way back, typically performed to take advantage of the difference in fuel prices between two airports. Because carrying excess fuel on the first leg of the journey results in a heavier aircraft, more fuel is consumed.

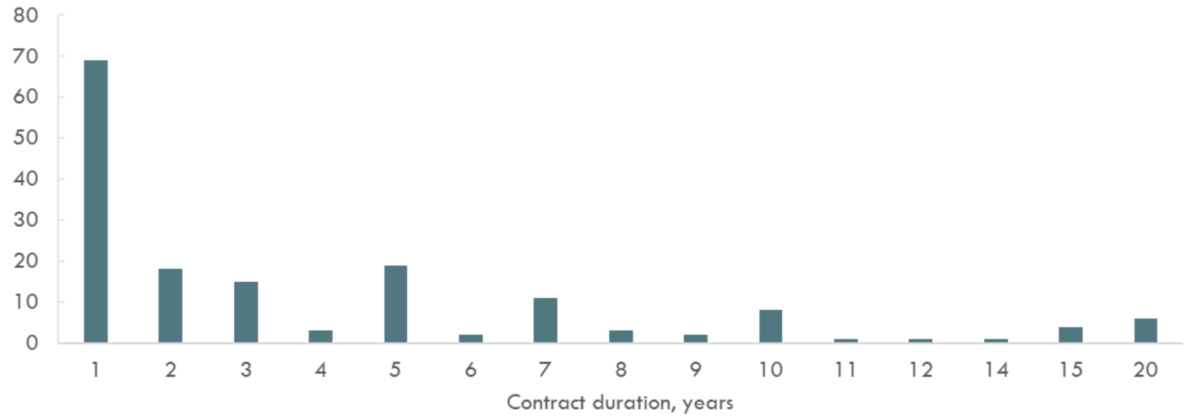
[58] T&E, Tankering in aviation (22 November 2022).

Hurdle 3. Lack of long-term offtake commitments

The third hurdle is the lack of long-term offtake commitments by aircraft operators, as evidenced by our analysis of the state of play of the market and corroborated by industry observers.[59]

According to Dentons, airlines tend to hedge out their fuel costs only two to three years ahead, significantly short of the 20-25-year maturity of a long-term loan.[60] Our analysis confirms this, showing that 63% of offtake commitments made since 2020 and categorised by us as binding have been concluded for 3 years or less, with a further 13% for between 4 and 5 years (see Figure N).

FIGURE 18. NUMBER OF BINDING OFFTAKE AGREEMENTS BY DURATION, 2020-JULY 2025



Source: Ishka SAVi, Carbon Tracker analysis

Notes: Binding agreements include supply, purchase, and offtake agreements, plus certificates. Supply data as of 21 July 2025

Aircraft operators are likely to stay hesitant to sign long-term offtake commitments above mandated levels, even if they do in fact intend to use more alternative jet fuel than required. According to a survey of alternative jet fuel developers and producers, the prevalent concern is that market prices may decrease over time, as unit production costs decrease or more supply comes online.

Aircraft operators would likely seek to retain flexibility to adapt rather than be locked into elevated prices under their contracts.

This is a serious constraint for fuel producers, which require significant upfront investments, which are in turn conditional on offtake agreements guaranteeing 70-80% and sometimes even 100% of capacity.[61]

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[59] ICCT, Industry perspectives on advanced sustainable aviation fuel (2025), p.i, 16-17.
[60] Dentons, The challenge of project financing Europe's SAF projects (2025).
[61] World Economic Forum, Financing Sustainable Aviation Fuels: Case Studies and Implications for Investment (2025), p.27.

Hurdle 4. Weak bankability

The fourth hurdle is weak bankability linked directly to offtaker hesitation to sign long-term commitments. Not only are alternative jet fuel projects capital-intensive, but they carry a whole suite of technology, supply chain, operational, and policy risks. These are nascent technologies that:

a) tend to compete with one another for the same feedstocks that are often in short supply;
b) have not been proven at scale; and
c) may not necessarily benefit from continuing policy support, if any exists at all.

These risks make alternative jet fuel projects ill-suited to traditional debt-funding.

A range of solutions have been proposed to spread the risk over the entire supply chain, from structuring contracts in ways that pass on parts of the costs to offtakers (through schemes like Book and Claim) to offering them an equity stake in refineries themselves.[62]

However, our analysis shows that the number of agreements involving offtakers as shareholders peaked at 10 in 2023, covering a cumulative 5.5 Mt, and dropped to 4, covering less than a third of the previous year, just 1.6 Mt (see Table 11).

TABLE 11. OFFTAKE COMMITMENTS INVOLVING THE CUSTOMER AS INVESTOR

Year	Number of agreements	Volume under agreements, Mt
2024	4	1.6
2023	10	5.5
2022	6	2.3
2021	3	5.1
2020	1	0*

Source: Ishka SAVi, Carbon Tracker analysis

*Notes: *Volume undisclosed*

As the market for alternative jet fuels deepens, it will inherently become more fundable, even if some of that demand is not guaranteed by offtake agreements. There are early signs of non-mandated demand adding depth to the market: 1 million tonnes of alternative jet fuel produced in 2024 were offtaken *before* mandates in major jurisdictions like the EU and the UK took effect. Furthermore, surveys suggest that corporate consumers may be willing to pay the "green premium" on alternative jet fuel from waste-based feedstocks procured under short-term contracts.[63]

However, until the market grows sufficiently deep, long-term offtake agreements are likely to remain a key requirement of securing funding. Even though solutions have been proposed to ensure revenue certainty at a policy level or to work around bankability by pooling capital and spreading risk over many actors, the question remains whether this will translate into widespread adoption of alternative jet fuel.

[62] World Economic Forum, Financing Sustainable Aviation Fuels: Case Studies and Implications for Investment (2025), p.27.
[63] RMI, Unraveling Willingness to Pay for Sustainable Aviation Fuel (17 September 2024; Accessed 17 September 2025).

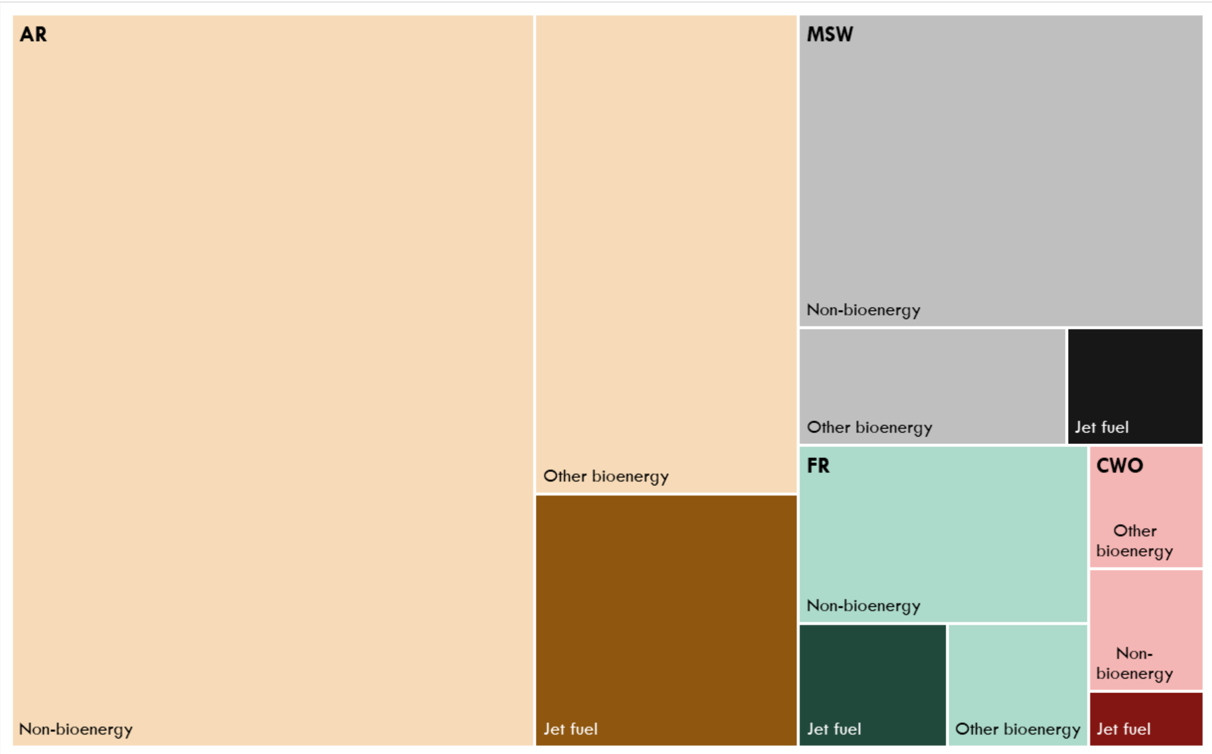
Hurdles 5 and 6. Feedstock availability and sustainability

The fifth and sixth hurdles come in tandem. Feedstock availability and feedstock sustainability are in most cases in an inverse relationship, meaning that where feedstock is sustainable, it is likely to be in short supply, and vice versa. The issue is further compounded by practical challenges such as collection and transport.

Only a fraction of global feedstocks could be converted into alternative jet fuels

If sustainability and practicality were not a concern, the global feedstock base would actually be sufficiently large. In an overview of global feedstocks from September 2025, IATA found 10,000 Mt of feedstocks that could in theory be converted into alternative jet fuels.[64] However, only 12.3% of that would be available for use in aviation, after accounting for competing uses, including other forms of bioenergy. From these, IATA sees agricultural and forestry residues accounting for a combined 79%, municipal solid waste accounting for 12%, and crop-based feedstocks and waste oils taking up the remaining 9% (see Figure 19).

FIGURE 19. FEEDSTOCK AVAILABLE FOR JET FUEL, OTHER BIOENERGY AND OTHER USES IN 2030



Source: IATA, Carbon Tracker analysis

Notes: AR means agricultural residue; FR means forestry residue; MSW means municipal solid waste; CWO means crops and waste oils.

Based on known yield factors for each type of feedstock, we estimate a theoretical limit of 220 Mt of alternative jet fuel that could be obtained from these 1,230 Mt of feedstocks (see Table 12).

[64] IATA, Global Feedstock Assessment for SAF Production. Outlook to 2050 (2025). Excludes energy crops such as miscanthus, jatropha, and switchgrass.

TABLE 12. THEORETICAL ALTERNATIVE JET FUEL OUTPUT LIMIT AS PER IATA'S FEEDSTOCK OUTLOOK, 2030[65]

Feedstock type	Feedstock volume, Mt	Assumed yield factor*	Maximum theoretical jet fuel volume, Mt
Agricultural residues	762.6	0.15	114.4
Municipal solid waste	184.5	0.16	29.5
Forestry Residues and wood waste	209.1	0.15	31.4
Crop-based feedstocks**	36.9	0.43	15.9
Waste oils**	36.9	0.77	28.4
Total	**1,230**	-	219.6

Source: IATA, Carbon Tracker analysis

*Notes: *Yield factors extrapolated from 2050 yield rates. **Crop-based feedstocks and waste oils were reported as a single figure and were pro-rated by Carbon Tracker on a 1:1 basis.*

Collecting, transporting, and processing feedstock can be impractical

Introducing practicality into the equation significantly reduces the amount of feedstock that could be converted into alternative jet fuel. Firstly, not all feedstock is easily collected or harvested. For example, agricultural and forestry residues are scattered across vast areas of land around the world and must be collected methodically by each farm or forestry company.[66]

Once collected, feedstock needs to be transported to processing facilities to be prepared for refining. Since feedstock is often heterogenous, which may corrode refinery equipment, it often needs pretreatment. This is a special challenge for municipal solid waste, whose contents are quite varied, even after being sorted at waste management plants.

Each of these steps requires additional process energy, time, and money. **Setting up an infrastructure to collect, transport, and pre-process feedstock is likely to take significant investment and time to scale up**. Feedstock availability and the logistical challenge should be a key consideration in the final investment decision for every alternative jet fuel project.

Some feedstocks are only marginally better than fossil fuels, even by industry standards

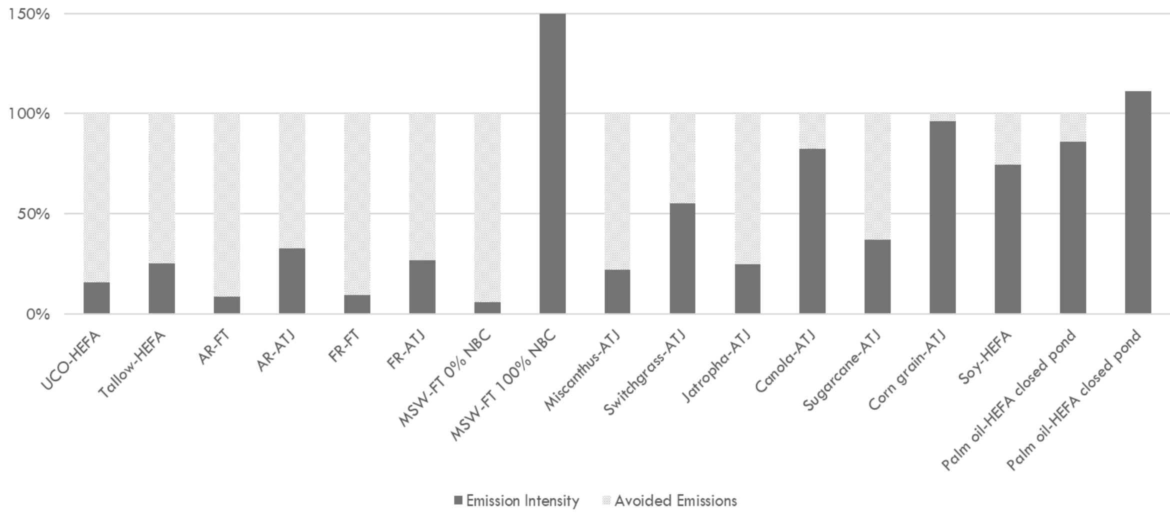
Sustainability considerations further reduce the amount of feedstock that could eventually be converted into truly sustainable alternative jet fuel. In the aviation industry, the preferred measure of pathway sustainability is lifecycle analysis (LCA), which assesses:

- Direct emissions associated with the production of fuel through a pathway.
- Indirect land-use change emissions associated with cultivating the feedstock.

[65] IATA, Global Feedstock Assessment for SAF Production. Outlook to 2050 (2025). Excludes energy crops such as miscanthus, jatropha, and switchgrass.
[66] Royal Society, Net zero aviation fuels: resource requirements and environmental impacts (2023), p.25.

Added up, these result in an estimate of emission intensity for each pathway, which can then be compared with the emission intensity of fossil jet fuel. Our calculations show that the carbon intensity of various pathways can range from close to zero to almost twice that of fossil jet fuel (see Figure 20).[67] Many pathways, like FT processing residues, do deliver substantial reductions in lifecycle emissions. But some, especially those involving food and feed crop feedstock, are almost as carbon-intensive as fossil jet fuel or even more so.

FIGURE 20. CARBON INTENSITY OF ALTERNATIVE JET FUEL PATHWAYS VS FOSSIL JET FUEL BASELINE



Source: ICAO, Carbon Tracker analysis

Notes: Emission intensity of each pathway calculated as a sum of direct and indirect land-use change emissions per MJ, as provided by ICAO in its Technical Documentation, divided by fossil jet fuel emissions per MJ. Vertical axis truncated at 150%. The carbon intensity of MSW-FT with a 100% non-biogenic content is 197%.

The overwhelming majority of alternative jet fuel today is derived from waste oils such as used cooking oil, which are a relatively more sustainable option than others. However, these feedstocks are in very short supply,[68] meaning that the **industry will have to rely on other options, some of which are much more emission-intensive, and others can carry significant implications not yet assessed by the industry.**

Sustainability analysis must assess broader impact on climate, biodiversity, and society

One of the most persistent critiques of LCA is that it does not encompass all of the impacts of alternative jet fuel production. LCA tends to ignore some of the more remote and sometimes unforeseen potential impacts, including those on climate, nature, society, and other supply chains.[69] The rest of this section is dedicated to the former three, with potential impacts on other supply chains explored as a separate hurdle in the next subsection.

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[67] See also ICCT, Assessing the sustainability implications of alternative aviation fuels (2021); Royal Society, Net zero aviation fuels: resource requirements and environmental impacts (2023).
[68] RMI, Fueling Up Sustainable Aviation (2023), p.15.
[69] Piris-Cabezas, P. The High-Integrity Sustainable Aviation Fuels Handbook (2022)

BOX 2. BROADER SUSTAINABILITY IMPACTS OF ALTERNATIVE JET FUELS

Besides their lifecycle carbon emissions, the climate impacts of alternative jet fuels include:

- ✓ Positive impact from reduced aromatics content, which result in the formation of soot
- ✓ Positive impact from reduced contrail formation
- ✗ Negative impact on carbon emissions, where residue is mixed in with virgin feedstock.

Other than the indirect emissions associated with displacing existing crops or vegetation, which are captured in the ILUC element of the LCA, **potential impacts on nature include**:

- ✓ Positive impact on soil health, where feedstock can be cultivated on degraded or arid land while also protection at-risk land from erosion[70]
- ✗ Negative impact on soil health, where repeated harvesting may deprive the soil of nutrients and/or lead to a higher concentration of chemicals (fertilisers, pesticides, etc)
- ✗ Negative impact on water quality and availability, where cultivating feedstock may deplete surface or groundwater resources
- ✗ Negative impact on biodiversity, where a preference for a particular feedstock type may result in monocultures with a knock-on effect on wildlife
- ✗ Negative impact on the gene flow, where overreliance on genetically engineered crops may result in genetic pollution among wildlife species further up the food chain.

Fewer in number but not smaller in magnitude, **potential impacts on society include**:

- ✓ Positive impact on socio-economic development, especially if feedstock is cultivated in regions of poverty
- ✗ Negative impacts on human and labour rights, as well as property rights to land, especially in indigenous communities
- ✗ Impacts on food security, where feedstock is diverted away from food supply chains.

Carbon payback time should be accounted for

Another critique of LCA is that it is unclear how well it accounts for the carbon payback period, if it does at all. Some models assume that the carbon released into the atmosphere at the point of combustion will be sequestered back quickly, so it is not modelled as an emission.[71]

However, there is a significant mismatch between the time it takes to burn a tonne of jet fuel and the time it takes to sequester that by regrowing, for example, poplar trees. It is for this reason, bodies like the EASAC have urged that forest wood, including residues, should be left as is for as long as possible, then used in construction when collected, and only burnt once it has outlived its use as a building material.[72]

For alternative jet fuel projects, this means that an assessment of a fuel's climate impact should take into account the amount of time it takes to sequester the carbon released on combustion. This is particularly important because the carbon budget linked to the Paris goals is small, shrinking fast, and cannot be inflated by factoring in carbon that will have been sequestered in the future.

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[70] See Nissim et al. Trace element phytoextraction from contaminated soil: a case study under Mediterranean climate (2018).

[71] Royal Society, Net zero aviation fuels: resource requirements and environmental impacts (2023) pp.29,37.

[72] Royal Society, Net zero aviation fuels: resource requirements and environmental impacts (2023), p.37.

E-fuels meet feedstock availability and sustainability criteria but are also expensive

PTL, whose product is known as e-fuel, is one of only pathways that can be fully sustainable, i.e. with zero lifecycle emissions and minimal impact on climate and nature. However, that sustainability is conditional on using dedicated renewable sources to both source the feedstock and convert it into fuel.

Its feedstock – water and ambient air – is also abundant.

The manufacturing of e-fuels involves three key technologies: direct air carbon capture, electrolysis, and FT. All three are technically feasible but are also currently expensive and contribute significantly to the unit production costs of e-fuels, which are likely to remain the highest of all four pathways even through 2045 (see Figure 16).

As one of only a few types of alternative jet fuel that deliver significant, theoretically complete reductions in lifecycle emissions, e-fuels may require additional support in the form of subsidies and grants, as well as policy incentives such as sub-mandates introduced in the UK SAF Mandate.

Scaling these up alongside other high-integrity, least carbon-intensive pathways may help decarbonise a portion of flight where other technological solutions, such as zero-emission aircraft, are unlikely to make significant progress in the near to medium-term. But stakeholders across the industry should take care to ensure that investment in these pathways does not come at the expense of emissions savings in other sectors or disadvantage other solutions in need of investment and policy support. We explore these in Subsection *Hurdle 7. Opportunity costs* below.

Hurdle 7. Opportunity costs

The seventh and final hurdle is opportunity costs. In this sub-section we explore potential impacts on supply chains at three distinct levels: feedstocks, biofuels, and economics.

Diverting feedstocks away from other industries may lead to increased use of fossil fuels

Most feedstocks that could be converted into biofuels are already in use in other industries. Food, explored above as part of potential impacts on society, is just one such example. Other industries relying on these feedstocks include agriculture, chemicals, and energy outside biofuels.[73] Table 13 below shows potential alternative uses for each major type of feedstock.

TABLE 13. ALTERNATIVE USES FOR ALTERNATIVE JET FUEL FEEDSTOCK[74]

Feedstock type	Examples	Industry	Uses and products
Agricultural residues	Straw	Agriculture	Animal bedding and feed, soil conditioner, fertiliser
		Energy	Power generation
		Food	Food additives
Forest residues	Stems, branches, brash, stumps, chips, slabs, sawdust, bark	Forestry	Soil protection, soil conditioner
		Energy	Power generation
		Agriculture	Animal bedding
		Manufacturing	Wood pulp, boards
		Food	Food additives
Waste oil	Used cooking oil, tallow	Chemicals	Soap, solvents, lubricants, cosmetics, plasticisers
		Agriculture	Animal feed
Energy crops	Miscanthus, jatropha, switchgrass	Chemicals	Plastics, cosmetics
		Energy	Heat and power generation
		Agriculture	Animal feed, animal bedding
Food crops	Corn, sugarcane	Food	Food, food additives
Municipal Solid Waste	Household waste, hospitality waste	Agriculture	Composting
		Energy	Heat and power generation
Wet biomass	Sewage sludge, algae	Agriculture	Fertiliser
		Energy	Heat and power generation
		Chemicals	Plastics, cosmetics

Source: Royal Society, ICCT

[73] See for example Carbon Tracker, Petrochemical Imbalance (2024).
[74] Royal Society, Net zero aviation fuels: resource requirements and environmental impacts (2023); ICCT, Estimating sustainable aviation fuel feedstock availability to meet growing European Union demand (2021).

As highlighted by the ICCT, even so-called waste products "are not true wastes–in fact, [sic] many of them have valuable existing uses"[75] **If diverted away from such uses in other industries, these feedstocks would now have to be replaced by substitutes, which are in many cases fossil fuels.** This could leave to indirect displacement emissions that are not accounted for in the LCA and "can be as high as ILUC emissions".[76]

Alternative jet fuel can displace other biofuels

Refinery distillates can be converted into more than one type of fuel, depending on how the refinery is configured and what the operator chooses to produce. For some fuels, there is a significant overlap between the distillates that go into making them. Kerosene, for example, is made up mostly of hydrocarbon molecules sitting in the C_8-C_{16} range, meaning each molecule contains between 8 and 16 carbon atoms, while diesel is a mixture of C_{10}-C_{22} range molecules. So, a large proportion of molecules that make jet fuel can be and *are* indeed used to produce diesel.

A refinery's product slate, also known as the refinery yield, will be shaped not just by plant economics but also by market dynamics. Assuming a steady supply of homogenous feedstock and a flexible configuration, the split between various end-products coming out of a given refinery will ultimately depend on demand and profit margins – the rational refiner will seek to optimise the yield of the products with the highest margins at the expense of products with lower margins.

Production of alternative fuels is currently skewed heavily towards diesel rather than jet fuel.[77] However, recent changes in policy landscape, including the introduction of mandates, may pull jet fuel margins up as demand grows more price-inelastic, at least up to the mandated level. This is likely to incentivise refiners to shift the product mix away from alternative diesel and towards alternative jet fuel.

The consequence is that diesel engines that would otherwise be powered by alternative fuel will then switch back to fossil fuels, which would cancel out any climate gains from diverting feedstock into aviation. Considering the costs and price premiums, the operator may as well have paid an extra on a product that delivers no benefit to the climate.

The obvious response is that it may be better to see feedstock diverted away from an industry where decarbonisation is easily achievable via electrification, towards an industry where the technical challenge is harder to resolve. We broadly agree with this view, but our caveat is that if fuel substitution occurs at a faster rate than electrification in road transport, some of the alternative diesel will be displaced, representing an opportunity cost of using alternative jet fuels.

[75] ICCT, Assessing the sustainability implications of alternative aviation fuels (2021), p.11.
[76] ICCT, Assessing the sustainability implications of alternative aviation fuels (2021).
[77] ICCT, Can alternative jet fuels crowd out demand from the road sector (24 October 2018).

Overinvesting in alternative jet fuels risks underinvesting in other viable solutions

Opportunity costs are not limited to fuel markets and can be considered at a broader level, in terms of all solutions available to the aviation industry. Investments could also be made and policy support provided to accelerate the roll-out of zero-emission aircraft, reduce non-CO_2 emissions, make further fuel efficiency improvements, and develop high-integrity carbon removal and offset projects.

How to allocate capital between different solutions is a question that has yet to be answered definitively and is beyond the scope of this report. But going forward, we believe that the aviation industry, its investors, and policymakers should thoroughly analyse all available solutions and develop a marginal abatement cost curve for all solutions that will account for direct emissions; indirect emissions; and broader impact on climate, nature, and society.

Conclusion and recommendations

Our analysis shows that alternative jet fuels will account for a fraction of global jet fuel consumption in 2030 if air travel demand grows in line with recent trends. Assuming existing, under-development, and planned projects run at a utilisation rate of 80%, they will only be able to offset 17%-30% of additional jet fuel demand, implying a net increase in aviation emissions, all things equal.

Policies in support of alternative jet fuels have been rolled out in several countries and regions around the world, introducing subsidies, tax credits and, most prominently, blending mandates.

However, the scalability of truly sustainable alternative jet fuels is constrained by seven hurdles: a) costs and price premiums; b) regulatory uncertainty; c) lack of long-term commitments; d) weak bankability; e) limited sustainable feedstock availability and other sustainability trade-offs; and f) opportunity costs.

Alternative jet fuels should complement other solutions

For the aviation industry to decarbonise at speed, at scale, and within economic and environmental constraints, stakeholders across the value chain should take a closer look at other available solutions. Alternative jet fuels may have a role to play in decarbonising aviation, but it should be reserved for long-haul flights.

Meanwhile, emissions from short- and medium-haul flights could be mitigated by deploying zero-emission and hybrid aircraft. As we discussed in our previous report, Awaiting take-off, these show a great deal of promise and are approaching commercial viability.

Residual emissions could be addressed using a range of outstanding solutions. Outside policy interventions aimed at managing air travel demand, aviation's carbon footprint could be reduced by increasing fuel efficiency, improving traffic management, and mitigating non-CO_2 emissions.

Investors should assess alternative fuel projects against three key criteria

In addition to recommendations outlined in Awaiting take-off, we provide investors with three further recommendations concerning alternative jet fuels:

1. **Assess alternative jet fuel projects for costs, feedstock availability, and climate and nature impact**. For any production pathway, compare the costs of production and resultant minimum selling prices, feedstock availability constraints, feedstock supply volatility, total lifecycle emission intensity, and broader impacts on biodiversity and food security.
2. **Consider the opportunity costs of diverting feedstock from alternative uses within the energy sector**. For any production pathway, calculate the opportunity cost of using the technology to produce aviation fuels as opposed to road or shipping fuels.
3. **Compare all levers of decarbonisation against one another using a marginal abatement cost curve**. Investors with a climate mandate should factor in the cost of the broader impact of each solution on climate and nature.

Appendix 1. Obligations under UK SAF Mandate

This Appendix maps out the three steps used to calculate a fuel supplier's obligations under the mandate and to show that, without a buy-out mechanism, it would effectively become a fuel intensity target.

Step 1. Calculate obligated amount (OBL) in megajoules[78]

$$OBL = V_f * LHV_f * \text{Target}$$

Where:
- **V_f** is the volume of jet fuel to which the target applies, expressed in litres (l).
- **LHV_f** (lower heating value) is effectively used to convert the amount of jet fuel from a unit of volume (litre) to a unit of energy (MJ) and is expressed in megajoules per litre (MJ/l). The DfT uses a standard LHV_f of 34 MJ/l.
- **Target** is the obligation percentage for the given period (e.g. 2.041% for 2025).

Explanation: this step converts the amount of fuel to which the target applies from litres to megajoules, then multiplies this amount by the target percentage. **OBL** expresses in megajoules (MJ) the amount of fuel that must be offset by SAF Certificates, a buy-out amount, or both.

Example: if a fuel supplier delivers a total of 1,000,000 litres in 2025, that amount will first be converted into 34,000,000 MJ using the LHVf of 34 MJ/l and then multiplied by 0.0241. The product of this formula - 819,400 MJ - is the amount of fuel that needs to be offset.

Step 2. Calculate the carbon intensity factor for each type of alternative jet fuel[79]

$$CIFactor_{SAF} = \frac{CI_f - CI_{SAF}}{CI_f - CI_b}$$

Where:
- **CI_f** is the lifecycle carbon intensity of fossil jet fuel expressed in terms of gCO_2e/MJ. The DfT uses a standard CI_f of 89 gCO_2e/MJ.
- **CI_{SAF}** is the lifecycle carbon intensity of a given type of alternative jet fuel expressed in gCO_2e/MJ. The CI_{SAF} is calculated as per the RTFO and SAF Mandate Technical Guidance and generally matches the LCA of alternative jet fuels as calculated by ICAO.
- **CI_b** is the lifecycle carbon intensity of a baseline alternative jet fuel, set at 26.7 gCO_2e/MJ. Effectively, this translates into an emissions savings of 70%.

Explanation: this step calculates in absolute terms the amount of emissions savings achieved through a particular alternative jet fuel relative to the amount of emissions savings achieved through a baseline alternative jet fuel, which are 70%. This is a ratio between actual emissions savings and baseline emissions savings of 70%.

Example: For alternative jet fuel derived from agricultural residues through ATJ, the CI_{SAF} is 29.3 gCO2e/MJ. It delivers emissions savings of 89 – 29.3 = 59.7 gCO_2e/MJ. The emission intensity of this fuel is compared with that of the baseline fuel using a CIFactor = 59.7 / (89 – 26.7) = 0.958. This means is that 1 litre of AR-ATJ is equivalent to .958 litres of a fuel delivering 70% reduction in emissions savings.

[78] Department for Transport, Sustainable Aviation Fuel Mandate: Compliance Guidance (2025), pp.14-15.
[79] Department for Transport, Sustainable Aviation Fuel Mandate: Compliance Guidance (2025), pp.31-33.

Step 3. Calculate the number of SAF certificates for each type of alternative jet fuel[80]

$$Certificate = \frac{V_{SAF} * LHV_{SAF} * CIFactor_{SAF}}{LHV_f}$$

Where:

- **V_{SAF}** is the volume of a particular type of alternative jet fuel that qualifies as eligible under the mandate.
- **LHV_{SAF}** (lower heating value) is used to convert this particular type of alternative jet fuel from a unit of volume (litre) to a unit of energy (MJ) and is expressed in terms of megajoules per litre (MJ/l). The DfT.
- **LHV_f** (lower heating value) is effectively used to convert the amount of jet fuel from a unit of volume (litre) to a unit of energy (MJ) and is expressed in terms of megajoules per litre (MJ/l). The DfT uses a standard LHV_f of 34 MJ/l.
- **CIFactor** is a ratio between emissions savings achieved through this particular type of alternative jet fuel and emissions savings achieved through the baseline alternative jet fuel. It is calculated in Step 2 above.

Explanation: This step converts a particular type of alternative jet fuel from a unit of volume (litre) to a unit of energy (megajoules), then normalises that energy amount to account for the carbon intensity of this particular fuel. Once normalised, the number in the numerator expresses in megajoules the amount of energy that has been released by burning this type of alternative jet fuel. Dividing this number by the conversion factor (which expresses the amount of MJ in a litre of fossil jet fuel) results in the volume of fossil jet fuel that has been displaced by using this particular type of alternative jet fuel if it were converted into a baseline alternative jet fuel.

Example: Assume a fuel supplier delivered 10,000 l of AR-ATJ with LHV_{SAF} of 34 MJ/l. We can calculate in megajoules the amount of energy that has been released on combustion (340,000 MJ), then normalise it using the CIFactor calculated in Step 2 above. Now, the numerator - 325,720 MJ - represents the amount of energy that would be released by an alternative jet fuel delivering a 70% emissions reduction. Dividing that by 34 MJ/l results in 9,580 litres, which is the amount of fossil jet fuel that has been displaced by this type of alternative jet fuel if it were converted into a baseline alternative jet fuel.

Conclusion

Note that certificates are measured not in numbers but in litres. One certificate represents 1 litre of fossil jet fuel displaced by 1 lite of alternative jet fuel with a carbon intensity of 26.7 gCO_2e/MJ. This means that **if a fuel supplier redeems its obligations using only SAF certificates, it will be as though it has met its target using an alternative jet fuel that delivers a 70% reduction**.

The energy intensity of the total fuel supplied, fossil and alternative put together, will go down by the target percentage multiplied by 70%. Without a buy-out mechanism, which allows to meet part of the obligation by paying a fixed charge, this product would effectively become a fuel intensity target

[80] Department for Transport, Sustainable Aviation Fuel Mandate: Compliance Guidance (2025), pp.31-33.

Appendix 2. Current AJF mandates and targets

Jurisdiction	Has binding force	Excludes crop-based fuels	Has lifecycle threshold	Includes mid-term target	Includes long-term target	Lifecycle emissions savings threshold	Mid-term target	Long-term target
UK	Yes	Yes	Yes	Yes	Yes	0.4	10% by 2030	22% by 2040
EU	Yes	Partial*	Yes	Yes	Yes	65% (biofuels), 70% (PTL)	6% by 2030	70% by 2050
South Korea	Partial†	No	Yes	Yes	Yes	0.1	4% by 2030*	8.5% by 2035
Brazil‡	Partial§	No	No	Yes	Yes	N/A	3% by 2030	10% by 2037
Japan	Partial‖	No	No	Yes	No	N/A	10% by 2030	N/A
India	No	No	No	Yes	No	N/A	5% by 2030	N/A
Singapore	No	No	No	Yes	No	N/A	4% by 2030**	N/A
UAE	No	No	No	Yes	No	N/A	1% by 2031	N/A
Chile	No	No	No	No	Yes	NA	N/A	50% by 2050

Source: Public disclosures, Carbon Tracker analysis

*Notes: *Excludes food and feed crops but does not exclude energy crops †Mandate applies to international flights only ‡Brazil's mandate is for GHG emissions rather than fuel volumes §Mandate applies to domestic flights only ‖Mandate applies to refiners*

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