

Out of the fryer

Rethinking feedstocks for sustainable aviation fuel



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Contents

Introduction	4
What constitutes a credible, scalable, and sustainable feedstock?	6
Low greenhouse gas emissions	7
Avoidance of competition or market conflicts	8
Mature and resilient supply chains	8
Primary crops: primarily for the US market	10
Covering new ground: carinata, camelina, and pennycress	12
Animal fats, lard, and tallow: sustainable but scarce	14
Distillers corn oil: the ‘other’ corn biofuel	16
Summary	17
Authors	18
References	20



Introduction

While a range of raw materials can be turned into fuel, the sustainable aviation fuels (SAF) market has primarily focused on using waste and residue fats as ‘feedstocks’ or input materials to convert into jet fuel.

These use the hydroprocessed esters and fatty acids (HEFA) pathway, which is currently the most mature and widely-used globally. Standalone HEFA production is expected to reach 3.3 billion gallons (10 million metric tonnes) by 2030, further boosted by additional ‘co-processing’ in oil refineries.¹

The main feedstock for HEFA has been used cooking oil (UCO), of which 2.8 billion pounds (1.27Mt) was imported into the US in 2024 from China. However, at a global level, UCO is supply-constrained, driven by sustained high global demand in Europe and Asia, and recent export restrictions in UCO-rich regions. The supply crunch is further complicated by recent US legislation, including proposed changes to federal incentives that prioritise domestic feedstocks, and tariffs

which impose costs on imports. The US biofuels industry will need to rely on its own supplies of used cooking oil, but domestic UCO production (3.3 billion pounds or 1.5Mt in 2024) will be insufficient to address demand (5.7 billion pounds or 2.6Mt in 2024), likely leading to price pressures.²

Therefore, to meet the needs of HEFA SAF production, it will be necessary to explore alternative oily feedstocks. However, there is a lack of awareness and clarity among SAF users and buyers like airlines and corporates about what constitutes a credible, scalable, and sustainable feedstock. Our goal with this article is to shed light on a number of available feedstocks for US domestic and export markets, and the relative advantages and risks of each of these feedstocks.

What constitutes a credible, scalable, and sustainable feedstock?

Feedstocks typically comprise the largest operational expenditure in fuel production, so producers will want to keep commodity costs or processing costs low. Most HEFA feedstocks rarely require complex processing

steps, often only needing pre-treatment to remove impurities and moisture. Beyond prices and processing, HEFA feedstocks will often differ in three key criteria. They must:



1

have low lifecycle greenhouse gas (GHG) emissions.



2

avoid competing for other uses or cause market distortions or conflicts.



3

be part of mature and resilient supply chains accessible to SAF producers.

These criteria hold true in the US, UK, EU, or internationally, and are true for feedstocks for both the HEFA pathway and more 'advanced' SAF pathways.



Low greenhouse gas emissions

The production and processing of feedstocks into fuels, and their subsequent use in combustion engines, results in a certain amount of greenhouse gas (GHG) emissions over their entire lifecycle. These ‘well-to-wake’ GHG emissions can be calculated for fuels from different feedstocks and compared to the emissions of jet fuel (89g CO₂/MJ) using certain well-known methodologies:

- **The US DOE GREET standard** is used in evaluating eligibility for incentives like the California Low-Carbon Fuel Standard (LCFS), federal RFS, or the 45Z Clean Fuel Production Tax Credits. It quantifies a carbon intensity (CI) score for a fuel made from a feedstock.
- **The CORSIA standard** – set by the International Civil Aviation Organisation (ICAO) – is used globally to determine if a product is a CORSIA Eligible Fuel (CEF). It quantifies a Life Cycle Emissions Value (LCEF) for a fuel made from a feedstock. Under the standard, a fuel must achieve GHG reductions of at least 10 percent to be considered a CORSIA Eligible Fuel.

While CORSIA provides ‘default’ values for common feedstocks, both GREET and CORSIA standards can account for these factors using a more detailed methodology, with variations resulting from how the feedstocks are processed (e.g. using gas vs. green electricity for heat) or from the impacts of feedstock production on land. Induced land-use change (ILUC) values can be tied to how use of the feedstocks puts direct pressure on agricultural land, but also if using the feedstocks indirectly results in more land demand (e.g. growing their substitutes). If the feedstock is a waste, residue, or by-product it won’t require additional land to grow, and is considered to cause zero land-use change.

Recently-proposed changes to US legislation could potentially lead to land-use change considerations being excluded from US GREET LCA computations, which may impact incentive schemes such as the Inflation Reduction Act’s 45Z Clean Fuel Production Credit, the federal Renewable Fuel Standard, and the California LCFS. The divergence from the global CORSIA standard implies that while some feedstocks may become more viable domestically, they and the fuels they produce may be treated differently by international or export markets.³

Avoidance of competition or market conflicts

Ideally feedstocks must also avoid competing with other uses, such as animal feed and chemicals production. Economically this makes sense, as competition will often mean lower availability, higher prices, or other unintended consequences such as redirection of food supplies, feedstock fraud, or depriving a different industry of its raw materials. This is why policymakers in the EU have specifically discouraged the use of such feedstocks if there is a risk that their use may result in these effects.

UCO, for example, has been criticised for causing such ‘market conflicts’. In 2024, the US EPA had to audit supplies of used cooking oil, as there were suspicions of unscrupulous biofuel producers labelling virgin oils as ‘used’ in order to benefit from incentives such as the RFS.⁴ Similarly, the demand for corn in biofuels has put upward pressure on the price of corn, with studies estimating anywhere from 0.4-8.2 percent price change per billion gallon increase in ethanol demand.⁵

Mature and resilient supply chains

Finally, the strength and maturity of a feedstock’s supply chain is also key. If a feedstock is a well-known commodity with many suppliers and logistics providers, it is more likely to have consistent feedstock volumes, efficient logistics, and predictable pricing. This makes the production process more cost-effective and scalable. But if the supply chain is not as well developed or as extensively built out then delays, limited feedstock supply, or more unpredictable costs can be a consequence. Producers will often have to rely on more complex strategies to ensure they have a reliable supply of feedstock, such as: using multiple feedstocks; drawing on multiple suppliers, middlemen and feedstock aggregators; and combining longer-term contracts with spot purchases.

Overall, the more these criteria are achieved, the better a feedstock could be for producing truly sustainable SAF. We will take a look at a number of HEFA feedstocks often mentioned in the US market, see how they square up against these criteria, and investigate whether any of them can be a good alternative to used cooking oil.

Table 1: Feedstock types in this report and their relative viability as SAF feedstocks⁶

	Emissions impact			Likelihood of causing market conflict	Maturity of supply chain
Feedstocks	Life-cycle assessment (LCA)	Induced land-use change (ILUC)	Life-cycle emission factor (LCEF)		
Used cooking oil (UCO)	Low	Low (zero)	Low	High	Mature
Primary food crops	High	High	High	High	Mature
Oilseed cover crops	High	Low (negative)	Low-moderate	Moderate	Immature
Animal fats	Moderate	Low (zero)	Moderate	High	Mature
Distillers corn oil (DCO)	Low	Low (zero)	Low	Moderate	Mature

Primary crops: primarily for the US market

Primary food crops have long been used in biofuel production, such as hydrotreated vegetable oil from soybean oil and ethanol from corn. Between 2000 and 2015, crop-based biofuels surged due to mandates in the US and EU requiring minimum biofuel volumes in transport fuels. In the US, biodiesel production rose from 14 million gallons (0.04Mt) in 2003 to 1.5 billion gallons (5Mt) by 2016 – a year-on-year increase of 43 percent.⁷ While intended to promote cleaner energy, these mandates also drove up commodity prices and induced land-use change, with farmers clearing new land or intensifying use of existing land to meet demand.

Today, biodiesel still relies heavily on food-based feedstocks. In 2023, palm oil made up 36 percent of global biodiesel production, followed by soybean oil at 23 percent and rapeseed oil at 14 percent.⁸ This reliance raised sustainability and land-use

concerns in Europe, so the EU introduced the Renewable Energy Directive II (RED II) in 2018, capping food-derived feedstocks at seven percent and later restricting or banning soybean and palm oil due to their land-use impacts.⁹ In general, while feedstocks consumable by humans or animals are still sometimes allowed in road transport biofuels, they are banned for SAF production in the EU, with few exceptions.

The CORSIA methodology reflects this broader consensus on the suitability of these materials becoming biofuel feedstocks. Under CORSIA's LCEF calculations, fuels from primary crop oils like canola seed or soybean exhibit higher GHG scores – and therefore less emission reduction – compared to fuels from used cooking oil. They still qualify as CORSIA-eligible fuels with an emission reduction of 10 percent compared to jet fuel:

Table 2: CORSIA methodology values for SAF from primary crops compared to UCO SAF

CORSIA LCEF for fuels made from:	Canola seed oil	Soybean oil	Used cooking oil
Life-cycle assessment (LCA) values	47.4	40.4	13.9
Induced land-use change (ILUC) values	26	24.5	–
Combined life-cycle emission factors (LCEF = LCA + ILUC)	73.4	64.9	13.9
All values in g CO ₂ /MJ. Compared with total life-cycle emissions baseline for jet fuel (89 g CO ₂ /MJ).			

With the US potentially less concerned with land-use change factors, the domestic US market may regard fuels from primary crops as even more viable to decarbonise aviation. However, even by considering only core GHG emissions, fuels from these feedstocks will still not achieve as much emissions reduction as fuels from used cooking oil.

Overall, while primary crops like soybean and canola oil have mature, well-established supply chains, higher relative GHG emissions factors and pressures on food use may make these feedstocks a less favourable option for those wanting to achieve greater emissions reduction.

Covering new ground: carinata, camelina, and pennycress

Carinata, camelina, and pennycress are oily plants that can be processed into HEFA SAF. These cold-tolerant crops grow well in the winter, fitting into existing crop rotations without displacing food crops like corn or soy. When cultivated as so-called 'cover crops', they improve soil health and water quality, reduce erosion, and suppress weeds, and cut emissions compared to traditional vegetable oils. With little current demand, they also avoid the market pressures tied to major crops like palm or soybean oil.

Under the CORSIA methodology, these oilseed cover crops have lower emission intensities than primary crops such as soybean and canola. Though their LCAs are comparable to those of primary crops, these species do not demand additional land when grown as cover crops and actually have positive effects on the soil. This is recognised in their negative induced land-use change (ILUC) values, reducing their total LCEF well below those of primary oil crops. However, the advantage may be lost in the US, with recent legislation potentially excluding land-use change from carbon intensity calculations.¹⁰

Table 3: CORSIA methodology values for SAF from oilseed cover crops compared to UCO SAF

CORSIA LCEF for fuels made from:	Carinata seed oil	Camelina seed oil	Pennycross oil	Used cooking oil
Life-cycle assessment (LCA) values	34.4	42.0	30.6 ¹¹	13.9
Induced land-use change (ILUC) values	-16.2	-11.5	-18.3 ¹²	–
Combined life-cycle emission factors (LCEF = LCA + ILUC)	18.2	30.5	12.3	13.9
All values in g CO ₂ /MJ. Compared with total life-cycle emissions baseline for jet fuel (89 g CO ₂ /MJ).				

Despite the benefits of using cover crops, there is low appetite in the US to integrate them into existing systems. Data suggests that in 2022 only about five percent of US cropland was planted with cover crops, comprising mostly winter wheat, rye, or oats, with the uptake of less-known cover crops even lower.¹³ Certain barriers limit adoption:

- Limited incentive:** Winter cereals like rye and oats work well as cover crops because they're easy to grow and can be sold profitably with minimal changes to land use. In contrast, niche oilseed cover crops like camelina, carinata, and pennycress lack strong market demand, making them less financially attractive. While USDA subsidies can help with seed and planting costs, they don't cover the more complex management these crops require, so farmers are hesitant to adopt them.¹⁴
- Weaker supply chain for biofuels processing:** Low adoption of oilseed cover crops makes it hard to build an efficient supply chain. Processing is scattered, and feedstock often travels long distances, raising costs and emissions. Regional hubs could help, but they need major investment and coordination. Even with planned expansions – like NOPA's \$6 billion investment to boost crushing capacity – most new infrastructure will focus on soybeans, leaving alternative oilseeds behind. These gaps make SAF from camelina, carinata, and pennycress less competitive.¹⁵

Overall, while oilseed cover crops could theoretically offer strong sustainability benefits, their advantages are diminished by possible changes to carbon intensity calculations, as well as wider industry and supply chain barriers to adoption.

Animal fats, lard, and tallow: sustainable but scarce

Animal byproducts like tallow and chicken fat are established feedstocks in many applications. Fats are processed or ‘rendered’ at sites like abattoirs or meat processing facilities, with edible fats allocated for human consumption, and less edible portions supplied to animal feed production, chemicals, and biofuel industries.¹⁶ Based on 2023-24 USDA figures, 9.7 billion pounds (4.4Mt) of animal fats were produced domestically, while 2.2 billion pounds (1.0Mt) were imported from countries like Brazil and Australia. Of this, 7.2 billion pounds (3.3Mt) went to biofuels.¹⁷

According to the CORSIA methodology, SAF from animal byproducts are more carbon-intensive than HEFA from UCO, but are less carbon-intensive than HEFA from primary and seed oil crops. Animal fats have core LCAs around 20-30 g CO₂/MJ, accounting for the emissions from processing and transporting feedstocks from slaughterhouses to rendering facilities. This is higher than UCO, but lower than the LCA for primary crops and cover crop seed oils. As byproducts and wastes of meat production, animal fat feedstocks are considered to have minimal impact on land use, resulting in an ILUC of 0.

Table 4: CORSIA methodology values for SAF from animal fats compared to UCO SAF

CORSIA LCEF for fuels made from:	Tallow	Beef tallow	Poultry fat	Lard fat	Mixed animal fat	Used cooking oil
Life-cycle assessment (LCA) values	22.5	29.7	33.7	27.8	28.6	13.9
Induced land-use change (ILUC) values	–	–	–	–		
Combined life-cycle emission factors (LCEF = LCA + ILUC)	22.5	29.7	33.7	27.8	28.6	13.9
All values in g CO ₂ /MJ. Compared with total life-cycle emissions baseline for jet fuel (89 g CO ₂ /MJ).						

However, the scale of feedstock available in the US is limited by rates of animal processing and imports. While the US has a healthy domestic supply, rates of domestic animal rendering are either flat or on a slight decline. Without increasing supply, and with legislation reducing reliance on imports, SAF production will need to compete with other applications for this key feedstock, increasing the potential for market distortion or price pressures. In the EU, this effect means even animal byproducts could be tricky, because if animal feed producers can't use the oils from

animal byproducts, they might require more oils from more land-intensive or carbon-intensive primary crops.

All in all, animal byproducts have fairly mature supply chains into biofuels, have comparatively low GHG values, and don't lead to a lot of additional land use, but SAF producers will struggle to meet their production targets relying on just this feedstock. It is likely that animal byproducts will be a key materials source for US SAF, but the industry will need to find other feedstocks to be used alongside it.

Distillers corn oil: the ‘other’ corn biofuel

Distillers corn oil (DCO), also known as technical corn oil (TCO), is inedible oil extracted from corn after fermentation, a co-product of the production of corn bioethanol. It is an abundant feedstock for both animal feeds and biofuels, and scales directly with production of corn ethanol, another popular biofuel. US DCO production was estimated by USDA to have reached 2.3 million tons (2.1Mt) in 2024.¹⁸

At face value, distillers corn oil has lower GHG emissions than most other feedstocks. The CORSIA methodology assigns DCO a default core LCA of 17.2 g CO₂/MJ. This low value is because most of the emissions from processing corn are assigned to corn ethanol production, so the remaining steps of removing DCO from ethanol distillates are much less carbon-intensive.¹⁹ Because it is classified as a byproduct of corn ethanol, DCO is considered to have minimal land-use change impacts, with an ILUC value of 0.

However, some studies raise concerns about its indirect market impacts. While DCO is a co-product, it is already in demand as an additive to swine and poultry feed rations as an energy-rich feed supplement alongside dried distillers' grains and solubles (DDGS). The EU has expressed “significant concern” that diverting DCO to biofuels away from uses like animal feeds would mean it would need to be replaced by cereals or crop vegetable oils, which themselves have higher LCAs and land-use change impacts. DCO's competing uses could mean it could lead to higher emissions than the CORSIA rating implies.

Regardless, DCO will continue to be produced alongside the considerable volumes of corn ethanol in the US. It is an approved and already well-known feedstock, and sourcing for DCO is mature and already accessible to biofuels producers, especially alongside corn ethanol production in the US. While SAF producers use of this key commodity may put pressure on the animal feeds industry, it is likely to be a better, more readily-available option that is worth consideration.

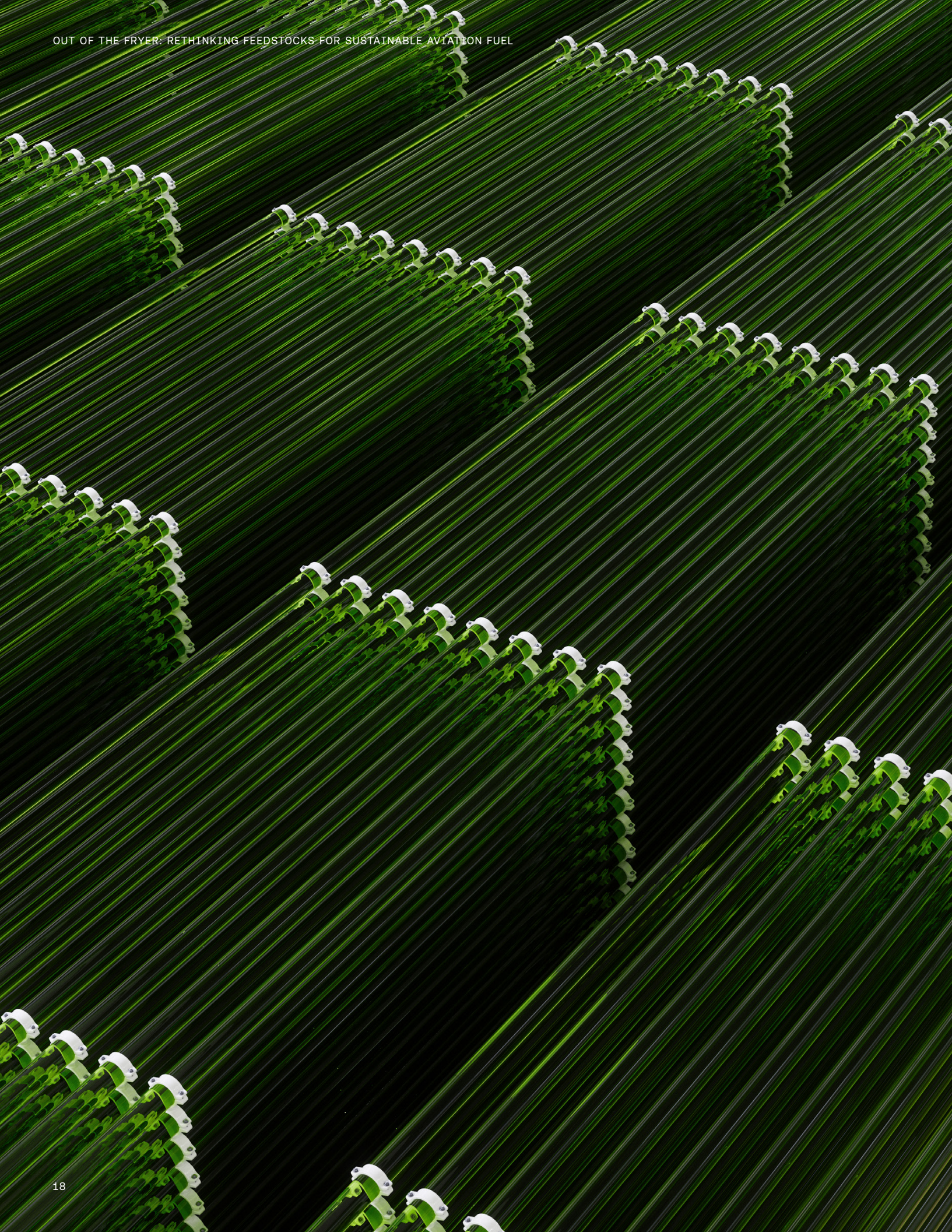
Summary

While the US has a number of readily-available HEFA feedstocks from primary crops, concerns regarding their lifecycle emissions and the indirect land-use change (ILUC) impacts may mean their decarbonisation potential is limited, especially in export markets.

Other feedstocks like oilseed cover crops, while well-regarded in the EU and internationally for their decarbonisation potential, are not as readily available or as simple to produce in the US.

The most promising feedstocks available in the US appear to be agricultural by-products and wastes like animal fats and DCO. Supply chain challenges and competing uses can make relying on any one of these feedstocks challenging, so HEFA producers and their stakeholders would do well to build a diversified portfolio of these feedstocks to reduce their risk.





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