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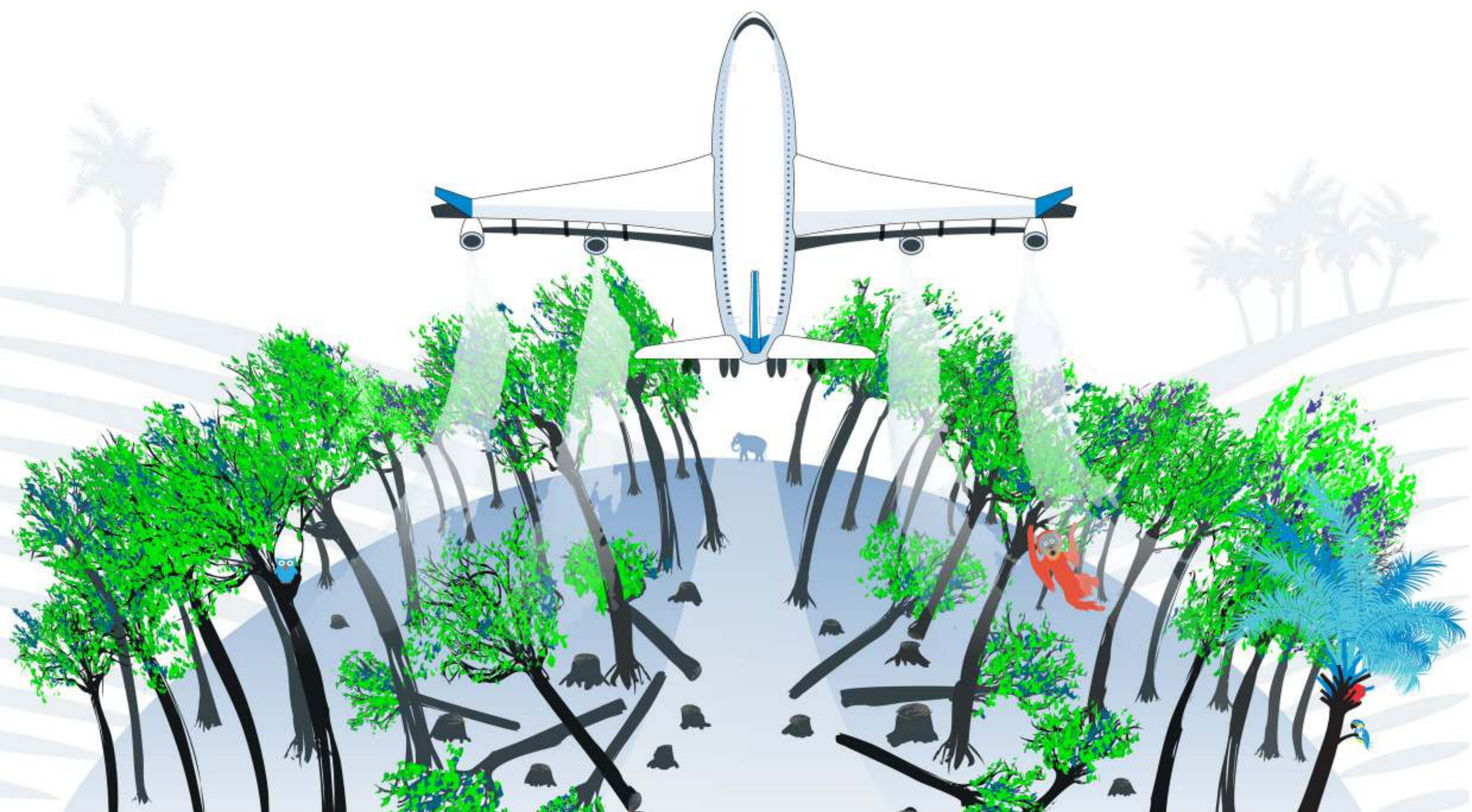
Destination deforestation

Aviation biofuels, vegetable oil and land use change

Cerulogy for Rainforest Foundation Norway



Rainforest Foundation Norway is one of the world's leading organisations in the field of rights-based rainforest protection. We are working for a world where the environment is protected and human rights are fulfilled.

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Research Report: DESTINATION DEFORESTATION
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Report commissioned by Rainforest Foundation Norway, October 2019.

Suggested reference:

Malins, C. (2019). Destination Deforestation - Aviation biofuels, vegetable oil and land use change. Report commissioned by Rainforest Foundation Norway.

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Front cover illustration: Jane Robertson Design

Executive Summary

In a world of increasingly ambitious climate change commitments, the aviation industry's fossil fuel use and CO_2 emissions continue to grow rapidly. The industry has set an aspirational goal to deliver 2050 CO_2 emissions that are half the 2005 level without limiting growth, and central to this vision is a near complete shift from conventional jet fuel to alternative aviation fuels. This long-term goal is complemented by a professed commitment to 'carbon neutral growth' in the aviation industry from 2020 onwards, with alternative aviation fuels seen as one tool to deliver on this commitment. A number of technologies are available to produce aviation biofuels, or even to produce aviation fuels from electricity (power-to-jet, 'PtJ'), but the only one of these technologies currently operating at a commercial scale is the 'HEFA' (Hydroprocessed esters and fatty acids) process to produce jet fuel (and on-road fuels as co-products) from vegetable oils and animal fats.

Based on near-term estimates of production costs (Figure A) HEFA fuel looks more economically viable than alternatives using cellulosic biofuel technologies or PtJ technologies, although all three technologies are likely to be significantly more expensive than fossil jet fuel production for decades to come. This suggests that airlines are unlikely to consume any significant volume of alternative aviation fuels without strong policy incentives to close the price gap to fossil fuels, and that if aviation alternative fuel targets are introduced without any differentiation between technologies, HEFA fuel investors will be the near-term winners.

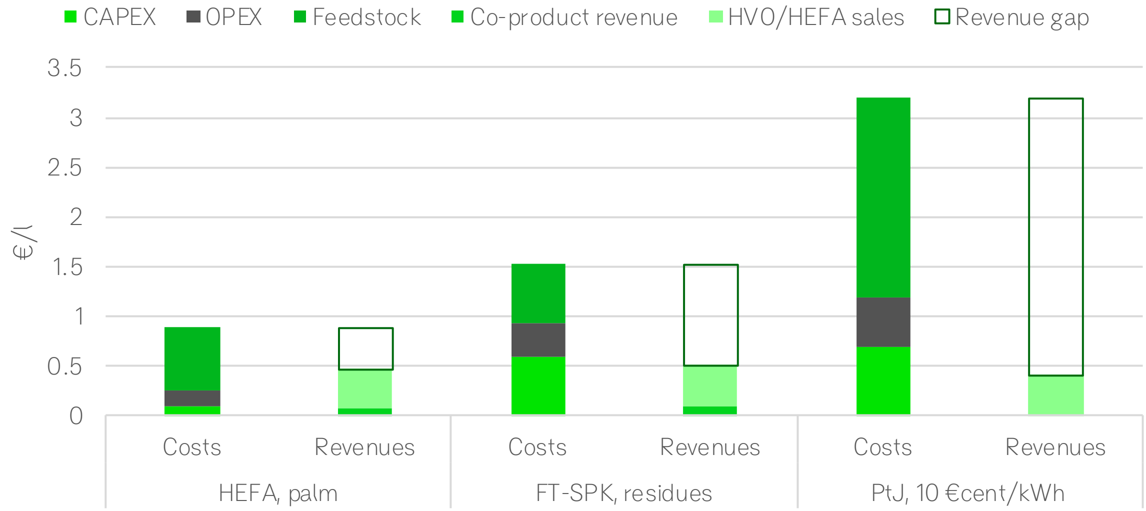

FIGURE A: COMPARISON OF ESTIMATED NEAR TERM PRODUCTION COSTS FOR ALTERNATIVE AVIATION FUELS

Source: As detailed in section on "Feedstock and cost"

While HEFA fuel is able to meet jet fuel standards, the sustainability and scalability of the HEFA industry are limited by the reliance for feedstock on high value food oils and on limited supplies of residual oils (which are in any case generally already being used elsewhere in the economy). The two cheapest virgin oils on the global market, palm oil and soy oil, are both associated with ongoing tropical deforestation. Unless government policy actively supports more sustainable alternatives, it is therefore likely that meeting industry aspirations to increase the use of alternative aviation fuels would lead to a large additional demand for soy and palm oils. In illustrative trajectories developed by ICAO for the aviation industry to reach 100% alternative fuel by 2050, 2030 demand for alternative jet fuel would be about 70 million tonnes. Delivering this as HEFA would require hydrotreating at least 140 million tonnes of vegetable oil a year, about double current global palm oil production[1]. The ICAO indicative trajectory to 50% alternative jet fuel in 2050 would imply hydrotreating at least 90 million tonnes. It is almost impossible to imagine this sort of growth in vegetable oil demand without serious negative consequences for food markets and land use change. If palm and soy oils each met a quarter of feedstock demand under the 100% scenario, based on current trends it could drive 3.2 million of hectares of forest loss and 5 gigatonnes of land use change CO_2 emissions.

By 2030, a trajectory towards 100% alternative aviation fuels could mean:

- **140 million tonnes of vegetable oil being hydrotreated**
- **3.2 million hectares of forest clearance**
- **5 gigatonnes of CO_2 emissions from land use change**

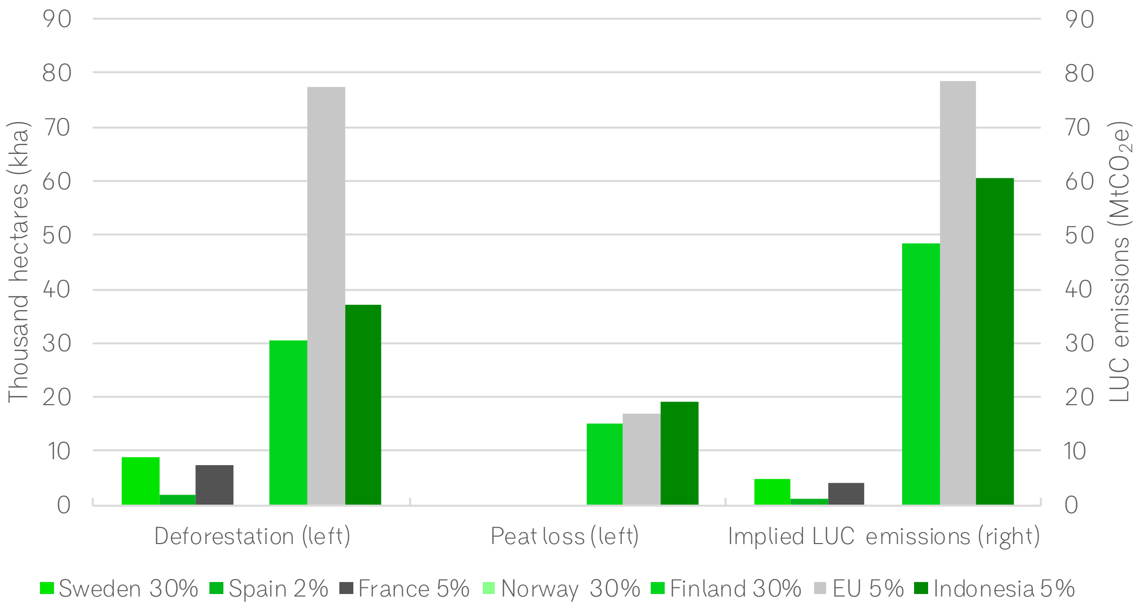

FIGURE B: POTENTIAL DEFORESTATION, PEAT LOSS AND ASSOCIATED LUC EMISSIONS FROM STATED NATIONAL AVIATION ALTERNATIVE FUEL TARGETS

1 Including some co-production of fuels suitable only for road transport applications.

Despite the hype around aviation alternative fuels, it seems that current targets both lack the volume ambition to deliver on industry pledges and the sustainability governance to avoid perverse consequences. The HEFA technology is simply not appropriate to delivering the volumes that would be needed for a large-scale transition to alternative fuels in the aviation industry, which only serves to emphasise the importance of commercialising more scalable technology options (cellulosic biofuels or PtJ) sooner rather than later. Setting undifferentiated mandates that reward the production pathways that are cheapest in the short term is not the best way to achieve this.

As we approach 2020 there is a renewed interest around the world in aviation biofuel policy, and while the members of the International Civil Aviation Organization have for now rejected the imposition of volume targets, several countries are looking to lay the groundwork to drive domestic consumption of aviation biofuels. Several European nations, along with Indonesia, have set domestic targets, although these commitments are generally non-binding for the time being, and it is therefore difficult to assess how close they will come to being met.

In Norway support for alternative aviation fuels is to be limited to advanced biofuels from feedstocks defined by the RED II, but in other EU countries' targets it seems that conversion of food oils to HEFA would be permitted. While the EU has set its intention to phase out by 2030 support for palm oil biofuels under renewable energy targets, which ought to limit demand in the EU for palm oil based aviation fuels, soy oil is currently still allowable as feedstock. Soybean cultivation remains linked to tropical deforestation, raising the risk that pursuing these targets could lead to carbon emissions and biodiversity loss from international land use changes. Figure B provides an indication of the potential for induced deforestation, peat loss and land use change CO_2 emissions if these targets are met by 2030 without excluding palm and soy oil based HEFA.

Part of the response to this dual problem would be for the industry to refocus finally and permanently on supporting the commercialisation of aviation fuel technologies that could be taken to a significant scale without these land use change risks – that means cellulosic biofuels and PtJ technologies. This may necessitate a slower ramp up in production than could be achieved through HEFA, but would take us closer to the long-term goal of real volumes of truly sustainable fuels, and offer the potential for longer term cost savings.

The other part of the response to the reality of an alternative fuel market that is already falling behind its aspirational trajectory would be to revisit the question of whether current rates of aviation growth can ever be sustainable in a carbon constrained world.

The industry may find that alternative fuels will turn out to be not a way to avoid demand-side measures, but a complement to those demand side measures in a portfolio with more efficient aircraft, operational improvements and new propulsion technologies such as electric planes.

This report recommends:

- Exclude HEFA fuels from the highest ILUC-risk feedstocks (palm oil, soy oil and PFAD) from targets, and exclude or limit support for HEFA from food oils.
- Policy should focus on mobilising investment for first of a kind plants to demonstrate electrofuels and cellulosic biofuels at commercial scale.
- The realistic potential for alternative aviation fuel deployment between now and 2050 needs to be reassessed.
- Reprioritising other options to decarbonise aviation, including novel airframes and electric propulsion.
- If business as usual demand growth is not realistically compatible with aviation industry climate targets, this should be integrated into ICAO decision making.

Contents

Introduction

In the era of climate change and global heating, the role of aviation as a source of carbon dioxide emissions is under ever greater scrutiny. In Europe, as the greenhouse gas (GHG) emissions from sectors other than transport have started to fall (European Environment Agency, 2018), aviation industry emissions have continued to increase. The industry hopes to continue to grow in size exponentially for the foreseeable future, with aviation fuel demand growing alongside[2], suggesting a potential incompatibility between attempts to meet the Paris climate targets and the pursuit of the industry vision. The Swedish concept of 'flygskam' or 'flight shame' has caught the imagination of the European public, challenging consumers to recognise that flights are one of the most carbon intensive activities most people might engage in and to reduce or eliminate their use of commercial aviation.

In this context, of an industry looking for ways to justify its social license to operate and to grow, the promise of a rapid expansion in alternative jet fuel production has great appeal for the aviation narrative. Modelling by organisations such as the International Civil Aviation Organisation shows that the aviation industry's professed goal to reduce CO_2 emissions to half 2005 levels by 2050 cannot realistically be achieved without either a dramatic reduction in demand growth or an almost complete switch to very low GHG intensity alternative fuels. Alternative jet fuels, which are currently limited to biofuels but in future may include other fuel production technologies, offer the opportunity to decarbonise aviation with the minimum possible disruption to existing aviation business models. If it is possible to produce alternative fuels with zero or near-zero GHG intensity, then it becomes possible to argue that there is no need to limit consumption of aviation services. It should be acknowledged however that even if aviation fuels could be reduced to zero GHG intensity, the CO_2 from fuel combustion is only responsible for part of aviation's climate impact. Effects associated with contrails, with cloud formation and with other chemicals in jet exhausts make a comparable contribution to global heating, and cannot be readily resolved by alternative fuel use.

While projections of rapidly expanding biofuel demand may seem on first sight to provide a solution for aviation emissions, they come with their own challenges. Biofuel production requires biomass, and biomass requires land to produce. Delivering all of aviation fuel from biomass would require a biofuel industry many times larger than the global industry is today, but even at the current scale many experts have expressed concerns that commodity demand from biofuel markets may be accelerating deforestation and biodiversity loss. Currently, the only commercially operational technology for alternative aviation fuel production is hydrotreating of vegetable oils and animal fats, creating a link between aviation biofuel demand and the controversial palm oil industry – either directly by processing palm oil into fuel, or indirectly through taking palm's competitor oils out of the marketplace for other uses. In this report, we review the status of aviation alternative fuel targets, and discuss how high the risk is that expanding biofuel use in aviation will drive increased deforestation.

2 Moderated to some extent by expected improvements in efficiency.

A note on 'advanced biofuels'

The use of the term 'advanced biofuels' is complicated by the fact that different commentators and stakeholders use quite different definitions for what it actually means, depending on the local legislative framework and on personal priorities. Environmentalists tend to focus on the sustainability of the fuels, technology developers on the sophistication of the processes being used, and engine manufacturers on the molecules being delivered. In the EU, the Renewable Energy Directive has made advanced biofuels synonymous with biofuels produced from a set of feedstocks listed in Part A of Annex IX of the Directive, a list of mostly cellulosic and ligno cellulosic materials that cannot be processed with first generation biofuel technologies. In this report, the term advanced biofuels is used in that same sense, to refer to biofuels produced using next generation processing technologies from those identified non-food feedstocks. This is quite different to the regulatory definition of advanced biofuels in the United States under the Renewable Fuel Standard. In the Renewable Fuel Standard, any biofuel assessed to have an adequately low greenhouse gas emissions intensity counts as advanced, which includes soy biodiesel and sugarcane ethanol.

Renewable jet fuel and vegetable oil

The technology to produce renewable jet fuel has existed for many years, but only in the last decade have renewable fuel pathways been certified for use in commercial aviation and has renewable jet fuel been supplied for commercial flights. As with renewable fuels for cars and trucks, there are several different chemical pathways that can be used to produce renewable jet fuel. The technology used determines what sort of materials can be used as feedstocks, and therefore the types of sustainability risk associated with each production pathway. The main potential technology pathways for renewable jet fuel are detailed in Table 1.

As is apparent from the table, technology options exist to produce renewable jet fuel from both 'first' and 'second' generation resources – vegetable oils, animal fats, sugars and starches might be considered as first generation resources, cellulosic and lignocellulosic material and electricity might be considered as second generation. There is a general agreement that the use of second-generation resources reduces the sustainability risks associated with renewable jet production by reducing the amount of land required to be devoted to fuel use, and by removing the direct connection to food markets. In several jurisdictions, including the EU and U.S., there are therefore more valuable incentives available for renewable jet fuel produced from second generation biomass resources rather than first generation biomass resources. For example, in the U.S. second generation renewable jet fuel would qualify to receive a 'D3 RIN' cellulosic renewable certificate that has been worth on average over five times more than a 'D6 RIN' corn ethanol renewable certificate, while in the EU, under the current regime cellulosic fuels may be counted double towards renewables targets.

Despite this recognition that processes converting non-food resources generally have less sustainability risk, there is not yet an agreement across the aviation industry on whether there is still a role for renewable jet from first generation materials in either the short- or long-term decarbonisation of the aviation sector. Indeed, the only technology identified in Table 1 that is currently producing aviation fuel on a commercial basis is HEFA (van Dyk et al., 2017) for which much of the feedstock is food-grade vegetable oils. For instance, recent analysis for ICAO[3] assumed that just under 7 billion litres (gasoline equivalent) of HEFA will be produced from virgin vegetable oils by 2035 (ICAO CAEP, 2019). This report shows that if the production of renewable jet fuel from virgin vegetable oils grows to meet a significant of jet fuel demand then that is likely to have significant implications for global forests.

3 Based on the IEA 450 scenario.

Photograph by Thomas Marent

TABLE 1: PATHWAYS FOR RENEWABLE JET FUEL PRODUCTION

Pathway[1]	Feedstock(s)	Technology description	Certification status and max blending with conventional jet fuel	Near term potential
Hydroprocessed esters and fatty acids (HEFA)	Vegetable oils and animal fats	Hydrogen addition is used to remove oxygen atoms from vegetable oils and produce a jet-substitute hydrocarbon	Certified for aviation use (50%)	High, already available
Fischer-Tropsch hydroprocessed Synthetic Paraffinic Kerosene (FT-SPK)	Cellulosic/ lignocellulosic material	Biomass is gasified at high temperature to produce a hydrogen/carbon monoxide syngas, a wax is produced by the Fischer-Tropsch process and that wax is upgraded to a jet-substitute hydrocarbon	Certified for aviation use (50%)	Low, limited by cost and lack of commercial plants
Hydrogenated Pyrolysis Oil (HPO)	Cellulosic/ lignocellulosic material	Biomass is pyrolysed at moderate temperature to produce a pyrolysis oil, which is upgraded through hydrogenation to remove oxygen and produce a jet-substitute hydrocarbon	Not yet certified	Medium, may be more cost viable than FT pathway
Alcohol to jet (ATJ)	Alcohols from sugars, starches, cellulose or carbon monoxide2	Ethanol or butanol from first- or second-generation biofuel plants or carbon monoxide fermentation is upgraded to a jet-substitute hydrocarbon through dehydration, oligomerization and hydrogenation.	Certified for aviation use (50%)	Low, value of product does not justify cost of upgrading ethanol
Direct Sugars to Hydrocarbons (DSHC)	Sugars (potentially from cellulosic material)	Biochemical conversion of sugars directly to hydrocarbons (farnesene) followed by upgrading to a jet-substitute hydrocarbon	Certified for aviation use (10%)	Low, limited by cost and lack of commercial plants
Power to jet (PtJ)	(Renewable) electricity	Electrolysis to produce hydrogen, reverse water gas shift reaction to produce carbon monoxide from part of the hydrogen, then Fischer-Tropsch synthesis and upgrading as above.	Not yet certified	Low, limited by cost and lack of commercial plants

Notes: 1) There are a range of different terms of reference used for each technology pathway – for instance, HEFA fuels may also be referred to as hydrotreated vegetable oils (HVO). The use of a different initialism does not necessarily imply a different technology pathway. 2) Lanzatech have pioneered a process for fermentation of carbon monoxide in industrial flue gases to ethanol.

Certification status based on:
https://www.icao.int/environmental-protection/GFAAF/Pages/FAQs.aspx

An important aspect of aviation biofuel production that is sometimes overlooked is that most production processes will not generate only jet fuel, but will generate a range of co-product molecules only some of which will be appropriate for upgrading for aviation use. For HEFA and FT-SPK, ICAO CAEP (2019) assumes that one quarter of produced fuel will be appropriate for aviation use and the other 75% will be co-products for on-road use, though for alcohol to jet pathways a higher jet fraction is assumed. Producing any larger fraction of renewable jet would require additional investment for further product processing, and would tend to reduce the overall fuel yield from facilities, increasing costs while potentially reducing returns.

Existing HVO facilities produce very little renewable jet fuel and therefore in the short term an increase in renewable jet output could be achieved by adding jet fuel upgrading capacity at facilities currently producing only renewable diesel and naphtha. In the longer term however, it should be understood that expansion in the use of HEFA as renewable jet fuel on the scale envisioned by industry goals will only be possible in the context of a parallel expansion of production of HVO renewable road fuel production. This means that overall feedstock demand for vegetable oil hydrotreating in an expanded industry could potentially be four times higher than the demand implied by HEFA production alone. This should be taken into account when considering land use and food markets impacts.

Feedstock and cost

There are large uncertainties around the future production costs of different alternative aviation fuels (AAF) pathways. This is especially true for novel production pathways that have not yet been commercialised. Here we provide indicative near-term cost estimates for the HEFA, FT-SPK and PtJ pathways. Costs are presented on a levelised cost of fuel production (LCOF) basis[4]. In each case it is assumed that the facilities are set up to maximise jet fuel yields, but the LCOF estimate is averaged across mid-distillate fuel production (i.e. renewable jet and renewable diesel) with other outputs such as naphtha treated as co-products. The cost estimates for HEFA and FT-SPK fuels are calculated based on cost data reported by Pavlenko, Searle, & Christensen (2019). The modelling is based on facilities optimised for jet fuel yield, with just over half of produced fuels being supplied as alternative aviation fuels, and the co-product fuels presumably supplied for on-road use. The e-fuel costs are calculated based on data reported by Brynolf, Taljegard, Grahn, & Hansson (2017). It is assumed that the cost of capital for HEFA facilities is 7.5% (cf. OpenEI, 2019), whereas the cost is higher for first of a kind FT-SPK and PtJ facilities at 15% (cf. Peters, Alberici, Passmore, & Malins, 2016).

The modelling is intended to illustrate the hierarchy of expected costs between technology options, and indicate the potential contribution of capital, operational and feedstock costs to the profile for each technology. It should be emphasised that there are large uncertainties on these costs, especially for FT-SPK and PtJ technologies. Some operators may claim to be able to deliver significantly lower levelised production costs, and indeed facilities able to out-perform the central estimates presented are more likely to draw investment.

The cases represented are:

- HEFA: palm oil as feedstock;
- HEFA: soy oil as feedstock;
- HEFA: used cooking oil as feedstock;
- FT-SPK: agricultural residues as feedstock;
- FT-SPK: biomass fraction of municipal solid waste (MSW) as feedstock. It is assumed this material is available at zero cost;
- PtJ: 10 €cent/kWh[5] electricity, near term base case cost assumptions from Brynolf et al. (2017);
- PtJ: 5 €cent/kWh electricity, near term low case cost assumptions from Brynolf et al. (2017).

4 Cf. for instance (OpenEI, 2019).

5 This is comparable to current wholesale industrial electricity prices.

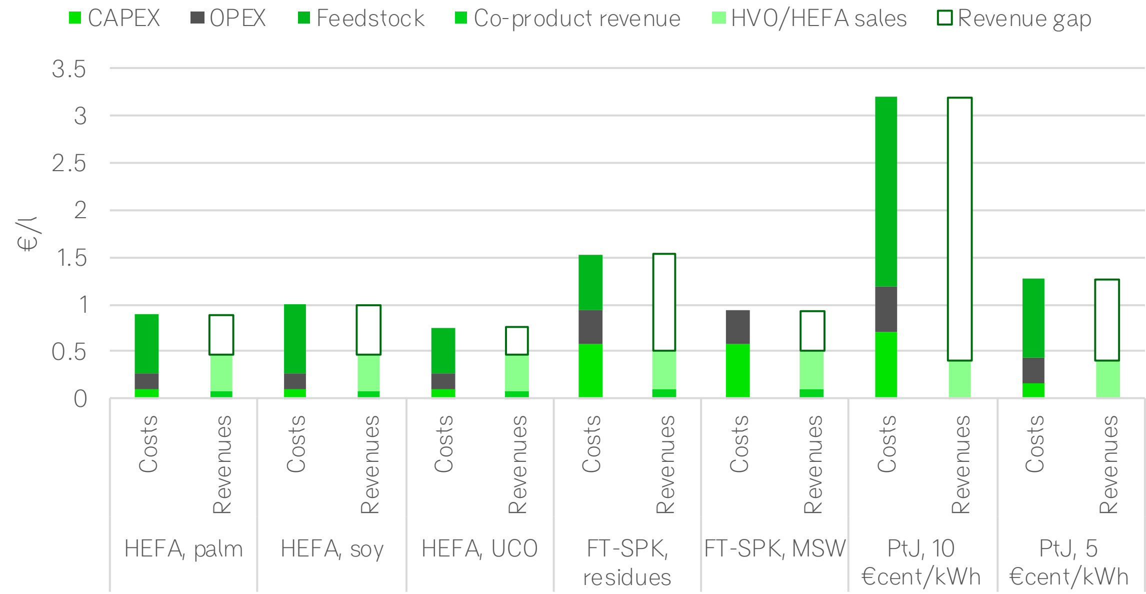

FIGURE 1: ILLUSTRATIVE ESTIMATES OF PRODUCTION COSTS FOR THREE ALTERNATIVE JET FUEL PATHWAYS

The indicative levelised cost of fuel production (averaged across diesel and jet fuel outputs) and potential revenues (based on current fossil fuel prices[6]) for these cases are shown in Figure 1, in € per litre of produced diesel and jet fuels. Any value from policy support is not included, but would help close the identified revenue gap. It is apparent that the most favourable cost estimates are achievable for HEFA fuels (with the lowest costs delivered by use of the lowest cost feedstocks, as one would expect) and for the FT-SPK pathway if MSW can be utilised as a zero-cost feedstock. The policy support required to close the revenue gap for these lower cost fuels would be comparable to the value of current biofuel incentives in some EU Member States under the RED.

The FT-SPK pathway from agricultural residues and the PtJ pathways are more costly, and would require policy support worth at least 1 €/litre to make the business case viable (much more for the PtJ case with 10 €cent/kWh electricity). For the biofuels, only the feedstock costs vary between cases. For PtJ, an optimistic case is presented combining an assumption of 5 €cent/kWh electricity with low-end estimates on capital and operational costs in order to illustrate the range presented in the literature. This low-cost pathway may well not be achievable in practice.

Three main conclusions emerge from this consideration of potential costs of alternative fuel production. Firstly, alternative jet fuel will almost certainly be significantly more expensive than conventional jet fuel in the coming decades. Secondly, because of this cost gap airlines are very unlikely to use significant volumes of alternative fuels unless this price gap is closed by policy measures (either mandating airlines to use fuels despite the cost,

6 The biofuel modelling follows Pavlenko et al. (2019) by assuming that a facility will produce part-renewable diesel, part renewable jet, and part light ends (co-products). The electrofuel modelling is based on 100% renewable diesel production, but for illustrative purposes this is an acceptable proxy for renewable jet costs.

or subsidising the wholesale price of alternative fuels). Thirdly, if the market develops with reference to near term costs alone we expect to see HEFA production increase before the commercialisation of cellulosic biofuel pathways from agricultural and forestry residues or of PtJ fuels, although in the longer term these are the most scalable and sustainable options. It is clear therefore that the alternative jet fuel market will be policy driven, and therefore that policy makers must make a choice about whether to actively support the development of the more sustainable options.

While HEFA fuels appear to have an advantage over cellulosic biofuels in the short term, this could change if reductions can be delivered in technology and financing costs for advanced biofuels. Feedstock costs constitute about 70% of the cost of HEFA production, but only 40% for FT-SPK. Reducing capital expenditure and the interest paid on capital could make a significant contribution to reducing the cost of capex for cellulosic biofuel production. There may also be opportunities to introduce pyrolysis oil from cellulosic material as an alternative to vegetable oils for refinery co-processing at similar or even lower cost if efficient supply chains can be developed. If policy makers see the long-term future of aviation alternative fuels in cellulosic technologies rather than HEFA, then the short-term imperative should be to help demonstrate the relevant technologies and bring costs down, rather than to set undifferentiated use mandates.

Vegetable oils, indirect land use change and deforestation

Palm oil

Palm oil has been repeatedly identified as one of the biofuel feedstocks likely to cause large indirect land use change emissions, because of the chronic association between the expansion of oil palm plantations and the clearance of forests and drainage of peat areas (European Commission, 2019a; Malins, 2017a). In recognition of analysis of deforestation and peat destruction that are likely to result from increasing palm oil demand, palm oil has been identified as a ‘high ILUC-risk feedstock’ by the European Commission (European Commission, 2019b), meaning that by 2030 palm oil biofuels will not be eligible to be counted towards targets under the RED (subject to a review of the data in 2023). In practice incentives for biofuel use in EU Member States are generally predicated on the eligibility of those biofuels to be counted towards RED targets, including for the use of biofuels in aviation. It is therefore to be expected that Member State support for palm oil biofuel use will be eliminated by 2030. Palm oil biofuels are already effectively excluded from support within the United States Renewable Fuel Standard, California Low Carbon Fuel Standard and Oregon Clean Fuels Program due to high estimated indirect land use change emissions.[7]

The European Commission’s review on the status of production expansion of relevant food and feed crops worldwide provides a good review of the current status of the relationship between palm oil expansion and the loss of peatland and forest, presenting original results from assessment of satellite mapping alongside a literature review of recent relevant studies. As detailed in Table 2, the substantial majority of global palm oil area expansion in the period 2008-15 occurred in Indonesia (67%) and Malaysia (15%), with over 60% of global palm oil area expansion occurring on the island of Borneo. Unfortunately, the literature suggests that the majority of new land for oil palm on Borneo is obtained through deforestation.

The link to deforestation is weaker in the rest of the world, but still non-negligible according to Vijay et al. (2016), with 13% of the palm oil area expansion occurring outside Indonesia and Malaysia being associated with deforestation.

7 With the exception of some grandfathering provisions for older facilities in the Renewable Fuel Standard.

TABLE 2: PALM OIL AREA EXPANSION AND FRACTION OF NEW PALM AREA ASSOCIATED WITH DEFORESTATION

	Years assessed	Malaysia		Indonesia		ROW
% of world palm expansion 2008-15	**2008-15**	15%		67%		17%
		Peninsula Malaysia	**Malaysian Borneo**	**Indonesian Borneo**	**Rest of Indonesia**	
% of national expansion 2008-15	**2008-15**	19%	81%	77%	23%	
Estimated percentage of expansion onto forest						
(Gaveau et al., 2016)	**2010-15**		75%	42%		
(Abood, Lee, Burivalova, Garcia-Ulloa, & Koh, 2015)	**2000-10**			>36%		
(SARVision, 2011)	**2005-10**		52%			
(Carlson et al., 2013)	**2000-10**			70%		
Gunarso et al. 2013	**2005-10**	47%		37-75%		
Austin et al. 2017	**2005-15**			>20%		
(Vijay et al., 2016)	**2013**	40%		54%		13%
Vijay et al. (2016) (global average)	**2013**	**45%**				

Source: (European Commission, 2019a)

The satellite analysis results presented by European Commission suggested an even stronger link between deforestation and palm oil expansion than the literature reviewed, identifying 70% of new oil palm area as replacing forest land. This higher value may reflect the methodological choice in the Commission's GIS work to treat any oil palm planted by 2015 on land that was forested in 2008 as being deforestation associated, a conversion window of up to 7 years. Most of the studies review only treat oil palm establishment as deforestation associated if it happens more quickly than this after the initial deforestation. Overall, the European Commission concluded that the best available estimate of the fraction of global palm oil expansion occurring at the expense of forest is 45%.

Photograph by Thomas Marent

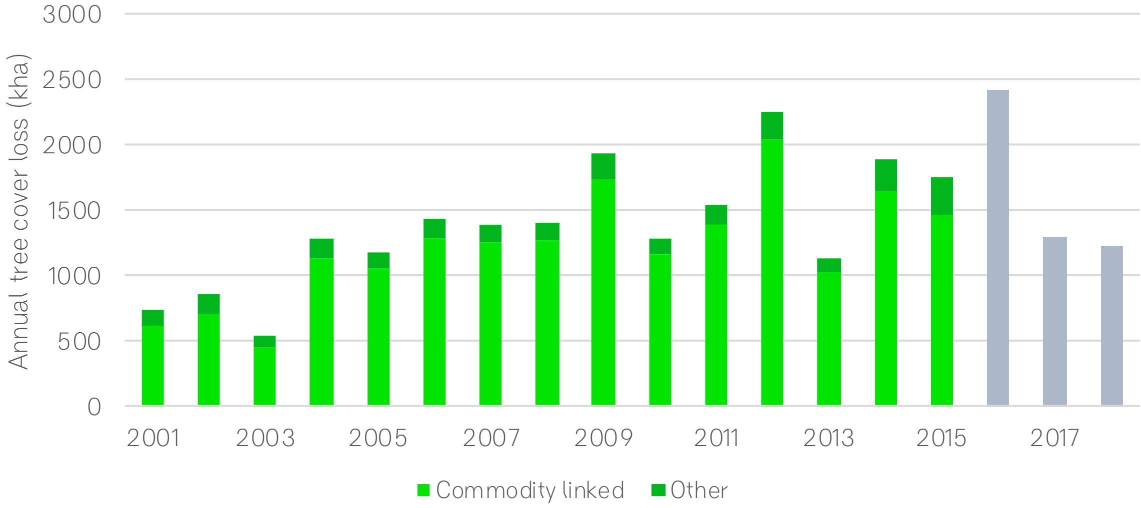

FIGURE 2: TREE COVER LOSS IN INDONESIA, 2001-2018

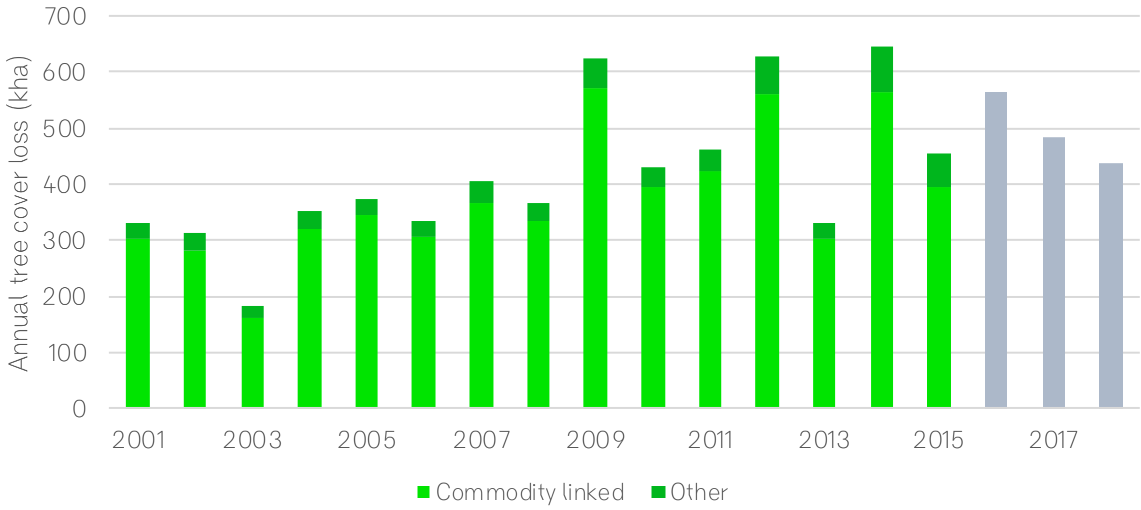

FIGURE 3: TREE COVER LOSS IN MALAYSIA, 2001-2018

Several initiatives have been introduced in Malaysia and Indonesia over the past decade aiming to reduce the link between palm cultivation and deforestation, including the expansion of sustainability certification schemes and some partial moratoria on expansion.

Unfortunately, the evidence available does not yet support a conclusion that these initiatives have led to a fundamental change in the character of the deforestation link from palm oil expansion.

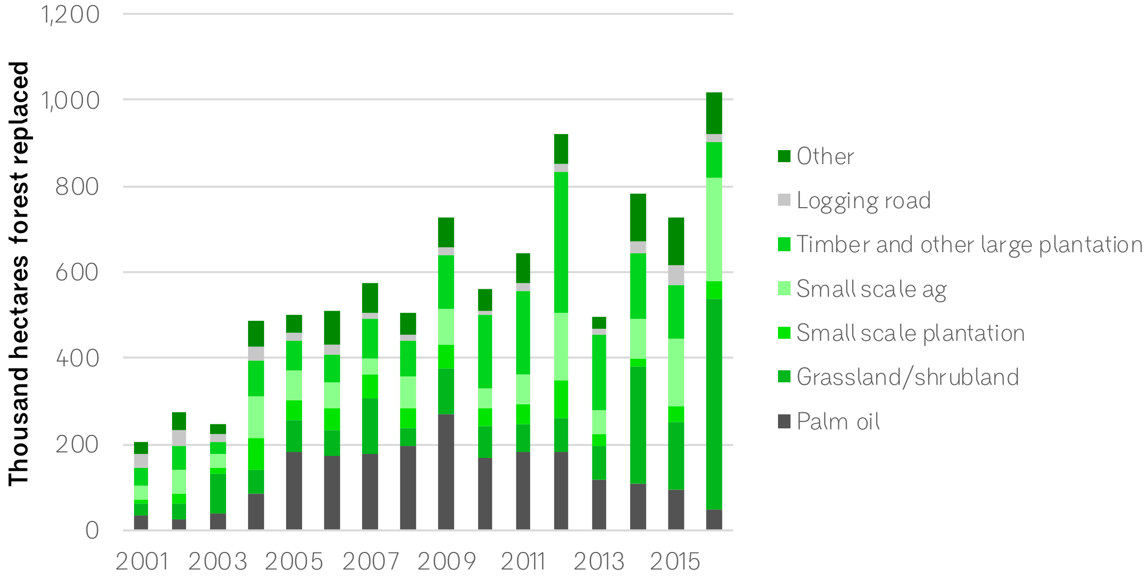

FIGURE 4: LAND USE OBSERVED FOLLOWING FOREST LOSS, (AUSTIN ET AL., 2019)

For example, analysis presented through Global Forest Watch[8] based on Curtis, Slay, Harris, Tyukavina, & Hansen (2018) shows that in the decade since introduction of the RED, deforestation has continued apace in both Indonesia and Malaysia with commodity expansion the primary driver, as shown in Figure 2 and Figure 3. There is some emerging evidence however that could be consistent with a weakening in the relationship between palm oil and deforestation. Recent analysis by Austin, Schwantes, Gu, & Kasibhatla (2019) found that the amount of deforestation in Indonesia that was followed by largescale oil palm plantation establishment within two years[9] fell significantly by 2016 compared to the rate observed in particular during 2005 to 2012, as shown in Figure 4.

While the reduction in observed cases of oil palm plantations replacing primary or degraded primary forest could be consistent with a weakening of the link between palm oil expansion and deforestation, there may also be other factors at work. Firstly, it is noteworthy that the low amount of palm oil identified as replacing forests lost in 2016 is more than offset by a large conversion of forest to 'grassland/ shrubland', likely related to a high loss of forest to fire in the preceding dry season (2015). Grassland/shrubland does not represent an economic use for the land, and Austin et al. (2019) find that deforested land sometimes is converted to agricultural use a few years after an initial identification as grassland. While oil palm plantation establishment had not followed on most of this area within two years, it is possible that as more data becomes available it would become apparent that oil palm expansion has indeed followed the forest loss events, but over a longer period. A longer than normal gap between forest loss and palm plantation establishment might be partly explained by

8 https://www.globalforestwatch.org

9 The period considered in the study is 2001-2016. For the most of the study period, changes within four years of a deforestation event were considered. For the last two years of the study period, the full four year time frame is not available, and therefore the data for 2015 and 2016 reflect changes within two or three years.

relatively low palm oil prices (World Bank, 2019), which will have reduced pressure for new plantings. The relatively low forest loss to oil palm reported for 2016 also coincides with a year in which Indonesian government statistics (Indonesian Central Bureau of Statistics, 2019) show a slight net reduction in planted oil palm area (against increases of hundreds of thousands of hectares in all other years). It would therefore be premature to assume that the reported reduction in forest loss to oil palm plantations marks a change in the underlying trend.

The Commission report also looked explicitly at the association between oil palm expansion and peat drainage, which results in even higher carbon dioxide emissions than deforestation (Page, S.E., Morrison, R., Malins, C., Hooijer, A., Rieley, J.O. Jaujiainen, 2011). Based on results presented in Miettinen et al., 2012; Miettinen, Shi, & Liew (2016) for palm–associated peat drainage in Indonesia and Malaysia, the Commission estimate that 23% of palm oil expansion globally occurs on peat soils that must be drained and consequently decompose, releasing large amounts of carbon dioxide as they do so. These results for the fraction of palm oil expansion associated with deforestation and peat loss respectively are similar to global estimates given by Malins (2019).

In the case of Indonesia, the government has attempted in recent years to reduce the rate of drainage and loss of peat soils through the development of a legal framework to support protection of peat ecosystems (Indonesian Government, 2014, 2016), and has established a programme to allow companies to exchange existing concessions for peatland areas that are now designated as protected for concessions in non-protected areas[10]. A series of increasingly broad moratoria on conversion of peatland to oil palm since 2011 are yet to produce clear results, and have been criticised for leaving too many loopholes for continued peat exploitation[11], but with proper enforcement the measures now in place ought to deliver some reduction in the rate of loss of Indonesian peatlands.

Palm Fatty Acid Distillate (PFAD)

Given the controversy around the use of virgin palm oil as a biofuel feedstock, HVO renewable diesel producers have been keen to find alternatives to palm oil that have good properties for hydrotreating and that are similarly low cost compared to other vegetable oils. One material stream that has been utilised by HVO plants that seemed to meet these conditions is itself a by-product of palm oil refining, palm fatty acid distillate. Fatty acids are formed when palm oil starts to degrade, for example due to rough treatment of fruit bunches and delays before oil extraction. These fatty acids are separated from palm oil at the start of the refining process, and account for about 4% of crude palm oil on a mass basis (SPOTT, 2017). While fatty acids are undesirable in refined palm oil, the separated PFAD stream is itself a valuable commodity with a number of industrial uses, and typically sells for a price about 80% that of palm oil itself (Malins, 2017a). PFADs should therefore not be considered as a waste or residue, but rather as a by-product of the palm oil production process. This is reflected in national classifications of PFAD in relation to support under the Renewable Energy Directive, under which fuels from wastes and residues are eligible for favourable treatment. Countries understood to treat PFAD as a by-product include Norway, France, the UK, Sweden, Italy, Austria, Denmark, Germany, and the Netherlands. The only country known to still classify PFAD as a residue is Finland. Other EU Member States may not have made an explicit classification decision.

Even without demand for PFAD as a biofuel feedstock, available PFAD is completely utilised

10 https://news.mongabay.com/2017/08/land-swap-rule-among-indonesian-president-jokowis-latest-peat-reforms/

11 https://news.mongabay.com/2016/12/green-groups-raise-red-flags-over-jokowis-widely-acclaimed-haze-law/

in applications including oleochemicals, soap production, animal feed and energy recovery as boiler fuel. Increasing the use of PFAD for biofuel production will therefore force current users to find alternatives, leading to indirect effects in the market and potentially to indirect emissions. The most obvious alternative in many applications is palm oil itself, as it is the lowest priced of the virgin oils and is available in the same markets as PFAD is available. If PFAD is replaced in these uses by palm oil to any significant extent, then the use of PFAD will inherit the deforestation and peat loss problem of virgin palm oil consumption.

The likely substitutes for PFAD and associated indirect effects are considered by (Malins, 2017b). This assessment concludes that utilising 1 tonne of PFAD for palm oil feedstock could reasonably be expected to have a knock on impact of increasing palm oil demand by 0.64 tonnes and soy oil demand by 0.12 tonnes, although it is noted that there is a lack of detailed data available on current disposition of PFAD and on likely replacements, and therefore there is significant uncertainty around these estimates.

Soy oil

Like the oil palm, soybeans are regularly identified as a high deforestation risk commodity (Malins, 2019). Soybeans are identified in the literature as driving more deforestation in total than oil palm, but the soybean crop is larger than the palm crop and the deforestation impact per unit of soy production is generally understood to be less.

TABLE 3: SOY AREA EXPANSION AND FRACTION OF NEW SOY AREA ASSOCIATED WITH DEFORESTATION

	Brazil			Argentina	Paraguay	Uruguay	Bolivia
% of Latin American soy expansion 2008-17	67%			19%	7%	5%	2%
	Amazon	**Cerrado**	**Rest of Brazil**				
% of national expansion 2008-17	11%	46%	44%				
Estimated percentage of expansion onto forest							
Estimated percentage of expansion onto forest	5%	14%	3%	9%	57%	1%	60%
Weighted average expansion into forest in Latin America				14%			
Fraction of world soy expansion in Latin America				53%			
Assumed % of expansion onto forest in RoW				2%			
Global average expansion of soy onto forest				**8%**			

Source: (European Commission, 2019a)

The European Commission's review on the status of production expansion of relevant food and feed crops worldwide concluded that about 8% of new soy area in the period 2008-15 came from deforestation. This is driven primarily by deforestation in Latin America, including in Brazil. Despite some success for the Amazon soy deforestation moratorium (Gibbs et al., 2015), deforestation for soy has continued elsewhere in the country. The largest contributors to direct soy related deforestation in Latin America are now the Brazilian Cerrado, and the Chaco forest in Paraguay and Argentina. The association between soy expansion and deforestation by region as identified in the European Commission's review is detailed in Table 3.

The assessment for the European Commission considers cases in which a direct conversion of forest to soy production is identifiable, but some analysts have also pointed to a strong link between the soy and cattle ranching industries, suggesting a system within which land is first deforested to pasture cattle and then brought predictably into use for soy cultivation several years later (Zalles et al., 2019). The overall impact of soy demand on deforestation rates including these indirect impacts is therefore potentially larger than shown by the European Commission analysis.

There is some risk at the moment that the deforestation footprint of soy production may grow worse again due to a relaxation of Brazilian deforestation protections and reduction in enforcement under the newly elected Bolsonaro administration. It has been reported that deforestation rates appear to have increased in 2019[12], but that simultaneously the number of fines issued for illegal deforestation has reduced[13]. The most recent reporting suggests that forest clearances in the year 2019 to August were nearly double those in the comparable period in 2018, and higher than in any year since 2008[14]. At the time of writing, an unusually high incidence of fire in the Amazon has become a major news story and has been associated with increased rates of land clearing (IPAM, 2019). It is too early to be sure whether these apparent increases in Brazilian deforestation will become a long term phenomenon, or the extent to which they relate to soy expansion as opposed to other activities such as cattle ranching, but with 44% of global soy expansion happening in Brazil (Malins, 2019) it is a cause for concern. Certainly, it would seem unduly optimistic at this time to think that the link between deforestation and soy will be reduced in the immediate future.

12 https://www.theguardian.com/world/2019/jun/04/deforestation-of-brazilian-amazon-surges-to-record-high-bolsonaro

13 https://psmag.com/environment/brazils-government-is-gutting-environmental-protections-from-the-inside

14 https://news.mongabay.com/2019/09/brazils-satellite-agency-resumes-releasing-deforestation-data/

International targets for aviation biofuels

United Nations through the International Civil Aviation Organisation

The International Civil Aviation Organisation is a United Nations specialised agency set up in 1944 to manage the 'Chicago Convention' on international civil aviation, developing policies and standards to support safe civilian aviation. In more recent years, the exclusion of international aviation from national greenhouse gas emissions inventories under the UN Framework Convention on Climate Change (UNFCCC) has seen ICAO take on the question of greenhouse gas emissions from international aviation. ICAO's mission is to, "Achieve the sustainable growth of the global civil aviation system" and therefore it should not be surprising that to date ICAO has not embraced demand management as a climate change mitigation solution. Instead, ICAO has focused on technical measures to manage the emissions from the sector. These include aircraft efficiency, operational changes to reduce fossil fuel use, offsets[15], and the use of alternative aviation fuels. These measures are intended to contribute to ICAO's 'aspirational goal' of carbon neutral aviation growth from 2020 onwards.

In March 2018, the ICAO Council endorsed the "2050 ICAO Vision for Sustainable Aviation Fuels"[16]. The Vision is described as a 'living inspirational path'. Its goals include:

- For SAF to be developed and deployed in an economically feasible, socially and environmentally acceptable manner;
- For a significant proportion of conventional aviation fuels (CAF) to be substituted with sustainable aviation fuels (SAF) by 2050;
- For ICAO and Member States to pursue any opportunities to implement necessary policies, technology and financing measures, with an increasing proportion of SAF into the fuel supply over time;
- To support the approval of new conversion processes under development, and explore means and policies for reducing time and expenses required for technical certification of SAF;
- For States to support the development and implementation of stable policy frameworks that facilitate the deployment of SAF;
- For States to foster the further development of innovative

15 Also referred to as 'market based measures', an offset means counting a reduction in greenhouse gas emissions in another sector against emission from the aviation sector.

16 https://www.icao.int/environmental-protection/GFAAF/Pages/ICAO-Vision.aspx

technological pathways to produce SAF from sources such as renewable electricity.

The Vision is explicit that it does not at this time create any specific obligations for ICAO Member States, and therefore the initiative remains with Member States to adopt measures to promote alternative fuel supply, although a 2025 update to the Vision is to “include a quantified proportion of CAF to be substituted with SAF by 2050, and carbon reductions achieved by SAF”. A proposal for specific targets to be adopted was rejected by ICAO Member States in 2017[17].

While the 2050 Vision does not directly create targets or provide support for alternative fuel use in aviation, alternative fuels are supported as a compliance pathway under ICAO’s “Carbon Offsetting and Reduction Scheme for International Aviation” (CORSIA). CORSIA creates an obligation for affected airlines to pay for a certain number of GHG offsets each year, determined based on the difference between calculated GHG emissions from the covered part of international aviation[18] and GHG emissions from the covered part of international aviation in 2019 and 2020. Airlines can reduce their offsetting obligations by the use of alternative fuels that meet the sustainability requirements of CORSIA. This mechanism in principle provides an economic incentive for airlines to increase utilisation of alternative fuels. In practice, however, it is likely that the cost of purchasing offset certificates will be significantly below the marginal additional cost of producing and using alternative fuels. Scenario analysis for ICAO (ICAO CAEP, 2016) considers CO_2 abatement prices for CORSIA in the range from 6 to 40 \$/tCO_2e, whereas estimates of implied CO_2 abatement prices for advanced biofuels are generally over 200 \$/tCO_2e (Sustainable Transport Forum sub group on advanced biofuels, 2017) and estimates for electrofuels higher still (Malins, 2017c). The value signal from CORSIA alone is therefore unlikely to be a significant driver of alternative fuel use in international aviation, as it will not be adequate to cover the price gap between alternative jet fuel and conventional fossil jet fuel. At most, the reduction of CORSIA offsetting obligations may be a complement to more significant alternative fuel use incentives offered at the national level, providing a modest impetus to supply alternative fuels to aviation rather than for on-road use.

The inclusion of sustainability criteria within the CORSIA system is intended to reduce the risk of environmentally perverse outcomes from alternative aviation fuel use. The CORSIA sustainability criteria (ICAO, 2019) as they currently stand require the following:

1. CORSIA eligible fuel should have reportable net GHG emissions at least 10% below the baseline value for conventional aviation fuel, including a characterisation of induced land use change emissions (or, if greater, emissions from direct land use change since 1 January 2008);
2. CORSIA eligible fuel must not be produced from land that has been converted from primary forest, wetland or peatland status since 1 January 2008.

The standard notes that, “Work on other themes such as Water; Soil; Air; Conservation; Waste and Chemicals; Human and labour rights; Land use rights and land use; Water use rights; Local and social development; and Food security, and related criteria, and on the application of these criteria, is ongoing.” Two AAF pathways identified by ICAO (ICAO CAEP, 2019) have default GHG emissions (as assessed by ICAO) that exceed the GHG emissions threshold – corn grain alcohol to jet, and palm oil HEFA from palm mills without methane capture on effluent ponds. For both feedstocks, however, selecting

17 https://www.transportenvironment.org/press/countries-reject-plan-aviation-biofuels-targets

18 Not all flights will be covered by CORSIA, and therefore the aspirational goal of carbon neutrality only applies to part of international aviation.

more efficient production practices would enable the minimum threshold to be met.

Industry through the International Air Transport Association (IATA)

Many of the elements that have been enshrined in the ICAO '2050 Vision' build upon goals suggested by the aviation industry itself. In the absence of binding requirements on ICAO Member States to ensure that these targets are delivered, the industry will need to either take some responsibility for accelerating the deployment of lower carbon aviation technologies, or confront the possibility of failing to deliver on these targets. For example, the aviation industry has committed in principle to 'carbon neutral growth' from 2020. The carbon neutral growth commitment has been advertised as preventing any increase in net emissions from the aviation sector beyond 2020[19] despite ongoing growth in aviation demand. The industry does not have tools in place to deliver on this commitment solely through direct reduction of the carbon intensity of flying, and therefore will rely on the CORSIA scheme to meet the commitment. As noted above, one option to meet CORSIA obligations is the use of alternative fuels, but purchasing emissions offsets is likely to be the more costs effective compliance option for airlines.

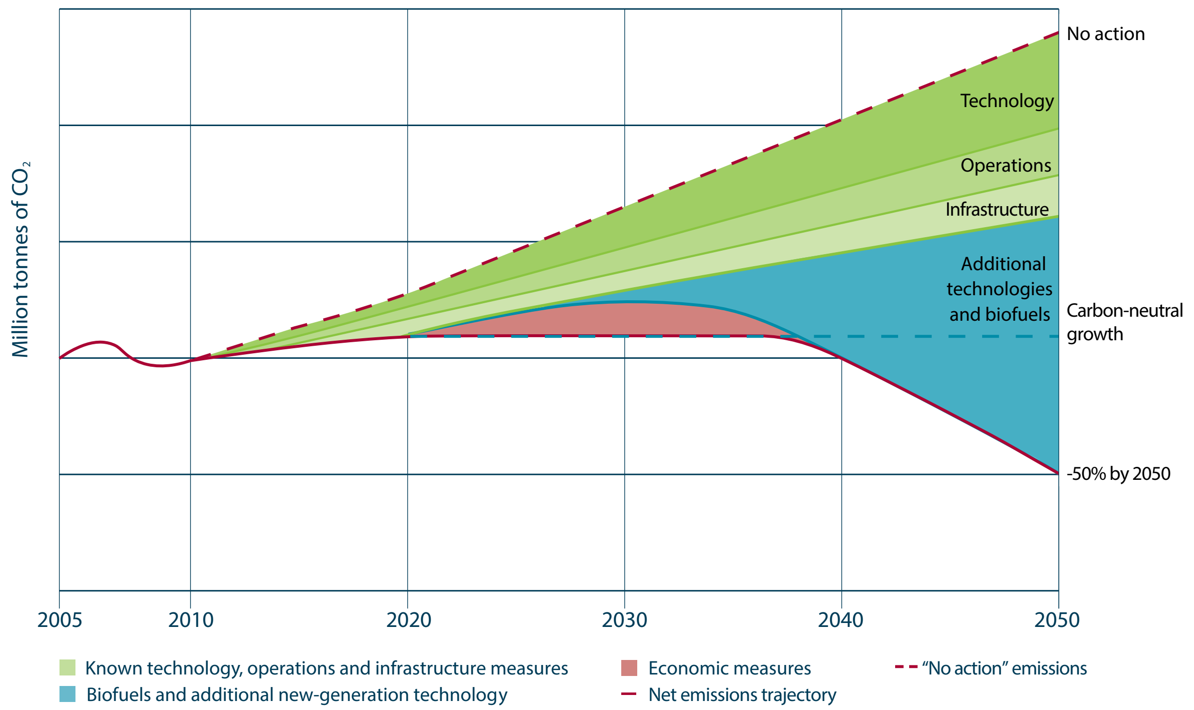

FIGURE 5: AIR TRANSPORT ACTION GROUP SCHEMATIC OF CO_2 EMISSIONS GOALS (ATAG, 2010)

Note: "Economic measures" refers to the purchase of emissions offsets.

19 E.g. https://www.iata.org/pressroom/pr/Pages/2009-06-08-03.aspx

Offsetting is controversial with many stakeholders because it can be seen as shifting the responsibility for reducing emissions outside the aviation sector, and there is disagreement about which projects can deliver 'real' emissions reductions[20]. It should be noted that due to exemptions from the CORSIA measure and phased introduction for some ICAO member countries, net emissions from the aviation industry will continue to increase after 2020 even if offsets are counted (ICCT, 2017).

Beyond the carbon neutral growth commitment, the industry has an ambitious target of reducing net carbon dioxide emissions by 50% in 2050 compared to 2005 levels (IATA, 2019). As illustrated in Figure 5, it has generally been understood that this commitment refers to direct reduction of aviation CO_2 emissions, with offsetting seen as an interim measure to meet the carbon neutral growth commitment while other CO_2 emission reduction technologies are being developed and adopted.

Delivering the 2050 target without significant demand curtailment in the sector will require large-scale deployment of low carbon alternative fuels, and almost complete replacement of fossil jet fuel. Near total replacement of fossil fuel would be needed to meet the 50% CO_2 reduction target because overall aviation fuel consumption is projected to more than double over the same period, and because in general alternative fuels still have some associated CO_2 emissions (they are not fully carbon neutral).

Figure 6 shows alternative fuel consumption scenarios developed by ICAO (ICAO Secretariat, 2017), with biofuels meeting 4% to 100% of aviation fuel demand in 2050 with alternative aviation fuel demand between 9 and 69 million tonnes in 2030, and between 20 and 570 million tonnes by 2050.

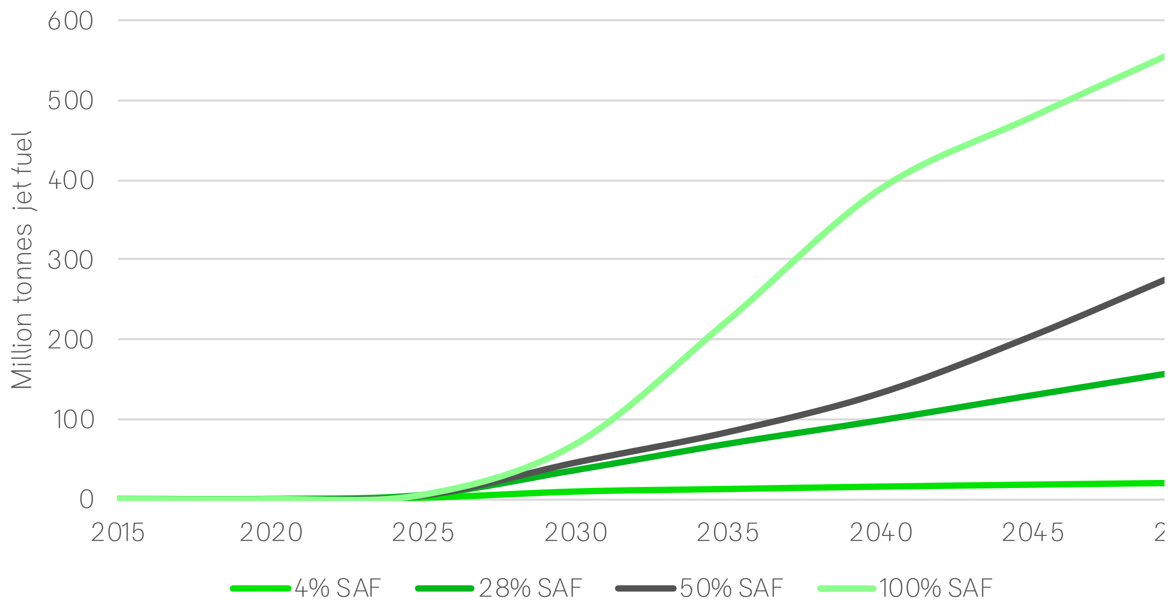

FIGURE 6: AVIATION ALTERNATIVE FUEL DEMAND SCENARIOS

Source: (ICAO Secretariat, 2017)

20 Cf. https://www.carbonbrief.org/corsia-un-plan-to-offset-growth-in-aviation-emissions-after-2020

For 100% replacement of fossil jet fuel, which is more or less what would be required to meet the industry target, that's over six times current total global biofuel production for all transport modes (IEA, 2019). The illustrative trajectory calculated by ICAO for this scenario would have aviation biofuel production approaching current global biofuel production by 2030.

Potential vegetable oil demand

The level of vegetable oil demand that could be created by pursuing aggressive aviation biofuel deployment scenarios is potentially extremely large. The trajectory considered by ICAO Secretariat (2017) for a 100% adoption of aviation biofuels by 2050 (necessary to meet the IATA target) has 69 million tonnes of annual jet biofuel requirement by 2030. For the 'Inspirational ICAO Vision 2050' scenario in which 50% of aviation fuel would be renewable by 2050, the trajectory reaches 46 million tonnes by 2030.

Based on the aviation fuel cost and production model detailed above, for HEFA facilities optimised for jet production and producing 50% jet fuel by mass, delivering 69 million tonnes of HEFA would require 140 million tonnes of vegetable oils and/or animal fats as feedstock, with 33 million tonnes of renewable diesel and 24 million tonnes of light hydrocarbons as co-products. That's about double total global palm oil production, 70% of total global vegetable oil production in 2018/19. To meet the 50% trajectory in 2030 through HEFA alone would require 90 million tonnes of vegetable oil, still larger than current global palm oil production.

It should be reasonably clear that it is unlikely that such a large conversion of vegetable oils to HEFA would be achievable or acceptable. On the other hand, given that HEFA is the only commercialised aviation biofuel process, it would be perhaps even harder to believe that other pathways such as FT-SPK could deliver such large volumes of fuel on that timescale. The illustrative scenarios to 2030 presented in ICAO (Secretariat, 2017) may therefore not be realistic.

Photograph by Rainforest Foundation Norway

European targets for aviation biofuels

In this section, we review aviation biofuel policy at the EU level and in selected Member States. For each Member State, we indicate potential demand for HEFA aviation fuel. Where necessary, 2030 aviation fuel demand in each Member State is estimated as 10% above 2016 demand as reported by Eurostat (2019). A 10% demand increase in this period is consistent with European Commission (2011).

EU

The European Union has no specific target for the use of biofuels in aviation. Under the EU's Flightpath 2020 initiative, an indicative target was set to supply two million tonnes of aviation biofuel a year by 2020, but this target will be missed by an order of magnitude (Deane & Pye, 2018). The large gap that has emerged between aspiration and performance is partly contextualised by slow progress in making road transport biofuel incentives available to aviation fuel users (only the Netherlands and UK have implemented this possibility), but primarily reflects the difficulty of producing aviation biofuels at a cost that allows them to compete with fossil jet fuel, even where incentives are available.

The recast Renewable Energy Directive (EU, 2018) will come into effect from 2021 and again allows for the supply of biofuels to aviation to be counted towards national targets for the use of renewable energy in transport. While it is unclear how quickly other Member States will introduce systems to reward the supply of aviation biofuels, there is a general expectation that the market will develop more quickly in the 2020s than it did in the 2010s. The contribution of aviation biofuels towards meeting targets may be multiplied by a factor of 1.2 provided they are not produced from food commodity feedstocks. This provides an incentive to biofuel suppliers to seek markets in the aviation sector, although opinions differ about whether this multiplier will have enough value to compensate for the additional costs of refining biofuels to meet the jet fuel standard and creating infrastructure to supply biofuels at airports.

The primary European Union incentive for advanced biofuel use comes from the target for the use of advanced biofuels. Advanced biofuels will also be eligible to be counted twice towards the underlying target for renewable energy in transport, and therefore can generally be expected to receive at least twice as much value of support as first generation biofuels (although this will be subject to implementation choices in each Member State). In the UK, a 'development fuel' mandate (UK Department for Transport, 2018) has been introduced towards which cellulosic aviation biofuels would be eligible to contribute, with a potential support value of up to €1.80 per litre of aviation biofuel. An incentive of that magnitude should be enough to make a strong business case to develop cellulosic aviation biofuel production, although value uncertainty in the scheme could still inhibit investment (cf. Malins, 2018a).

Potential vegetable oil demand

The RED II sets an overall renewable energy in transport target for Europe of 14% of total road transport energy demand, towards which the use of biofuels in aviation may be counted. If HEFA biofuel reached a 5% share of EU aviation fuel as a contribution towards this target, this would require 3.4 million tonnes of HEFA. For the modelled jet-optimised HEFA facility this would create demand for 6.9 million tonnes of vegetable oil, and generate as co-products 1.6 million tonnes of renewable diesel for on-road use and 1.2 million tonnes of lighter hydrocarbons.

Sweden

One EU Member State with a stated agenda to develop the aviation biofuel industry is Sweden. A special commission (Wetterstrand, Kann Stone, & Elofsson, 2019) has proposed the introduction of a GHG intensity reduction obligation in Swedish aviation (similar in some respects to the Low Carbon Fuel Standard of the California Air Resources Board) with a set penalty of 560 €/tCO_2e for airlines not meeting the obligation by utilising alternative aviation fuels. The proposal would seek to increase alternative jet fuel consumption to 30% of the Swedish jet fuel supply by 2030 (i.e. 30% of all fuel supplied for flights leaving Swedish airports), making it one of the most ambitious national proposals out there. The special commission's proposal does not call for the target to be restricted to advanced biofuels or for ILUC factors to be included in the GHG emissions intensity ratings, and therefore as it stands this proposal might be expected to primarily support the use of HEFA biofuels. The proposal noted that a delegated act on high ILUC-risk biofuels was forthcoming, and therefore we assume that any biofuels supplied under such an alternative aviation fuel mandate would be required to conform to the high ILUC-risk rules of the RED II alongside the other sustainability criteria. Any support for palm oil-based fuels would therefore need to be phased out by 2030, as for road biofuels.

Potential vegetable oil demand

Replacing 30% of Swedish jet fuel (international plus domestic) in 2030 would require 560 thousand tonnes of HEFA. For the modelled jet-optimised HEFA facility this would create demand for 1.1 million tonnes of vegetable oil, and generate as co-products 260 thousand tonnes of renewable diesel for on-road use and 190 thousand tonnes of lighter hydrocarbons.

Netherlands

The Netherlands became, in 2013, the first EU country to make the use of biofuels in aviation eligible for crediting under its implementation of the RED. It does not yet however, to the best of our knowledge, have specific legislative targets or defined policy goals for the amount of renewable energy supplied into aviation as compared to other transport modes. We therefore do not present a separate potential demand estimate for the Netherlands.

Spain

A draft climate law being considered by the Spanish Government[21] would introduce a specific target on the use of aviation biofuels, suggested at 2% of supplied fuel in 2025 in a paper submitted by the Spanish representation to ICAO (ECAC, 2018). The draft suggests that support would be limited to advanced biofuels, but correspondence with relevant officials leads us to believe that this requirement would be likely to be relaxed in a final law such that HEFA fuels would be included in the mandate.

A 2% target for 2025 would be relatively ambitious, but the paper to ICAO emphasises the commitment to find collaborative solutions

21 https://www.miteco.gob.es/es/cambio-climatico/participacion-publica/1anteproyectoleyccyte_tcm30-487336.pdf

with the Spanish aviation industry and the past resistance from the industry to imposed mandates, and therefore it seems likely that any Spanish legislation would have much lower associated penalties for non-compliance than, for example, have been proposed for the Swedish scheme. The lack (at present) of clear long-term targets and the emphasis on finding a 'regulator-industry balanced comprehensive approach' may suggest that any Spanish target could be ineffective as an investment driver. There is no target yet suggested for 2030, and given that it is unclear whether the 2025 target will have adequate regulatory force to drive compliance we treat 2% of supplied fuel as the potential level of consumption of alternative jet fuel by Spain by 2030.

Potential vegetable oil demand

Replacing 2% of Spanish jet fuel (international plus domestic) in 2030 would require 120 thousand tonnes of HEFA. For the modelled jet-optimised HEFA facility this would create demand for 240 thousand tonnes of vegetable oil, and generate as co-products 60 thousand tonnes of renewable diesel for on-road use and 40 thousand tonnes of lighter hydrocarbons. The use of HEFA to meet the target would only be allowable if the suggested advanced biofuel requirement is relaxed.

France

The French Government has signed a Green Growth Commitment[22] with a group of airlines and fuel suppliers, which calls for an action plan for aviation biofuel development. The French Government has indicated to ICAO an intention to discuss the introduction of aviation biofuel use targets of 2% for 2025 and 5% for 2030 (ECAC, 2018). The roadmap produced following the green growth commitment identified HEFA as the only available commercial channel for aviation biofuel production. While some of the French documentation specifically refers to advanced biofuels, it therefore seems likely that in the first instance HEFA fuels from food oils may be counted towards achievement of any targets.

Potential vegetable oil demand

Replacing 5% of French jet fuel (international plus domestic) in 2030 would require 470 thousand tonnes of HEFA. For the modelled jet-optimised HEFA facility this would create demand for 960 thousand tonnes of vegetable oil, and generate as co-products 220 thousand tonnes of renewable diesel for on-road use and 160 thousand tonnes of lighter hydrocarbons.

Finland

The latest Finnish Government Programme includes a target for 30% "sustainable biofuels" in air transport by 2030 through a blending obligation (Government of Finland, 2019). Finland is home to Neste, the world's largest producer of hydrotreated renewable diesel. As the Government Programme does not specify advanced biofuels, it might be expected that HEFA fuels would be eligible to count towards such a mandate.

Potential vegetable oil demand

Replacing 30% of Finnish jet fuel (international plus domestic) in 2030 would require 300 thousand tonnes of HEFA. For the modelled jet-optimised HEFA facility this would create demand for 610 thousand tonnes of vegetable oil, and generate as co-products 140 thousand tonnes of renewable diesel for on-road use and 100 thousand tonnes of lighter hydrocarbons. Finland currently continues to treat PFAD as a waste eligible for additional incentives, and therefore Finland could be an appealing market for PFAD derived HEFA.

22 https://www.ecologique-solidaire.gouv.fr/engagements-croissance-verte

Norway

Earlier in 2019, the Norwegian Government introduced a blending obligation for 0.5% of aviation fuel used in Norway in 2020 to be biofuels produced from feedstocks in Annex IX of the RED II[23] (advanced biofuels or HEFA from UCO and animal fats) (Ministry of Climate and Environment, 2019a). The Norwegian Government has a target for this to increase to 30% by 2030 (Ministry of Climate and Environment, 2019b).

Potential vegetable oil demand

Replacing 30% of Norwegian jet fuel (international plus domestic) in 2030 would require 280 thousand tonnes of HEFA. For the modelled jet-optimised HEFA facility this would create demand for 570 thousand tonnes of vegetable oil, and generate as co-products 130 thousand tonnes of renewable diesel for on-road use and 100 thousand tonnes of lighter hydrocarbons. Virgin vegetables oils (including palm and soy) and PFADs would not be eligible as feedstocks to meet the target.

23 Plus biofuels produced using bacteria as a feedstock, as in Annex IX of the first RED.

Other targets for aviation biofuels

Indonesia

In 2015 Indonesia introduced a 5% target for 2025 for the use of biofuels by domestic aviation (Government of Indonesia, 2015). If met, this would represent 320 million litres of biojet demand that would be likely to be delivered by hydrotreating palm oil and/or PFADs (Widiyanto, 2017). While this target is in principle the most ambitious aviation biofuel target in the world, it is not yet clear whether it will be met, and it has been noted that “the industry is very reluctant to its implementation” (Government of Indonesia, 2017). In the past, Indonesia has often fallen short of its targets on biofuel use in road transport (Kharina, Malins, & Searle, 2016), and the aviation biofuels target is likely to be still more challenging to meet. We therefore assume that if this target is met it will not be until 2030.

Potential vegetable oil demand

Replacing 5% of Indonesian jet fuel in 2030 would require 250 thousand tonnes of HEFA. For the modelled jet-optimised HEFA facility this would create demand for 500 thousand tonnes of vegetable oil, and generate as co-products 12 thousand tonnes of renewable diesel for on-road use and 9 thousand tonnes of lighter hydrocarbons.

Support through on-road alternative fuel targets

While there are relatively few policies in place around the world setting specific targets for aviation alternative fuel use, let alone binding mandates, the supply of alternative aviation fuel has increasingly been given access to support from instruments primarily designed to increase the use of biofuels on-road, in particular through biofuel mandates and through low carbon fuel standards. The supply of aviation fuels is eligible to be counted towards on-road biofuel targets under the EU RED (subject to Member State discretion) and in the U.S. under the Renewable Fuel Standard and California and Oregon low carbon fuel standards.

Potential deforestation impact

The deforestation implications of increased demand for vegetable oils due to aviation biofuel demand are sensitive to a number of factors. These include the locations in which any expansion of crop production occurs, whether yield or cropping intensity increase in response to demand, and whether consumption of those materials for food reduces as consumption for biofuels increases. The balance of these factors can be assessed through ILUC modelling.

Here, we present a simple assessment of the amount of deforestation that would be expected if demand for palm oil, soy oil or PFAD for aviation biofuel resulted in expansion of the palm and/or soy crop at average global yields, with a historically typical relationship with deforestation and peat loss (based on the assessment given in European Commission, 2019a). This is not an equivalent substitute for more detailed ILUC modelling, but can be used to provide an indication of the scale of risk to forests and peatlands from increasing use of those biofuels. Because this analysis does not consider the role of demand reduction or yield change in meeting part of the additional feedstock demand, it can be considered a high-end estimate of the potential impact. Table 4 shows the resulting calculated potential deforestation impact for increasing use of each feedstock by one tonne, given global average yields from FAOstat. For PFAD, it is assumed (as explained above) that one tonne of PFAD consumption leads indirectly to 0.64 tonnes of additional palm oil demand and 0.12 tonnes of additional soy oil demand, with the associated deforestation link.

TABLE 4: POTENTIAL IMPACT OF INCREASED BIOFUEL FEEDSTOCK DEMAND ON DEFORESTATION AND PEAT LOSS

	Deforestation* (ha/tonne)	Peat loss (ha/tonne)
Palm	0.15	0.08
Soy**	0.03	
PFAD	0.10	0.05

**The assumed area of deforestation includes areas of peat forest – so for palm we anticipate 0.15 hectares of forest lost for every tonne of additional palm oil demand, of which 0.08 hectares are expected to be on peat soils.*

***For soy, we assume for simplicity that the deforestation impact can be allocated equally by mass between the vegetable oil and the meal.*

Table 5 provides a characterisation of the potential for deforestation and peat loss to be triggered by pursuit of aviation biofuel targets. Working on the assumption that biojet fuel production would be accompanied by road-fuel co-products, the table shows the total vegetable oil demand that would be needed to produce the full product slate if optimised for biojet yield as discussed above. Simple illustrative assumptions about the potential role of palm oil, soy oil and PFAD in the feedstock mix for each region are made as follows:

- ICAO: it is particularly difficult to forecast what role feedstocks may play at the global level, as this would be determined by the aggregation of hundreds of national policies. If the very challenging levels of deployment implied by ICAO trajectories were to be met by 2030, it would almost certainly be dependent on HEFA use. We consider the case that a quarter of required fuel would be palm based, a further quarter soy based and 2.5% PFAD based.
- Sweden: the proposal for a Swedish aviation biofuel target does not rule out the use of virgin vegetable oils for HEFA, but we assume that palm oil will not be supported by 2030 in line with the EU phase out. We assume that PFAD will not be given incentives as a waste and will therefore no longer be used in Sweden. It is assumed that one quarter of production could come from soy oil.
- Spain: the proposal for a Spanish aviation target currently specifies advanced biofuels only, but it is understood that this is likely to be relaxed before such a target would be legislated. It is assumed that palm oil would not be used due to the EU phase out, but that half of production could come from soy oil.
- France: again, it is assumed that the EU phase out would prevent the use of palm oil in the 2030 timeframe, but it is assumed that half of production could rely on soy oil.
- Norway: the Norwegian policy does not allow virgin vegetable oils or PFAD to be used as feedstock, so it is assumed that there would be no direct use of these deforestation risk materials.
- Finland: as the only EU country known to still offer a double counting incentive to PFAD based fuel, and home to Neste, Finland would be an appealing market for PFAD fuels. We therefore consider the case that PFAD would be the dominant feedstock for the Finnish market.
- EU: following the phase out of support for palm oil-based biofuels as high ILUC-risk, expansion in HEFA production at the EU level would likely increase consumption of rapeseed oil and soy oil, alongside other smaller market developments. We consider the case that 40% of feedstock for HEFA would be soy oil, and 10% PFAD.
- Indonesia: it is assumed that the Indonesian market would be dominated by palm oil (95%) with a further 5% coming from PFAD.

The deforestation implications are based on the hectare per tonne deforestation and peat loss values in Table 4, and it is assumed that conversion of a hectare of forest to palm oil results in a net carbon loss of 150 tonnes, plus 106 tonnes per year of CO_2 from peat oxidation (counted for twenty years) (cf. Malins, 2018b).

TABLE 5: POTENTIAL DEFORESTATION IMPACT IN 2030 OF AVIATION BIOFUEL TARGETS

	Veg oil demand (Mt, 2030)	Attributable to aviation* (Mt, 2030)	Assumed palm %	Assumed soy %	Assumed PFAD %	Forest loss (kha)	Peat loss (kha)	Implied LUC emissions ($MtCO_2e$)
ICAO 100%	140	77	25%	25%	2.5%	3,234	1,509	4,977
ICAO 50%	93	51	25%	25%	2.5%	2,156	1,006	3,318
Sweden 30%	1.1	0.6	0	25%	0	9	0	5
Spain 2%	0.2	0.1	0	50%	0	2	0	1
France 5%	1.0	0.5	0	50%	0	7	0	4
Norway 30%	0.6	0.3	0	0%	0	0	0	0
Finland 30%	0.6	0.3	0	0	100%	30	15	48
EU 5%	6.9	3.8	0	40%	10%	54	0	29
Indonesia 5%	0.5	0.3	95%	0	5%	37	19	61

**Allocation land use impacts by mass to fuel co-products from HVO process*

The results in Table 5 show that growing HEFA production in line with the trajectories suggested by ICAO as consistent with the 2050 Vision targets would require a profound increase in vegetable oil consumption by the industry, and could potentially have significant consequence for global forests. The trajectory towards 100% alternative fuel use by 2050 could drive three million hectares of tropical deforestation, resulting in five gigatonnes of CO_2 emissions. At the national level, where policy does not preclude the use of palm oil (Indonesia) or still supports the use of soy oil and PFAD, the risk of deforestation is still significant compared to the ambition of the programmes.

While the delivery of HEFA production growth consistent with a pathway to 100% replacement of aviation fuel by alternative fuels by 2050 implies a very large deforestation impact, the table is also striking in the gap it exposes between the sum of volumes to meet stated national targets and these aspirational trajectories. Current national targets are neither as ambitious on volume nor as ambitious on sustainability as they would need to be to put the aviation industry on a path towards meeting its climate commitments.

Producers of hydrotreated renewable fuels and deforestation risk

The vegetable oil hydrotreating industry has grown rapidly over the past five years, but there are still a relatively small number of major operators in the industry. In this section we briefly review some of the major market players, the feedstocks currently being used at their facilities (where data is available) and any public sustainability commitments these operators have made, with a view to identifying which operators may have significant deforestation risk associated with their operations. Data on production capacity is taken from Nyström, Bokinge, & Franck (2019). In general, producers of hydrotreated renewable fuels are not yet producing renewable jet fuel and would require additional investment to upgrade some of the material currently being supplied as renewable jet fuel into a standard compliant alternative jet fuel. Where an operator already produces or is known to plan to produce aviation fuels this is noted.

Neste

Neste is the world's largest vegetable oil hydrotreater, with an annual capacity of about 3.3 billion litres across plants in Finland, Singapore and Rotterdam. Historically, Neste was a significant consumer of palm oil as a renewable diesel feedstock and implemented a requirement for its palm oil suppliers to be RSPO certified[24]. Over the past decade Neste has however reduced the use of 'virgin' vegetable oils as feedstock in favour of residual and by-product oils, and states that certified palm oil now constitutes about 20% of its feedstock mix, 445 thousand tonnes of material in 2018[25]. Neste states that none of this palm oil is currently used to produce alternative aviation fuels[26]. All or nearly all of the non-palm oil material used as feedstock by Neste is reported by Neste to be "waste and residues" (identified as the other 80% of feedstock[27]). This does however include PFAD, which as noted above is identified as a co-product of palm oil refining

24 https://www.neste.com/first-batch-rspo-red-certified-palm-oil-arrived-neste-oils-refinery-rotterdam

25 https://www.neste.com/corporate-info/sustainability/sustainable-supply-chain/sustainably-produced-palm-oil

26 https://www.neste.com/releases-and-news/neste-not-using-palm-oil-raw-material-renewable-aviation-fuel

27 https://www.neste.com/companies/products/renewable-fuels/renewable-raw-materials/waste-and-residues

for regulatory purposes by several EU countries. It has been argued that displacing PFAD away from other existing uses for biofuel production will result in its replacement by alternative materials including fuel oil and palm oil, with consequent indirect emissions, and that for this reason producing renewable diesel from PFAD is likely to be worse for the climate than using fossil diesel (Malins, 2017b). Neste do not report the contribution of PFAD to their feedstock mix, but it can be reasonably assumed that it constitutes some significant fraction of the 80% of their feedstock that they identify as wastes and residues. For example, PFAD was identified as the largest feedstock contributor to renewable diesel supplied in Sweden in 2017, driven by Neste's use[28]. We are not aware of Neste using soy oil as feedstock.

Neste produce a HEFA fuel brand named, "Neste MY Renewable Jet Fuel".

Deforestation risk:

Significant risk of contributing to deforestation pressure through continued use of palm oil, and through use of PFADs.

UPM

UPM's plant in Lappeenranta, Finland, has a capacity of about 130 million litres per year, and uses tall oil as feedstock. While there may be indirect emissions associated with tall oil use, this facility does not (to the best of our knowledge) consumer any palm or soy oil.

Deforestation risk:

No direct link to high deforestation risk commodities.

Eni

Eni's plant at Venice, Italy, a converted oil refinery, has a capacity of about 400 million litres per year. As of 2016, Eni identified that palm oil was the feedstock for production at the Venice refinery, but indicated an intention to seek alternatives in future (Eni, 2016). Eni has reported research on algal oil production as a palm oil alternative, and has a project seeking to cultivate castor bean as a palm alternative oil crop in the Tunisian pre-desert (Eni, 2017).

Deforestation risk:

Significant risk of contributing to deforestation pressure through continued use of palm oil.

Diamond Green

Diamond Green has 1 billion litres of capacity in the United States. They identify animal fats, used cooking oil and technical corn oil (a co-product from ethanol production) as feedstocks, but examination of the approved carbon intensity pathways for fuels under the California Low Carbon Fuel Standard[29] shows that they have also obtained a carbon intensity score for production from soy oil, suggesting that some use of soy oil is anticipated. Soy oil used at the U.S. facility is likely to be from U.S. produced soy and may therefore have a somewhat different deforestation profile to the global or Latin American average. We are not aware of any use of palm oil or PFAD as a feedstock by Diamond Green.

Deforestation risk:

Some risk of contributing to deforestation pressure through use of soy oil.

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28 https://newsnowfinland.fi/news-now-original/investigation-new-biofuel-law-puts-palm-oil-products-in-your-tank-that-neste-fights-to-claim-as-waste

29 Cf. https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm

REG

Renewable Energy Group (REG) has about 300 million litres of capacity at its Geismar plant. Documentation filed with the California Air Resources Board identifies used cooking oil, tallow, technical corn oil and soy oil as feedstocks, but it is not known what the volume breakdown is between these materials.

Deforestation risk:

Some risk of contributing to deforestation pressure through use of soy oil.

Preem

Preem has 220 million litres of capacity in Göteborg, Sweden. They state that they primarily process tall oil, complemented to some extent by animal fats and rapeseed oil, and that Preem renewable diesel is free of both palm oil and PFADs.[30]

Deforestation risk:

No direct link to high deforestation risk commodities.

AltAir

AltAir Fuels has about 150 million litres of capacity in California. The only feedstock for which AltAir has a California LCFS pathway registered is tallow and animal fat, which matches the description of their feedstocks in Nyström et al. (2019). AltAir is RSB certified[31] as a user of waste and residual feedstocks, and are a member of the Sustainable Aviation Fuels Users Group. AltAir has traditionally been aviation focused, but it is not known precisely what fraction of its output is renewable jet as opposed to road fuels – it has California LCFS pathways for both renewable diesel and renewable naphtha.

Deforestation risk:

No direct link to high deforestation risk commodities.

Cepsa

Cepsa has about 76 million litres of capacity in Spain, co-processing vegetable oils with fossil oil. Cepsa is actively engaged in the palm oil supply chain in the context of renewable chemicals and is a member of the Roundtable on Sustainable Palm Oil[32], and has previously indicated that palm oil would be a primary feedstock for its hydrotreating facilities (Cepsa, 2011). It is not known what fraction of Cepsa's current feedstock mix is palm oil, or whether they process soy oil or PFADs.

Deforestation risk:

Significant risk of contributing to deforestation pressure if using palm oil and/or soy oil.

Repsol

Repsol also has about 76 million litres of capacity in Spain through co-processing. Repsol has a stated interest in co-processing pyrolysis oils from cellulosic biomass as an alternative to vegetable oils (Yuste, 2016), but it is not known whether this pathway is commercially active.

30 https://www.preem.se/om-preem/insikt-kunskap/gronare-drivmedel/satsning-pa-fornybar-diesel-ar-viktigare-an-nagonsin/

31 https://rsb.org/2018/01/29/altair-rsb-certification-biofuel-refinery/

32 https://sinarmascepsa.com/

Deforestation risk:

Low if using pyrolysis oils, but potential risk of contributing to deforestation pressure if using palm oil and/or soy oil.

Total

Total has recently opened about 640 million litres of capacity at La Mede in France. The feedstock mix is expected to contain a significant fraction of palm oil, limited to about half of overall feedstock use by agreement with the French government[33]. At least 50,000 tonnes of French rapeseed oil will also be processed, with most or all of the remaining feedstock supply coming from waste and residual oils, presumably mostly animal fats and used cooking oil. Reuters report that the facility will produce renewable jet fuel as well as road fuels[34]. Total is committed to meet the minimum EU RED sustainability criteria, and to apply additional human rights checks on its palm oil supply chain.[35]

Deforestation risk:

Significant risk of contributing to deforestation pressure through continued use of palm oil.

33 https://www.greencarcongress.com/2019/07/20190704-total.html

34 https://uk.reuters.com/article/uk-total-biofuels-refinery/energy-group-total-starts-biofuel-production-at-la-mede-refinery-idUKKCN1TY0O4

35 https://www.total.com/en/energy-expertise/projects/bioenergies/la-mede-a-forward-looking-facility

Discussion and recommendations

Having made nominal commitments to a dramatic upscaling of alternative fuel use, the aviation industry is caught in a bind – the current likely rate of deployment of those fuels falls well short of what would appear to be consistent with 2050 climate goals, while the HEFA fuels for which production could be most readily increased come with land use and associated emissions risks. Given the current costs of production of different alternative aviation fuels, the economics of a 'level playing field' policy for developing an aviation biofuel industry seem set to divert investment into HEFA expansion, a part of the industry that has the most sustainability risk and the least long term scalability, while promising an intensely challenging investment environment to technologies like FT-SPK and PtJ that have more long term potential.

The global palm oil price has fallen fairly steadily since the food price crises of 2008 to 2011, helped by the decision by the EU and other countries to reduce the level of vegetable oil demand from food-based biodiesel mandates, and by consumers either demanding RSPO certified palm oil or avoiding palm oil entirely. These lower prices reduce pressure for new oil palm plantation establishment, creating an opportunity for countries like Indonesia and Malaysia to improve forest governance. A dramatic increase in the production of HEFA fuels for aviation would add pressure to a global vegetable oil market that is already expected to grow significantly over the next ten years to meet food demand, and undermine efforts to reduce deforestation. In the context of alternative fuel use as a climate policy we tend to focus on the CO_2 emissions implications of increased deforestation, but it is also important to remember that the loss of primary or even degraded forests in the tropics has devastating consequences for biodiversity, and that oil palm expansion in parts of Indonesia and Malaysia has been endemically associated with human rights abuses and land rights conflicts with local communities. Avoiding the direct use of palm oil and soy oil as feedstocks can reduce the likely deforestation impact of alternative fuel policies, but due to the connectivity of global vegetable oil markets any use of food oils as biofuel feedstock is liable to drive some expansion of tropical oil crops, with associated indirect land use change emissions.

A review of companies with investments in the HEFA sector shows a general caution about the highest deforestation risk feedstocks and some positive signalling about intention to find alternatives, but several companies still believed to be reliant on palm oil and/or soy oil (and in the case of Neste on PFAD) as major feedstock constituents. Until the industry turns firmly and finally away from these food oils associated with tropical deforestation any further expansion of HEFA capacity will be fraught with environmental risk.

Part of the answer to this question is already present in the adjustments to EU road transport biofuel policy made for the RED II. The introduction through RED II of enhanced incentives for advanced biofuel technologies able to use cellulosic feedstocks could be echoed by limiting national aviation alternative fuel targets to fuels from Annex IX feedstocks, as has already been proposed by Norway. Only

Photograph by Thomas Marent

once these other technologies have reached real, persistent commercial scale production will it be possible to set realistic goals for the rate of expansion of that industry, and the contribution it can make to aviation decarbonisation.

Behind the discussion of biofuels lies the broader question of whether it is indeed realistic to pursue business as usual rates of aviation growth while paying lip service to the climate targets of the Paris agreement. The aviation industry seems to be falling behind on aviation alternative fuel targets before they have even been set, and even if a dramatic shift to alternative fuels could be achieved it would not resolve climate forcing associated with non-CO_2 effects of aviation. We may well be approaching a moment at which alternative fuels start to be understood as a complement rather than an alternative to measures that would reduce the rate of aviation demand growth.

Recommendations:

- Any targets for aviation alternative fuel use should exclude HEFA fuels from the highest ILUC-risk feedstocks (palm oil, soy oil and PFAD) and exclude or limit support for HEFA from food oils more generally.
- Policy to support alternative aviation fuel should focus in the near term on mobilising investment for first of a kind plants to demonstrate successful application of electrofuel and cellulosic biofuel technologies at commercial scale.
- Given that aviation alternative fuel use by 2030 is likely to fall well short of ICAO's indicative deployment trajectory to meet aviation industry decarbonisation commitments, the realistic potential for alternative aviation fuel deployment between now and 2050 needs to be reassessed.
- Options outside the liquid fuel supply chain to decarbonise aviation should be reprioritised, including innovative airframes and electric propulsion.
- If business as usual aviation demand growth is not realistically compatible with aviation industry climate targets, this should be acknowledged and integrated into ICAO decision making.

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Rainforest Foundation Norway supports indigenous peoples and traditional populations of the world's rainforests in their efforts to protect their environment and secure their customary rights. RFN was established in 1989 and works with local environmental, indigenous and human rights organisations in the main rainforest countries in the Amazon region, Central Africa, Southeast Asia, and Oceania. RFN is an independent organisation, and part of the international Rainforest Foundation network, with sister organisations in the United Kingdom and the USA.

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