BRIEFING

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Considerations for the ReFuelEU aviation trilogue

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In July 2021, the European Commission released its proposal for ReFuelEU, the European Union (EU)'s first regulation mandating sustainable aviation fuel (SAF) blending at European airports.[1] The proposed regulation would include binding volumetric SAF targets with synthetic aviation fuel submandates from 2025 to 2050.[2] Following its release, as a part of ordinary legislative procedure, the Council of the European Union and the European Parliament assessed the proposal and suggested amendments, which were released in June and July 2022, respectively.[3] In September 2022, the two bodies entered a "trilogue" discussion with the Commission to consider these proposed changes and decide on a compromise agreement for the regulation. Tables 1 provides an overview of the key elements of the Commission's proposal and the Council and Parliament amendments.

1 European Commission, "Proposal for a Regulation of the European Parliament and of the Council on ensuring a level playing field for sustainable air transport," (2021, July 14), https://ec.europa.eu/info/ strategy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en.

2 For additional information on the Commission's original proposal, see: Stephanie Searle, "Alternative transport fuels elements of the European Union's "Fit for 55" package," (ICCT: Washington, DC, 2022), https://theicct.org/wp-content/uploads/2021/12/alternative-fuels-fit-for-55-eu-sept21.pdf.

3 European Parliament, "Amendments adopted by the European Parliament on 7 July 2022 on the proposal for a regulation of the European Parliament and of the Council on ensuring a level playing field for sustainable air transport," (2022, July 7), https://www.europarl.europa.eu/doceo/document/TA-9-2022-0297_EN.html; Council of Ministers, "Proposal for a Regulation of the European Parliament and of the Council on ensuring a level playing field for sustainable air transport," (2022, June 2), https://www.consilium.europa.eu/media/56725/st09805-xx22.pdf.

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Table 1. Volume share of sustainable aviation fuels and synthetic aviation fuels in the European Commission ReFuelEU proposal, the European Parliament amendments, and the Council of the European Union amendments.

Year	Original European Commission proposal		European Parliament amendments		Council of the European Union amendments	
	Overall SAF target	Synthetic sub-target	Overall SAF target	Synthetic sub-target	Overall SAF target	Synthetic sub-target
2025	2%	–	2%	0.04%	2%	–
2030	5%	0.7%	6%	2%	6%	0.7%
2035	20%	5%	20%	5%	20%	5%
2040	32%	8%	37%	13%	32%	8%
2045	38%	11%	54%	27%	38%	11%
2050	63%	28%	85%	50%	63%	28%

Note: Shaded cells denote where the ambition in the Parliament or Council amendments is the same as the Commission proposal.

This briefing paper assesses the differences between the original Commission proposal and the Parliament and Council's amendments, and identifies which proposals would increase low-greenhouse gas (GHG) compliance options and reduce GHG emissions. Our assessment, summarized in Table 2, finds that, overall, the Commission's original proposal for a sustainable aviation biofuel definition would provide more GHG savings compared to the Parliament and Council amendments because it would only qualify advanced biofuels with lower lifecycle emissions. However, a cap on the oily feedstocks found in Annex IX, B of the recast of the Renewable Energy Directive (RED II) would help reduce fraud risk and send a strong policy signal supporting the nascent advanced biofuel industry, which requires significant investment upfront to support capital costs. Further, the Parliament's proposal to allow electrolysis hydrogen and renewable electricity to count towards the targets and to increase the submandate for synthetic fuels would increase zero-carbon compliance options.

A more detailed comparison of key topics in the ReFuelEU aviation proposal and the associated Parliament and Council amendments, including an explanation of the climate risk posed by expanding the biofuel definition, is provided below.

Table 2. ReFuelEU aviation proposal and amendments and recommendation for the trilogue.

	Original European Commission proposal	European Parliament amendments	Council of the European Union amendments	Recommendation
Synthetic aviation fuels	Only drop-in hydrocarbons (electrofuels) qualify	• Expand definition to include all renewable fuels of non-biological origin (RFNBOs) (e.g. green hydrogen) and renewable electricity • Increase sub-mandate ambition	Same as Commission	Parliament amendments
Biofuels that qualify as sustainable aviation fuel (SAF)	Only advanced (Annex IX, A in the Renewable Energy Directive II) or Annex IX, B	• Until 2034 all biofuels qualify except those produced from food and feed crops, intermediate crops, all palm and soy-derived materials including palm fatty acid distillate, and soapstock and its derivatives. • Starting in 2035, only feedstocks found in Annex IX qualify	• All biofuels except food- and feed-based biofuels • Cap on all biofuels except Annex IX of 3%	• Only Annex IX feedstocks • Cap Annex IX, B (waste oils) at 1.7% to promote nascent fuel industries and reduce fraud risk
Allowing "low-carbon" fuels to count towards the SAF targets	Not included	Not included	Included	Do not include

INCLUSION OF RENEWABLE HYDROGEN AND RENEWABLE ELECTRICITY UNDER THE SYNTHETIC AVIATION FUELS DEFINITION

In the Commission's proposal, SAFs are defined as drop-in fuels that are either synthetic or biofuels. The term drop-in refers to fuels that can directly replace or be blended with conventional jet fuel to use in existing aircraft engines. Therefore, the only fuels that would meet the definition of SAFs are liquid hydrocarbon fuels, which excludes renewable electricity and hydrogen. While the Council amendments did not change this definition of SAF, the European Parliament voted that the definition should be expanded to include renewable fuels of non-biological origin (RFNBOs), as defined in the recast Renewable Energy Directive (RED II), which includes hydrogen produced from renewable electricity via electrolysis (green hydrogen), as well as renewable electricity used in electric planes. These alternative fuels would count towards the synthetic aviation fuel sub-targets within the overarching sustainable aviation fuel mandate.[4] Further, the Parliament amendments include an obligation for airports to provide the infrastructure for aircraft that can take advantage of these alternate fuels, commensurate with the uptake of such aircraft.

Hydrogen- and electricity-powered aircraft are developing technologies that could service short- and medium-haul routes. We estimate that zero-emission planes could replace fossil-fueled aircraft on more than two-thirds of all intra-European airline routes, based on a previous performance analysis of hydrogen-powered aircraft.[5] Including renewable electricity and hydrogen produced from renewable electricity under the SAF definition would provide a long-term policy signal to investors and help develop a level playing field for electric and hydrogen-powered aircraft. In the long-run, hydrogen may be a cheaper fuel than e-kerosene if the necessary inputs for e-kerosene production, such as direct air capture, remain expensive. Thus, including green hydrogen and renewable electricity in the ReFuelEU regulation could provide additional cost-effective compliance mechanisms. We therefore recommend the Council consider accepting Parliament's broader definition for synthetic fuels to include renewable electricity and hydrogen produced from renewable electricity.

INCREASING THE SYNTHETIC FUEL MANDATE TO ACCOUNT FOR GREEN HYDROGEN AND ELECTRICITY

The Parliament also voted to increase the synthetic aviation fuel submandate and the overall target accordingly. The inclusion of green hydrogen and renewable electricity under the synthetic aviation fuel definition increases the available pathways that can be used to meet the synthetic fuel submandate. Increasing the synthetic fuel mandate would be commensurate with the expected adoption of electric- and hydrogen-powered aircraft while maintaining the market incentive for drop-in hydrocarbon fuels. At the same time, an increase in the synthetic fuels mandate would only improve ReFuelEU if RFBNOS are required to meet addtionality requirements, a type of sustainability safeguard, as stipulated in the RED II. At the time of writing, it is unclear whether these additionality requirements will remain in the RED II.

Multiple organizations have put forward pathways to making the aviation industry net-zero by 2050. The Air Transport Action Group estimates that 20% of aviation's

4 The comparison between different energy sources is done by expressing all fuels in terms of tonnes of kerosene-equivalent, as mentioned in the text adopted by the European Parliament.

5 Jayant Mukhopadhaya and Dan Rutherford, "Performance Analysis of Evolutionary Hydrogen-Powered Aircraft," (ICCT: Washington, DC, 2022), https://theicct.org/publication/aviation-global-evo-hydrogen-aircraft-jan22/; Jayant Mukhopadhaya and Brandon Graver, "Performance Analysis of Regional Electric Aircraft," (ICCT: Washington, D.C., 2022), https://theicct.org/publication/global-aviation-performance-analysis-regional-electric-aircraft-jul22/.

energy demand could be satisfied by hydrogen and 2% by electricity in 2050.[6] The Netherlands Aerospace Centre and SEO Amsterdam Economics also estimate that 20% of European aviation emissions could be mitigated using hydrogen-powered aircraft.[7] In the ICCT's *Vision 2050* report, a net-zero aviation operations scenario results in 27% of the global aviation's energy demand being met by hydrogen and electricity.[8]

These projections suggest that the 2050 targets for synthetic aviation fuel could be increased by as much as 27%. The Parliament voted to increase this target from 28% in the original Commission proposal to 50% in the adopted version. Commensurately, the overall SAF target in 2050 also increases by 22%, from 63% in the original Commission proposal to 85% in the version accepted by the Parliament. The increased 2050 targets are accompanied by smaller increases in the interim targets for SAF and synthetic aviation fuels. These increases are necessary to maintain the original incentives for drop-in SAFs, while increasing the feedstock pool to include green hydrogen and renewable electricity.

Further, a previous ICCT study found that the high RFNBO target in the proposed RED II revision would result in higher drop-in synthetic jet fuel volumes than the ReFuel sub-target in 2030.[9] Even without assuming renewable electricity or green hydrogen would count towards the targets, the study found that the 2030 synthetic fuel submandate could be increased to 2.75%, which would come at no additional carbon abatement costs. This is because the target level for RFNBO's in the Renewable Energy Directive, which is 2.6% of all transport energy, in conjunction with the RED's 1.2x multiplier for aviation fuels, encourages much more synthetic fuel production than the aviation-only 2030 0.7% synthetic fuel target in ReFuelEU. Thus, a 2030 0.7% synthetic fuel sub-target risks irrelevancy.

BIOFUELS QUALIFYING FOR THE SAF DEFINITION

The SAF definition in the Commission's original proposal states that the biofuels that qualify towards the targets must be produced from feedstocks found in Annex IX of the RED II. Aligning the ReFuelEU's biofuel definition with the RED II's current Annex IX list, as the Commission originally proposed, would achieve the greatest GHG savings.

Annex IX has two parts: part A and part B. Part A includes a number of feedstocks that are generally lignocellulosic wastes and residues, most of which require advanced technologies to process into biofuel. Part B includes used cooking oil and inedible animal fats (category 1 and 2), which can be used to produce hydroprocessed esters and fatty acids (HEFA) fuel, the only commercially mature SAF technology. While these lists are finite, there is already a legislative process in place to add feedstocks to this list.

The Parliament amendments broaden the list to include all biofuels which qualify for sustainability and greenhouse gas criteria in the RED II (Articles 29 and 30), except for those produced from food and feed crops as defined in the RED II, intermediate crops, all palm and soy-derived materials including palm fatty acid distillate, and soapstock and its derivatives. The biofuel feedstocks not found in Annex IX will no longer qualify

6 Air Transport Action Group, "Waypoint 2050," (2021), https://aviationbenefits.org/media/167187/w2050_full.pdf.

7 Royal Netherlands Aerospace Centre and SEO Amsterdam Economics, "Destination 2050: A Route to Net Zero European Aviation," (2021), https://www.destination2050.eu/wp-content/uploads/2021/03/Destination2050_Report.pdf.

8 Brandon Graver, Sola Zheng, Dan Rutherford, Jayant Mukhodpadhaya, and Erik Pronk, "Vision 2050: Aligning Aviation with the Paris Agreement," (ICCT: Washington, DC, 2022), https://theicct.org/publication/global-aviation-vision-2050-align-aviation-paris-jun22/.

9 Chelsea Baldino and Stephanie Searle, "Changes to the Renewable Energy Directive Revision and ReFuelEU proposals: Greenhouse Gas Savings and Costs in 2030," (ICCT: Washington, DC, 2022), https://theicct.org/publication/changes-to-the-renewable-energy-directive-revision-and-refuel-eu-proposals-greenhouse-gas-savings-and-costs-in-2030/

after 2034. The Council has broadened the list of biofuels that qualify in the same way, but they chose only to exclude food and feed crops. They also limited the contribution of biofuels not listed in Annex IX by capping them at 3%. These proposed changes are summarized above in Table 2.

While broadening the definition of biofuel in the Commission's original proposal would greatly expand the pool of eligible SAFs under the policy, this would come at the cost of undermining the GHG savings achieved and the policy's long-term ambition. There are few, if any, biofuel feedstocks of commercial interest that are not listed in Annex IX that would deliver very high GHG savings without impacting food, feed, and material markets. The food and feed definition in the recast of the Renewable Energy Directive (RED II) does not cover all feedstocks fit for food and feed—it only includes main crop products. Almost all feedstocks that would qualify towards the SAF definition with the European Parliament's and Council's changes to the SAF definition are used in food and feed or carry fraud risk. While these materials are not explicitly food and feed crops, their use in biofuel production would likely result in significant food price, fraud, and land use change impacts.

Though the Parliament's and Council's proposed exclusion of food and feed crops will prevent the use of some of the highest risk SAF feedstocks,[10] their expanded SAF definitions nevertheless would encourage the use of some feedstocks with similar sustainability risks.

One group of feedstocks that could qualify as SAFs with a broadened definition are intermediate crops. Intermediate crops are any crop grown outside the main growing season. In some countries, this includes business-as-usual cash crops. For example, the majority of maize grown in Brazil is grown as an intermediate crop (77 million tonnes in 2020).[11] While Parliament decided intermediate crop biofuel would not count towards the ReFuel EU targets, the Council includes these biofuels in the targets. Even though intermediate crops are often food and feed crops, Article 2, paragraph 40 of the RED II explicitly excludes them from the food and feed crop definition. The potential volumes of intermediate crop biofuel produced from cash crops are very large and could easily expand to meet the proposed 3% cap or higher.

There is a clause in the definition of food and feed crops in Article 2, paragraph 40 of the RED II that stipulates the exclusion of intermediate crops "provided that the use of such intermediate crops does not trigger demand for additional land." However, neither the RED II nor any European Commission documents explain how Member States should interpret and implement the condition of triggering "demand for additional land." Without such guidance, presumably all biofuel produced from intermediate crops could be certified as not from food and feed crops.

Further, the European Parliament's and Council's proposed changes would allow many other types of unsustainable feedstocks to contribute towards the mandates, all of which have current uses or carry fraud risk. Diverting feedstocks with current uses to SAF production would lead to indirect GHG emissions, since a replacement material would be necessary for that use. For example, in many cases these feedstocks are used in food and feed, so their diversion to SAF production would lead to an expansion of food and feed crop production to replace them.

A Commission-funded study on the evaluation of feedstocks that could be added to Annex IX helps identify the feedstocks that are not currently in Annex IX but could

10 Hugo Valin, Daan Peters, Maarten van den Berg, Stefan Frank, Petr Havlik, Nicklas Forsell, and Carlo Hamelinck, "The land use change impact of biofuels consumed in the EU," (Ecofys, 2015), https://ec.europa.eu/energy/sites/ener/files/documents/Final%20Report_GLOBIOM_publication.pdf.

11 Chris Malins, "Multiple and cover cropping in Brazil: Status and opportunities for biofuel production," (ICCT: Washington, DC, 2022), https://theicct.org/publication/bio-fuels-production-brazil-jan22/.

be used to produce SAF were the biofuel definition to be expanded.[12] Among the highest risk feedstocks in this report are the oily and fatty feedstocks used to produce HEFA, since it is the only commercially mature SAF technology. At present, HEFA fuels are estimated to cost approximately 1 euro per liter to produce, which is much less expensive than expected price of SAF produced from lignocellulosic material or e-kerosene.[13] In the near-term before 2030, these oily and fatty feedstocks will be in high demand to produce SAF to meet the ReFuelEU ambition.

The overall climate risk of these feedstocks is informed by two factors: 1) their indirect GHG emissions, which are based on the substitutes for their current uses, and 2) the volume of feedstock available globally. Based on these two factors, we find the greatest climate risk to be from palm fatty acid distillates (PFADs), category 3 (edible) animal fats, and soapstock and its derivatives.

Palm fatty acid distillates are excluded from the Parliament's amendments, but not the Council's (see Table 2). These feedstocks are a byproduct of the production process for palm oil. The definition of food and feed crops in the RED II states that only the main crop qualifies as food and feed, which in this case would be palm oil. Thus, PFADs would be eligible towards ReFuelEU the way the SAF definition is phrased in the Council proposal. Relatedly, PFADs do not qualify as high-ILUC feedstocks, even though palm oil does. Article 26, paragraph 2, subparagraph 1 of the recast of the RED II describes that only food and feed crops can be defined as high indirect land-use change risk biofuels. As shown in Figure 1, when used to produce HEFA fuels, PFADs are worse than fossil fuels because they indirectly cause increased palm oil production.[14]

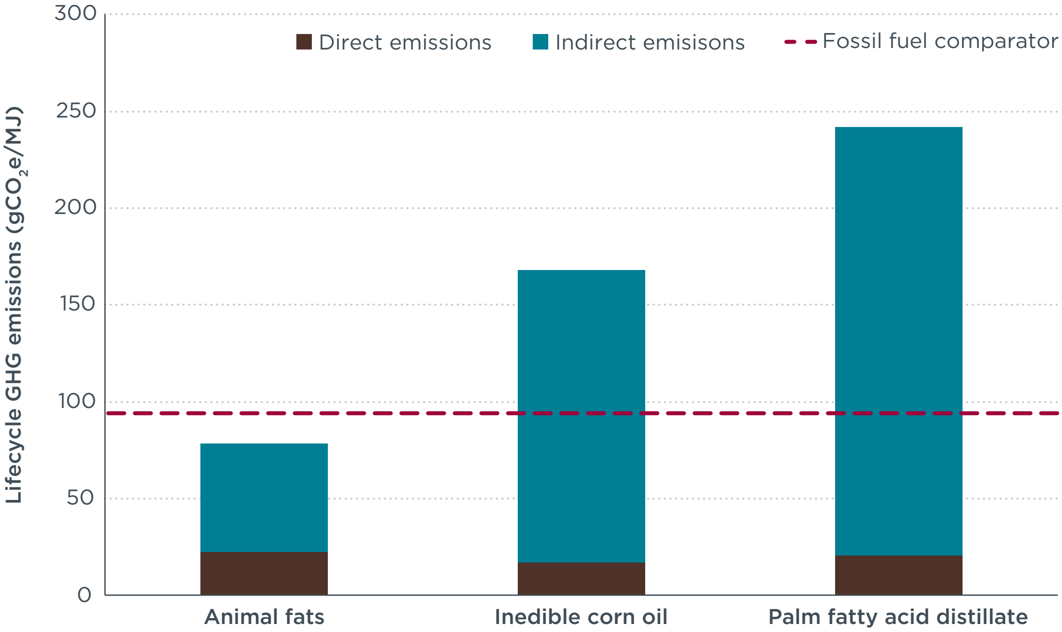

Figure 1. Life-cycle greenhouse gas emissions from animal fats, inedible corn oil, and palm fatty acid distillate HEFA fuels, as well as the fossil fuel comparator in the Renewable Energy Directive.

12 E4Tech, "Assessment of the potential for new feedstocks for the production of advanced biofuels," (July 2020), https://www.e4tech.com/resources/239-assessment-of-the-potential-for-new-feedstocks-for-the-production-of-advanced-biofuels-renewable-energy-directive-annex-ix.php.

13 Nikita Pavlenko, Stephanie Searle, and Adam Christensen, "The cost of supporting alternative jet fuels in the European Union," (ICCT: Washington, DC, 2019), https://theicct.org/publication/the-cost-of-supporting-alternative-jet-fuels-in-the-european-union/.

14 Direct emissions were retrieved from Table 29 in International Civil Aviation Organization, "CORSIA supporting document: CORSIA eligible fuels- life cycle assessment methodology," (Retrieved September 8, 2022), https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA%20Supporting%20Document_CORSIA%20Eligible%20Fuels_LCA%20Methodology.pdf. Indirect emissions were retrieved from Chris Malins, "Waste not, want not: Understanding the greenhouse gas implications of diverting waste and residual materials to biofuel production," (Cerulogy: London, 2017), https://theicct.org/wp-content/uploads/2021/06/Waste-not-want-not_Cerulogy-Consultant-Report_August2017_vF.pdf, assuming GLOBIOM, 2015 indirect land use change emission values.

Global palm oil production is growing at a linear rate.[15] We project that nearly all of a 6% 2030 SAF mandate could be met with PFADs if the synthetic fuels submandate were to remain at 0.7%, as in the Council amendments. We estimate jet fuel demand in 2030 will be 49.37 million tonnes, based on a previous ICCT analysis.[16] Thus, 5.3% of total jet fuel (subtracting the 0.7% synthetic fuel submandate) is 2.61 million tonnes. We calculate that 2.38 million tonnes of PFAD-derived HEFA fuel could be produced in 2030, crowding out the contributions of domestic feedstocks and lower-risk SAF pathways necessary for long-term decarbonization.[17] In the years following 2030, even more PFAD-derived HEFA fuels could contribute to the targets, further diluting the efficacy of the mandate.

Soapstock is another byproduct of vegetable oil refining that is available at a large global scale. It is a mixture of free fatty acids, glycerides, and water that have been separated from vegetable oil, such as palm and soy, and it can undergo further chemical processes to create derivatives such as acid oil.[18] Like PFADs, it can be used to produce commercially mature HEFA fuel and poses a climate risk because of its indirect emissions when crops are produced to replace it in livestock feed and industrial uses. Therefore, we expect its indirect emissions to be similar to PFADs.[19] Similarly, corn oil pressed from distillers grains, also known as technical corn oil, a byproduct of ethanol refining, is currently fed to livestock. The likely replacement for its use in livestock feed is palm oil, so it is also associated with high GHG emissions (see Figure 1).[20]

Category 3 animal fats, which are edible animal fats like lard from pigs, beef drippings, and goose and chicken fat, are already entirely used in other sectors, such as food, feed, and soapmaking. According to the European Fats Processers and Renderers Association (EFPRA), around 12 million tons of animal by-products are produced in the EU each year, suggesting wide availability of animal fats for biofuel production.[21] The most likely substitute for the existing uses of category 3 animal fats in Europe is palm oil, given that it has the most similar chemical properties to animal fats of all vegetable oils and is generally the least expensive alternative.[22] Similar to the other HEFA byproduct feedstocks, category 3 animal fats could potentially make a large and

15 FAOSTAT, "Crops and livestock products," (Retrieved June 30, 2022), https://www.fao.org/faostat/en/#data/QCL.

16 Dan Rutherford, Sola Zhang, Brandon Graver, and Nikita Pavlenko, "Potential tankering under an EU sustainable aviation fuels mandate," (ICCT: Washington, DC, 2021), https://theicct.org/publications/tankering-eu-SAF-mandate-apr2021.

17 To calculate the amount of HEFA that could be produced from PFADs in 2030, we first projected the amount of palm oil that will be produced in 2030, using FAOSTAT production data obtained from FAOSTAT, "Crops and livestock products," (Retrieved June 30, 2022), https://www.fao.org/faostat/en/#data/QCL). We created a linear regression based on palm oil production between 2010 and 2020. 0.045 kg PFADs are produced per kg palm oil [from Argonne National Laboratory, The greenhouse gases, regulated emissions and energy use in transportation (GREET) model, version 2020, https://greet.es.anl. gov/index.php]. We assumed a hydroprocessing conversion rate of 0.9 tonnes HEFA per tonne PFAD (also from GREET), and a ratio of 0.55 HEFA per tonne hydroprocessed fuel, when maximizing for SAF (Pavlenko, Searle, and Christensen, "The cost of supporting alternative jet fuels in the European Union."

18 B. Casali, E. Brenna, F. Parmeggiani, D. Tessaro, F. Tentori. "Enzymatic methods for the manipulation and valorization of soapstock from vegetable oil refining processes." Sustainable Chemistry 2, no. 1. (7 February 2021), https://doi.org/10.3390/suschem2010006

19 For example, acid oil is listed in the European Commission's feed catalogue and it can be used to make rumen-protected fats for cattle, an important source of nutrition for these animals: European Commission, "Commission Regulation (EU) 2017/1017 of 15 June 2017 amending Regulation (EU) No 68/2013 on the Catalogue of feed materials," (2017), https://eur-lex.europa.eu/legal content/EN/TXT/PDF/?uri=CELEX:32017R1017&from=EN; P. Naik, S. Saijpaul, R. Neelam. Evaluation of rumen protected fat prepared by fusion method. Animal Nutrition and Feed Technology 7, no. 1. (January 2007).

20 Malins, "Waste not, want not: Understanding the greenhouse gas implications of diverting waste and residual materials to biofuel production."

21 European Commission, "Protein recovery and recycling from animal by-products processes," (LIFE public database, accessed August 18, 2022), https://webgate.ec.europa.eu/life/publicWebsite/index.cfm?fuseaction=search.dspPage&n_proj_id=6194.

22 "Waste not, want not: Understanding the greenhouse gas implications of diverting waste and residual materials to biofuel production."

economically attractive contribution to the the ReFuelEU SAF mandate, despite their impacts on global land use change and emissions.

Likewise, category 1 and 2 animal fats, which are listed on Annex IX, B of the RED II, are also attractive feedstocks to meet the SAF target. While on their own category 1 and 2 animal fats could be low-GHG waste feedstocks, they also pose a climate risk. This is because category 3 fats can be downgraded to categories 1 or 2 when they are combined. When different categories of animal fats are mixed, they are labelled as the lowest category, which would be incentivized were category 1 and 2 animal fats be allowed to count towards ReFuelEU but not category 3.[23] Figure 1, shows the greenhouse gas intensity of category 1 and 2 animal fats, in the case category 3 animal fats are mixed in. We would expect category 3 animal fats alone to have a GHG intensity that is even higher due to their current use in food.

Biofuel produced from palm mesocarp fiber would also pose a climate risk. Palm mesocarp fiber is the empty palm fruit bunch leftover after the oil is pressed out. This fiber contains residual oil that can be extracted with methanol. While this additional palm oil could qualify as a waste, it would be simple to commit fraud with this oil. For example, palm oil producers could simply extract less oil from the palm fruit, so that more oil remained in the palm mesocarp fiber, meaning that additional oil would qualify as waste oil to be used to produce ReFuelEU-compliant SAF were this feedstock to qualify towards the targets.

Other problematic feedstocks associated with high GHG emissions could be used to produce ethanol, which would then be used to produce jet fuel through a process called alcohol-to-jet. Many of these feedstocks, also identified in the Commission report, are available in large quantities and used in livestock feed. Thus, when they are diverted to biofuel production, their likely replacement is food and feed crops. For example, distillers dried grain with solubles (DDGS) is a byproduct of ethanol production that is used in animal feed due to its high nutritional value, including protein, fat, fiber, and vitamins.[24] Displacing it from its current use in animal feed will likely distort the DDGS market and lead to indirect emissions as its replaced with other feed sources, such as corn or soymeal. It is the same case for food processing byproducts that could be used for ethanol production which are currently used feedstocks that are used in livestock feed, such as potato and beet pulp, molasses, bakery and confectionary byproducts, and citrus peel and pulp.

To partially address the risk posed by expanding the list of biofuels qualifying towards the SAF targets, the Council proposed a cap of 3% on all biofuel feedstocks except for those listed in Annex IX, while the Parliament proposed to exclude intermediate crops, all palm and soy-derived materials, and soapstock and its derivatives, as well as a phase out of all non-Annex IX feedstocks by 2034. A compromise between these two proposals, in the case it is not politically feasible to support the Commission's original biofuel definition, could be an exclusion of all problematic feedstocks identified by Parliament and a 3% cap on all feedstocks not found in Annex IX, with a gradual reduction in this cap to 0% by the end of 2034.

Nevertheless, even with limitations on feedstocks not found in Annex IX, the feedstocks found in Annex IX, B, which can be used to produce HEFA, still pose a risk. In neither the Commission's original proposal nor the Council and Parliament amendments is there a cap on Annex IX, B feedstocks, i.e., category 1 and 2 animal fats and used cooking oil, even though the contribution of these feedstocks is capped in the RED II.

23 "Waste not, want not: Understanding the greenhouse gas implications of diverting waste and residual materials to biofuel production."

24 U.S. Grains Council, "User Handbook, 4th edition," (2018), https://grains.org/buying-selling/ddgs/user-handbook/

While we estimate that domestic used cooking oil and category 1 and 2 animal fats could be used to meet a 2% SAF target, these feedstocks could be imported to meet higher targets.[25] There is a particularly high fraud risk for used cooking because it is impossible to distinguish it from tampered virgin vegetable oils using chemical testing. The lack of a cap would greatly exacerbate the risk of fraud from used cooking oil and the indirect emissions associated with down-grading category 3 animal fats into categories 1 and 2.

A limit on the oily feedstocks including Annex IX, B would encourage investment in advanced biofuel made of lignocellulosic feedstocks in the near term. Investment is critical for the development of these nascent biofuel technologies since they require significant capital cost which will only pay off in the long term.[26] The lignocellulosic feedstocks needed to produce advanced SAF are available in the much greater quantities necessary to meet the SAF mandate in 2050.[27] On the other hand, the low-GHG oily feedstocks needed for HEFA production are limited and carry fraud risk.

LOW-CARBON FOSSIL FUELS QUALIFYING FOR THE SAF DEFINITION

The Council's amendments state that the obligation to blend SAFs can be met using "low-carbon fuels" for aviation. This addition would mean that SAF could be produced from blue hydrogen, which is derived from fossil fuels like natural gas or coal. To produce these SAFs, natural gas would undergo reforming to produce hydrogen, and the resulting CO_2 would be stored in a process called carbon capture and storage (CCS). The blue hydrogen would then undergo the Fischer-Tropsch refining process to produce a type of drop-in synthetic aviation fuel similar in chemical nature to e-kerosene. Alternatively, coal could be gasified into hydrogen alongside CCS, and the hydrogen would then undergo Fischer-Tropsch synthesis.

A 2021 ICCT study highlighted the climate risks associated with blue hydrogen pathways and, in particular, the risks associated with upstream methane leakage and CCS.[28] Figure 2, shows the greenhouse gas intensity of fossil-based low-carbon synthetic fuel pathways, which we calculate by combining the life-cycle GHG intensity for blue hydrogen from the 2021 study and the conversion loss during synthetic fuel production using Fischer-Tropsch synthesis.[29]

25 "Estimating sustainable aviation fuel feedstock availability to meet growing European Union demand."

26 Pavlenko, Searle, and Christensen, "The cost of supporting alternative jet fuels in the European Union."

27 Jane O'Malley, Nikita Pavlenko, and Stephanie Searle, "Estimating sustainable aviation fuel feedstock availability to meet growing European Union demand," (ICCT; Washington, D.C., 2021), https://theicct.org/publication/estimating-sustainable-aviation-fuel-feedstock-availability-to-meet-growing-european-union-demand/.

28 Yuanrong Zhou, Diana Swidler, Stephanie Searle, and Chelsea Baldino. "Life-cycle greenhouse gas emissions of biomethane and hydrogen pathways in the European Union," (ICCT: Washington, DC, 2022), https://theicct.org/publication/life-cycle-greenhouse-gas-emissions-of-biomethane-and-hydrogen-pathways-in-the-european-union/.

29 We assume the conversion rate for hydrogen to jet kerosene to be 73% as cited in Yuanrong Zhou, Stephanie Searle, and Nikita Pavlenko, "Current and future cost of e-kerosene in the United States and Europe," (ICCT: Washington, DC, 2022), https://theicct.org/publication/fuels-us-eu-cost-ekerosene-mar22/.

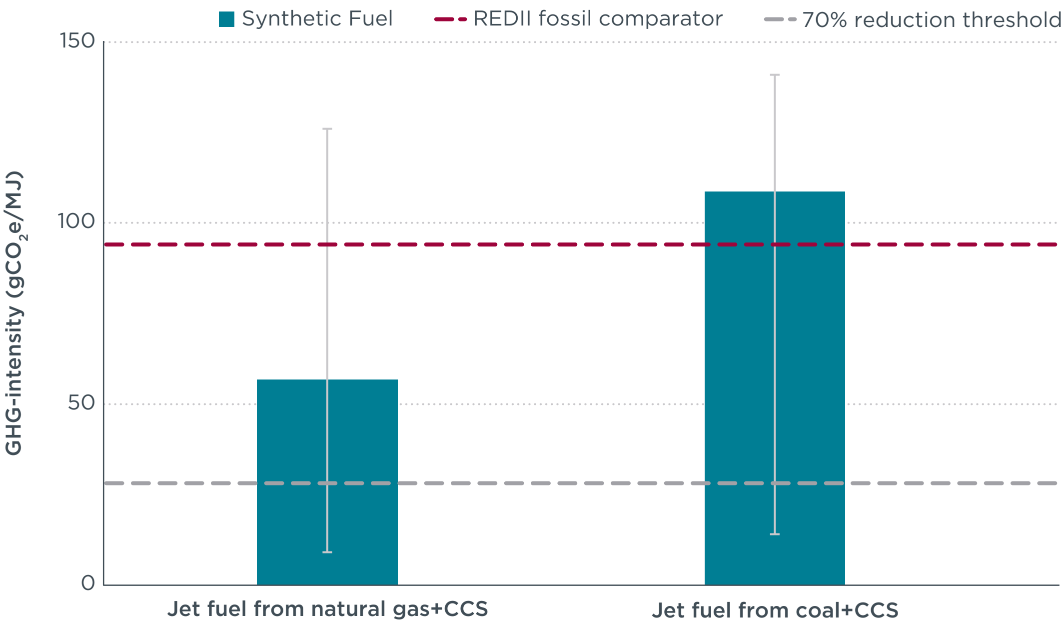

Figure 2. The life-cycle greenhouse gas intensity of two low-carbon jet fuel pathways compared to a 70% GHG reduction relative to the RED II's fossil fuels comparator. The bars represent the GHG intensity of the central case and vertical error bars indicate the maximum and minimum GHG intensity that each pathway can possibly achieve.

High upstream methane leakage during natural gas extraction and transportation can negate any climate benefit provided by CCS. While methane leakage is difficult to measure, a literature review for the 2021 study revealed that the methane leakage rate from natural gas extraction can be as high as 9%, and it can be as high as 10% during natural gas transmission and storage. Because methane is a very potent climate pollutant, even a slight amount of leakage can have devastating climate impacts. As for CCS, current industrial practices only capture around 50% of the carbon during steam methane reforming to produce blue hydrogen. There is an option to capture more carbon emissions with another technology, but it is nearly double the cost of commonly used capture technologies. Further, in Europe, CCS is often used to perform enhanced oil recovery. Thus, the carbon captured to help reduce the climate impact of the European aviation jet fuel would likely be used to extract additional oil. Due to these climate risks, we recommend policymakers exclude low-carbon fuels from ReFuelEU.

While the Council's proposal states that low-carbon SAF would need to meet a 70% GHG emissions savings requirement, there is no methodology in place from the European Commission on how to calculate life cycle GHG emissions savings for these fuels. The Commission would need to create a new methodology to properly account for all the GHG emissions associated with these fossil pathways, which each carry unique climate risks. Without proper carbon accounting to determine whether these low-carbon fuels meet the 70% GHG reduction threshold, low-carbon fuels likely do not provide significant GHG savings, and, in the worst case, could result in more GHG emissions than fossil kerosene.

CONCLUSIONS

The Commission's original proposed definition for biofuels in ReFuelEU would achieve greater GHG savings than the Parliament and Council proposals. Including a cap on Annex IX, B would provide even greater GHG reductions. On the other hand, the Parliament and Council proposals to expand the definition of SAF biofuel beyond the Annex IX list would allow many feedstocks associated with increased food prices and indirect emissions to count towards the targets. Parliament's efforts to exclude some problematic feedstocks, namely intermediate crops, palm and soy-derived products, and soapstock and its derivatives, would be a step towards improving the climate impact of Europe's jet fuel. However, many problematic feedstocks would remain, such as category 3 animal fats.

For synthetic fuels, the Parliament's proposal to expand the SAF definition to include RFBNOs and renewable electricity would encourage investment and innovation in these zero emission technologies for the aviation sector. Several studies, including ICCT's, find that renewable electricity and hydrogen produced from renewable electricity can play a significant role in decarbonizing aviation by 2050. Expanding the definition of synthetic fuels to include these fuels would also mean that the ambition of the synthetic aviation fuel submandate can be increased. At the same time, in 2030, the proposed RFNBO target in the RED II would allow for a higher RFNBO target in ReFuelEU, since the RED II target is much more ambitious.

Finally, the inclusion of low-carbon fuels in ReFuelEU, namely blue hydrogen and its derivatives, could risk significantly undermining the ambition of the regulation due to upstream methane leakage and poor carbon capture and storage. Only fuel pathways that utilize green hydrogen produced from renewable electricity can provide the GHG reductions that policymakers seek in the aviation sector with certainty.