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To: Rt Hon Grant Shapps MP, Transport Secretary
Robert Courts MP, Minister for Aviation
Aviation Decarbonisation Division
Great Minster House, 33 Horseferry Road, London SW1P 4DR

Date: 8 September 2021

Re: Jet Zero Consultation

Dear Ministers:

The International Council on Clean Transportation (ICCT) welcomes the opportunity to comment on the UK Jet Zero consultation. The ICCT is a research-based environmental nonprofit that supports policymakers worldwide in developing effective environmental standards for the transport sector. We commend the United Kingdom for its efforts to proactively address aviation emissions, which are responsible for about 7% of UK GHG emissions in 2018 and have increased by 88% above 1990 levels.[1] As one of the world's largest aviation markets, and a leader in establishing binding emission targets for both domestic and international aviation, UK policy holds global implications for aerospace manufacturers, airlines, investors, and consumers alike.

The following sections respond to several questions raised in the Jet Zero document, including overall goal setting, policies to promote Sustainable Aviation Fuels (SAFs) and Zero Emission Planes (ZEPs), efforts to inform consumer decisions through the disclosure of emissions at the point of booking, and supporting actions to curb non-CO_2 climate forcings from aircraft.

Goal setting

The Jet Zero Evidence and Analysis document and supplemental data presents five potential emission scenarios for UK aviation, ranging from a "Policy off" baseline to two "Breakthrough" scenarios, one focused on SAFs (Scenario 3) and the second on ZEPs (Scenario 4). Under Scenario 1 (Continuation of current trends), efficiency improvements and traffic growth largely

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[1] UK Climate Change Committee (2020). *The Sixth Carbon Budget: Aviation*. https://www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-Aviation.pdf

balance each other out, with aviation carbon dioxide (CO_2) increasing modestly through 2030 before falling back to 2018 levels in 2050. Under Scenario 2 (High ambition), emissions likewise grow through 2029 before falling to 21 Mt (- 43% from 2018 levels) as SAFs and ZEPs mitigate an additional 10 million tonnes (Mt) of CO_2 in 2050. Scenarios 3 and 4 project larger (76% and 52%) reductions due to revolutionary breakthroughs in SAFs and ZEPs, respectively.

We offer several observations about these pathways. First, none of the scenarios outlined in the Jet Zero consultation are consistent with a 1.5 or Well Below Two Degree proportional carbon budget pathway for UK aviation without offsets or removals (Table). As estimated from the *IPCC WG1 Contribution to the 6th Assessment Report*, UK aviation would increase its share of a proportional global aviation budget from its current 4.0% in 2018 to between 6 and 12% under 1.7 and 1.5 degree pathways.[2] Only under a 2 degree pathway, with at least High Ambition (Scenario 2+), would UK aviation not increase its share of a global carbon budget. Note that this analysis is conservative as it doesn't consider continuing emissions post-2050.

Temperature limit relative to 1850-1900 average (C)	Remaining carbon budget from 2020 (Gt)		UK % of global aviation budget				
			UK 2018	Through 2050			
	Total	Global aviation		Scenario 1	Scenario 2	Scenario 3	Scenario 4
1.5	400	9.6	4.0%	12.1%	10.6%	9.5%	9.9%
1.7	700	16.8		6.9%	6.0%	5.4%	5.7%
2	1150	27.6		4.2%	3.7%	3.3%	3.4%

Table: Cumulative UK aviation emissions and global aviation carbon budgets

The figure below shows cumulative emissions by scenario from 2020 to 2050 against proportional carbon budgets derived from IPCC's post-2020 1.5 (green dotted line), 1.7 (orange), and 2 degree (red) cumulative carbon budgets. Residual CO_2 emissions from UK aviation are projected to exceed a proportional 1.5 degree carbon budget in 2030, the 1.7 degree pathway sometime between 2036 and 2038, and sometime after 2050 for the 2 degree pathway for the High Ambition and Breakthrough Scenarios. Notably, varying the rate of technology adoption across scenarios has little influence over when the 1.5 and 1.7 degree carbon budgets are exceeded.

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[2] This assumes a 66% probability of achieving a given pathway and that global aviation maintains its share of the global inventory (2.4% of anthropogenic CO_2 from energy production). See IPCC (2010). *IPCC WG1 Contribution to the 6th Assessment Report.* https://www.ipcc.ch/assessment-report/ar6/.

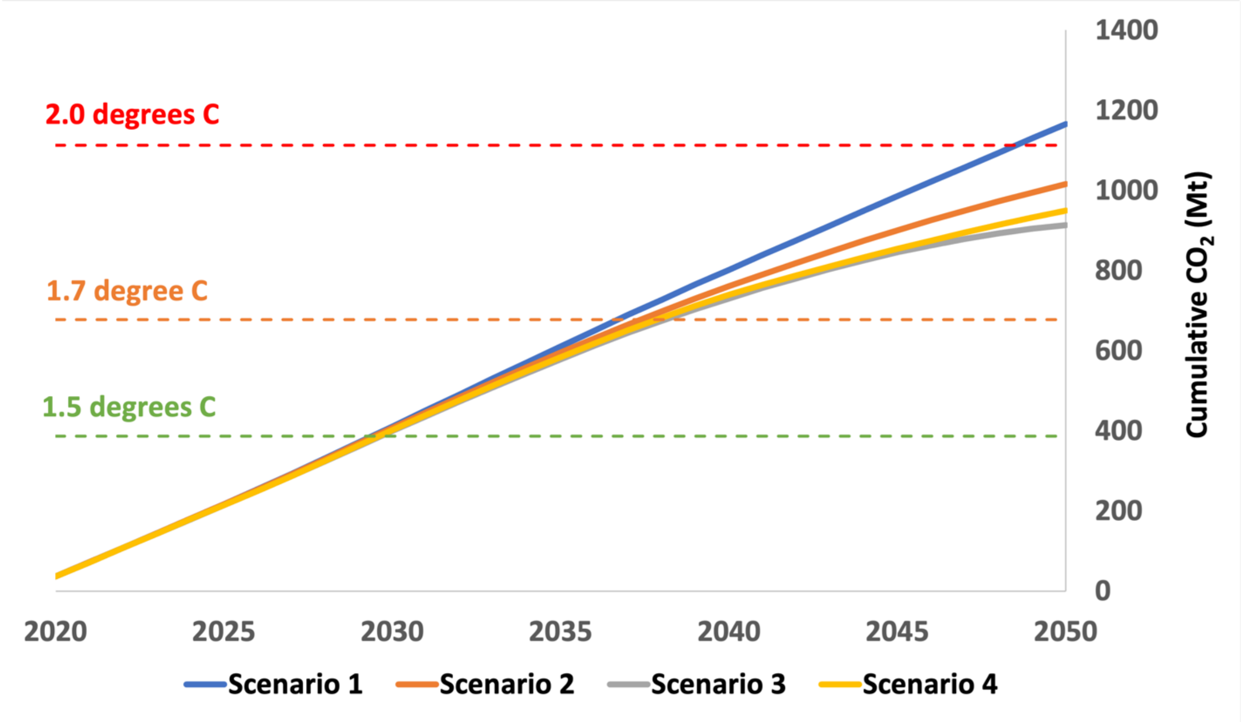

Figure: Cumulative UK aviation CO_2 by scenario and temperature threshold, 2020 to 2050

Considering the specific technologies incorporated into the scenarios, UK DfT assumes that fuel efficiency improves by 1.5 to 2.0% per annum through 2050 for the policy cases. This rate of improvement is comparable to that seen globally today[3] but could require additional policy support to maintain through 2050. Policies to promote fuel efficiency, notably efficiency standards for airlines that accelerate both new aircraft improvements and fleet renewal, will likely be needed to ensure higher rates of fuel efficiency improvement.[4]

Across the scenarios, SAF usage varies from 5% under Scenario 1 (Continuation), to 30% under Scenario 2 (Breakthrough), and up to 75% in Scenario 3 (SAF Breakthrough). The 75% SAF blend rate in particular greatly surpasses the availability of sustainable biomass and therefore implies a vast increase in the production of e-fuels. Brynolf (2017) suggests a range of possible configurations and facility sizes, with liquid e-fuel projects ranging from under 1 megawatt of electricity (MW_e) capacity to 830 MW_e (i.e., up to 600,000 tonnes of annual production).[5] The authors consider facilities under 50 MW_e of capacity would be first-generation, demonstration projects possible by 2030. Larger, commercial-scale projects of up to 200 MW_e of capacity may be feasible towards 2050.

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[3] Graver, Rutherford, & Zheng, *CO_2 emissions from commercial aviation: 2013, 2018, and 2019*, (ICCT: Washington, DC, 2020), https://theicct.org/publications/co2-emissions-commercial-aviation-2020.

[4] Rutherford, D., *Standards to promote airline fuel efficiency*, (ICCT: San Francisco, 2020), https://theicct.org/sites/default/files/publications/Airline-fuel-efficiency-standard-2020.pdf.

[5] Brynolf, Selma, Maria Taljegard, Maria Grahn, and Julia Hansson. "Electrofuels for the Transport Sector: A Review of Production Costs." *Renewable and Sustainable Energy Reviews* 81 (January 2018): 1887–1905. https://doi.org/10.1016/j.rser.2017.05.288.

Achieving a 30% blend from e-fuels (3.6 Mt) would necessitate over 20 commercial-scale e-fuel production facilities, compared to zero today in the UK. Note that this calculation does not take into account the further split of middle distillates between diesel fuel and jet fuel. Assuming a 60% conversion yield for the electrofuel production process, these targets would necessitate an additional 73 to 130 terawatt-hours (TWh) of renewable electricity production, or a 24 to 43% increase over current UK electricity production (~300 TWh).

We note with concern that the Jet Zero document assumes zero lifecycle emissions for SAFs. SAFs have varying GHG emissions and proper LCA accounting is needed ensure that only the best-performing fuels are used. Assuming zero lifecycle emissions from SAFs will underestimate long-term residual emissions and there the share of UK and global carbon budgets consumed by airlines.

On ZEPs, all electric aircraft will be severely range and payload limited, particularly in the near-term. Evolutionary designs fueled by liquid hydrogen (LH_2), such as those under consideration under Airbus's ZEROe initiative, may be suitable for flights up to 4000 km in stage length, provided that safety standards can be met, and the infrastructure and cost barriers are addressed. Those designs won't enter into service until 2035 and will require time to roll into the fleet. Accordingly, while the Scenario 2 (High Ambition) assumption of meeting 21% of available tonne miles (ATMs) in 2050 using ZEPs may be achievable, the breakthrough goal (Scenario 4) of covering 53% of ATMs is extremely unlikely. This highlights the importance of accelerating fuel efficiency improvements and investments in SAF production capability, especially for long-haul flights.[6]

In balance, we find that Scenario 2 (High Ambition) represents a more likely technology future than the more optimistic (Breakthrough) scenarios. This assumes significant policy intervention, including a SAF mandate, standards and infrastructure to support ZEPs, and aircraft fuel efficiency targets. We note that the High Ambition Scenario assumes a 60% increase in terminal traffic in 2050 relative to 2018 along with a 45% increase in available tonne miles (ATMs). As shown above, UK aviation would consume from 3.7% (2 degree) to 10.6% (1.5 degree) of a proportional global aviation carbon budget through 2050 under this scenario, compared to only 4% of aviation CO_2 today. Thus the UK will likely need to consider options to constrain traffic growth if it intends to reduce in-sector emissions in line with the Paris agreement.

On the question of target setting, we believe that an absolute target is needed to promote zero carbon aircraft and fuels, to be supplemented with limited removals funded by airlines. A purely net target relying upon offsetting, for example similar to the UN's CORSIA program, should be avoided due to concerns about the quality, additionality, and permanence of offsets. Moreover, access to cheap offsets risks could undermine investments in more expensive SAFs and ZEPs. Likewise, we support a domestic absolute zero target by 2040 at the latest, starting with obligations for Public Service Obligation (PSO) routes starting in 2030.

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[6] Per Section 3.15 of the Jet Zero consultation, longer flights (greater than 5000 km stage length) account for 60% of UK emissions and, therefore, are unlikely to be addressed by near-term ZEPs.

Finally, we support periodic review of this strategy over time, with a key priority being the integration of non-CO_2 climate forcers into targets as soon as possible (see below). Specifically on SAFs, experience with road transport highlights that too frequent reviews of alternative fuel targets run the risk of undermining policy certainty. For this reason, we recommend waiting at least 10 years before reassessing SAF targets in order to ensure policy stability.

Sustainable aviation fuels

JetZero correctly identifies SAFs as one component of an overall strategy to reduce aviation emissions, rather than the primary mode of emissions abatement. The low levels of commercialization for most SAF production pathways, the cost gap between SAFs and conventional petroleum fuels, and the lack of commercial incentives for SAF use means that policies are needed to deploy these fuels at meaningful volumes.

The climate impact of SAFs vary significantly depending on which feedstocks and conversion processes are used. It is critical to ensure that policy support goes towards those SAFs capable of generating deep, long-term GHG reductions.[7] In contrast, policy support for food-based biofuels or already-commercialized hydroprocessed esters and fatty acids (HEFA) pathways risks undermining the climate impact of these policies and may delay the transition to ultra-low carbon biofuels and electrofuels.[8]

The policy commitments described in the JetZero Consultation, particularly the proposed SAF blending mandate, could help to expand the use of SAFs in the UK. A SAF blending mandate will be most effective with a stable, long-term target and clear, transparent eligibility criteria. Conversely, the UK should avoid adopting a blending mandate without strong sustainability requirements, and a clear sense of what quantity and type of SAFs are likely to be available.

Several existing policies are worth considering when the UK defines appropriate SAF feedstocks. The European Commission's proposed ReFuel EU SAF mandate would only credit advanced SAFs made from either lignocellulosic wastes and residues, waste lipids, and electrofuels toward its targets.[9] On the other hand, the International Civil Aviation Organization's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) includes SAF sustainability criteria that could promote risky feedstocks such as palm oil. It is therefore critical that UK domestic sustainability criteria go beyond CORSIA to ensure that crop-based biofuels with high

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[7] Pavlenko & Serle, *Assessing the sustainability implications of alternative aviation fuels*, (ICCT: Washington, DC, 2021), https://theicct.org/publications/alternative-aviation-fuel-sustainability-mar2021.

[8] Pavlenko, N., *An assessment of the policy options for driving sustainable aviation fuels in the European Union*, (ICCT: Washington, DC, 2021), https://theicct.org/sites/default/files/publications/Sustainable-aviation-fuel-policy-eu-apr2021.pdf.

[9] European Commission, "Proposal for a Regulation of the European Parliament and of the Council on ensuring a level playing field for sustainable air transport," (July 2021), https://ec.europa.eu/info/sites/default/files/refueleu_aviation_-_sustainable_aviation_fuels.pdf.

indirect land-use change emissions do not crowd out contributions from advanced SAFs with lower lifecycle GHG emissions.

A SAF mandate target level should be set based on the assessed quantity of sustainable feedstocks, particularly in the near and medium term (i.e., prior to 2035). This includes feedstocks with low lifecycle emissions and those which have limited existing uses and competition with other sectors. A preliminary ICCT analysis (see Appendix) suggests that up to 4.5% of 2030 jet fuel demand could be met using new sustainable feedstocks, including domestic lignocellulosic wastes and residues (1.2%)[10], industrial flue gas to jet technology (0.5%), and electrofuels (up to 2.7%).[11] An additional 5.7% of 2030 demand could be met through the diversion of existing waste fats, oils and greases (FOGs) from the road sector and expanded use of imported waste FOGs.

Given the slow uptake to date, along with the larger structural disparities for SAF deployment, the imposition of taxes on petroleum jet fuel would help promote SAFs. Duties on diesel and petrol used in the road sector are £0.58 per liter, whereas petroleum kerosene in aviation is untaxed.[12] Introducing a jet fuel duty equal to road transport could have several beneficial effects. First, it could help close the cost gap between SAFs and conventional fuels. Second, it could level the playing field for alternative fuel producers of road and aviation fuels. Third, it could raise funds for targeted investments in SAF projects. The European Commission recently proposed a minimum €10.74/GJ duty on petroleum jet fuel in its revisions to the European Energy Tax Directive. Since advanced SAFs would be assessed only a €0.9/GJ tax; this approach would narrow the cost gap by approximately €0.34 (or £0.30) per liter of fuel.[13]

Though a mandate can create a strong demand signal for SAFs, complementary policies are likely necessary to ensure that new suppliers enter the market and scale up production. We recommend direct, targeted policy support for novel and emerging SAF pathways that face

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[10] The full assessment concludes that larger supplies of lignocellulosic wastes and residue are available long-term but that only a small percentage of those will be available within 10 years. Eventually, the UK has sufficient waste and residue resources to produce the equivalent of 13% of its projected 2030 jet fuel demand from sustainably available wastes and residues; of that total, approximately 7% could be produced from domestic lignocellulosic wastes and residues. However, these pathways are in the early stages of commercialization; consequently, we estimate that the contribution of agricultural residues, forestry residues and municipal solid wastes to jet fuel demand will be limited to approximately 0.8% in 2030.

[11] The contribution of e-fuels is highly uncertain due to the early stage of commercialization and high production costs. An economic assessment of EU RED and ReFuel policy interaction with high carbon prices and binding sub-mandates for electrofuels estimates that approximately 2.6% of EU jet fuel demand in 2030 could be met from electrofuels. This is likely an upper bound for the quantity that could be delivered in the UK in the same time frame. See Christensen, A., *Transportation carbon intensity targets for the European Union: Road and aviation sectors*, (ICCT: Washington, DC, 2021), https://theicct.org/publications/transport-carbon-intensity-targets-eu-aug2021.

[12] UK Office for Budget Responsibility, "Fuel Duties," (n.d.), https://obr.uk/forecasts-in-depth/tax-by-tax-spend-by-spend/fuel-duties/.

[13] European Commission, "Council Directive for restructuring the Union framework for the taxation of energy products and electricity (recast)," (July 2021), https://ec.europa.eu/info/sites/default/files/revision_of_the_energy_tax_directive_0.pdf.

technical and economic hurdles to ensure that there is sufficient fuel in the early stages of a mandate. Direct financial support should be provided only for projects using novel or emerging technologies, and which use high-performing and abundant feedstocks, including waste and residue gasification, and electrofuels. Direct grant funding can reduce the upfront costs of producing new facilities, whereas a central auctioning mechanism (similar to Contracts for Difference in the electricity sector) can reduce offtake risk by guaranteeing new producers a fair price for their finished fuel.[14]

A separate, binding SAF mandate is more likely to meaningfully promote SAF production than inclusion in the existing Renewable Transport Fuel Obligation (RTFO)—particularly if there is no binding obligation on aviation fuels in the RTFO. Further, if SAFs are included within the RTFO with a policy multiplier that increases their compliance value, it may lead existing hydrotreated vegetable oil (HVO) producers to adjust their product slate to produce more SAF in place of diesel fuel, diverting fuels from one sector to another without any net impact. Optimizing for a greater share of jet fuel production requires additional hydrogen and energy and may decrease the overall liquid fuel yield of the fuel conversion process.[15]

Zero emission planes

In addition to SAFs, there is growing interest in the potential for ZEPs powered by hydrogen and electricity to curb the climate impact of flying. As noted above, near-term ZEPs are expected to be range and payload limited, in particular for electric aircraft. Still, electric aircraft may have low operating costs, help address aircraft noise, and also provide zero emission mobility over specific routes, for example Public Service Obligation (PSO) routes. Initiatives such as FlyZero and Future Flight Challenge can provide the capital required to develop and assess zero-emission technologies.

We agree with recommended focus on R&D into understanding airport infrastructure requirements for future zero-emission aircraft. Infrastructure investment will be essential to establish feasible routes for the zero-emission aircraft. Still, the UK's overall approach to promoting ZEPs seems relatively unfocused. The UK's current approach relies heavily on the results of a few ongoing studies (e.g. Jet Zero, Hydrogen Strategy). Specific actions will be needed to realize their benefits, for example using PSO routes as ZEP testing grounds. Greater than 75% of the active UK PSO routes in 2019 were shorter than 200 km in distance and carried less than 20 passengers. This makes them ideal candidates to be replaced by electric and compressed hydrogen aircraft.

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[14] Pavlenko, N., *An assessment of the policy options for driving sustainable aviation fuels in the European Union,* (ICCT: Washington, DC, 2021), https://theicct.org/sites/default/files/publications/Sustainable-aviation-fuel-policy-eu-apr2021.pdf.

[15] Pearlson, Matthew, Christoph Wollersheim, and James Hileman. "A Techno-Economic Review of Hydroprocessed Renewable Esters and Fatty Acids for Jet Fuel Production." *Biofuels, Bioproducts and Biorefining* 7, no. 1 (January 2013): 89–96. https://doi.org/10.1002/bbb.1378.

We recommend that UK DfT establish a target to service all PSO routes that carry fewer than 20 passengers over less than 200 km flight distance with zero-emission planes (ZEPs) no later than 2035. This target would require electric and hydrogen infrastructure development in the regions serviced by these PSO routes. Starting this development in the Orkney Island airports (Kirkwall, Eday, Sanday, North Ronaldsay, Stronsay, and Westray) is recommended. The islands already produce excess renewable energy that is used to produce green hydrogen.

Following the results of the current R&D efforts, the UK should develop a roadmap to build hydrogen and electric infrastructure at airports across the country to meet the goal of zero emission domestic aviation no later than 2040. Specific infrastructure investments must be swiftly decided upon, following the results of the current R&D efforts. The government will need to help cover infrastructure costs to support the business case for these new aircraft. The Tees Valley Hydrogen Hub project and electrification projects from the Future Flight Challenge should provide blueprints for the hydrogen and electric infrastructure needs of aviation.

Influencing customers

We agree that influencing consumers can help curb aviation's climate impacts by providing market pull for investments in fuel efficiency, SAFs, and ZEPs. ICCT research has consistently shown large gaps in fuel efficiency among different carriers, both overall and on individual routes. Our most recent assessment, covering US domestic routes in 2019, found that the lowest-emitting itineraries emitted on average 63% less than the highest-emitting option and 22% less than the typical flight.[16] Empowering consumers to choose lower-emitting itineraries could reward more fuel-efficient carriers today, and those that invest proactively in SAFs and ZEPs tomorrow.

Our work also shows the importance of transparent, credible, and easy-to-use data – lacking that, it is not easy for an average consumer to identify low-emitting flights. A range of factors, including routing, aircraft, seating density, and passenger and belly freight load factors, all influence the carbon intensity of a given flight.[17] Displaying emission estimates by itinerary at the time of ticket booking would be most useful in influencing consumer behavior.

Governments have a role to play in mandating emissions disclosure and ensuring data quality. ICCT research supports CAA's survey findings that work is needed to standardize emissions data reported by airlines and to establish vigorous third-party validation. Key considerations for standardization include emissions apportionment, emissions factors that incorporate the climate impact of non-CO_2 forcers, and SAF accounting.

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[16] Zheng & Rutherford, *Variation in aviation emissions by itinerary: The case for emissions disclosure*, (ICCT: San Francisco, 2021), https://theicct.org/publications/itinerary-aviation-emissions-jul2021.

[17] Graver & Rutherford, *Transatlantic airline fuel efficiency ranking, 2017*, (ICCT: Washington, DC, 2018), https://theicct.org/publications/transatlantic-airline-fuel-efficiency-ranking-2017.

On apportionment, airlines carry varying amounts of freight on the same route and use different methods to apportion emissions between both passenger and air freight and among cabin classes (e.g. premium vs. economy passengers). These factors can have a material impact on the carbon intensity of passengers moved across different itineraries. Even larger variation is seen in how to reflect the impact of non-CO_2 climate forcers, for example through the use of a Radiative Forcing Index (RFI) multiplier. Regulators will also need to develop protocols on how SAF blends are attributed to individual flights and how to account for differences in emissions from upstream fuel production, which can vary substantially across different fuel pathways.

Finally, third-party audit of airline-reported data will be crucial. The validation should focus on how recent fuel burn data were collected, whether the fuel burn is within reasonable range (compared against historical data and modeled results), and whether the airline followed the standard of emissions estimation.

Non-CO_2 climate mitigation

While the Jet Zero consultation focuses on carbon dioxide (CO_2), attention is growing toward the need to controlling other emissions from aviation, including nitrogen oxides (NOx), black carbon, water vapor, and precursors to aviation-induced cloudiness (AIC). According to the European Union Aviation Safety Agency (EASA), aviation's non-CO_2 climate impact of flying is estimated to be roughly double that of CO_2.[18] Echoing that, Lee et al. (2021)[19] estimates that in 2018, the overall climate impact of flying was about three times that of CO_2 alone, with contrails/cirrus responsible for more than half (57%). This implies that, on a CO_2-equivalent basis, UK aviation may have been responsible for about 100 Mt of CO_2e prior to the COVID downturn.

There are several opportunities to reduce contrail forcing in particular. One is to modify flight altitudes and/or flight paths to avoid contrail forming in ice-supersaturated climatic conditions. Evidence suggests that a small number of flights are responsible for a disproportionate share of contrail formation[20], suggesting that emissions can be reduced at little cost to industry.[21] Another option is to reduce the aromatic content of jet fuel. Aromatics generate black carbon when combusted, creating nucleation sites for contrails and eventually cirrus clouds. Hydrotreating jet fuel can reduce its aromatic content; an appropriate policy goal could be to limit aromatics to the level needed to maintain fuel lubricity and engine compatibility

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[18] European Union Aviation Safety Agency, "Updated analysis of the non-CO_2 climate impacts of aviation and potential policy measures pursuant to EU Emissions Trading System Directive Article 30(4)," (September 2020) https://eur-lex.europa.eu/resource.html?uri=cellar:7bc666c9-2d9c-11eb-b27b-01aa75ed71a1.0001.02/DOC_1&format=PDF.

[19] Lee et al., "The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018," Atmospheric Environment, Volume 224, (2021), https://doi.org/10.1016/j.atmosenv.2020.117834.

[20] Evidence suggests that 2% of flights could be responsible for 80% of contrail formation. See DS Lee, EASA, aerosociety.com/news/easy-does-it-for-greener-skies/

[21] Teoh et al., "Mitigating the Climate Forcing of Aircraft Contrails by Small-Scale Diversions and Technology Adoption," Environmental Science & Technology, Volume 54, Issue 5 (2020): 2941-2950, https://doi.org/10.1021/acs.est.9b05608.

(minimum of 8%). Additionally, SAFs have zero to very low aromatic content, meaning that a SAF mandate could also address contrails by increasing blend fractions.[22]

Given their large climate impact, and the increasing options for control, we recommend that UK DfT give additional consideration to non-CO_2 climate forcers from aviation in future policymaking.

In closing, thank you again for the opportunity to comment on this important policy. If you have any questions, please reach out to me at dan@theicct.org or by phone at +1 650 336 3536.

Best regards,

Dan Rutherford

Dan Rutherford, Ph.D.

Aviation Director, International Council on Clean Transportation

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[22] As a rough calculation, a 50% reduction in fuel aromatics, either via 50% SAF blend or a Jet A standard cutting aromatic content from 18% to 9%, could reduce black carbon emissions by 58 to 86% and contrail radiative forcing by approximately 30 to 45%. See *Updated analysis of the non-CO_2 climate impacts of aviation and potential policy measures pursuant to EU Emissions Trading System Directive Article 30(4).* https://eur-lex.europa.eu/resource.html?uri=cellar:7bc666c9-2d9c-11eb-b27b-01aa75ed71a1.0001.02/DOC_1&format=PDF.

Appendix: UK Feedstock Availability Assessment

Estimated 2030 Jet Fuel Demand

We estimate 2030 jet fuel demand from emissions data published by the UK Department for Transport.[i] Business-as-usual aviation emissions are projected to be 40.1 million tonnes (Mt) CO_2 in 2030, equivalent to roughly 12.7 Mt of jet fuel. Previous passenger growth estimates used by ICCT were based on five-year average trends in EU-27 jet fuel demand.

Availability Assessment

We assess the availability of sustainable aviation fuel (SAF) feedstocks including waste fats, oils & greases (FOGs), biomass residues, electrofuels, and industrial flue gas upgraded via the Lanzatech process. We report data for both domestic and imported fuel volumes in 2030 as a percentage of UK jet fuel demand.

In summary, we find that SAF feedstocks could provide approximately 10.2% of 2030 UK jet fuel demand (Table 1). The majority of this fuel would come from imported waste oil feedstocks, with a smaller share from electrofuels, domestic biomass residues, and recycled carbon fuels.

Table 1. Estimated UK SAF production potential by feedstock

Feedstock	Mt SAF	%2030 jet fuel demand
Waste FOGs (imported)	0.63	4.9%
Electrofuels	0.26	2.7%
Waste FOGs (domestic)	0.10	0.8%
Agricultural residues	0.10	0.6%
MSW	0.03	0.6%
Industrial flue gases	0.07	0.5%
Total	**1.19**	**10.2%**

Fats, Oils & Greases

Fats, oils, and greases (FOGs) can be upgraded to SAF via hydroprocessing, a technologically mature conversion pathway. We assume used cooking oil (UCO) and inedible tallow will comprise the largest share of upgraded feedstocks, known as hydroprocessed esters and fatty acids (HEFA), although sewage FOGs, inedible vegetable oil pressings, industrial food waste, and soap stock acid oil can also be used. Virgin vegetable oils are not designated as eligible feedstock under the UK Department for Transport's (DfT) recent SAF consultation,[ii] therefore we exclude them from our analysis.

We estimate the total quantity of waste FOG supply in the UK based on existing use (as tracked by the DfT) and estimated potential for additional domestic collection. Today, approximately 1.3 Mt of waste FOGs are used in the road sector;[iii] in our analysis, here we assume the entirety of these volumes could be diverted from on-road fuel applications and used for jet-optimized SAF production via the HEFA pathway in 2030. We also assume that 15,000 tonnes of additional

UCO from commercial sources and 37,000 tonnes from household sources could be collected with improved commercial collection practices.[iv]

We note that diversion from the on-road sector would largely divert existing emissions savings generated within the road sector to the aviation sector, with little net benefit. However, for existing hydrotreatment facilities processing waste FOGs, optimizing refineries to produce a higher share of jet fuel would be less costly than building entirely new SAF capacity.[v] However, increasing their share of jet production would require additional hydrogen and energy inputs to achieve shorter chain length kerosene. With respect to existing FAME biodiesel use, which comprises approximately 97% of UK waste FOG biofuel production, the net benefits are even more dubious. Diverting this feedstock instead toward SAF production would require significant investment to construct new facilities.

We estimate the quantity of HEFA produced from waste FOGs by applying yield conversion factors from the Greenhouse gases, Regulated Emissions, and Energy Use in Technologies (GREET) model. We also assume that roughly 60% of the refinery product yield is jet fuel in a jet-optimized slate. Taking into account existing waste FOG usage and increased collection, we estimate approximately 0.7 Mt of waste oil SAF could be supplied to the UK in 2030, or 5.7% of annual jet fuel demand. These volumes are highly import dependent, with waste oils imported from outside the UK accounting for 89% of total volumes.

Biomass Gasification (Ag Residues, MSW)

Biomass feedstocks could also provide a substantial share of SAF in 2030. These feedstocks are converted to jet fuel via gasification to produce Fischer-Tropsch Synthetic Paraffinic Kerosene (FT-SPK). We source data from Eurostat to determine the quantity of available biomass material in 2030. We include agricultural residues, forestry residues, and the biogenic portion of municipal solid waste as qualifying SAF feedstocks. Stakeholders in the EU have also proposed using cover crops as eligible feedstocks under this category; however, under a biofuels policy, cover crops present significant sustainability concerns due competition for land and the risk of additionality issues. Planting cover crops for biofuel can displace available land to grow crops for food and livestock feed, driving land-use change. Low-ILUC risk certification is one method to minimize these risks but would require extensive monitoring and reporting.[vi]

To assess the share of biomass wastes and residues suitable for SAF production, we update an existing analysis of European waste and residue availability,[vii] separating out the UK portion of sustainably available feedstocks. That analysis assumes that feedstocks consumed in non-biofuel sectors today are unavailable for SAF conversion. This includes biomass burned for heat and power under National Renewable Energy Action Plans (NREAP) and crop and residues left in-situ to promote soil health. Total biomass availability also decreases through 2030. This is in part due to shrinking landfilled MSW volumes as a result of statutory targets. These include a maximum 10% MSW landfill rate in 2035 under the Landfill Directive.[viii]

We estimate that 7.4 Mt of agricultural residues are available for FT-SPK production in 2030, comprising the largest source of biomass feedstock. This is followed by 3.6 Mt of MSW and 0.2

Mt of forestry residues. Unlike HEFA facilities, gasification-FT biorefineries are still in the early stages of commercialization so we apply an additional ramp-up constraint to this fuel pathway to factor in the time delay to scale-up of the industry.

We source data on hypothetical future facility sizes to determine the maximum number of FT-SPK plants built in the UK by 2030. With a design and scale-up timeline of approximately five years, we assume one demonstration scale facility will become fully operational before 2030, and one commercial-scale facility (with approximately 0.2 Mt production capacity) will begin ramping up production at half capacity by 2030.[ix] Applying these constraints, we find there is insufficient availability of forestry residues to build a dedicated FT-SPK plant but that there is sufficient capacity to convert 11% and 62% of agricultural residues and MSW to fuel in 2030, respectively. In total, approximately 155,000 tonnes of SAF could be produced from this pathway, or 1.2% of 2030 jet fuel demand. This estimate assumes that the product slate will be optimized for jet production in a 50% jet optimized product slate.

Renewable Fuels of Non-Biological Origin (RFNBOs) and Recycled Carbon Fuels (RCFs)
RFNBOs are defined as fuels produced from renewable, non-biomass feedstocks. These include green hydrogen, ammonia and e-kerosene. Another potential SAF pathway involves upgrading ethanol intermediates produced from the fermentation of carbon-rich industrial flue gas.[x] This RCF pathway is known as the Lanzatech process and is being demonstrated at steel mills. The UK aims to operate zero-carbon short-haul flights powered by hydrogen and all-electric aircraft; however, a realistic entry-into-service data is not set until 2035.[xi] Thus, we assume the only commercially ready pathways for RFNBO production in 2030 are alcohol-to-jet (ATJ) produced via the Lanzatech process and power-to-liquids, or electrofuels.

To calculate the volumes of SAF produced from alcohol-to-jet upgrading, we source steel production data from annual reports published by the World Steel Association.[xii] We assume domestic production remains steady from 2019 levels, or 7.2 Mt. For the purposes of this analysis, we assume a 70% capture rate across all steel mills and a conversion yield factor for synthesized ethanol reported by Bazzanella and Ausfelder.[xiii] A more complete description of this calculation is given in a 2021 ICCT report on EU SAF availability.[xiv] Although the Lanzatech process is not widely used today, it could be scaled up through subsidies or a SAF volume mandate. We assume a linear deployment for alcohol-to-jet upgrading through 2030 for a total of 0.7 Mt of SAF. We assume that 75% of the fuel produced from this process would go towards aviation, based on the product slate.[xv]

In principle, there is an unlimited supply of renewable energy that could be used to generate electrofuels, but high electricity prices, conversion losses, and the limited commercial penetration of electrofuels will constrain deployment in the short term. It is also important that this electricity is additional, or sourced from new generation capacity, rather than diverted from existing plants serving the power sector. Further, if grid-average electricity is used, electrofuels may have greater climate impacts than conventional petroleum jet fuel.[xvi] In the absence of detailed modeling for UK's complementary incentives and specific fuel deployment targets, we draw upon existing economic modeling for the EU-27 to estimate a potential share of electrofuels in aviation. The European Commission proposed a 2.6% RFNBO mandate as part of its “Fit for 55” package to update the Renewable Energy Directive (RED II), along with a simultaneous 0.7% electrofuels blending target for aviation for and 13% GHG intensity reduction for transportation by 2030. Modeling the cost and availability of compliance pathways, we estimate that the EU-27 would achieve compliance for its fuels policies with 2.7% electrofuels deployment as a share of aviation demand. [xvii] However, we note that this is likely an upper limit for electrofuel supply, as it relies on a combination of complementary policies and high carbon prices.

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[ii] UK Department for Transport, “Sustainable Aviation Fuels Mandate: A Consultation on Reducing the Greenhouse Gas Emissions of Aviation Fuels in the UK,” 2021, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005382/sustainable-aviation-fuels-mandate-consultation-on-reducing-the-greenhouse-gas-emissions-of-aviation-fuels-in-the-uk.pdf.

[iii] UK Department for Transport, “Renewable Fuel Statistics,” GOV.UK, August 8, 2019, https://www.gov.uk/government/collections/renewable-fuel-statistics.

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[x] Alexis Michael Bazzanella and Florian Ausfelder, “Low Carbon Energy and Feedstock for the European Chemical Industry,” June 2017, 168.

[xi] UK Department for Transport, “Jet Zero Consultation: Evidence and Analysis.”

[xii] World Steel Association, “2020 World Steel in Figures,” 2020, https://www.worldsteel.org/en/dam/jcr:f7982217-cfde-4fdc-8ba0-795ed807f513/World%2520Steel%2520in%2520Figures%25202020i.pdf.

[xiii] Bazzanella and Ausfelder, “Low Carbon Energy and Feedstock for the European Chemical Industry.”

[xiv] O’Malley, Pavlenko, and Searle, “Estimating Sustainable Aviation Fuel Feedstock Availability to Meet Growing European Union Demand.”

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[xvi] O’Malley, Pavlenko, and Searle, “Estimating Sustainable Aviation Fuel Feedstock Availability to Meet Growing European Union Demand.”

[xvii] Christensen, Adam. “Transportation Carbon Intensity Targets for the European Union – Road and Aviation Sectors”. https://theicct.org/sites/default/files/publications/GAMS%20EU%20fuels%20modeling%20consultant%20report%20Aug2021.pdf