Jet Zero: a critical appraisal of the government's draft strategy for decarbonising UK aviation by 2050

Produced by the Group for Action on Leeds Bradford Airport - for MPs, journalists and campaigners, August 2021

Exec Summary

- *Jet Zero consultation:* Jet Zero is the government's draft strategy to make UK aviation carbon net zero by 2050. It is out for consultation until 8 September.

- *Jet Zero allows aviation emissions to continue to grow till 2030:* the IPCC issued a 'code red' warning about the climate crisis in August. They warned that in order to prevent climate breakdown, we must cut global emissions by 45% by 2030 from 2010 levels. Jet Zero proposes to allow UK aviation emissions to increase into the 2030s from 2019 levels, rising to 39Mt CO2; allow unconstrained passenger growth of 60% up to 2050; and leave over one third of UK aviation emissions still needing to be removed from the atmosphere in 2050.

- *Jet Zero ignores Climate Change Committee advice and opts for aviation industry proposals:* there are no measures to limit the growth of emissions and passenger numbers, nor to prevent the net expansion of UK airport capacity, nor to put a price/tax on aviation fossil fuels. These are key recommendations from the Climate Change Committee. Instead Jet Zero prioritises "in-sector reductions through technological and operational improvements, then seeks to address residual carbon emissions through robust, verifiable offsets and additional greenhouse gas removals." Offsetting cannot reduce emissions in the next 10 years, nor can new technologies and alternative fuels on their own. The reliance on long term technology developments is contrary to the precautionary principle - what if the promised new technologies and alternative fuels do not cut emissions fast enough? All of the developments proposed in Jet Zero have been promised in the past but never materialised at scale. The words 'uncertain', 'uncertainty' and 'uncertainties' appear 27 times in the Jet Zero consultation documents.

- *Emissions pricing and taxes on flying:* Jet Zero states: "By pricing CO2 emissions, market based measures can drive cost-effective and technology-agnostic emissions reductions, making system efficiencies, SAF and zero emission flight more economically attractive, and influencing the travel choices of consumers. They also implement the 'polluter pays' principle – that those who engage in activity that has an environmental impact should bear the cost of that impact." But Jet Zero makes no proposals to introduce a realistic level of emissions pricing, nor to add any taxes on aviation fossil fuels, nor to increase UK flight ticket taxes (APD).

- *Unjustified hope for high rate of annual efficiency gain:* Jet Zero assumes a higher rate of annual efficiency gain than is supported by any evidence. It also claims that "improving the efficiency of our current aviation system offers the best opportunities for short- to medium-term reductions in CO2 emissions." This is not correct: measures to limit the growth of flying would be much more effective and definite ways to achieve short- to medium-term emissions reductions. We need to cut aviation emissions now and allow time for efficiencies to be developed and measured; and to learn the extent to which, and the timescale within which, they can be deployed commercially.

- *Unrealistic hope for Sustainable Aviation Fuels (SAF) development - 1) biofuels:* aviation biofuels are not a sustainable or scalable solution without causing price rises and scarcities for other, more important, sectors of our economy. There simply isn't enough land to grow enough biomass to meet all our other needs plus an unconstrained expansion of aviation. Biofuels may contribute to reducing aviation emissions to some degree in future but we need to cut those emissions now and allow time to assess the extent to which, and the timescale within which, they can be deployed commercially without damaging the rest of our economy.

- *SAF - 2) synfuels (synthetic or e-fuels):* aviation synfuels are not a scalable solution because of the high quantity of renewable energy required and the high costs involved to create them in large quantities. There simply won't be enough renewable electricity for all our other needs plus an unconstrained increase in flying. Synfuels may contribute to reducing aviation emissions to some degree in future but we need to cut those emissions now and allow time for synfuels to be developed and tested; and to understand the extent to which, and the timescale within which, they can be deployed commercially.

- *SAF - 3) green hydrogen:* green hydrogen is not a scalable solution within the next 20-30 years because of the technical challenges and high costs involved in redesigning aircraft and building extensive new ground infrastructure; the quantity of renewable energy required to make green hydrogen; and the long timescale for replacing aircraft in airline fleets. Green hydrogen may contribute to reducing aviation emissions in the long term but we need to cut those emissions now and allow time for green hydrogen to be developed and tested; and to understand the extent to which, and the timescale within which, it can be deployed commercially.

- *SAF - 4) cost and quantity:* all types of SAF face major uncertainties and obstacles to scaling up production sufficiently due to the high costs and long timescales involved. SAF is exclusively needed by the aviation industry but what guarantees are there that the industry will be prepared to meet the scale up costs? SAF may contribute to reducing aviation emissions to some degree in the long term but we need to cut those emissions now and allow time for SAF development to be funded; and to understand the extent to which, and the timescale within which, SAF can be deployed commercially at the scale required.

- *Zero Emission Flight - electric and hydrogen:* renewable electricity battery powered flight will only be feasible for small aircraft on short haul routes, even by 2050 - the batteries are simply too heavy. Green hydrogen is not a scalable solution within the next 20-30 years because of the technical challenges and high costs involved in redesigning aircraft and building extensive new ground infrastructure to use hydrogen; the quantity of renewable energy required to make green hydrogen; and the long timescale for replacing aircraft in airline fleets. What guarantees are there that the aviation industry will be prepared to meet the cost associated with scaling up green hydrogen sufficiently? Zero emission flight will make only a minimal difference to the aviation industry's emissions by 2050. We should prioritise electrifying and subsidising zero carbon ground travel options over less efficient and less capable (i.e. carrying fewer passengers) aircraft.

- *Markets and Removals - carbon offsetting and emissions pricing:* offsetting schemes do not stop aircraft from immediately putting emissions into the

atmosphere and they typically involve tree planting, which takes decades to remove emissions from the atmosphere. The UK Emissions Trading Scheme is an ineffective measure for incentivising airlines to reduce their emissions because of the low cost of credits and the quantity of credits given to the aviation industry for free. The United Nations Environment Programme estimated in 2020 that the international CORSIA aviation offsetting scheme "will result in the offset of only 12% of total international and domestic aviation emissions by 2030". The CCC advised the government not to use CORSIA as a way to meet our 2050 net zero target but Jet Zero ignores this advice.

- *Markets and Removals - emissions pricing:* measures that put a realistic price on emissions and tax aviation are crucial to make the cost of flying with fossil fuels reflect the true scale of the damage this activity does to the climate. Increasing the cost of fossil fuelled flying is likely one of the most effective measures to cut aviation emissions by reducing demand and there are ways to achieve this without disproportionately impacting low income households. Jet Zero makes no proposals to increase emissions prices, nor to tax aviation fossil fuels, nor to increase flight ticket taxes. The government's recent consultation on aviation taxation proposed to cut Air Passenger Duty (the only tax levied on the aviation industry) and makes only one proposal to amend APD and make those who fly most, pay most

- *Markets and Removals - greenhouse gas removal (GGR) technology:* there is a high level of uncertainty about the costs and potential for sufficient GGR technology development and deployment by 2050. What guarantees are there that the aviation industry will be prepared to meet its share of the costs involved? Cutting aviation emissions <u>now</u> will reduce the quantity of emissions that need to be removed from the atmosphere in 2050. It will take time for GGR technology to be developed and tested; and to understand the extent to which, and the timescale within which, it can be deployed commercially.

- *Other - 1) international cooperation:* Jet Zero notes: "Achieving net zero will also rely heavily on a collaborative, international effort and these scenarios should be viewed in that context - these scenarios will not be possible based on domestic action alone." There is no contingency plan if the necessary level of cooperation does not materialise. Domestic demand management measures are within the government's own control and are key CCC recommendations.

- *Other - 2) influencing consumers:* the most effective way to do this is by introducing a realistic carbon price and aviation fuel tax that would send a price signal to consumers, rather than by using a labelling metric, which may or may not influence behaviour.

- *Other - 3) five yearly review:* Jet Zero proposes to review progress on its solutions every five years. Given the urgent nature of the climate crisis and the need to make radical reductions in GHGs by 2030, this proposal is wholly inadequate. The government should carry out an annual review of the extent to which aviation emissions are reducing. If they are not, measures should be introduced as quickly as possible, including measures to limit demand for flying.

- *Other - 4) non-CO2 emissions:* in addition to CO2, aviation emits other GHGs - nitrogen oxides, soot and water vapor, which create contrails and cirrus clouds. While Jet Zero acknowledges that these exist, it says little about how they should

be addressed. Recent research has found that non-CO2 emissions exacerbate aviation's climate damaging effects by a factor of two to three. Jet Zero needs far greater ambition on non-CO2 emissions.

- *Conclusion:* Jet Zero describes its ambitious emissions reduction scenarios as "illustrative pathways rather than forecasts." This strongly suggests that the government does not actually have any forecast in which UK aviation can reach net zero by 2050 using only the measures proposed in Jet Zero. It will allow emissions to increase up to 2030, contrary to all scientific warnings about the urgent need to reduce emissions by 45% by 2030 from 2010 levels.

- Allowing aviation to expand before new technologies and alternative fuels have been scaled up and deployed is completely the wrong way round. The precautionary principle requires us to prevent flying from increasing until and unless the promised technology improvements have actually materialised at a commercial scale and delivered the necessary emissions reductions. This requires the immediate introduction of demand management measures - stopping all airport expansions and taxing fossil fuelled flying.

- While the Government remains relaxed about growing passenger numbers and airport expansions, aviation emissions will grow and grow while we wait and hope for the best. This is a gamble that no responsible government should take. We need more than a 'wing & a prayer' to stop climate breakdown - we need immediate and credible action.

Jet Zero: a critical appraisal of the government's draft strategy for decarbonising UK aviation by 2050

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In a nutshell

- Jet Zero is the government's draft strategy to make UK aviation carbon net zero by 2050 in which the government has chosen to ignore key recommendations from its expert climate advisers on how to achieve this.

- The Climate Change Committee (CCC) has repeatedly advised the government that aviation emissions and passenger growth must be limited by immediate demand management measures as well as developing new technologies for the longer term.

- Demand management means immediately stopping UK airport expansions and introducing meaningful emissions pricing and taxes on flying.

- Instead the government proposes to accept the UK aviation industry's proposals which claim that carbon net zero flying can be achieved by 2050 purely from efficiency gains, new technology, 'sustainable' fuels and offsetting.

- By putting all its bets on the industry's unproven techo-fixes, the government is taking a huge gamble with our future - the words 'uncertain', 'uncertainty' and 'uncertainties' appear 27 times in the Jet Zero consultation documents.

- There is no credible evidence to support the assertion that the measures in Jet Zero can, on their own, reduce UK aviation emissions to net zero by 2050, nor can they cut those emissions in half by 2030 - in fact, Jet Zero actually proposes *increasing* aviation emissions up to 2030.

- Climate scientists warn that radically reducing emissions in the next 10 years is absolutely essential if we are to prevent the worst impacts of the climate crisis.

- The IPCC has repeatedly said we must cut global emissions by 45% by 2030 from 2010 levels - this is at the heart of their most recent 'code red' warning to humanity.

- The UK government has set a new goal of reducing our emissions by 78% by 2035 compared to 1990 levels but Jet Zero allows UK aviation emissions to increase from 37Mt CO2 pa in 2018 to 39Mt CO2 pa in 2030.

- We need more than a 'wing & a prayer' to stop climate breakdown - we need credible climate action now.

- The Jet Zero consultation period ends on 8 September.

The policy background and timescale

- In December 2020, the CCC's 6th Carbon Budget recommended including international aviation emissions in the UK's carbon budget. The Aviation Sector Summary Report also recommended scaling up new technologies and alternative fuels, preventing any net expansion of UK airport capacity and capping any passenger increase to a maximum of 25% from 2018 levels up to 2050.

- In April 2021 the government accepted the CCC's recommendation to include international aviation emissions in the UK's carbon budget but gave no indication as to how flying would be made net zero by 2050.

- On 22 June 2021, the industry lobby group 'Sustainable Aviation' announced its approach to making aviation net zero. It focussed entirely on new technology, efficiency gains, new fuels and offsetting. It was welcomed by Grant Shapps.

- On 24 June 2021, the CCC published its Progress Report to Parliament. This said several times that the government needs to use demand management measures to limit passenger growth and noted that because its recommended 25% maximum growth is within the existing capacity of UK airports, there should be no expansions.

- On 14 July 2021, the government published its Transport Decarbonisation Strategy alongside Jet Zero, which essentially adopted the industry's proposals.

- Jet Zero is out for consultation until 8 September 2021 - unless something significant happens before then it is likely to become UK government policy.

1. Introduction

1.1. The years to 2030 are crucial for the future of humanity and our planet. Scientists warn that the choices we make in the next 10 years are critical for preventing catastrophic climate breakdown. In order to have a chance of keeping average global temperature rise to below 1.5C, the Intergovernmental Panel on Climate Change says we must cut global greenhouse gas (GHG) emissions by 45% from 2010 levels by 2030 (see p12 of summary for policy makers). Recent research by Klöwer et al asks the question: how much global heating will global aviation have caused in 2050 if the industry returns to its pre-pandemic 'business as usual' growth trajectory? The answer is that it will have contributed a 6-17% share to the remaining 0.3-0.8℃ left to us if we are serious about staying within a 1.5-2℃ temperature rise target. And we must be serious about that.

1.2. In 1990, before the arrival of low cost flying, UK aviation emissions were about 17Mt CO2. By 2019, they had reached 37Mt CO2. Jet Zero proposes to allow aviation emissions to *increase* into the 2030s, up to 39Mt CO2; allow unconstrained passenger growth of *60%* up to 2050; and still require over *one third* of UK aviation emissions to be removed from the atmosphere in 2050. This amounts to a huge gamble with everyone's future and places all bets in as yet untested technological developments.

2. Jet Zero ignores Climate Change Committee recommendations

2.1. Jet Zero states it has 'one goal, multiple solutions'. However it ignores key solutions recommended by the government's own Climate Change Committee (CCC) - to place a cap on the growth of flying, stop airports from expanding, introduce meaningful emissions pricing and tax aviation fossil fuels. The CCC has repeatedly told the government that for UK aviation to have any chance of reaching net zero by 2050, the forecast growth in the number of flights and passengers (and therefore emissions) must be limited immediately, alongside making aviation system efficiencies and developing new technologies and alternative fuels for the longer term.

2.2. That is, the CCC accepts that in the longer term we need all the technological innovations set out in Jet Zero. But the CCC also warns they are highly unlikely to be sufficient on their own and cannot cut aviation emissions in the crucial next 10 years. In September 2019, the CCC stated clearly: "Zero-carbon aviation is highly unlikely to be feasible by 2050." As Jet Zero itself accepts: "many of the technologies we need are in their infancy and will take time to develop." The IPCC's recent 'code red' warning is clear - we do not have the luxury of time.

2.3. Para 3.35 of Jet Zero states: "By pricing CO2 emissions, market based measures can drive cost-effective and technology-agnostic emissions reductions, making system efficiencies, SAF and zero emission flight more economically attractive, and influencing the travel choices of consumers. They also implement the 'polluter pays' principle – that those who engage in activity that has an environmental impact should bear the cost of that impact." But Jet Zero makes no proposals to introduce a realistic level of emissions pricing nor any taxes on aviation fuel. This is a grave omission.

2.4. It's important to remember that the CCC is made up of the country's leading climate science experts, who have carefully considered all of the options for how the UK can reach net zero by 2050. They were aware of all the technological possibilities included in Jet Zero and they still concluded that aviation cannot realistically become net zero by 2050 unless we also immediately limit demand for flying.

2.5. It's not just the CCC who say that getting aviation emissions to net zero by 2050 will require, at the very least, limits on demand growth. The International Energy Agency reached a similar conclusion in its pathway to net zero by 2050, which assumes that: "aviation growth is constrained by comprehensive government policies that promote a shift towards high-speed rail and rein in expansion of long-haul business travel, e.g. through taxes on commercial passenger flights." (p135). The UK Climate Assembly supported the introduction of measures to limit growth and the UK FIRES academic coalition says flying must be reduced as quickly as possible. Yet the government has chosen to ignore all this independent, expert advice and adopt the aviation industry's proposals.

2.6. ***<u>Key point:</u> there are no measures to limit the growth of emissions and passenger numbers nor to prevent the net expansion of UK airport capacity nor to put a realistic price on aviation fossil fuels. These are the Climate Change Committee's key recommendations. Instead Jet Zero prioritises offsetting and "in-sector reductions through technological and operational improvements, then seeks to address residual carbon emissions through robust, verifiable offsets and additional greenhouse gas removals. It relies on the rapid scaleup and deployment of technologies that are currently at a relatively early stage of development..." Offsetting cannot reduce emissions in the crucial next 10 years, nor will new technologies and alternative fuels on their own. The reliance on long term technology developments is contrary to the precautionary principle - what if the promised new technologies and alternative fuels do not cut emissions fast enough?***

3. Problems with Jet Zero's proposed techno-fixes

3.1. There are well documented problems and massive uncertainties associated with all of the proposed technical measures in Jet Zero: System Efficiencies, Sustainable Aviation Fuels, Zero Emission Flight, Markets and Removals. The words 'uncertain', 'uncertainty' and 'uncertainties' appear 27 times in the Jet Zero consultation documents.

3.2. *<u>System Efficiencies</u>*

3.3. Jet Zero's three 'ambitious' scenarios assume a higher rate of efficiency gain (2% pa) than the CCC's balanced net zero pathway (1.4% pa). They all fail to take into account the 'rebound effect'. As recent past experience has demonstrated, it's a misconception to assume that efficiency gains inevitably result in corresponding emissions reductions. In reality, efficiency gains bring down the cost of flying so people simply fly more frequently and fly further on the same fuel but ultimately produce the same emissions. As noted on p11 of the <u>latest report</u> by the OECD's <u>International Transport Forum</u>: "over the past few decades, and despite significant fuel-efficiency improvements achieved by the sector, the number of flights taken has been increasing so rapidly that the sector's carbon emissions have been on an upward trajectory."

3.4. Jet Zero's assumed 2% pa rate of efficiency gain appears to be based on two sources: 1) the 'optimistic scenario' in Air Transport Analytics (ATA) research paper <u>Understanding the Potential and Costs of Reducing UK Aviation Emissions</u> (commissioned by the CCC and Dept for Transport); and 2) the International Civil Aviation Organisation's (ICAO) 'aspirational goal'. Page 24 of ATA's report explains that their Likely scenario assumes "the most likely technologies are adopted based on the current well-developed technology plans" and their Optimistic scenario assumes "some high-risk technologies are adopted in addition to the 'Likely' case." Jet Zero does not explain the basis for assuming these 'high risk' technologies will become commercially viable within the timescale needed.

3.5. ICAO's 2% pa 'aspirational goal' is just that - aspirational. ICAO's Environmental report in 2019 assumed long-term overall efficiency gains "even under the most optimistic scenario" of 1.37% pa. The report explains: "The computed 1.37% per annum long-term fuel efficiency includes the combined improvements associated with both technology and operations" (p17). This is the same approach used in Jet Zero yet it assumes 2% pa. Why? A recent review requested by ICAO, using independent experts (link), found that targets deemed challenging but possible by 2037 were: reductions in fuel burn for single-aisle and twin-aisle aircraft of 21.6% and 21% respectively, which are annual improvements of 1.22% and 1.28% (page 56).

3.6. Para 2.3 of Jet Zero's Evidence and Analysis paper suggests "efficiency improvements such as these could reduce the fuel burn of aircraft *coming into service in the mid-2040s* by 40-50% compared to types entering service in the early 2000s." However, aircraft entering service in 2045 will only account for a tiny proportion of airlines' fleets in 2050. Fleets will predominantly be composed of aircraft entering service in the 2020s and early 2030s, which will be aircraft designed in the 2010s.

3.7. Para 3.11 of the same paper acknowledges that: "Achieving such a high rate of fuel efficiency improvement will also be challenging, and may not be met if airlines cannot afford to invest in modernising their fleets at sufficient speed, or if the aerospace sector cannot afford to invest in creating the necessary aircraft advancements (made even more likely by the huge financial impact of Covid-19 on the aviation industry)." Jet Zero offers no evidence to suggest this obstacle can be overcome in reality.

3.8. Even the CCC's assumption of 1.4% pa efficiency gain is optimistic. The CCC's Aviation Sector Summary report (Table M8.1 on page 10) shows the baseline Dept for Transport modelling of efficiency gain to be 0.7% pa. Research published in 2020 for the United Nations Environment Programme (UNEP) states: "In general, there are likely to be improvements in aircraft airframes and engines in the next 20 or so years, which will improve the burn-fuel metric by around 1.2% per year. However, the crucial conclusion is that the sum of the potential improvements does not come near to matching the projected growth in aviation, let alone to reducing emissions from the current level." (section 5.3.2). It goes on to say: "Recent reports suggest that about 1.2–1.4% in fleet efficiency gain is possible per year, which falls short of the ICAO target of 2% per year and is significantly less than the projected annual growth in aviation." (Section 5.4.2).

3.9. Recent research by Klower et al concludes on p10: "Planning on fuel efficiency improvements does not significantly reduce aviation's contribution to warming, as past progress in efficiency was overcompensated by air traffic growth and further efficiency potential is limited. More efficient jet engines tend to produce more contrails, such that savings in fuel could be over compensated by the warming effect of contrails (Schumann 2000)."

3.10. Aviation design expert Finlay Asher, who worked at Rolls Royce for nearly a decade, says: "Between 2000 and 2020 the aviation industry struggled and

failed to achieve its 1% pa target. At Rolls Royce, the promised efficiency spec was regularly missed. The next decade is going to be characterised by modification packages to older engines to try and 'return-to-spec' as originally promised. There are no large step-changes in efficiency around the corner and it takes 10-15 years to certify any significant new aircraft and engine designs. So anything we do see (e.g. new designs entering service in 2035) will not be the predominant aircraft in service in 2050, due to the 20-30 year lifetime of aircraft. Furthermore, efficiency gain is not compound whereas the anticipated 4% pa growth in air traffic is compound. This is important - air traffic doubled from 2000-2015, meanwhile efficiency gain was 15%, so that resulted in roughly 80% increase in emissions."

3.11. The most effective way to ensure efficiency improvements accelerate and aviation emissions reduce is to increase the price of aviation fossil fuel by introducing a realistic level of tax on fossil fuelled flying. This would send a price signal that incentivises manufacturers to accelerate their technology development and consumers to alter their behaviour. Jet Zero seems only to suggest carbon pricing as a way to fund greenhouse gas removal technology in 20-30 years time. This is inadequate to deal with the urgent need to cut emissions in the next 10 years. As the UK is no longer a member of the EU, the government is free to introduce an aviation fossil fuel tax on domestic flights and flights to the EU immediately.

3.12. Jet Zero also suggests that making efficiencies at airports (e.g. using renewable electricity for all airport ground operations) can play a significant role in reducing emissions. While welcome, the gains would be marginal and the 2040 target date should be earlier. Typically, the GHGs from an airport's ground operations are around 1% of its total emissions – 99% are from flights and passenger vehicles driving to the airport. For example, Leeds Bradford Airport claims that its ground operations will be reduced to virtually zero if its current planning application is approved. This prompted the chair of Leeds Climate Commission to observe that the airport's ground emissions are like 'grains of sand' compared to the emissions from flights.

3.13. It's also important to note that all current proposed airport expansions are based on an assumption of 'business-as-usual' growth based on using *existing* types of aircraft and fuel, rather than the proposed alternative fuels. This reinforces the need to stop current expansion plans until the future zero emissions flying landscape is better understood and agreed upon.

3.14. ***Key point:*** ***Jet Zero assumes a higher rate of annual efficiency gain than is supported by any evidence. It also claims that "improving the efficiency of our current aviation system offers the best opportunities for short- to medium-term reductions in CO2 emissions." This is not correct: measures to limit the growth of flying would be much more effective and definite ways to achieve short- to medium-term emissions reductions. We need to cut aviation emissions now to allow time for efficiency measures to be developed and tested; and to learn the extent to which it can be deployed commercially and within what timescale.***

3.15. *Sustainable Aviation Fuels (SAF)*

3.16. The strategy places particular faith in the development of SAF for use in existing and future aircraft to bring about medium- and long-term CO2 emissions savings on long-haul flights, which are responsible for around 96% of the aviation industry's emissions.

3.17. Biofuels: the future available quantity of sustainable biomass 'waste' is strictly limited and should be considered a precious resource. Global economies will need to use biomass for feeding a growing human population while also decarbonising the grid, domestic heating and ground transport. Aviation biofuels are not a sustainable or scalable solution without causing increased global food prices, water shortages, deforestation, drainage of peatland, loss of biodiversity and emissions from land-use changes. In other words, we need to use land for many other, more important, purposes than making fuel for aircraft - and there's not enough land for everything.

3.18. The 2020 UNEP report also notes: "The International Energy Agency estimated that the mean production costs of aviation biofuels in 2018 were approximately two to three times that of fossil jet kerosene… The major uncertainty lies in the cost and availability of the primary energy sources, such as sustainable biomass and renewable electricity" (section 5.3.3).

3.19. It should be widely accepted that aviation biofuels cannot come directly from agricultural crops, competing with human food and animal fodder for land, but they could come from agricultural, forestry and domestic wastes. However there are significant problems with competing uses for these 'feedstocks'. There are already markets for used cooking oil - it can all be used for animal food and in other industries. Taking crop wastes off the land not only means lower organic matter returned to the soil (thus reducing its structure and fertility) but also its removal from other uses, such as animal bedding. There are competing uses for forestry waste too, such as the paper and pulp industry. Feedstocks could be used to make fuel for road vehicles, or burned to produce electricity. So if aviation also wants these feedstocks, there will be competition and price rises for other sectors.

3.20. There is currently no meaningful definition of what counts as 'sustainable' for SAF. The current definition used by the international aviation CORSIA scheme is not credible. For example, if fossil fuel is blended with just 10% of non-fossil fuel, CORSIA counts this as 'sustainable'. This needs to be fully addressed in the government's consultation on SAF mandating by ensuring high criteria for what counts as 'sustainable'. In so doing, this would likely further limit the availability of biofuels for aviation.

3.21. It should also be noted that paras 3.13-3.20 of Jet Zero list "Non-biogenic waste: e.g. unrecyclable plastics or waste fossil gases from industry" as SAF. These fuels are not sustainable. This approach would basically mean taking fossil fuel and burning it, thus putting additional GHGs into the atmosphere. If there is plastic waste, it's far better to leave it as plastic, with the carbon stored, than to burn it and release the carbon.

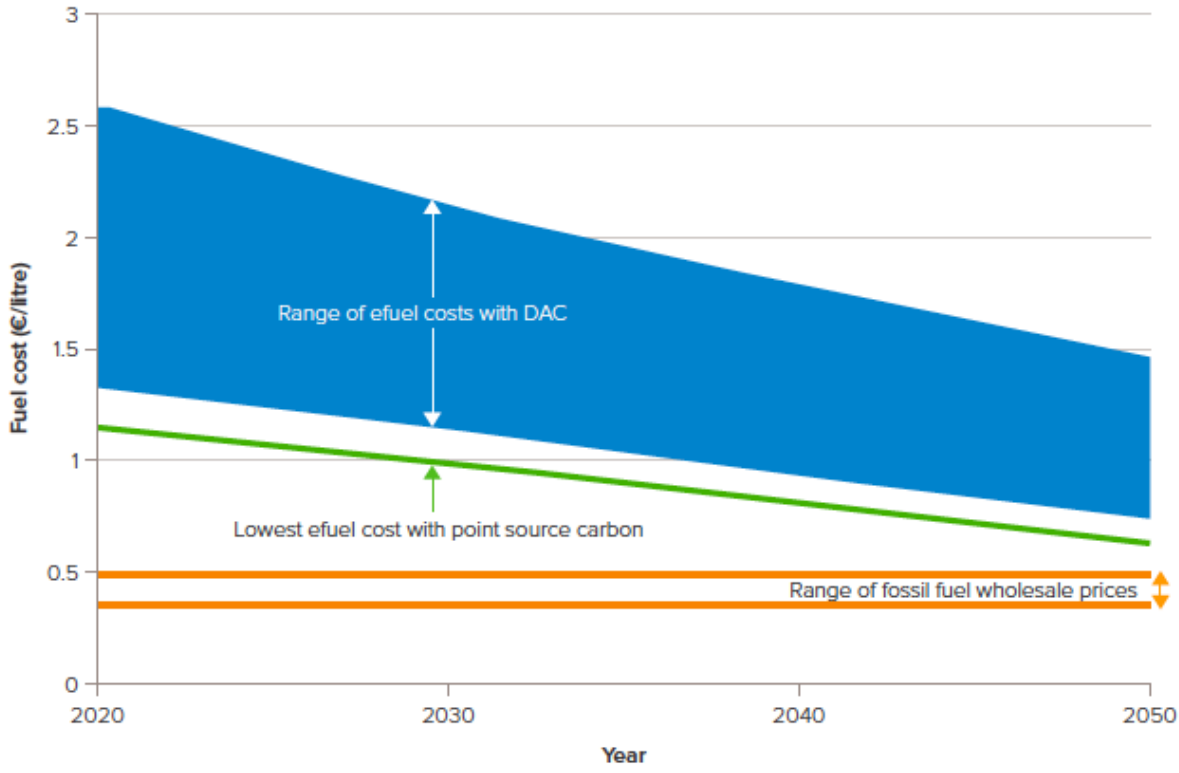
3.22. An EU report in 2020 (contributed to by Airbus, Boeing and easyJet) confirms the above problems: “Biofuels are already commercially available... But biofuels’ reliance on feedstock, changes in land use, high water use, and/or monoculture (i.e. the production of a single crop) means that the aviation industry will be competing with other interests that need the feedstock for other purposes.” (p18). The 2020 UNEP report also warns: “Assuming that biofuel combustion is carbon neutral is ... a fundamental accounting error that rests on implicit spatiotemporal boundaries and assumptions…” and notes that “for many biofuels, the energy return on investment is comparatively low or possibly negative” (section 5.3.3). So it is highly unlikely that biofuels can be scaled up to more than a small fraction of aviation fuel consumption by 2050 without damaging other sectors.

3.23. ***Key point:*** ***aviation biofuels are not a sustainable or scalable solution without causing price rises and scarcities for other, more important, sectors of our economy. There simply isn’t enough land to grow enough biomass to meet all our other needs plus an unconstrained expansion of aviation. Biofuels may contribute to reducing aviation emissions to some degree in future but we need to cut aviation emissions now to allow time to assess the extent to which, and the timescale within which, they can be deployed commercially without damaging the rest of our economy.***

3.24. Synfuels or e-fuels: aviation synthetic/e-fuels are produced from electricity by synthesising hydrogen with carbon captured from the atmosphere to create a liquid hydrocarbon. They too face problems of scaling up, cost and the disproportionate use of renewable energy resources – i.e. there won’t be enough green electricity to meet all our other needs and also produce enough synfuels for an unconstrained increase in flying. The 2020 UNEP report adds: “Notwithstanding the significant barriers of sufficient available renewable energy and CO2 from direct air capture, creating synthetic fuel is technologically feasible, though at much greater costs than direct fossil fuel extraction and refining.” (section 5.3.3). Figure 7 (below) from the Royal Society’s 2019 policy briefing, ‘Sustainable synthetic carbon based fuels for transport’, illustrates the likely difference in costs between fossil fuels and e-fuels up to 2050.

FIGURE 7

Efuel cost forecasts.



Note: Based on 3 technology options for diesel using Direct Air Capture[80–82], 6% interest rate, 25 years' project lifetime, using solar (2344 hours/year) and wind power (3942 hours/year).

3.25. Even if increased synfuel production is funded by the aviation industry, the inefficiency of the processes involved would require huge quantities of renewable energy. The electrical energy required to produce enough synfuel to displace current global annual aviation fuel consumption would exceed all of the global renewable energy generated today. Whilst renewable energy generation is growing every year, this electricity is also needed for decarbonising every other sector of the economy.

3.26. <u>Key point:</u> aviation synfuels are not a scalable solution because of the high quantity of renewable energy and the high costs required to create them. There simply won't be enough green electricity for all our other needs plus an unconstrained increase in flying. Synfuels may contribute to reducing aviation emissions to some degree in future but we need to cut aviation emissions <u>now</u> to allow time for synfuels to be developed and tested; and to understand the extent to which, and the timescale within which, they can be deployed commercially.

3.27. Green hydrogen: Jet Zero expects hydrogen "to play a key role in fuelling zero emission aircraft." For hydrogen to be 'green', it must be produced using renewable electricity, which raises the same issue of availability - we will not have enough green electricity for everything we want: priorities have to be chosen. While green hydrogen offers some potential, there are significant costs and long timescales required to develop, test and deploy it, to make infrastructure changes at airports, to redesign aircraft to use and store hydrogen and to upgrade airlines' fleets to replace fossil fuel powered aircraft. This means that it will not credibly support significant decarbonisation of aviation within the timescale needed. What guarantee is there that the industry will be prepared to meet these costs?

3.28. As noted on p13 of Roland Berger's 2020 report, 'Hydrogen - A future fuel for aviation?': "The main drawback of hydrogen is that, due to its low volumetric density, it requires four to five times the volume of conventional fuel to carry the same onboard energy." So the size, shape and weight requirements of fuel storage for commercial flying will require a major re-design of aircraft fuselages. Commercialisation and certification of new aircraft and engine designs can take more than 10 years and it takes much longer (20-30 years) for airlines to upgrade their fleets. An EU research report in 2020 concluded that even assuming the necessary technical developments occur "hydrogen propulsion is best suited for commuter, regional, short range, and medium-range aircraft" (p5) and notes that hydrogen is "less suitable for evolutionary long-range aircraft designs from an economic perspective" (p6). The 2020 UNEP report also states that the development of green hydrogen "is only likely under a larger-scale hydrogen oriented energy economy." (section 5.3.3).

3.29. Key point: green hydrogen is not a scalable solution within the next 20-30 years because of: the technical challenges and high costs involved in redesigning aircraft and building extensive new ground infrastructure; the quantity of renewable energy required to make green hydrogen; and the long timescale for replacing aircraft in airline fleets. Green hydrogen may contribute to reducing aviation emissions in the long term but we need to cut aviation emissions now to allow time for green hydrogen to be developed and tested; and to understand the extent to which, and the timescale within which, it can be deployed commercially.

3.30. Problems with the cost and availability of SAF

3.31. There are high costs associated with introducing large scale use of SAF. The 2020 UNEP report warns: "Ultimately, the price gap between incumbent fossil fuels and post-fossil fuels represents a key challenge that prevents investment both in the [aviation] sector and infrastructure on land. Without sufficiently stringent regulation in place to force or enable a business case for zero-carbon fuel use, these investments are unlikely to flow at the required scale until there is either a customer preference or a price premium for zero-carbon [aviation] services." (section 5.3.3). A price premium means introducing a carbon tax, at a realistic level, on aviation fossil fuels.

3.32. Jet Zero assumes between 30% and 75% of total aviation fuel by 2050 will be SAF but on current trends it will be just 5% by 2030. Para 2.5 of the Evidence & analysis paper accepts that "current SAF use in UK aviation is negligible and there is significant uncertainty around the availability and cost of SAF in the future." Recent research for the International Council on Clean Transportation into the potential for SAF use in EU aviation concluded: "Taking into account sustainable availability and an optimistic assumption for the deployment rate of novel conversion technologies, we estimate that there is a resource base to meet approximately 5.5% of the European Union's projected 2030 jet fuel demand using advanced SAFs" (p.15). This is too little to cut emissions in the next 10 years and unlikely to be scaled up.

3.33. The Chief Exec of French energy giant Total, Patrick Pouyanné, seems to share these concerns. He recently said: "The decade to come will be based on animal fat biofuels. We will be able to accompany this transition from 1% to 2%, 3% and 5% with our production capacities… and then we will have to find something else, but for hydrogen, it will be for short-range aircraft of no more than 1000 miles. Afterwards, we look at plant waste and that is very complicated, it works in the lab but the passage to an industrial scale is complex. Total has had to invest around 500 million euros in R&D, and we still don't have any convincing results on an industrial scale. Then we have to move towards a holy grail, an 'e-fuel' - we take green hydrogen and combine it with CO2, and there we make a synthetic fuel. It's complex, it's expensive, green hydrogen is three to four times the price of normal hydrogen. CO2 has to be captured, and we are working on these avenues, but it is in the medium and long term, not before 2040-2050." This is too late to seriously tackle aviation's role in exacerbating the climate crisis.

3.34. Jet Zero's own Evidence and Analysis document, at para 2.8, accepts: "The costs of SAF are high and uncertain. A recent ICCT report suggested that, in general, SAF is around two to three times the cost of kerosene, and potentially up to eight times the cost of kerosene for certain pathways." The same paragraph also says "we estimate the abatement costs of SAF to currently be broadly in the range of £200-600/tCO2" in the short/medium term. What guarantee is there that the industry will be prepared to meet the costs of scaling up SAF production?

3.35. In relation to its scenario 3 (75% SAF use in 2050), Jet Zero says at para 3.14: "Achieving such a high proportion of SAF would require a high share of more advanced SAF pathways in particular... which are currently much more expensive than others. Secondly, there will need to be a substantial ramp up of SAF production. There are currently a number of barriers to these two conditions, including the high capital costs of building first-of-a-kind plants, the high risk for investors due to low technological maturity, the stringent certification requirements for new fuel pathways and blend limits... the lack of secure and sustainable supply chains for feedstocks, competition for feedstocks with other sectors... potential changes needed to aircraft engines and re-fuelling infrastructure... and the lack of a domestic market." Jet Zero provides no evidence to suggest that these obstacles can be overcome. No SAF yet exists that can deliver 100% reduction in GHGs.

3.36. For context, in 2019 ICAO (p20) estimated that for 100% SAF use to be possible in 2050, that means that by 2035 "328 new large bio-refineries would need to be built each year at an approximate capital cost of US$29 billion to US$115 billion per year."

3.37. Key point: all types of SAF face major uncertainties and obstacles to scaling up production sufficiently due to the high costs and long timescales involved. SAF is exclusively needed by the aviation industry but what guarantees are there that the industry will be prepared to meet the costs? SAF may contribute to reducing aviation emissions to some degree in the long term but we need to cut aviation emissions now in order to allow time for SAF development to be funded; and to understand the extent to which, and the timescale within which, SAF can be deployed commercially at the scale required.

3.38. Zero Emission Flight
There are two possibilities: electric and hydrogen.

3.39. Battery electric flight: aircraft powered by green electric batteries, whether hybrid-electric or fully-electric, will not realistically be viable for anything but very short-haul commercial flights by 2050. Even if we have enough renewable electricity available to meet all our other needs plus the unconstrained growth of aviation, the batteries are simply too heavy for medium- and long-haul flights. Unlike burning liquid kerosene, the weight of batteries does not reduce as the journey progresses. The 2020 UNEP report states that electric flight "will only slightly contribute to reductions in aviation sector emissions." (section 5.3.3). Battery powered aircraft have limited capacity for passengers and freight and can only fly limited distances.

3.40. This BBC report concludes: "long-haul flights by large aircraft are not going to become fully electric any time soon. Certainly not within the next 50 years – and the jury's out as to whether that will even happen this century." It's important to remember that long-haul, international flights by large aircraft are responsible for 96% of UK aviation's GHGs. Duncan Walker, Senior Lecturer in Applied Aerodynamics at Loughborough University, has calculated that the world's largest passenger plane (Airbus A380) could only fly 1,000km with batteries versus its standard range of 15,000km: "To keep its current range, the plane would need batteries weighing 30 times more than its current fuel intake, meaning it would never get off the ground."

3.41. Hydrogen electric flight: as noted above, hydrogen faces serious obstacles of cost, weight, storage, aircraft redesign, fleet renewal, availability of green energy and timescale for its development, testing and commercial deployment. What guarantee is there that the industry will be prepared to meet the costs of developing and scaling up hydrogen? When announcing Jet Zero, Transport Secretary Grant Shapps highlighted the recent trial of a small hydrogen powered plane as evidence of a technology breakthrough.

However he omitted to say that this small aircraft did not use green hydrogen but hydrogen produced from fossil fuels.

3.42. In relation to Jet Zero's scenario 4 (breakthrough in zero emission flight), para 3.17 of the Evidence and Analysis paper states: "In order for such a scenario to be feasible, a number of challenges will need to be overcome. For example, a step change in battery density improvements and other technological advancements will be required (enabled by a greater investment in R&D), certification and safety regulations will need to keep up with new technologies as they emerge, airport infrastructure (e.g. re-fuelling infrastructure for hydrogen and electricity supply for charging electric aircraft) will need a coordinated change to facilitate the use of new aircraft types, and airlines will need to be able to quickly incorporate new aircraft types into their fleets. For hydrogen specifically, the development of a hydrogen strategy and supply-chain across the economy is crucial. Furthermore, for both electric and hydrogen aircraft, the costs of these technologies will ultimately need to fall so that zero emission aircraft offer a cost-effective approach to decarbonisation, relative to using SAF or greenhouse gas removals." Jet Zero provides no evidence that these obstacles can be overcome.

3.43. Currently, the aviation industry has not even decided if hydrogen is the best solution for aircraft with manufacturers such as Boeing stating it is "unlikely" and Airbus having recently admitted that "hydrogen won't be widely used in planes before 2050".

3.44. Para 2.11 assesses the potential high cost of hydrogen powered flight in 2050 and notes that "in the initial years, as the technology first begins rolling out on commercial aircraft, it is likely that the abatement costs will be considerably higher than these estimates". Finally para 3.28: "For zero emission aircraft to be able to operate in the UK, we need to ensure that our airports and airfields have the infrastructure to fuel, take-off and land those planes"

3.45. Para 2.9 of the Evidence and Analysis suggests that electric and green hydrogen aircraft "could start to play a role within the next decade, with 2035 often suggested as a plausible entry-into-service (EIS) date…" Even if this is correct, it's far too late to cut emissions in the next 10 years. Para 2.11 notes: "the timelines for zero emission flight are still uncertain and depend on continual progression in battery, fuel cell and liquid hydrogen propulsion technologies." Para 3.12 acknowledges that these aircraft will "have a minimal impact on total emissions in 2050. This is because these only enter into service on the shortest routes." The shortest (ie domestic) routes account for just 4% of UK aviation emissions.

3.46. Key point: green electric battery powered flight will only be feasible for small aircraft on short haul routes - the batteries are simply too heavy. Green hydrogen is not a scalable solution within the next 20-30 years because of the technical challenges and high costs involved in redesigning aircraft and building extensive new ground infrastructure to use hydrogen; the quantity of renewable energy required to make green hydrogen; and the long timescale for replacing aircraft in airline fleets. What guarantees are there that the aviation industry will be

prepared to meet the cost associated with green hydrogen? Zero emission flight will make only a minimal difference to the aviation industry's emissions even by 2050. We should prioritise electrifying and subsidising zero carbon ground travel options over less efficient and less capable (i.e. carrying fewer passengers) aircraft.

3.47. *Markets and Removals*

3.48. Carbon Offsetting and Emissions Pricing: the only carbon pricing and offsetting schemes currently proposed (ETS and CORSIA) will not be effective in reducing emissions.

3.49. The UK Emissions Trading Scheme (ETS) only applies to domestic aviation and flights to the EU and Gibraltar. The price of ETS credits is low, especially when compared with the actual cost of removing GHGs from the atmosphere so the ETS will not incentivise airlines to reduce their emissions. As the recent OECD International Transport Forum report notes: "Sufficiently high and stable carbon prices are even more important for sectors with relatively costly abatement options, such as aviation. At insufficiently high carbon price levels, and in the presence of cheaper abatement options in other sectors, airlines will likely simply pay the carbon price and pass the cost on to passengers." (p58). The current cost for actually removing GHGs, using DACCs technology, is over £800/tCO2. Para 2.15 of the Evidence and Analysis paper notes that the UK ETS auction price for the December-21 contract was £45.25/tCO2.

3.50. Analysis by Transport & Environment of the impact on aviation emissions resulting from the EU ETS (of which the UK was a member and which has been largely replicated in the UK ETS) found that: "aviation emissions continued to grow by an estimated 1.5% in 2019. This compares to a fall of 8.9% in the emissions from other sectors covered by the ETS, such as power, coal, steel and cement." The evidence shows that ETS is ineffective at cutting aviation emissions. Many ETS credits are simply given away to the aviation industry for free. A report by the Oko Institute for Applied Ecology, covering the period when the UK was a member of the EU ETS, notes: "The sector received mainly free allowances (85%) in the third phase of the EU ETS from 2013 to 2020 and only 15% in [purchased] allowances from auctions." (section 2.4.1).

3.51. The UK government argues that ETS free credits are necessary to prevent 'carbon leakage' - i.e. displacing UK emissions to another part of the world, rather than actually reducing emissions. However there is no practical opportunity for carbon leakage arising from airlines taking passengers between, e.g. London and Edinburgh (or anywhere in the UK to destinations in Europe) via airports and routes not covered by the UK ETS. Who would fly from Manchester to Malaga via Turkey? The likelihood of passengers choosing to do so, or of non-UK ETS airlines successfully attracting passengers to do so (by offering lower fares) is so small that it can be dismissed. Removing aviation's free ETS credits would be an important way to reduce the preferential treatment of aviation compared to other sectors of the economy. It would also increase the incentive effect for emissions

reductions and could generate considerable additional revenue from auctioning ETS allowances to airlines.

3.52. The United Nations CORSIA scheme covers other international aviation carbon emissions. While theoretically charging airlines for some carbon emissions, the CORSIA terms are weak and the majority of emissions will not be effectively offset. CORSIA does not become mandatory until 2027, is due to end in 2035 and will only require airlines to buy credits to offset emissions *above* a 2019 baseline - a level unlikely to be reached globally until at least 2024 due to the impact of the pandemic. For the emissions that are offset, CORSIA credits are cheap. As the Evidence & Analysis paper notes at para 2.16: "Future prices of CORSIA eligible emission units are also uncertain. In 2016, estimates for 2020 used in ICAO analysis ranged from $6/tCO2e to $20/tCO2e. However, these estimates are considerably higher than the prices of CORSIA eligible emission units in recent years". There are also serious credibility problems with international offsetting markets. A higher carbon price would be commensurate with the cost of greenhouse gas removal technology required to re-sequester emissions from conventional jet fuel and residual emissions from alternative jet fuel.

3.53. In order to offset the 36 million tons of aviation emissions remaining in 2050, a *mature* tree coverage area twice the size of Greater London would be needed. Given the timescale involved, a much larger area would actually be needed because newly planted trees absorb less CO2 than mature ones. When CO2 is emitted, it starts heating the atmosphere immediately and continues doing so during the decades that it takes trees in offsetting projects to grow. In addition, trees are not as safe a way to store carbon as leaving fossil fuels in the ground - trees can be cut down or burned by wildfires. Overall, it is anticipated that the purchase of offsets under CORSIA will have very little mitigation effect. Furthermore, based on past experience, it is highly doubtful that the political will exists to make CORSIA significantly more ambitious on an international level.

3.54. Jet Zero gives an example of Loganair's voluntary offset scheme saying: "A £1 Carbon Offset charge will be included in the ticket price for every customer's flight from summer 2021. The mandatory carbon offset programme is the first such initiative by a UK regional airline to directly reflect the cost of offsetting emissions in ticket prices". This £1 per tonne of CO2 charge is meaningless when compared to the projected cost of £320/tCO2 for greenhouse gas removal in 2050 and the current cost of over £800/tCO2.

3.55. It is also very important to remember that the UK ETS and CORSIA do not cover 50-66% of aviation's climate damaging emissions because they only apply to CO2, not the other greenhouse gas emissions caused by flying. Recent research has found that aviation's non-CO2 emissions increase the industry's total global heating effect by a factor of two to three. These non-CO2 effects could be included in emissions trading schemes by introducing a simple multiplier for CO2 emissions, based on the radiative forcing of non-CO2 effects. This is not proposed in Jet Zero.

3.56. More fundamentally, the 2020 UNEP report notes: "The nature of offsetting means that there will be no absolute reductions in the aviation sector itself

through the use of such credits, and could in fact result in a potential increase in CO2 emissions. Instead, aviation relies on other sectors' avoidance or removal of carbon. By not only continuing to emit but potentially increasing emissions, the net effect will be that no overall reductions can be achieved. This outcome is in stark contrast with the reduction pathway necessary for limiting warming to within 1.5°C… Regardless of concerns around the net benefit of offsetting, Scheelhaase et al. (2018) estimate that CORSIA will result in the offset of only 12% of total international and domestic aviation emissions by 2030" (section 5.4.2).

3.57. The report goes on to warn: "International aviation currently intends to meet its [carbon reduction] goals through heavily relying on carbon offsets, which do not represent absolute reductions, but at best, provide time to transition to low-carbon fuels and introduce energy efficiency improvements. At worst, offsets create a disincentive for investment in in-sector decarbonization and delay the necessary transition. Current carbon offsetting is clearly not a long-term solution and therefore needs to be minimized and eventually phased out." (section 5.5). Jet Zero supports the use of offsets by the aviation industry.

3.58. The CCC's 6th Carbon Budget concluded that CORSIA is not compatible with the UK's net zero commitments and told the government that it should not be used to contribute to meeting the UK's net zero by 2050 carbon reduction target (p425).

3.59. Key points: offsetting schemes do not stop aircraft from immediately putting emissions into the atmosphere and they typically involve tree planting, which takes decades to remove emissions from the atmosphere. The UK ETS is an ineffective measure for incentivising airlines to reduce their emissions because of the low cost of credits and the quantity of credits given to the industry for free. The United Nations Environment Programme (UNEP) estimates that the international CORSIA aviation offsetting scheme "will result in the offset of only 12% of total international and domestic aviation emissions by 2030". The CCC advised the government not to use CORSIA as a way to meet our 2050 net zero target but Jet Zero ignores this advice. The 'polluter pays' principle requires the immediate introduction of realistic carbon prices for fossil fuelled flight.

3.60. Carbon taxes: The 2020 UNEP report notes that raising the cost of aviation "will likely suppress demand … which may ultimately be the most effective means to manage the sector's emissions." (section 5.5). The latest report by the OECD's International Transport Forum notes on p11: "Phasing out fossil-fuel subsidies, phasing in carbon prices, and internalising the costs of carbon emissions into consumer and firm decision making are important to enabling the green energy transition." It also recommends that "Covid-19 recovery plans should be tied to clear decarbonisation requirements..." This has not been implemented in UK aviation bail-outs.

3.61. Jet Zero's Policy Proposal on p37 is welcome: "We will strengthen carbon pricing for aviation to ensure we continue to apply the 'polluter pays' principle

and consider incentives for greenhouse gas removal methods." However neither Jet Zero nor the government's recent consultation on aviation taxation propose to tax aviation fossil fuels. The government actually proposes to lower the basic rate of Air Passenger Duty - the only form of tax which is levied on the UK aviation industry. Current APD rates are already far below the revenue that the government would collect in tax if it priced aviation fuel with the same fuel duty rates as petrol or diesel for road vehicles. The Treasury has previously estimated that imposing duty and VAT on aviation fuel at the rates paid by motorists could generate revenue in excess of £10billion per annum. APD could also be levied on arrivals, as was the case in the USA for 20 years.

3.62. Aviation industry advocates may suggest that taxing kerosene is prevented by international law but this is not true. The Chicago Convention only prohibits a tax on fuel that is already on board, i.e. not on refuelling. The UK government could, and should, immediately impose a tax on aviation fossil fuels for all domestic and EU-bound flights. The rate should mirror the level of damage that fossil fuelled flying does to the climate, e.g. set at the same rate as the current cost of effectively removing GHGs from the atmosphere. This would send a clear price signal to both the industry and consumers.

3.63. Research by Clarity/ATA for the Dept for Transport found that increasing UK flight ticket prices would be a particularly effective way to cut UK aviation emissions. Considering the risk of 'carbon leakage' (as discussed above) if UK flight ticket prices rise, the report found that: "... a decrease in emissions from UK aviation is matched by a decrease in emissions from non-UK aviation. This is because the main effect of a policy which increases UK-specific ticket prices is to decrease passenger demand to and from the UK… passenger journeys are generally round-trips with both an arriving and a departing leg. If demand decreases on these journeys, half of the emission reduction will be on departing flights, and half on arriving flights... This means that the net global reduction in CO2 will be roughly twice the reduction in CO2 from UK departing flights only" (p5).

3.64. Aviation industry advocates also claim that taxing ticket sales would have a disproportionate effect on low-income travellers. However, the OECD's International Transport Forum report notes on p67: "most flights are taken by a small and relatively wealthy segment of the global population: it is estimated that 1% of most frequent flyers accounts for over half of passenger air transport CO2 emissions (Gössling and Humpe, 2020). Ticket taxes can also be designed and implemented in a way that does not disproportionately burden low-income or other categories of individuals."

3.65. Jet Zero also leaves a significant amount of uncertainty about the government's valuation of carbon emissions. For its scenarios 1 and 2, an assumption of the BEIS central carbon price on all flights, reaching £231/tCO2 in 2050 (2018 prices) has been adopted. However paragraph 2.18 of the Evidence and Analysis document recognises that:

a. There is uncertainty about the values to use when modelling future carbon prices.

b. The value the government places on changes in carbon emissions is currently under review now that the UK has increased its domestic and international ambitions by committing to 100% net zero by 2050.
c. Accordingly, current BEIS central carbon values are likely to undervalue GHG emissions in the long term since they were developed by reference to the previous decarbonisation target of 80% reduction in emissions by 2050.
d. The potential impact of placing a higher value on GHG emissions has been explored by using the existing BEIS high carbon values series in our scenarios, in addition to the prescribed central values.

3.66. Jet Zero gives no indication when the review of values (in sub-para b. above) will be completed nor whether it will be considered before finalising the Jet Zero strategy. Contrary to sub-para d. above, there seems to be no analysis of scenarios 1 and 2 using the existing BEIS high carbon values in the Jet Zero consultation documents.

3.67. Carbon pricing requires putting a realistic price on fossil fuels immediately. This would help to incentivise the aviation industry to invest in synfuel and GGR technology developments; and ensure the cost of fossil fuelled flying reflects the true damage that it does to the climate. How could the government justify aviation users paying a low carbon price over the coming decades while the rest of society pays an increasing carbon price – particularly given that flying is an emissions-intensive activity utilised by predominantly high income groups?

3.68. <u>Key points:</u> putting a realistic price on carbon immediately is crucial to make the cost of fossil fuelled flying reflect the true scale of the damage it does to the climate. Increasing the cost of fossil fuelled flying is likely one of the most effective measures to cut aviation emissions by reducing demand in the longer term - and there ways to achieve this without disproportionately impacting low income households. However Jet Zero makes no proposals to tax aviation fossil fuels, nor to tax ticket sales. The government's recent consultation on aviation taxation proposes to cut Air Passenger Duty and makes only one proposal to make those who fly most, pay most

3.69. <u>Greenhouse gas removals:</u> Jet Zero forecasts that 36.7% of UK aviation emissions in 2050 will still have to be removed from the atmosphere. As well as tree planting schemes (see above), the strategy talks of using greenhouse gas removal (GGR) methods. However this technology only exists at a small scale and the prospects of scaling it up to an industrial level face significant obstacles of cost and time. It would be more prudent simply to reduce the amount of emissions that aircraft put into the atmosphere in the first place.

3.70. Jet Zero itself says: "GGRs are not yet implemented at commercial scale, either in the UK or globally, and forecasts of costs and scale-up potential are highly uncertain" (p36). Yet the accompanying Evidence and Analysis paper claims at para 2.19 that "there would be sufficient GGR capacity to offset the residual aviation emissions that are estimated in all the scenarios..." but offers no evidence or explanation of that analysis. Likewise, there is no

evidence provided to support the assertion in para 2.22: “This analysis suggests that capping demand may not be necessary to reduce emissions to levels which can be offset by GGRs to achieve net zero” even though the same para accepts: “There is much uncertainty…”

3.71. Para 2.20 considers the future costs involved in different types of GGR technology: "At the lower end, in their Sixth Carbon Budget report, the CCC suggest that BECCS costs could be around £50-160/tCO2e removed, and DACCs costs around £120-£180/tCO2e removed in 2050. Research by Vivid Economics, which considers how GGRs may support a net zero target, finds the costs of BECCS may be around £80-230/tCO2, and DACCS around £160-470/tCO2." Currently the cost for DACCs is over £800/tCO2. What guarantee is there that the industry will meet its share of the high cost involved in scaling up GGR to sufficient quantities in time?

3.72. It’s important to note that both BECCS and DACCS GGR technologies use large quantities of water which is very likely to prove an issue in a future water-scarce world. A New Scientist report in 2021 suggests that BECCS may mean “water shortages for 4.5 billion people.” Cultivating energy crops in large monoculture fields for BECCS would also deepen the dependency of synthetic fertilisers, pesticides and herbicides, destroying biodiversity. This can lead to land-use change emissions that are worse than fossil fuels. They can also result in humanitarian impacts e.g. land conflicts, rising food prices, water scarcity and pollution that affects neighbouring communities to plantations and refineries. It is possible to minimise the risk of these impacts by only utilising ‘sustainable’ feedstocks (e.g. biomass waste from cities, farms and forestry) but this is likely to completely utilise the feedstocks and prevent biofuels being used in transport e.g. for aviation.

3.73. The Chief Executive of the CCC recently told the Parliamentary Environmental Affairs Committee that Jet Zero’s reliance on technology and the lack of any focus on reducing demand for aviation would please the industry and added: “But obviously a big risk is that the technology doesn’t deliver.” He also said the aviation industry must meet the costs of developing GGR technologies rather than rely on using tree planting to claim they are reducing emissions.

3.74. Key point: there is a high level of uncertainty about the costs and potential for sufficient GGR technology development and deployment by 2050. What guarantees are there that the aviation industry will be prepared to meet its share of the costs involved? Cutting aviation emissions now will reduce the quantity of emissions that need to be removed from the atmosphere in 2050. We need time for GGRs to be developed and tested; and to understand the extent to which, and the timescale within which, they can be deployed commercially.

3.75. *Other matters*

3.76. Aviation emissions are a very British problem: Jet Zero says that global aviation emissions are 17 times greater than the UK's international aviation emissions. However this fails to point out that the UK only accounts for around 1% of the global population. So per capita, UK aviation emissions are much higher than the global average.

3.77. The impact of Covid on airport expansions: Jet Zero asserts that "the industry's need to rebuild from a lower base is likely to mean that plans for airport expansion will be slower to come forward." This is contradicted by what is currently actually happening. There are seven UK airports (Heathrow, Stansted, Luton, Leeds-Bradford, Bristol, Southampton, Manston) with live planning applications seeking permission to expand and not one has abandoned or reduced those plans in light of the Covid pandemic.

3.78. Influencing consumers: the most effective way to do this is most probably by introducing a realistic carbon price that would send a price signal to consumers, rather than by using a labelling metric, which may or may not influence behaviour.

3.79. International cooperation: para 3.2 of the Evidence and Analysis paper notes: "Achieving net zero will also rely heavily on a collaborative, international effort and these scenarios should be viewed in that context - these scenarios *will not be possible* based on domestic action alone." Jet Zero proposes no contingency plan if the necessary level of cooperation does not materialise and past experience does bode well. The government could implement effective, domestic measures to control aviation emissions - e.g. by stopping airports from expanding and by introducing realistic taxes on aviation fossil fuels. Domestic demand management is within the government's control and is a key CCC recommendation.

3.80. Five yearly review: Jet Zero proposes to review progress on its technological solutions every five years. Given the urgent nature of the climate crisis and the need to make radical reductions in GHGs by 2030, this proposal is wholly inadequate. The government should carry out a verifiable, annual review of the extent to which aviation emissions are reducing. If they are not, further measures should be introduced as quickly as possible, including measures to limit demand for flying.

3.81. Non-CO2 emissions: in addition to CO2, aviation emits other GHGs: nitrogen oxides (NOx), soot, and water vapor, which create contrails and cirrus clouds. While Jet Zero acknowledges that these exist and are a problem, it says little about how they should be addressed. This is deeply disappointing. As noted above, recent research has found that non-CO2 emissions exacerbate aviation's climate damaging effects by a factor of two to three: "...

the warming footprint of aviation is at least twice as large as its carbon footprint in the coming decade, clearly highlighting that non-CO2 effects are non-negligible to assess the contribution of aviation global warming." (p9). Jet Zero needs to show far greater ambition on reducing non-CO2 emissions, for example, it could propose a simple multiplier of 2.5 to carbon prices to make the cost of flying reflect the full extent of aviation's impact on the climate.

3.82. While increasing fuel efficiency can lead to a reduction in CO2 emissions per mile flown, research by Schumann (2000, p1) shows it can also lead to an increase in non-CO2 emissions. This means that reductions in CO2 from a given flight, due to improved fuel efficiency, may be counteracted by the non-CO2 warming effect of contrails. Without assessing the effect of non-CO2 emissions, it cannot be guaranteed that the climate impact per passenger-mile would actually reduce.

3.83. Recent research by Klower et al warns on p10: "... low-carbon fuels could replace fossil fuels over the next decades - a strategy that has to be treated with caution, as non-CO2 climate impacts of alternative fuels are less well understood (Burkhardt, Bock, and Bier 2018)." Furthermore, scaling up SAF as a tool for reducing non-CO2 will be hindered by air traffic growth and the associated increase in total fuel consumption. We have limited global resources for truly 'sustainable' SAF and we are also limited by the timescale for scaling up its supply. So the higher the total fuel consumption, the lower the proportion can be provided by SAF. This reinforces the need for policies that limit and reduce total aviation fuel consumption.

4. *Conclusion*

4.1. Jet Zero states at 3.42: "The approach we intend to set out in our strategy will prioritise in-sector reductions through technological and operational improvements, then seek to address residual carbon emissions through robust, verifiable offsets and additional greenhouse gas removals. It relies on the rapid scaleup and deployment of technologies that are currently at a relatively early stage of development..."

4.2. In so doing, Jet Zero ignores the urgent need to reduce aviation emissions in the next 10 years. A 3% increase in CO2 emissions by 2030 is completely contrary to the IPCC's 'code red' warning that we must achieve global emissions reductions of 45% by 2030 from 2010 levels to have any chance of keeping average global temperature rise to below 1.5C. Jet Zero also ignores repeated advice from the CCC to urgently manage down demand for aviation (and to avoid the use of offsets) in order to at least limit the growth of aviation emissions in the next 10 years. As the Oko Institute for Applied Ecology observes: "The simplest and most effective way of making aviation climate neutral is the avoidance of flights."

4.3. While acknowledging the very expensive, near term investment costs needed to scale up the proposed technological developments, Jet Zero fails to consider whether the aviation industry will actually meet those costs. It

seems to assume these very high costs will be met by the taxpayer. That approach would not implement the 'polluter pays principle' which the government itself says is important. Expanding airports at this time can only happen by using 'business-as-usual' technology, which means increasing GHGs. In the crucial next 10 years, alternative fuel supply cannot be scaled up quickly so any fossil fuelled flying should incur the real cost of removing GHGs from the atmosphere - currently over £800/tCO2

4.4. The words 'uncertain', 'uncertainty' and 'uncertainties' appear 27 times in the Jet Zero consultation documents. Para 4.3 the Evidence and Analysis paper recognises: "There is significant uncertainty surrounding the abatement potential, uptake and costs of the measures described in this document and therefore these scenarios [for aviation decarbonisation] should be seen as *illustrative pathways* rather than forecasts." This strongly suggests that the government does not actually have any forecast in which UK aviation can reach net zero by 2050 using only the measures proposed in Jet Zero, while allowing unconstrained passenger growth and airport expansions.

4.5. By contrast, recent research by Klower et al finds: "if global aviation were to decline by about 2.5% per year, even with no change in current fuel mix or flight practices, the impacts [would lead]... to no further increase in aviation-induced warming with immediate effect… Consequently, aviation would not actually need to cease immediately to end its contribution to further global warming - an optimistic message given the limited options of near-operational alternatives to carbon-intensive intercontinental flights" (p7). A small annual reduction in flights would completely stop aviation emissions from rising, even without any of Jet Zero's proposed solutions. It is deeply disappointing that the government appears to have rejected demand control measures before its consultation was even published.

4.6. As the Aviation Environment Federation says: "technology ambition is important but without a plan to make sure it's delivered, or that the industry pays for it, what confidence can we have that the aviation sector will rapidly step up the pace?" Allowing aviation to expand in advance of the development, scaling up and deployment of new technologies and alternative fuels is completely the wrong way round. The precautionary principle requires us to prevent flights from increasing until and unless the promised improvements have actually materialised at a commercial scale and delivered the necessary emissions reductions.

4.7. While the Government remains relaxed about growing passenger numbers and airport expansions, aviation emissions will grow and grow - while we wait and hope for the best. This is a gamble that no responsible government should take. We need more than a 'wing & a prayer' to stop climate breakdown - we need credible action now.

Note: this briefing would not have been possible without very extensive guidance from Finlay Asher at Green Sky Thinking and Bill Hemmimgs at Clean Up Aviation. However any errors or omissions are entirely due to the author, Nick Hodgkinson of GALBA, not Finlay or Bill.

APPENDIX 1

Climate Change Committee recommendations

The CCC has repeatedly warned the government that technological solutions alone will be insufficient to make the UK aviation sector net zero by 2050.

- In September 2019, the Chair of the CCC, Lord Deben, wrote to Grant Shapps saying: “Zero-carbon aviation is highly unlikely to be feasible by 2050.”
- In the 6th Carbon Budget, the CCC called for measures to constrain increasing demand for flying as well as for the rapid development of new technology and alternative aviation fuels. They also said that the use of international carbon offsetting schemes should not be used to meet the UK’s net zero target.
- The CCC reiterated their advice in their Progress Report to Parliament in June 2021. Among the many recommendations, the CCC said:
    - “An assessment of the UK’s airport capacity strategy and a mechanism for aviation demand management should be part of the aviation strategy” (p32)
    - “Government should not plan for unconstrained leisure flying at or beyond pre-pandemic levels in its strategy for airport capacity and demand management” (p72)
    - “Government must recognise that planning for an ever growing aviation sector is not consistent with the UK’s Net Zero target as part of its aviation decarbonisation consultation and strategy” (p74)
    - “Our advice from the Sixth Carbon Budget remains unchanged – there should be no net expansion of UK airport capacity unless the sector is on track to outperform its net emissions trajectory. Government needs to assess its airport capacity strategy and develop and put in place a demand management framework to assess and, if required, control sector GHG emissions and non-CO2 effects” (p185).
    - “Outperforming the net emissions trajectory means making significant progress on nascent and untested technologies like hybrid electric planes, and developing and scaling up markets for sustainable aviation fuels (SAF) and greenhouse gas removals.” (p185)
    - “It is not possible to have certainty today over the pace of development of these technologies in future. It is therefore difficult at present to justify [airport] capacity expansion on the basis of outperforming the emissions trajectory, particularly given the uncertainty around the permanence of impacts on aviation demand from COVID-19.” (p185)
    - “Priority recommendation: There should be no net expansion of UK airport capacity unless the sector is on track to sufficiently outperform its net emissions trajectory and can accommodate the additional demand. A demand management framework will need to be developed (by 2022) and be in place by the mid-2020s to annually assess and, if required, control sector GHG emissions and non-CO2” (p211)

Appendix 2

Useful contacts for MPs and journalists

Aviation Environment Federation: Tim Johnson and Cait Hewitt
An initial statement on Jet Zero by the AEF can be found here.

- 0203 859 9371 or info@aef.org.uk
- Website: https://www.aef.org.uk/press-enquiries/
- Twitter: @The_AEF

Green Sky Thinking: Finlay Asher, expert on aircraft design, ex-Rolls Royce designer.

- 07984 602404 or finlayA@hotmail.com
- You Tube: https://youtube.com/channel/UCE8tv_Kk-bLBqLjwc0BkCfw
- Video on Sustainable Aviation Fuels (SAF):
- https://www.youtube.com/watch?v=XNgmKyw4qfo
- Facebook: https://m.facebook.com/GreenSkyThink
- Instagram: https://instagram.com/greenskythinking?utm_medium=copy_link
- Twitter: @Green_Sky_Think

Professor Julian Allwood: Professor of Engineering and the Environment at the University of Cambridge, IPCC lead author and Head of the Use Less Group and UK FIRES research group. You can see his recent presentation on the limits of new technologies to contribute to net zero here.

- Academic Division: Civil Engineering
- Research group: Structures
- Telephone: +44 1223 3 38181
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- Personal website

New Economics Foundation: Alex Chapman, senior researcher on aviation
Recently published a report on the cumulative impact of UK airport expansion plans, setting out the scale of the climate impact and monetising that impact using Treasury calculation methods: Turbulence Expected.

- Email: alex.chapman@nefconsulting.org
- Website: www.neweconomics.org