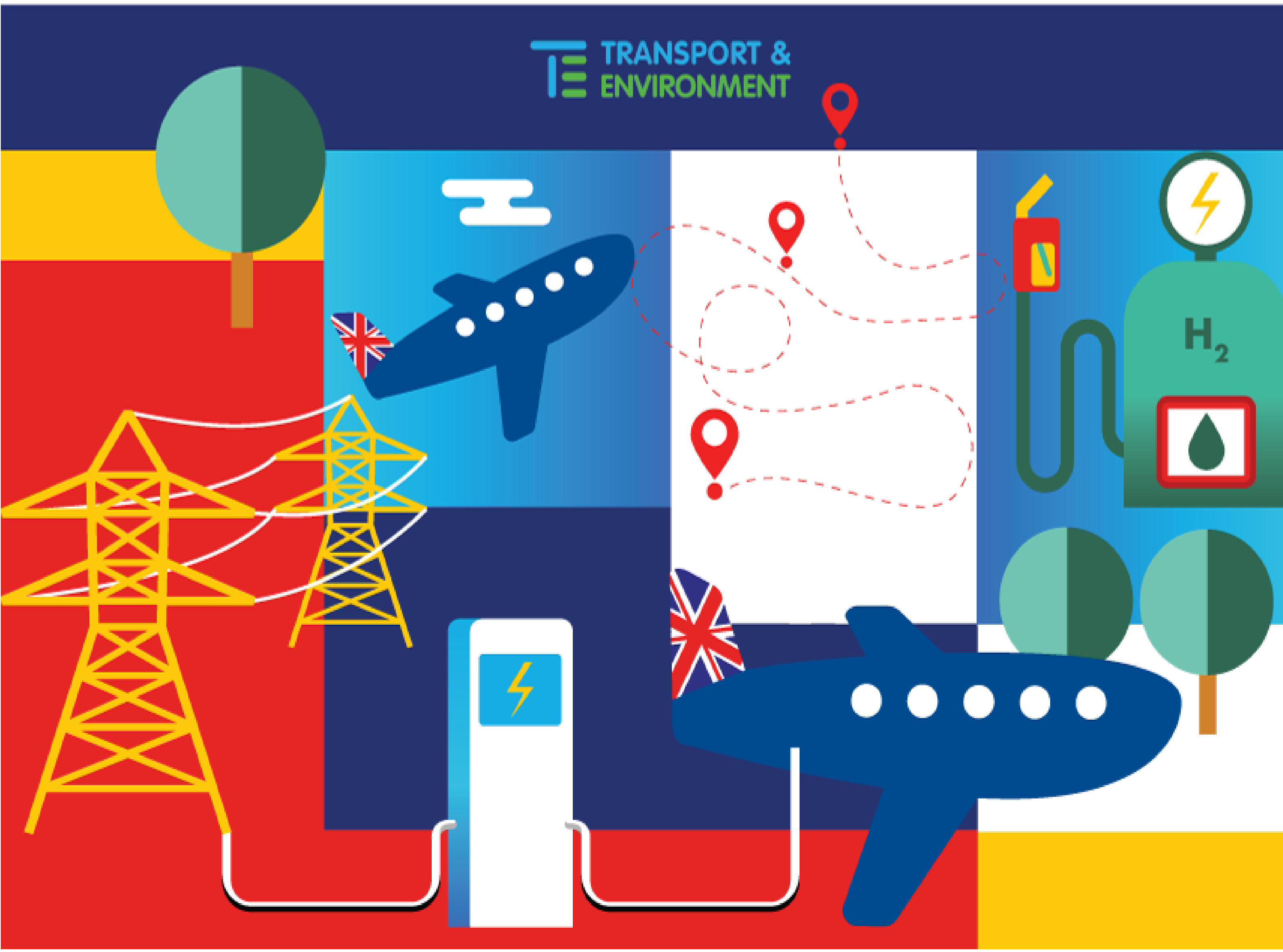
Reducing UK Aviation's Climate Impacts

TRANSPORT & ENVIRONMENT



Reducing UK Aviation's Climate Impacts

How to set UK aviation on a net zero trajectory

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Executive Summary

UK aviation is beginning to emerge from the worst crisis in its history. The pandemic has reduced the numbers of passengers and flights to a fraction of previous levels. At the same time, the urgency around the climate crisis has grown, and the UK Government has committed itself to deliver net zero aviation by 2050.

To date, measures to decarbonise UK aviation have been virtually non-existent. Since 1990 greenhouse gas emissions from the sector have steadily risen, in direct contrast to overall UK emissions. Attempts to decarbonise the sector through international measures adopted via the UN aviation agency have failed, and not a single country legislates for the non-CO_2 warming effects that flying causes. This is important, as (over 100 years) the non-CO_2 effects cause twice as much warming as the carbon emissions.

However, the 2020s have so far seen notable policy progress. The Jet Zero Council was established in July 2020, and the Government announced an intention to consult on a SAF mandate In November 2020. In April 2021, the UK Government announced an intention to include emissions from all departing flights from the UK in its carbon budgets. By taking responsibility for these emissions the government has committed itself to implementing policies that ensure carbon emissions from the sector reach net zero by 2050.

2022 is a crucial year in climate change policy terms for UK aviation. The UK government will consult and decide on both how to make the UK ETS net-zero compliant; what the specific details of the sustainable aviation mandate (SAF) mandate are; and lay out a final Jet Zero strategy.

Civil society, the aviation industry and the Government are all agreed that the sector should reach net zero carbon emissions by 2050, however there is disagreement about how to do so. This policy paper suggests that, in the short-medium term, increased levels of investment needs to be directed into zero emission aircraft (ZEA) and SAF: these in combination are the only tools that can fully decarbonise the sector. This increased spending should be funded by borrowing against future revenues from increased taxes on the industry in the medium to long term: principally by imposing a kerosene tax from 2025; but also by broadening the scope of the UK ETS to cover all carbon emissions from all departing flights; and, introducing specific non-CO_2 charges. This spending will not only boost the UK aviation's decarbonisation efforts, but should also turn the UK into a global leader of ZEA and SAF development and deployment.

T&E believes that ZEA and SAF policies should follow a *Support, Regulate, Ban* pattern. This means that a new technology should be supported, using public funds in the early years. Regulation then ensures the increasing commercial use of the new technology. Finally, a ban on the old technology should be implemented - and the exact date of that ban should be communicated a long time in advance.

Both ZEA and SAF are still in the support stage, but the regulate and ban stages should be agreed on quickly: the design of new rules should be finalised in 2022 to provide policy certainty to the sector. This paper recommends that airlines that serve domestic routes should be required to use ZEA for a small percentage of its flights / miles flown from 2028. This percentage should then increase over the next decade until all domestic routes have to be flown by ZEA in 2040. In effect this is the ban stage, where hydrocarbon-burning planes would not be allowed to fly domestic routes.

There have been many industry discussions about the details of the regulate stage for SAF, but it is commonly agreed that a SAF mandate should, and will, be implemented. This paper suggests policies that should ensure that the SAF provided by the mandate has high sustainability criteria. Furthermore, separate rules, regulations and targets are needed for waste-based and synthetic SAF, recognising the limited feedstock availability of the former and high current cost of the latter. A ban on conventional kerosene use should take effect from 2050.

Building UK industries for both SAF and ZEA requires investment throughout the 2020s, starting now. To retrospectively pay for this up-front investment, a kerosene tax should be announced soon, to take effect from 2025. This paper demonstrates how such a tax could be immediately applied to flights that produced 12 $MTCO_2$, or 30% of total UK aviation emissions in 2019, and potentially on flights that produced 23 $MTCO_2$, or over 60% of emissions in 2019. Changes should also be made to the UK ETS, to align it with a net zero compliant pathway and include non-CO_2 charges.

The proposed suite of policies will progressively move aviation towards carbon neutrality in the long term. But in the short-term, it is also important to ensure emissions do not rise above 2019 (pre-pandemic) levels. Before the pandemic, greenhouse gas emissions, driven by an increased number of flights, had been steadily rising every year. Whilst demand in itself is not the problem, the corresponding emissions are and therefore, this paper suggests ways to ensure the industry's costs automatically rise if emissions do (and that costs fall when emissions fall), via the tax system.

The pandemic has caused a collapse in flying, but the climate crisis did not recede. The industry will reset, but this reset must be greener, and reflect the urgency that the climate crisis demands. This reset presents an opportunity to build back better towards a net zero future.

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1. UK Aviation and the Climate Crisis

1.1. Introduction to the paper

2022 is a crucial year in the government's efforts to decarbonise UK aviation. By the end of the year, if all has gone to plan, the Government should have laid out its long-term "Jet Zero" plan on how to decarbonise the sector, whilst also providing details about the SAF mandate and how the UK ETS will be made net zero compliant. This paper focuses on near-term policies that should be announced before 2023, that come into effect prior to or around 2025, and will set the sector on a pathway to make a meaningful contribution to the UKs crucial climate target of reducing emissions by 78% by 2035.

The main crux of this policy paper is that, from now until 2030, decarbonisation efforts should be dramatically boosted, via increased government spending and targeted regulation. Government funding should be dramatically increased to ensure sustainable aviation fuel and zero emission aircraft - the only two tools that can fully decarbonise the sector - are in regular usage by the end of the decade, and in a position to dramatically grow throughout the 2030s. This funding should come from borrowing against future revenues of a kerosene tax, and that all policies should be implemented quickly: at speeds the climate crisis demands of it.

This paper gives some details about the current state of UK aviation and its environmental record. It then goes on to provide overviews of both the ZEA and SAF, shows what the UK potential is for both, and then suggests policies that will ensure uptake of both technologies moves rapidly.

The paper then moves on to showing that, contrary to perceived wisdom amongst many industry observers, a kerosene tax can be applied to a significant amount of UK-uplifted fuel. This tax would provide a 'warchest' of funds to pay for the above mentioned ZEA and SAF support. It also makes suggestions as to how the UK emission trading scheme should be reformed.

Finally, the paper outlines how air passenger duty can be used as a 'backstop', to ensure that emissions never breach 2019's levels again.

1.2. Context

"If there's one great positive that today's aviation sector can cling to, it's that the market is always going to grow over the years and decades ahead….. But this time, aviation has to earn the right to grow by addressing its environmental impacts"

So said the UK's Transport Secretary, Grant Shapps, in a speech given to the Royal Aeronautical Society in November 2020 [1]: a speech that highlighted the twin challenges the aviation sector faces right now - adapting to the post-pandemic world, whilst reducing, and eventually eliminating, greenhouse gas emissions that the sector produces in the coming decades. The scale of these twin problems can be demonstrated in two graphs. Flight numbers plunged in April 2020, and every month since has been a fraction of pre-pandemic levels: This is reflected in the number of passengers arriving to the UK, shown below in Figure 1. However, prior to the pandemic greenhouse gas emissions from the aviation sector had been rising inexorably, with seemingly little prospect of the deep cut in emissions that (rest of the) UK economy had undertaken in the same time period, shown in Figure 2.

Figure 1: Air passenger arrivals since the outbreak of Covid-19, as a percentage of the equivalent month in 2019 [2].

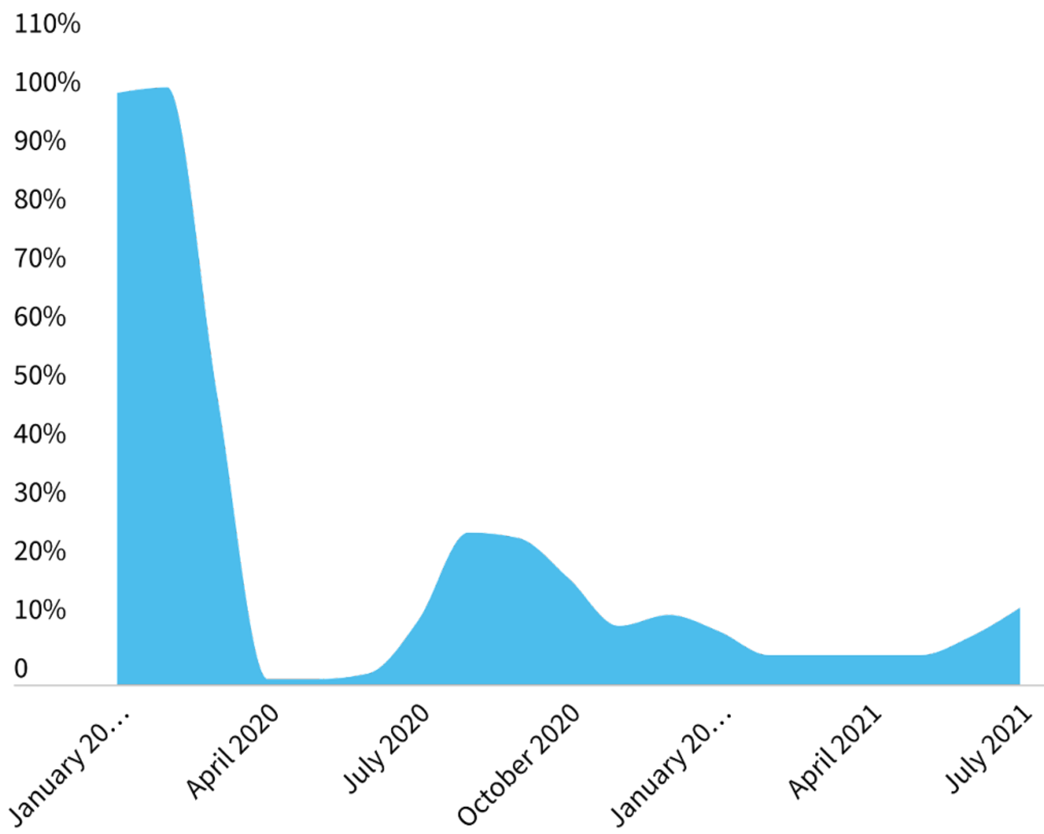

Figure 1: Passenger numbers have been dramatically reduced as a result of the pandemic

Figure 2: Percentage change in total UK emissions and emissions from UK international aviation

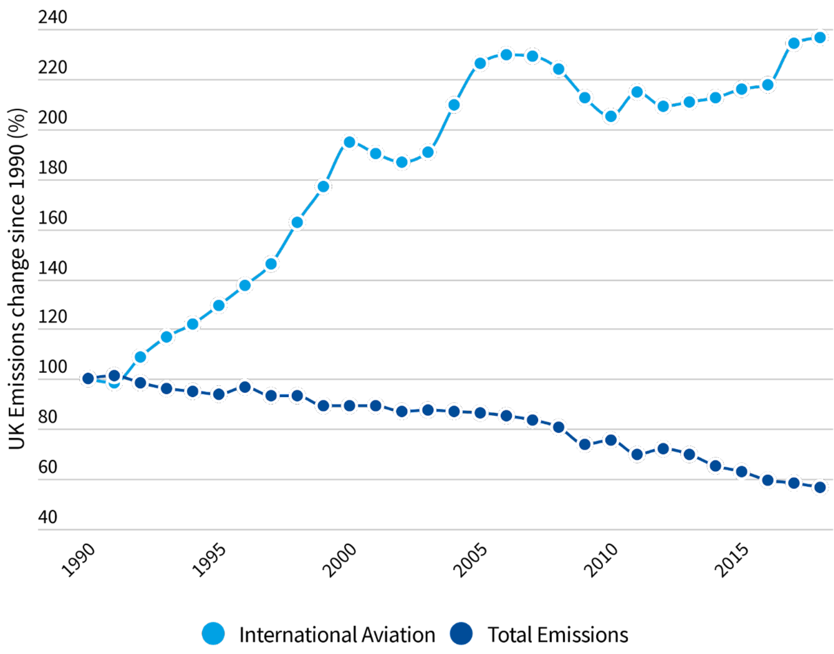

Figure 2: The UK's international aviation's emissions have increased by 125% since 1990 (from 17 $MtCO_2$), which compares poorly to the reduction in the UK's territorial emissions of 43% [3].

The environmental policy landscape has now shifted. Prior to this year, only emissions from domestic aviation were included in the UKs carbon budgets. However, the UK Government has followed the advice of the Climate Change Committee [4] and will formally include them [6]. The recently announced legally-binding target of a 78% emissions reduction by 2035 (compared to 1990 levels) now also includes emissions from all UK-departing flights, no matter the end destination.

A credible policy plan is now urgently needed to ensure that aviation 'plays its part' in the near term. This needs to ensure there is no gap between government ambition and policy. Furthermore, this needs to ensure that aviation emissions never reach 2019's levels again, whilst taking into account the fact that the aviation industry is still adapting to the post-pandemic world.

1.3. Climate effects

British citizens like to fly, and more fly internationally than any other nationality - 8.6%, or 1 in 12 of all international passengers worldwide in 2018 were British [7]. The UK has the largest air transport system in Europe, and is the third largest globally, behind the USA and China. Pre-pandemic (2019), the UK carried just over 300m passengers [8],[1] dwarfing the figures of the other European countries (only Germany and Spain also carried over 200m passengers that year [9]). Pre-Brexit, the UK regularly accounted for around a quarter of all passengers carried amongst EU nations [10].

[1] Data is specifically to be found in Table 10.3 of the associated citation

All of this came at a massive environmental cost. In 2019, UK-departing flights (domestic and international) were responsible for emitting 38.2 $MtCO_2$, 9.3% of the UKs overall 'territorial' carbon emissions [3]. UK-departing flights were responsible for 4% of aviation's global emissions [11]: the third highest absolute amount globally, behind the USA and China. The UK is also the 4th highest emitting nation when measured on a per-capita basis, behind the UAE, Australia and the USA respectively.[2] In 2019, British Airways alone emitted as much CO_2 as all the vans on the UKs roads combined [12].

Aviation also causes a significant amount of warming due to the non-CO_2 effects. These effects represent over two thirds of (global) aviation's total climate impact over 100 years [13]. When aircraft burn jet fuel, some of the waste emissions change the chemical composition of the atmosphere. The main effect comes from the forming of contrails,[3] which traps heat. Other effects come from the release of NOx, sulphate particles and water vapour. Crucially, these tailpipe emissions have different effects depending on the atmospheric conditions, and therefore the non-CO_2 warming effects caused by an individual plane is not proportionate to the amount of miles flown, or fuel burnt. Regardless, since it is now firmly established that the aviation sector as a whole is not only causing additional warming from these effects, but that these effects actually cause more warming than the carbon effects [14], these emissions must be legislated for, and the polluter pays principle applied. The UK should introduce specific non-CO_2 charges onto the aviation industry as soon as possible. There are ways to reduce non-CO_2 climate effects, such as by rerouting and using fuel with reduced aromatic contents. By charging non-CO_2 costs the industry will be incentivised to actively reduce the warming effect non-CO_2 effects cause.

UK aviation has made some significant environmental commitments. It has not only declared that it wants to achieve decarbonisation via the industry group *Sustainable Aviation*, but has laid out a roadmap of how to do so by 2050 [15]. Whilst it is necessary to question some aspects and challenge some assumptions contained within the roadmap, it shows that UK aviation is seriously considering how to limit its environmental impact. Furthermore, the UK Government launched the 'Jet Zero Council' in 2020, whose explicit goal is to "demonstrate flight across the Atlantic - without harming the environment" [16]. This ambition is backed up by comments given by the Transport Secretary in January 2021 [17]:

"Our single overriding goal is to make net zero a possibility in aviation and to do so well before 2050"

In short, the collective will to decarbonise aviation is there, but the policies needed to achieve these collective goals are currently lacking. The easy bit of declaring what is needed has now been done. The hard bit of exactly how to do so now needs to be addressed.

1.4. Policies

Globally, aviation has always been considered 'hard-to-decarbonise', but it is now becoming clear that, with the right policies in place, aviation can not only reduce its emissions to net zero, but can do so before 2050. This will be achieved via the introduction of zero-emission aircraft on shorter routes, and the use of

[2] T&E working using ICCT emissions data and World Bank population data.
[3] Contrails, or condensation trails, are the long cloudy strips that form when moisture in ice-saturated air freezes around soot particles released when jet fuel is burned.

sustainable aviation fuel on longer routes. However, you cannot 'bend the curve' by only thinking about 2050, you have to start now. This paper focuses on policies that should be announced before 2023, that come into effect prior to or around 2025. These policies will start the process of lowering aviation emissions, helping ensure that it is on track to meaningfully contribute to the UKs 2035 target. The proposals are a framework that helps to "build (the industry) back better". Many of the suggestions were previously suggested in T&E's responses to the recent Jet Zero and SAF Mandate consultations [18] [19].

The industry has benefited enormously from government support over the past year during the pandemic. The Bank of England has lent over £5bn to the sector [20], and 55,000 aviation employees have been furloughed [21]. Government support should not be long-term though, but since the industry is adapting to a new, post-pandemic reality, additional short-term, pre-2025 costs have been largely avoided (a time period that reflects industry estimates of when things will be 'back to normal' [22]). This does mean that the industry will have to adapt over the medium term. The UK Government, and by extension, the UK's taxpayers will have to fund some initiatives in the short-term. However, these should not be seen as a cost to the government, but as an investment: whilst there will be initial government spending, this will be paid back via increased tax take, more exports and increased GDP in future years. Decarbonising aviation brings with it new economic opportunities, in terms of jobs, exports and GDP. In fact, if implemented, the policies in this paper should help turn the UK into the world leader in zero emission fuel and planes.

Our vision of UK aviation is that in 2050:

- All flights that can be flown using zero-emission aircraft are, including all domestic flights and a lot of 'near' European destinations.
- Flights by jet aircraft will fly on 100% sustainable aviation fuel.
- Due to practical limitations around waste-based fuels, and sustainability concerns that rule out crop based biofuels, most SAF by 2050 is synthetic.
- Removals would only be used to address non-CO_2 emissions that cannot be eliminated.
- The *Polluter Pays Principle* should be fully applied. All externalities should be 'priced in' and polluters (or in this case airlines) should be charged at the point of polluting. This includes both carbon and non-CO_2 effects.
- Net carbon industry emissions should follow a predetermined downwards trajectory that never peaks above 2019 levels , hitting zero by 2050.

Crucially, this paper should not be taken as a full roadmap to 2050. It is not. This paper deliberately does not try and set out the whole path to full decarbonisation, instead it suggests a suite of initial policy suggestions that will ensure the industry starts to make the investments and technological leaps required for net zero emissions flight. It focuses on zero emission aircraft and sustainable aviation fuel, since these are the tools that can get the industry to net zero carbon emissions (whilst also reducing or eliminating some non-CO_2 effects). It suggests how to use government funding and the tax system to good effect. This does not mean that aircraft efficiency, airspace modernisation, or other measures are not important: they are, but on their own could never reach net zero and are therefore outside the scope of this paper.

1.4.1. Policy Principles

The question now arises as to what the UK Government should do, given that all emissions from UK aviation are now part of UK carbon budgets. This paper will recommend some policy initiatives, but it is worth initially setting out the principles that underpin these:

Emissions Need to Reduce

2019 emissions from UK departing flights equalled 38.2 $MtCO_2$. The climate crisis demands that this level should not be breached again. Total annual emissions from the industry should start trending downwards towards the end of the 2020s, with steeper falls throughout the 2030s and 2040s.

Build on UK Expertise

The UK's aerospace industry is the 3rd largest in the world, and the second largest in Europe [23]. In 2019, this sector turned over £33.9bn, exported £31.8bn worth of goods and employed 114,000 people [24]. It is already recognised as a strategic UK sector by the Government: both the Aerospace Growth Partnership [25] and (importantly for zero-emissions flight) the Aerospace Technology Institute [26] have been established relatively recently (within the last decade). This support is already bearing fruit: Zeroavia recently made the first test flight of a commercial-sized hydrogen fuel-cell aircraft at Cranfield, Bedfordshire [27], and has plans for a 200 mile test flight soon.

Furthermore, the UK is a leader in electrolyser development and production - the world's largest electrolyser factory is in Sheffield, Yorkshire [28] . This is in addition to growing offshore wind resources which in future will be used for hydrogen production.

In short, the UK is already a global aerospace powerhouse, and has the potential to be a global electrolyser and e-kerosene powerhouse. The Government should build on this by trying to capture as much of the future global zero emission aircraft and low carbon aviation fuels markets as possible.

Use Taxes and Spending Appropriately

Taxes and spending should be both fiscally and environmentally responsible, and should have a clear - and stated - purpose. This means that different taxes should be used to achieve different objectives. Whereas untargeted spending will simply increase the UK's deficit, targeted and purposeful spending, that has a distinct objective, should be seen as an investment that will be repaid, both in financial and environmental terms.

New taxes should influence behaviour, and should be seen as price signals to deter behaviour that creates costs on society. There are numerous examples throughout the UK of taxes that do just this, including the sugar tax and Vehicle Excise Duty (which is a tax on the CO_2 emissions of a car). Notably, the UK implemented the Carbon Price Floor in 2013 [29], which underpinned the price of carbon in the EU Emissions Trading Scheme, and has been a major factor in driving coal out of the UK's power system. The polluter pays principle should mean that (any) consumption should be taxed at a level that at least covers the external costs it imposes on society.

Support, Regulate, Ban

The policies offered broadly follow a *Support, Regulate, Ban* pattern: that is, initially government support investment with taxpayer money should be offered for the first makers and takers of clean technology. This should be followed by a period of regulation, where industry players are obliged to use an increasing amount of the newly introduced technologies. Finally, there should be an end date by which old technologies are phased out and their use banned.

Don't Discriminate Between Airlines

Finally, and pragmatically, there is a sensible embedded principle within aviation: that of not distorting competition between airlines operating the same routes. This has been followed in this paper. UK airlines are not favoured: all airlines that fly to and from the UK should be treated equally.

INFO BOX: What about CORSIA?

After the EU legislated for the inclusion of international flights within its EU carbon market (EU ETS), the UN's aviation agency (ICAO) launched an initiative to attempt to address aviation emissions through the creation of a global offsetting scheme for international aviation, known as the Carbon Offsetting Scheme for International Aviation (CORSIA). Unfortunately, CORSIA has increasingly been reported to be an ineffective scheme that will never deliver sufficient price signals to encourage the sector to decarbonise. This is why the UK should implement its own measures to address international aviation emissions, such as integrating long haul aviation emissions into its emissions trading scheme and taxing all jet fuel uplifted in the UK.

- **Offsetting enables aviation emissions to continue growing**: CORSIA does not require airlines to reduce their own emissions, but to pay someone else to reduce emissions, while they keep burning fossil fuels. This is incompatible with both the Paris Agreement and the UK's carbon budgets.
- **Offsets don't actually lead to CO_2 savings**: none of the offsetting programmes approved under CORSIA meet all of the required sustainability criteria. All have issues with double counting: many existing projects are delivering emission reductions in sectors that are already covered by their respective country's current climate targets.
- **Offsets are too cheap to decarbonise**: CORSIA will suffer from an oversupply of cheap offsets (analysis commissioned by the European Commission suggests less than £1). These offsets will never incentivise airlines to change behaviour to use cleaner fuels or zero emission aircraft.
- **Global schemes lead to weaker ambition:** a scheme crafted by over 180 different countries will lead to decisions being adopted at the lowest common denominator, penalising those regions who want to be more ambitious. ICAO also does not have the power to enforce CORSIA itself, as it is up to member states to implement it. It cannot therefore ensure that any of the environmental measures it adopts will be fully implemented by all countries

2. Zero Emissions Aircraft

2.1. Overview

Zero Emission aircraft (ZEA) are the panacea of the aviation industries decarbonisation efforts. Aircraft that can be powered by either electricity produced by renewable means and stored in a battery, or by zero carbon electrically-produced green hydrogen (via a fuel cell) would not only release no carbon at all, but would also bring other benefits, such as less non-CO_2 warming impacts, better air quality and less noise on take-off. However, whilst there are a few zero emission aircraft in existence today, they are small and there are currently no commercially available flights globally. Furthermore, this means that there is no airport infrastructure ready for them and no ZEA-specific regulations in place.

The first commercial ZEA will be small (probably only seating six passengers) and not able to fly far compared to most current commercial planes, but the potential world-wide market is huge. Globally, 45% of flights are under 500 miles, and 5% of those - 1.8m flights - were less than 100 miles [30]. Indeed, the shortest regular commercial flight in Europe that does not cross water is between Stuttgart and Zurich, a distance of only 78 miles.[4] There are around 9000 'regional' aircraft (planes that typically seat less than 100 people) in operation today [31]. In a (pre-pandemic) average year, 2-3% of the airplane fleet was retired annually [32], meaning that (presuming travel demand returns to pre-virus levels in the future, which is by no means certain), there will always be a demand for some hundreds of these types of plane. Both Boeing and Airbus give an annual market assessment, and in 2019 Boeing expected to deliver 2430 regional aircraft over the next 20 years [32], and Airbus expected to deliver 1550 [33]. One (pre-pandemic) EU report estimated that regional air traffic would increase by an average of 6% per year over the next 20 years [34], and investment bank UBS estimated that the future hybrid-electric airplane market could be worth $178bn [35]. Finally, the UK market is also large. In 2019 there were more domestic airplane movements than long-haul airplane movements.[5] 22.4m passengers flew domestically[6], with over 5% of those moving between Heathrow and Edinburgh Airport alone [8].[7]

Clearly question marks should be raised about the most suitable mode of transport on some of these routes, and policies should be enacted that restricts (any) plane usage when there are clear, more environmentally friendly alternatives. However, what is equally clear is that there are some pre-existing domestic routes that exist where the best route will always be by plane, and that all efforts should be made to fully decarbonise these regional flights as quickly as possible.

Once viable ZEA will become the best option for some routes, since they will have lower operating and maintenance costs than the current fleet of aircraft that service those routes (particularly if and when the emissions trading scheme price rises substantially). Furthermore, there is an expectation in some parts of the aviation industry that these will arrive relatively soon: one survey of the European Regions Airline Association members expected battery electric aircraft to enter service post 2022, hydrogen electric aircraft to enter commercial service post 2023 and hybrid electric aircraft to enter commercial service

[4] There were 2599 flights between Stuttgart and Zurich in 2019. Data taken from p.11 of the downloadable report found at this web address: https://www.oag.com/reports/busiest-routes-2020.
[5] Long-haul flights do not include any flights to the EU. There were 557,071 domestic movements in 2019, versus 478,317 long-haul movements.
[6] This includes all flights to/from the Channel Islands and the Isle of Man.
[7] T&E calculations based on CAA data, taken from Table 12.2 of the associated citation.

post 2025 [36]. This is backed up by a recently launched partnership between Zeroavia, Royal Schiphol Group and Rotterdam that is planning the first zero emission commercial flights between Rotterdam and London in 2024 [37].

Of crucial importance here is the fact that globally a lot of these flights will be domestic, and therefore the emissions these planes produce are already covered within a country's decarbonisation targets. At the time of writing, 50 countries have pledged to reach net zero emissions by 2050, with a further 4 (including China) pledging to be net zero by 2060 [38]. These net zero commitments mean that these nations will be looking to reduce their emissions where possible to absolute zero, and only ZEA can do that within aviation.

2.2. UK Potential

Due to the size of the UKs current aerospace industry, and the Government's zero carbon ambitions, turning the nascent UK ZEA industry into a global leader for ZEA research, design and production is a realistic and worthwhile ambition. The Transport Secretary stated in Parliament in July 2020 that "we set up the Jet Zero Council specifically to take forward the objective of being the first country to develop a jet commercial airliner to fly at zero carbon across the Atlantic" [39]. Additionally, working on ZEA fits in with the UKs Clean Growth Strategy [40].

The building blocks are already in place. The Government is funding the 'FlyZero' project at the Aerospace Technology Institute (ATI) [41], which is a strategic research project into ZEA. It is expected that substantial further funding will be made available for the research and development of the planes themselves.

Government support has already resulted in the world's first ever test flight of a hydrogen electric passenger plane, which took place in September 2020. The Piper M-class six-seater plane took off and flew a full circuit before landing without a problem. As mentioned previously, this was carried out by Zeroavia, which is just one of a small number of UK-based start up companies in the ZEA world (others include EAG [42] and Cranfield Aerospace Solutions [43]). The UK's nascent ZEA industry is small, but already something to build on.

There are some obstacles in the path though. Only a small amount of money (£3m) has been pledged to investigate the associated infrastructure [44]. Additionally, there has not been any thought given to required regulations. Proposed funding is only a tiny fraction of the aerospace industry's annual R&D spend: £1.7bn in 2018 alone [45].[8] (it should be noted that the aerospace industry covers a number of areas, not just aviation, and the breakdown between sectors is not available). It is clear that the vast majority of the aerospace sector's aviation research and development is still channeled towards fossil-driven flight. However, the main underlying reason ZEA have not been invested in is the fact that there is currently no demand driver for them. To kick-start the market, and change the focus of the aerospace industry's R&D, that demand driver will have to be Government-mandated.

[8] It should be noted that France, which already has the largest aerospace industry in Europe, has previously pledged a $17bn bailout to its aviation and aerospace industries, with just under $2bn dedicated to developing greener aircraft: https://www.bbc.co.uk/programmes/w172xlwh8v8q4qq

2.3. ZEA Policies

Policies should therefore be aimed at cementing the UK as a ZEA centre of excellence, and for commercial ZEA flights to be in the air above the UK as soon as possible. This requires funding to address both the technical challenges and policies needed to create a market for ZEA use that will ensure that airlines will a) want to procure them, and b) may invest themselves. For the UK to be a centre of excellence, an 'ecosystem' of organisations needs to be established. An ecosystem should consist of customers (e.g. airlines), competitive manufacturers (e.g. hydrogen fuel-cell and electric plane manufacturers), suppliers (e.g. battery manufacturers and hydrogen producers) and government agencies (e.g. the Civil Aviation Authority). Each entity in a fully-established ecosystem has some effect on the others, and the entities can work in both cooperation and competition. The UK ZEA ecosystem does not have any customers yet, nor enough suppliers, and only a few manufacturers, although there are clearly interested observers. Policies are therefore needed to ensure that all parts of the ZEA ecosystem are populated.

Investment in ZEA is already being channelled via the ATI, but is focused on incremental, short term projects rather than radical developments like blended wing planes. These are the type of projects needed to achieve the aforementioned ambition of flying across the Atlantic in a zero carbon plane.

T&E proposes additional investment is made available for both industry and academia to research and develop transatlantic ZEA, raised from borrowing against additional future revenue from taxes on fossil kerosene (more on that below). Money should be funnelled via the ATI, but some money should be specifically reserved for new UK entrants (with the idea of further creating the ZEA ecosystem) and would form the next phase of the fly zero programme[9] (funding could include the manufacture of the recently unveiled liquid hydrogen concept plane [46]).

R&D funding needs to be complemented by early market support. As a (relatively) small country, the UK is well placed to move its domestic air fleet towards ZEA, as there are no routes over 500 miles. Government support should be offered for the first airlines and airports to offer regular commercial domestic flights on either a battery electric plane, or a hydrogen fuel cell plane.[10] [11]

To ensure demand, and grow the number of commercial flights using ZEA, a zero-emission-miles-flown (ZEMF) mandate on all airlines that offer domestic flights should be implemented. Mandates are not new: both California and China operate a zero emission vehicle (ZEV) mandate, which obligates manufacturers to sell an increasing proportion of ZEVs, or buy credits from other manufacturers. The UK has committed to implementing a zero emissions vehicle mandate, which would require car manufacturers to sell an increasing percentage of electric vehicles, and implementing a SAF mandate (more details on the SAF mandate below). Responsibility for delivering the ZEMF mandate would fall on the airlines operating domestic routes. From (for instance) 2028, a small percentage of the domestic miles flown by an airline

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[9] The Fly Zero programme was launched in July 2020 as a 12 month study. Details here: https://www.ati.org.uk/events-media/news-blog/ati-launches-flyzero-initiative/

[10] This is similar in nature to two prizes already on offer: both Heathrow and the Manchester Airport Group are offering free landing fees for the first zero emission flight to use their runways. More details here: https://airportsinternational.keypublishing.com/2020/11/25/mag-announces-prize-for-first-zero-emission-flight/ and https://www.heathrow.com/latest-news/first-electric-aircraft-at-heathrow-airport-wont-pay-landing-fees-for-a-year

[11] Since it is likely that there will be both electric and hydrogen fuel cell planes, then this support should be offered twice - once for each technology.

must use a ZEA. This percentage would increase over time reaching 100% by 2040. Any airline that does not meet the percentage should have to buy credits from those that overachieve, or face penalties (which could include fines, or could include other measures, such as being stripped of landing rights). In effect, this would transition ZEA out of the ‘support’ stage, into the ‘regulation’ stage.

Norway’s (state-owned) airport operator has plans to ensure that all domestic flights in the country are electric from 2040 [47]. Scotland is working towards decarbonising scheduled flights within its borders by 2040 as well [48]. Announcing a phase out date for the use of conventional aircraft for domestic flights will in itself create a powerful investment incentive and drive the market.

Whilst it is obvious that there is no domestic route that is the size of an Atlantic crossing, focusing on completely decarbonising the domestic market will result in the boost needed for the ZEA industry as a whole to explore larger ranges. More (initially European) routes will gradually open up as ZEA with longer ranges become available.

Other policies can, and should, be implemented in parallel. In an extension of the support phase, the tax system should be used. To further encourage ZEAs into commercial use, VAT should be 0% on the landing fees, electricity and hydrogen that would be used by zero emission aircraft until 2028. Again, this initial exemption would provide airlines with some of the impetus needed to increase demand. Air passenger duty should also not be applied to ZEA tickets until 2028 as well. Tax breaks should finish when the regulation phase begins.

The tax system should also be used to discourage fossil-fuelled domestic flights. A key consideration for domestic flights is “could the route reasonably be travelled alternatively, via ground means?” Clearly the word ‘reasonable’ is subjective here. This paper’s suggestion is if the route could be travelled without crossing a sea - in other words, domestic to mainland England, Wales and Scotland, then there should be a further disincentive to use air travel, as any other form of transport has a better carbon intensity. 54% of 2019’s 22.4m domestic passengers travelled on flights that did not cross a sea [8].[12]

One simple way to do this would be to simply apply VAT to land-crossing fossil-fuelled domestic flights. Doing this makes sense, as it follows the long-standing principle of applying VAT to ‘luxury’ items, and reducing the rate for ‘essential’ items. This principle is reflected elsewhere in the British VAT system: For instance, most food and drink for human consumption is zero-rated, but restaurants must charge VAT [49]. VAT is not applied to rail and bus tickets, but is applied to taxi fares.[13] Alternatively, the Government could reverse the recent APD cut for land-crossing domestic flights.

[12] T&E analysis of Table 12.2 of the associated citation. This includes flights to/from the Isle of Man and the Channel Islands.
[13] Provided the taxi company’s turnover is above the VAT threshold.

3. Sustainable Aviation Fuel

3.1. Overview

Sustainable aviation fuel (SAF) is jet fuel that has been produced without using crude oil, meaning that the carbon contained in the fuel has been drawn from the air, a waste stream or biofeedstock. Crucially, this means that the lifecycle greenhouse gas emissions of SAF are far lower than its fossil counterpart. SAF is virtually chemically identical to fossil kerosene, and therefore when burnt in a plane, greenhouse gases are still emitted into the air (although the lower aromatics mean that there will be fewer non-CO_2 effects [50]).

There are numerous pathways to create SAF, each with its own pros and cons. However all certified pathways have two common characteristics; firstly, they are technically possible right now using existing technologies; and secondly, they are all more expensive than untaxed fossil jet fuel. SAF costs will decline as production scales (due to learning effects and economies of scale), but SAF will remain more expensive than (untaxed) fossil kerosene. Therefore there is no significant market for SAF without regulation. As a result, currently, the amount of SAF produced is tiny: 0.004% of global jet fuel demand [51]. However, with strong regulations, the size of the potential market is as big as the jetfuel market,[14] US$ 300bn [52] or 7 Mb/d in 2018 [53].

E-kerosene, manufactured from hydrogen and captured carbon, is a particularly promising pathway that can be scaled without wider environmental impacts.[15] Currently unproven at scale (but using well established chemical processes), it is the only pathway that has the potential to be 100% carbon neutral. Globally, the practical availability of waste and bio feedstocks are limited. In contrast, e-kerosene, using direct air capture (DAC) of CO_2 and green hydrogen has no theoretical supply constraints, but does have practical constraints in the amount of zero carbon electricity available. Previous T&E analysis for European jet fuel demand concluded that waste-based SAF would only account for 11.4% of total demand in 2050 [54]. E-kerosene is therefore essential in order to achieve a high share of SAF and ultimately replace jet fuel. It then follows that SAF policies must explicitly encourage e-kerosene production, even though this currently offers a more expensive pathway. Options to do this include giving it its own mandate and/or providing some Government price support (possibly via CfDs). Germany has already made e-kerosene mandate commitments (more details below), and the European Commission has also suggested minimum e-kerosene levels as part of a pan-European mandate.

A further reason for supporting e-kerosene using DAC is that atmospheric carbon removals will be needed after 2050 in order to limit warming, however there is currently no demand driver for them. DAC technology provides a potentially useful complement to CO_2 capture through tree planting and other forms of biological capture.

[14] Currently, not all planes can fly on a fuel mix formed of 100% SAF. However, new planes being produced now can.
[15] E-kerosene does not have any unintended land use or biodiversity problems associated with first generation biofuels. Provided the hydrogen is made via electrolysis of water, then there can not be any fugitive carbon emissions in that stage. The electricity used has to be created by zero carbon generators to be considered sustainable.

3.2. UK Potential

In 2019, the UK used 12.4m tonnes of jet fuel [55]. Of this, 9.6m tonnes were imported, which included just under 3m tonnes from Saudi Arabia (31% of imports), 1.2m tonnes from India (12.8%) and 1.2m tonnes from Kuwait (12.5%) [56]. Producing SAF in the UK would bring considerable economic and energy security benefits.

The UK generated 222.2 million tonnes of waste in 2018 (latest figures available). Crucially, a significant proportion of this came from local authorities, who had to pay for it to be disposed of. This included 26.4 million tonnes of household waste (2019 figures), of which 46% was recycled. This left 14.2 million tonnes that was disposed of by incineration, landfill or export. This included 6.6m tonnes of biodegradable municipal waste ("food scraps", garden waste, paper and cardboard) which went to landfill [57]. Whilst these figures should be reduced (for instance, only 67.2% of packaging waste was recycled that year), this clearly equals a large potential feedstock source for a UK waste-to-SAF industry.

However, there are currently no dedicated operational waste-to-SAF plants in the UK (and indeed, very few worldwide). There are advanced plans for three, by three separate companies: Velocys, Lanzatech and Fulcrum. Velocys and Fulcrum use municipal waste as their feedstock, whilst Lanzatech uses waste gases.

The planned Velocys plant (in Lincolnshire) will process 500,000 tonnes per annum of household and commercial waste (that would otherwise go to landfill), and produce 50,000 tonnes of fuel, of which the majority would be jet fuel (the rest would be naphtha). It has received planning permission, but no building work will commence until suitable policies are in place. Building work is expected to take two years [58].

The planned Fulcrum plant (on Merseyside) also takes (predominantly biogenic) waste destined for landfill. It will produce 100m litres of SAF that will be destined for Manchester airport. It's plant is slightly further behind in the planning application process, but a site has been identified [59].

The Lanzatech plant would take waste gas (which would otherwise be ejected into the atmosphere) and converts it into ethanol, which can then be converted into different products, including jet fuel. It has plans for a plant in South Wales that would produce 100m litres of SAF [60].

Crucially, there are no (publicly-announced) plans for a UK-based commercial e-kerosene production plant. The UK plans to have 40GW of offshore wind capacity and 5 GW of low carbon hydrogen production capacity by 2030 [61], and e-kerosene plants clearly complement these plans.

3.3. Policies

UK based airlines already have strong commitments to SAF, via the February 2020 Sustainable Aviation Roadmap [62]. SAF is also at a more advanced stage of its development lifecycle when compared to ZEA. SAF policy should actively encourage airlines to use UK-manufactured SAF and therefore focus on a) ensuring that SAF provided in the UK has high sustainability standards, b) ensuring that there is demand for the finalised product, and c) ensuring that SAF plants begin to get built in the UK.

SAF policy is evolving rapidly in other jurisdictions . Indeed, SAF mandates are in place in both Norway and Sweden, and were being actively considered in Spain, Germany, France, the Netherlands, Denmark and Finland [63], before the European commission proposed a pan-EU mandate in July [64]. The idea of a mandate is simple - either a supplier or airline is required to sell / buy a set percentage of SAF in its total fuel mix. In all proposed and active schemes, the percentage increases over time, meaning that more and more SAF (or less fossil jet fuel) is required). Crucially, this requirement means that there is a sufficiently strong market signal to ensure that SAF plants are built.

The UK Government has also pledged to implement a SAF mandate [61], and is consulting on what the exact details should be. Fuel suppliers in the UK already have mandates on providing non-fossil fuels into their fuel mix, via the Renewable Transport Fuel Obligation (RTFO) [65]. However, whilst renewable fuel used in aviation in the UK is eligible for reward under the RTFO, it is not mandatory for aviation SAF to be used. The UK's proposals are therefore to implement a separate system to the RTFO, and for the mandate to fall on fuel suppliers. This makes sense, as there are a small number of fuel suppliers (as opposed to many airlines), and they already provide information on fuel supplied to the relevant Department for Transport team.

T&E agrees that the SAF mandate should fall on fuel suppliers and that it should apply to all jet fuel uplifted in the UK. Strict sustainability criteria should be applied to the supplied fuels from the beginning, and support should be given to ensure that some SAF is produced in the UK.

Specifically, T&E recommends that the conclusion of the SAF mandate results, in essence, with a "twin-track" mandate, with one side covering waste-based SAFs, and the other covering synthetic SAFs. Government support (supplementary policies and taxpayer money) should be provided to both sides, including support to help de-risk the first (currently unplanned) commercial e-kerosene plant in the UK.

3.3.1. General Mandate Principles

- Any SAF supplied should strictly exclude all crop-based biofuels, due to their direct and indirect negative impacts, such as land use change, biodiversity loss and food insecurity. This should include all palm and soy products, including waste products and by-products (specifically including PFADs). This means that only waste-based SAF (from specific agreed waste streams) and e-kerosene should be allowed.
- Only fuels that are judged to have a 70% lifecycle greenhouse gas saving or above should be considered as SAF. Furthermore, this minimum level should rise with time.
- The mandate should be to reduce nominal emissions by a minimum percentage, as opposed to providing a minimum percentage volume level. ie a 10% mandate should mean that a fuel supplier has to reduce the lifecycle emissions from the fuel it supplies by 10%.
- Since e-kerosene and waste-based SAF use entirely different processes and feedstocks, and therefore will need different rules and regulations, separate requirements should be put in place for e-kerosene and waste-based SAF.

- Strict penalties should be applied for non-compliance with the scheme. The buy-out (or penalty) price should be set at a level in excess of the gap in price between fossil kerosene and the most expensive eligible SAF. In its proposed implementation of the Renewable Energy Directive, Germany has put forward a non-compliance penalty of €70 per Gigajoule for compliance with its e-kerosene mandate. Previous analysis commissioned by T&E [66] shows that the production costs of e-kerosene in the near term are likely to be €3,000/tonne, which is very close to the €70 per Gigajoule figure. The UK SAF mandate penalty rate should therefore be in excess of this figure.
- Airlines should be obliged to uplift at least 90% of the fuel they require to undertake their next flight at the airport that flight is due to depart from. This would prevent airlines trying to avoid the SAF mandate by purchasing more fuel in a non-mandated country. This measure matches the European Commission’s proposals. It also has the added bonus of preventing tankering (where an airline takes on more fuel than is required for its flight in order to reduce or avoid taking on fuel at its destination, due to higher fuel costs at the destination. Carrying more fuel increases weight and therefore results in more fuel being burnt, which increases the greenhouse gas emissions from that flight).

3.3.2. Waste-Based SAF Mandate Principles

- Measures should be put in place to ensure that all waste-based fuels adhere to the waste hierarchy. Many wastes and residues are used by other industries already, or are of value for ecosystem(s) health. SAF suppliers should be required to demonstrate that the (current) commercial market and ecosystem demand for the wastes and residues they intend to use as feedstocks is less than the available supply of those said feedstocks. The simplest way for this to happen is for SAF suppliers to prove that gate fees have been received for all the waste they process - that is that they have been paid to dispose of the waste, and have not had to pay to obtain the waste.
- Particular attention should be paid to the various feedstocks for HEFA, and absolute volume caps should be introduced on HEFA-based SAF. This prevents undesirable and unsustainable feedstocks (eg virgin cooking oil) creeping into the supply chain. The UK is already a net importer of used cooking oil, with 244m tonnes coming from China alone [67], and there is no scheme in place to ensure full transparency of feedstock sources.

3.3.3. E-kerosene Mandate Principles

- All e-kerosene produced should only be derived from green hydrogen, which itself should be made using additional renewable electricity.
- The e-kerosene mandate should also reward e-kerosene suppliers that use direct air capture in the short term (from start date to 2035, possibly via a higher CfD strike price), and then require a minimum volume of direct-air-captured carbon dioxide in the medium to long term. T&E recommends this level be set at a minimum of 30% of the e-kerosene supplied from 2035.

As suggested by the consultation, the mandate should start in 2025, for the simple reason that this gives the industry enough time to prepare, and also aligns with the European Commission's proposals.

Only once the exact sustainability criteria of the SAF is known can exact decisions be made on what percentage volumes should be supplied, by what year. However, there are a few markers in place as to predicted near-term levels. IAG - parent company of British Airways - has pledged to purchase and use one million tonnes of SAF annually by 2030 [68]. This is backed up by both Shell and Air BP making pledges: Shell has committed to produce 2 million tonnes of SAF per year by 2025, and that at least 10% of its global fuel sales will be SAF from 2030 [69]. Air BP has pledged to provide 20% of the global SAF market by 2030 [70]. Currently there are no details on the feedstocks for these pledges, and therefore exactly how sustainable this SAF will actually be.

The UK Government has also committed to "enable the delivery of 10% SAF by 2030" (this is backed up by £180m in funding to support the development and building of UK SAF plants)[71]. The question that then remains is how that 10% should be divided between e-kerosene and waste-based SAF. T&E recommends that the UK's e-kerosene mandate should, at a minimum, mirror Germany's, which is that e-kerosene should equal 0.5% of total jet fuel supplied in 2026, 1% in 2028, and 2% in 2030 (2% of 2019 UK level of jet fuel demand equals 248,000 tonnes). Furthermore, the e-kerosene mandate should require that all e-kerosene produced before 2030 should come from UK production facilities. This last regulation would ensure that the UK fully utilises its current strengths in the offshore wind and electrolyser industries, in the hope that this domestic impetus allows these industries to become future world leaders. Post 2030, imports of e-kerosene should be allowed.

The SAF mandate should also incorporate forward guidance as to *minimum* levels post-2030 (with a mechanism to increase those levels if achievable and desirable), ultimately rising to a 2050 volume level of 100%: in effect, this equals a ban on fossil jet fuel being uplifted on UK soil from this date. This aligns with the UK's date to be net zero. It also provides enough forward guidance to airlines and fuel suppliers that the future of jet fuel is SAF and not fossil kerosene,[16] and means that investment decisions can be taken that ensure individual airlines fleets are ready to use 100% SAF blends in 2050.

Whilst there are no commercial SAF plants in the UK, three proposals are relatively advanced and as first-of-a-kind projects, should qualify for the UK Guarantees Scheme [72]. This scheme previously offered a government-backed guarantee to help infrastructure projects access debt finance, but is now administered by the newly-created UK Infrastructure Bank. The bank should actively invite applications from e-kerosene plants to participate in this scheme. This guarantee eliminates any risk a bank has of lending to the companies behind the SAF plant, which in turn should lower the capital costs of the project. The guarantee should mean that building work on the Velocys plant should start straight away, and would be completed by 2023/2024: potentially before any SAF mandate would kick in. The UK Government should therefore also immediately put in place a contract with Velocys to buy any SAF it produces before the mandate starts. The UK Government is already a significant purchaser of jet fuel, buying 472m litres (377,600 tonnes[17]) between April 2019 and April 2020 [73], and the Ministry of Defence has already changed its own rules to be able to receive up to 50% SAF in its fuel mix.

Furthermore, the Government should offer capital grants to companies prepared to build first-of-a-kind e-kerosene and DAC plants in the UK.

[16] This would also implicitly mean that all UK planes would have to be ready and prepared to only take 100% SAF by 2050.
[17] Using BP's conversion factors, taken from: http://www.bp.com.au/products/aviation/news/BPJETA1.PDF

3.4. Secondary Effects

A UK SAF mandate would have some knock-on effects. The obvious initial effect is that fuel costs will be raised, and airlines are likely to pass on this rise through higher ticket prices. However, whilst the initial mandate percentages are low, the effects on ticket prices will be small, and certainly less than the variations in the global jet fuel price (which many airlines hedge to manage).[18] Nevertheless, airlines will be worried that some passengers may choose not to travel by air. It should be noted though that a recent Eurocontrol think paper concluded that the main influence on demand was economic output, not ticket prices [74].[19]

The second effect would be a potential increase in tankering. Whilst tankering may make sense economically, it does not make sense from a climate perspective, as carrying that extra fuel supply requires fuel itself, resulting in increased greenhouse gas emissions. Tankering almost certainly happens already: Eurocontrol modelling shows that around 20% of flights in its area would be economically better off engaging in the practice [75]. It should be noted that all domestic flights would not be affected by tankering (as both ends of the route would be covered by the same mandate rules), and neither would long-haul flights (since the fuel tank capacity is simply not large enough to engage in the practice).[20] From a climate point of view, this is important, as most of UK aviation's emissions come from long-haul flights.

Tankering will only happen when there is a clear price differential between UK and European airports, but as the EU is also actively considering a SAF mandate and a kerosene tax this is unlikely, provided the UK adopts similar policies.

4. Revenues

The suggested measures above should ensure that both ZEA and SAF enter their respective markets in substantial quantities. However, some initial funding to kickstart the new technologies will be needed. This money should be borrowed by Government against future revenue from the industry: principally via increased fuel duty taxes that start from 2025, and also via increased ETS revenues that start from 2023. This way, it is clear that the industry is funding its decarbonisation efforts, and as the industry decarbonises, revenues from kerosene taxation and the UK ETS will fall.

4.1. Kerosene Taxation

Jet fuel uplifted in the UK has always been exempted from taxes, despite the UK always being able to apply fuel duty to kerosene for domestic use. Clearly not taxing greenhouse gas producing fuel is not compatible with the polluter pays principle (and, of course, deprives the Treasury of a source of revenue). The oft-quoted reason for this is that taxation is explicitly banned in the many Air Service Agreements (ASAs) in place between different countries, and that these ASAs are international agreements that have

[18] At the time of writing (8th July 2021), the price had risen 1.2% vs one week previously, 5.4% vs one month previously, and 79.9% vs one year previously. Information obtained from: https://www.iata.org/en/publications/economics/fuel-monitor/

[19] This is further reinforced by the fact that in the UK Air Passenger Duty rates have been increased a number of times since its introduction, with no corresponding decrease in demand.

[20] For more information, see pages 69-70 of this carbon leakage report: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/763260/carbon-leakage-report.pdf

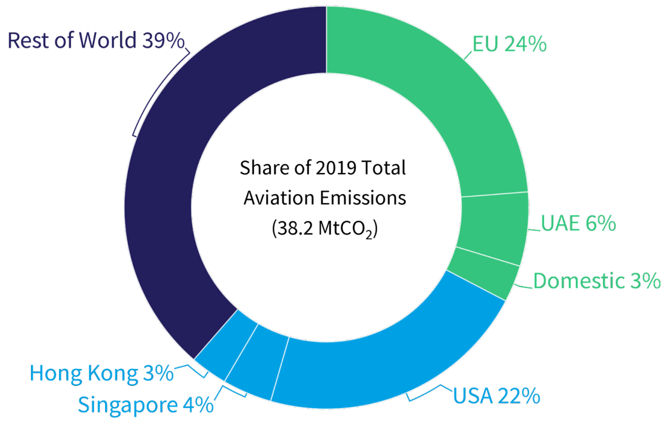
been layered on top of the Chicago Convention of 1947.[21] This assumption needs to be questioned though: a closer examination of some of the ASAs in place reveals this simply is not the case.

The ‘top’ five country/region destinations from the UK (in terms of total carbon emissions) account for well over half of the total UK emissions from aviation (see table 1, below). And analysing the ASAs between the UK and those countries shows that taxes could be applied on routes that produced 12.6 $MtCO_2$ in 2019.

Table 1

Country / Region	**Emissions in 2019 ($MtCO_2$)[22]**	**Taxation allowed?**
EU [76][23]	9.04	Yes
USA [77]	8.22	on the basis of reciprocity
UAE [78]	2.40	Yes
Singapore [79]	1.36	on the basis of reciprocity
Domestic UK	1.15	Yes
Hong Kong [80]	1.09	on the basis of reciprocity

Figure 3: Taxes on Emissions



[21] Contrary to popular belief, the Chicago Convention itself does not prohibit taxing fuel that is added to a plane in a particular country. The Convention bans parties from imposing taxes on fuel already on board an aircraft when it lands in another country, but does not say anything about the fuel that is sold and added in an individual country (furthermore, the Chicago Convention is not applicable to domestic aviation, only international aviation). Please follow this link for more information: https://www.transportenvironment.org/sites/te/files/publications/2010_01_Briefing_domestic_fuel_taxation_briefing.pdf

[22] T&E analysis of commercial aviation CO_2 emissions. T&E's in-house model estimates aircraft emissions using AIS aircraft data purchased to PlaneFinder and EuroControl's "Master emissions calculator", developed for EMEP/EEA, and available at: https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-a-aviation-1/view.

[23] These results are obtained by considering EU outermost regions part of the EU. Emissions from departing flights to “Continental EU” only equals 8.06$MtCO_2$.

The UK is now able to apply duty to kerosene intended for planes that will travel to the EU because of the *Trade and Cooperation Agreement* negotiated as part of leaving the EU, and already could for fuel used on flights to the UAE. Furthermore, the Air Transport Agreement recently concluded between the UK and the USA, and those previously agreed with Singapore and Hong Kong *potentially* allows kerosene to be taxed. The agreements exempt fuel from fuel duty, *on the basis of reciprocity*, however this phrase is not defined. CE Delft previously undertook legal analysis [81] with regards to aviation fuel taxation, and concluded that the phrase "would leave the door open for one of the two bilateral partners to go its own way as to tax exemption", and means that either the UK or it's partner countries could start taxing fuel uplifted without violating the agreement: ie that the wording is not a ban on fuel taxation, rather an agreement that if one party begins to tax fuel, the other party may too.

Finally, the UK has always been free to tax fuel used for domestic flights. Domestic fuel has excise duties applied to it in (amongst others) Canada, the USA, and Australia [82]. Based upon the CE Delft's legal opinion, a kerosene tax could therefore be applied to fuel that accounted for 23.3 $MTCO_2$ in 2019, or over 60% of 2019's carbon emissions.

The UK is now, post-Brexit, free to pursue its own trade deals.[24] As part of this, it should prioritise allowing jetfuel taxation as part of future negotiated air service agreements with other countries. The UK should use the 'template' wording in the ASA with the UAE, which explicitly allows taxation.[25]

The European Commission has proposed that jet fuel for intra-EU flights is taxed at a rate of €0.38 per litre (which is indexed every year to inflation). The UK should, at the very least, match this rate. CE Delft previously modelled the effect of a kerosene tax in the UK at a rate slightly below the proposed levels (€0.33 v €0.38), and concluded that this would raise €7.3 billion [83].

To put all of this in context, in 2018, UK aviation purchased and used 12.3m tonnes of petroleum, and the UK's Treasury received zero duty payments on this fuel spend. This is in stark contrast to the £27.9bn received by the UK Government from fuel duty (with a further £5.58bn coming via VAT applied to this duty) for road transport [84]. For context, the nation's drivers used 36.3m tonnes of petroleum [85], so collectively paid £922 per tonne. If this rate were applied to aviation, the Treasury would have raised £11.3bn.[26]

The UK should start charging duties on fossil jet fuel from 2025. This not only corrects the anomaly that is zero taxation on a clear public 'bad' (and therefore starts internalising the externalities for airlines), but, equally importantly, starts reducing the price differential between SAF and fossil kerosene. SAF and fossil kerosene are commoditised products, and in theory the market should simply demand whichever is

[24] Whilst the UK was a member of the EU, it was always allowed to negotiate bilateral air service agreements. It just could not do so in a way that discriminated against other member states. This is still the case for EU member states.

[25] The wording, found in Article 8, paragraph 5, is: *"Nothing in this Agreement shall prevent the United Kingdom from imposing, on a non-discriminatory basis, taxes, levies, duties, fees or charges on fuel supplied in its territory for use in an aircraft of a designated airline of the UAE that operates between a point in the territory of the United Kingdom and another point in the territory of the United Kingdom or in the territory of another EU Member State. In such case, the UAE would have a similar right to reciprocate without discrimination the imposition of similar taxes, levies, duties, fees or charges on fuel supplied in its territory."*

[26] This is just an illustrative figure and presumes there would not have been a change in demand. Realistically, demand for fuel should fall as the price increases.

cheaper. Should the price of SAF ever fall below the price of fossil kerosene then the market should switch to demanding more of that.

This tax should be announced as soon as possible, but should only start the same year as the mandate starts (2025), to give the industry time to prepare. To be clear, SAF should not have duty applied to it.

Taxing fossil jet fuel would mean that, all things being equal, an airline that buys a higher percentage of SAF in its fuel mix would pay less tax than one that did not. Taxes would obviously be returned to the Treasury, and would offset the increased funding levels for zero emission aircraft and UK-produced SAF and SAF plants. Furthermore, consideration should be given to setting rising taxation levels from the mid 2030s, in a similar fashion to the way the SAF mandate would increasingly rise. Tax levels would therefore be part of the future policy landscape that investors and airlines would consider when deciding on future ZEA and SAF decisions (plant investment plans and offtake agreements). This is important, as, ultimately, SAF levels must get to 100% of global jet fuel consumption. When that happens, the kerosene tax will stop bringing in revenue - but by that point will have bought in billions of pounds and not only provided the government with the money needed to decarbonise the sector, but also have acted as a disincentive to burning fossil kerosene.

4.2. The UK's Emissions Trading Scheme

The other major financial decarbonisation instrument available to the government is the UK's emissions trading scheme (UK ETS). This started on the 1st January 2021, and is the UKs flagship carbon pricing scheme. The UK ETS' first period is, intentionally, mirroring the EU ETS. This means that airlines are being charged for some of the carbon pollution they cause, but not all. The UK ETS only applies to departing flights that will land in the UK, the European Economic Area, or Gibraltar. Crucially, this means that airlines providing long-haul flights do not pay anything for their carbon emissions, nor do any airlines pay for the non-CO_2 warming effects they cause. British Airways, which emitted just over 18 $MtCO_2$ in 2019, only submitted a carbon allowance on 14% of those carbon emissions. This is in stark contrast to Ryanair, which had to submit ETS allowances on 86% of its emissions [86]. Neither paid anything for the non-CO_2 climate warming effects they caused.

Perversely, for historical reasons, airlines receive some allowances for free. Free allowances were originally introduced to the EU ETS to stop carbon leakage. Carbon leakage refers to the situation where businesses move production abroad to avoid climate policy costs, which could lead to an increase in overall emissions. But carbon leakage levels in aviation are low since the core 'product' is transporting passengers from one destination to another - which cannot, by definition, be moved to third countries. In 2021, the UK ETS administrators awarded 4.4m free allowances [87], which covered at least 41% of the estimated in-scope carbon emissions.[27] Not only is this the exact opposite of the polluter pays principle, but it is also a direct subsidy to the airline industry (the price of a UK allowance has not been below £40 for the second half of 2021. It's highest level was £79.20 on December 16th [88].[28] Presuming that an allowance costs £40, this equals a direct subsidy to the airline industry in 2021 of £176m).

[27] Emissions under the UK ETS scope are estimated from in-house calculations of 2019 emissions based on the ICAO calculator methodology, using AIS aircraft data for 7 weeks, purchased from PlaneFinder. In the coming years, this share will be in practice much higher due to reduced traffic because of the COVID-19 pandemic.
[28] At the time of writing (21st december 2021)

The European Commission has recognised that the sector unfairly benefits from free allowances, and has proposed that the EU phases out free allowances in the EU ETS by 2027. The UK Government has already indicated that the UK ETS will be changed to be 'net zero compliant' in 2023 or 2024, and is actively considering options as to how to do so. T&E recommends that the below changes are implemented, to correct the anomalies of the current scheme:

- Free allowances to airlines should be halved (from 2022 levels) in 2023, halved again in 2024, and phased out completely in 2025. This timescale matches the ambition and timelines that the Government has proposed to be net zero compliant [89].
- The scope of the ETS should be increased to cover all flights, to all destinations (this includes both long-haul flights, and incorporating airlines that currently do not make the minimum number of flights to qualify for ETS inclusion). To be clear, this means that every airline that flies from a UK airport will be required to submit allowances to cover the emissions their UK-departing flights will produce - even if they only partake in one departing flight.
- The auction reserve price should be ratcheted up from £22 over time. This will cause airlines to investigate and invest in low and zero carbon options. The Jet Zero Consultation [90] suggested a carbon price of £231/tCO_2 in 2050 for its "High Ambition" scenario. To achieve this using the UK ETS only, the auction reserve price would have to rise at a linear rate of £7.74 per annum. Forward guidance on these figures, announced soon, will provide airlines with the policy certainty that is needed to ensure sufficient investment in SAF and ZEA. This is in direct contrast to the government's current intention [91], which is to withdraw the auction reserve price. The Government's current approach would provide less certainty for business, and decrease the chances of up-front investment in zero emissions aviation and negative emission technologies.
- An additional non-CO_2 cost should be applied to airline allowances. This is aligned with the Government's commitment to "exploring expanding the UK ETS to the two thirds of uncovered emissions" [92]. There is a precedent of imposing additional costs via the ETS: since 2013 UK power generators have been charged an additional £18 per allowance.

These changes are very much in line with the Government's stated ambition to use the UK ETS to go "further, faster" [93]. Changes should be communicated as early as possible in 2022, so all parties are as well-prepared as possible by the time the changes are implemented.

Furthermore, the UK ETS should also be used to encourage SAF uptake. The SAF mandate described above would oblige fuel suppliers to supply a certain percentage of SAF, and airlines should not receive any credit for SAF burnt in planes provided by fuel suppliers in adhering to this mandate. However more progressive airlines may wish to buy additional SAF, and those that do should be actively encouraged to do so, by not having to provide allowances for carbon emitted from the burning of SAF. For simplicity's sake, this should be applied to all SAFs, whatever the pathway utilised, and should be in force until 2035.

Example 1: The mandate is set at 10%. Shell supplies 100 tonnes of fuel. This includes 15 tonnes of direct-air captured carbon based e-kerosene which are judged to have net zero lifecycle emissions. This means that Shell has reduced it's GHG intensity by 15%. British Airways buys the 5 tonnes of SAF Shell has produced above the mandate level, and does not have to provide ETS allowances for that 5 tonnes of fuel burnt.

Example 2: The mandate level is 15%. Shell provides 15 tonnes of direct air captured e-kerosene, out of a total of 100 tonnes. British Airways buys all 15 tonnes via an offset agreement. Shell is deemed to be fulfilling its mandate, however British Airways can not claim any free ETS allowances when the resulting fuel is burnt in planes.

Example 3: The mandate is 15%. Shell provides 21 tonnes of direct air captured e-kerosene, out of a total of 100 tonnes. British Airways buys 7 tonnes, Ryanair buys 7 and Easyjet buys 7. Only 6 tonnes can be 'claimed' in the ETS system. Shell would have to detail which of the SAF it provides are part of the mandate, and which are additional, with the airlines that purchase additional allowances claiming the available free allowances.

4.3. Pricing non-CO_2 effects

Whilst all the focus has historically been on reducing carbon emissions, there are also non-CO_2 warming effects associated with aviation, and the industry should still pay for the warming it causes (it's worth noting that this would still be true even if SAF were 100% of the UKs fuel mix). As previously mentioned, the primary non-CO_2 impacts result from the emissions of nitrogen oxides, water vapour and soot that form contrails, and crucially, contrails only form in certain atmospheric conditions. This means that the non-CO_2 effects that an airline causes is not proportional to the amount of miles flown, or fuel burnt: there will be flights that cause less warming from non-CO_2 effects, and flights that cause more. Additionally, there are some effects that have not been quantified yet. Regardless, the scale of the non-CO_2 problem is now well established, and it is increasingly noticeable that the industry is allowed to cause this warming with impunity. That situation has to change soon, to force the industry to tackle this problem head-on.

As mentioned above, an additional charge should simply be added to the UK ETS allowances that need to be relinquished. This follows previous ETS precedent, and is relatively easy to implement, but would not differentiate between those flights that cause contrails and those that don't. Therefore this measure should only apply until a more rigorous system could be implemented: where airlines would have to supply detailed flight data to a central authority, which would then estimate the non-CO_2 warming effects per flight and charge accordingly. This system would be a lot more complicated to implement, but fairer on the airlines that cause less warming from non-CO_2 emissions. The point that needs stressing is that the aviation industry as a whole is currently being allowed to pollute with impunity, and that situation needs changing quickly. Crucially, non-CO_2 emissions will almost certainly still be being emitted in 2050, and so a long-term fair way of both reducing and accounting for the warming effects needs to be established.

T&E recommends that an additional ETS charge is applied in the short-term (from 2023 onwards), whilst a fairer way of pricing non-CO_2 effects is drawn up, with a view to having that system in place by 2028.

5. Capping Emissions at 2019 Levels

Whilst the above policies are all important to move the industry to carbon neutrality in the long term, it is clear that emissions could still rise past 2019 levels over the next decade. Pre-pandemic, demand had been rising year-on-year for the previous decade [8],[29] and whilst demand in itself is not the problem, the corresponding emissions are. Should UK aviation's emissions grow over the next decade like they did in previous decades, then this will make the decarbonisation challenge much more difficult. UK SAF and ZEA manufacturers need the next decade to address and scale the supply-side challenges of both sectors. Regardless of government funding levels, increasing the size of the problem, whilst working out the details of the solutions simply does not make sense. Therefore policies should be implemented that are specifically tied to a net zero baseline emission level which never peaks above 2019 levels. The policies should reward airlines when emissions are lower than the baseline, and financially penalise airlines when emissions are higher. Implementing a system where UK aviation is rewarded for achieving lower emissions in the short-medium term aligns with the industry's goals [94], whilst also acting as a safeguard to ensure it does. This can most easily be achieved via the tax system and reform of air passenger duty. Additionally, an immediate moratorium on airport expansion should also be implemented, until at least 2030.

5.1. Reform of Air Passenger Duty

Currently, the aviation industry is lightly taxed. Aviation fuel is not taxed. Tickets for flights do not attract VAT, although other parts of an airline's operating costs (e.g. landing fees) do. However, there is a tax that is unique to the industry: Air Passenger Duty (APD), which is a tax on passenger tickets that was introduced in 1994. The Government has recently consulted on aviation taxes [95] (to which T&E responded [96]) and subsequently announced changes to APD, to take effect in 2023.

APD was explicitly designed to raise money, rather than being an environmental tax [97] [98]. However, with reform there is no reason why it could not be both. APD is applied to every ticket that departs from airports across the UK. The duty is currently charged at two rates, and the rate payable is dependent on how far away the final destination is. Band A for shorter flights, where the vast majority of tickets are charged £13 per flight, and Band B for longer flights, where the vast majority of tickets are charged £82 per flight [99]. Because the majority of commercial flights from the UK are domestic or short-haul, 77% of passengers (pre-pandemic) were on tickets that attract the £13 levy [100]. Overall, APD has brought in £3.6bn per year for the UK Government over the last couple of years, although 2020/21's receipts were much lower (£582m [100]) due to the pandemic.

The Chancellor announced changes to APD in October 2021, halving the domestic rate, and adding an "ultra long haul" distance band. These measures will take effect from April 2023, and are expected to cost the Treasury £35m per year [101]. Despite these changes only just being announced, T&E believes that passenger duties should be further reformed as a per kilometre tax, with a minimum contribution level of

[29] From 213.4m passengers in 2010, to 300.2m in 2019: Figures to be found in Table 10.3 of the associated citation.

£13 (today's minimum level). Currently, APD is based on the distance away the final destination's country's capital is from London, and rates are based on the two bands described above: Band A is up to 2000 miles (which incorporates the whole of Europe). Band B is over 2000 miles (and is generally regarded as long-haul).[30] This should be changed to the exact distance between the airports. This way, APD becomes directly proportional to distance flown and class of seat, thereby more accurately reflecting the actual emissions caused by an individual. For simplicity, ticket duties should be fixed and collected by airlines, much the same way as now.

The above moves would obviously fully reform APD along environmental principles, but would not stop overall emissions increasing above 2019 levels. Therefore a further measure should be applied: Should UK aviation's collective absolute emissions go higher than the net zero compliant baseline level, then the pence per kilometer rate should be automatically raised. Equally, should emissions fall faster than against a net zero compliant baseline, then it should be reduced. This gives UK aviation the collective incentive to decarbonise even faster.

Note: as with any tax, the base rate should increase (or decrease) with inflation each year.

5.2. Airport Expansion

Finally, the UK Government should immediately impose a moratorium on airport expansion, which is something that was effectively previously suggested by the Climate Change Committee as part of its sixth carbon budget policy suggestions [102]:

"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"

There are a number of airports that have formal applications to expand, including Bristol, Heathrow, Leeds Bradford, Luton, Manston, Southampton and Stansted. Furthermore, it is expected that Gatwick will formally submit a development consent order in 2022. If all these planned expansions were to happen, then annual passenger numbers could increase by nearly 200m [103] and would exacerbate the absolute volumes of ZEA and SAF needed to decarbonise the sector. The moratorium should stand until at least 2030.

6. Conclusion

The UK's aviation and aerospace industries are strong, powerful and successful on the global stage. The UK Government has major ambitions for the UK to be a world leader in the research, design and manufacture of zero emission planes, the production of sustainable aviation fuels, and wants to be a world leader in combating climate change: ultimately reducing the UKs overall emissions - including those from both domestic and international aviation - down to no net contribution within the next 28

[30] There are also 3 rates of duty for each destination band; Reduced rate, which is the lowest class seating (seat pitches less than 1.016m or 40in); Standard rate, which is any other class of seating (seat pitches more than 1.016m or 40in); and Higher rate, which applies to travel in planes of 20 tonnes or more, equipped to carry fewer than 19 passengers.

years. Taxpayers money will be directed to the aviation and aerospace industry over the next couple of years. This paper suggests that the amount needs to be dramatically increased, to ensure that UK aviation emerges from the pandemic greener, and on course for the industry to produce no net carbon emissions from its in-sector activities by 2050. T&E has laid out some options as to how this could happen, and it is hoped that these measures will be seriously considered by not only the relevant ministers and civil service members, but also all members of the jet zero council and other interested industry bodies.

These options broadly follow one of two principles. Firstly, applying the Support, Regulate, Ban pattern to ensure not only uptake of new technologies, but the reduction and elimination of polluting technologies. Secondly, by applying an increasing price to all carbon emissions and non-CO_2 warming effects originating from all UK departing planes, thus giving the sector ample incentive to move towards zero-emissions aircraft and sustainable aviation fuel with high sustainability standards. Crucially, by applying a carbon price on all emissions, and taxing kerosene fuel the Treasury will receive substantial additional revenue from the sector, and a large proportion of that revenue should be ploughed back into aviation, to aid the transition to a zero carbon aviation sector.

It is now up to the Government to decide its level of ambition. UK aviation is now “rebuilding” after a torrid two years. The term “Build Back Better” is now commonplace worldwide, and the UK’s Government now needs to boost the building process, whilst defining the speed and shape of “better”. The Government should ensure that 2019 becomes the peak of aviation emissions, and should implement measures that ensure UK aerospace shifts its focus onto zero emission aircraft and fuels, whilst increasing costs on those airlines that continue burning fossil fuels.

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