BAAN/W2/1

TOWN AND COUNTRY PLANNING ACT 1990

Appeal by Bristol Airport Limited concerning land at North Side Road, Felton, Bristol, BS48 3DY

DEVELOPMENT OF BRISTOL AIRPORT TO ACCOMMODATE 12 MILLION PASSENGERS PER ANNUM

Appeal Reference APP/D0121/W/20/3259234

PROOF OF EVIDENCE

of

Finlay Asher (MEng)

Founder at Green Sky Thinking

15 June 2021

CONTENTS

1. INTRODUCTION

1.1. My name is Finlay Asher. I am an aerospace engineer with extensive experience working in the aviation industry, with industry-leading companies, on the latest cutting-edge aircraft technology that will emerge over the coming decades.

1.2. From 2012 to 2020, I was employed by Rolls-Royce, designing aircraft engines. I worked as a Systems Integrator on the Trent 7000 engine (Airbus A330neo), Structural System Design team lead on the Trent XWB engine (Airbus A350), Development Engineer for composite fan blade testing, System Design architect on the UltraFan™ geared turbofan engine, and within the Vision 20 future programmes team studying novel aircraft propulsion such as Variable Pitch Fan engines and integrated airframe/engine concepts for the 2030s onwards. All of these projects were collaborations between Rolls-Royce and aircraft level engineering teams in either Airbus or Boeing. They involved designing engines for aircraft either recently entering service in the past 5 years (Trent 7000 and Trent XWB) or planned for entry-into-service over the next 10-20 years (UltraFan, Variable Pitch Fan, integrated airframe/engines) – so I have a detailed understanding of the challenges and timescales involved with designing, developing, and certifying new aircraft technology.

1.3. In 2020, I was the winner of the Royal Aeronautical Society (RAeS) NE Rowe Branch Lecture Competition with my lecture and associated paper on "Sustainable Aviation" [**CD 9.79**].

1.4. As a result of my technical knowledge of "sustainable aviation", and my experience of working in the aviation industry, in November 2020 I founded Green Sky Thinking, to focus on the topic of Sustainable Aviation. I am also a co-founder of "Safe Landing": a group for climate-concerned aviation workers.

1.5. I understand that my duty as an independent expert witness is owed to the inquiry. The evidence which I have prepared and provide for this appeal in this proof of evidence is true to the best of my knowledge and belief. I confirm that the opinions expressed are my true and professional opinions based on the facts I regard as relevant in connection with the appeal.

2. OVERVIEW OF "SUSTAINABLE AVIATION"

2.1. In mid-2019, under increased pressure from climate activists, the world's largest aviation companies released a joint statement at the Paris Air Show, setting out the industry's "sustainability strategy" [**Appendix 1**]. This downplays aviation's environmental impact, and contains numerous misconceptions that are regularly repeated by the industry when arguing in favour of unconstrained air traffic growth, and expansion:

- Aviation contributes only a small % to global emissions and global warming
- Aircraft efficiency improvements are reducing emissions from the sector
- Electric aircraft will soon be a viable alternative to jet fuel powered flight
- Hydrogen aircraft will soon be a viable alternative to jet fuel powered flight
- Alternative jet fuels such as biofuel, or synfuel/electro-fuel can be scaled ecologically and economically – without affecting the price of air travel and undermining the business case for airline/airport expansion plans
- Existing carbon offset schemes will be effective in reducing emissions.

2.2. As I will show in this proof of evidence, these misconceptions are mostly based on the false hope that technological innovation alone will lead to decarbonisation, without the need for government policies that constrain air traffic growth. My evidence also shows that existing policy measures such as carbon offset are too weak and ineffective to deliver the emissions reductions claimed and relied on by BAL.

2.3. I will also show that even if additional policy measures such as emissions pricing, aviation fuel duty, or reform to air passenger duty (APD) are put in place to constrain air traffic growth and accelerate the adoption of lower-emissions technologies and airline operations, such policy measures will also undermine the case for expansion, which is based on existing pricing and policy measures only, and assumes that air travel will remain relatively cheap across future decades.

2.4. This conclusion is also reflected in the UK Climate Change Committee (CCC) "The Sixth Carbon Budget: Aviation" [**CD 9.66**] report which considers aircraft efficiency improvements and significant use of alternative jet fuels, but still concludes that air traffic demand management is crucial to achieving a "Balanced Net Zero Pathway". They state that "*Airport expansion could still occur under the Balanced Pathway, but would require capacity restrictions elsewhere in the UK (i.e. effectively a reallocation of airport capacity).*" [**CD 9.66** pg 11]

3. THE ENVIRONMENTAL IMPACT OF AVIATION

3.1. The aviation industry is eager to highlight that flying only produces 2-3% of global CO2 emissions [**Appendix 1** pg 1 BAAN/W2/2 pg 4]. This is correct, but 2-3% is still a significant amount: if aviation was a country, it would rank amongst the top 10 emitters [**Appendix 2** pg 2 BAAN/W2/2 pg 9], ahead of nations like Brazil, Mexico, and the UK.

3.2. Furthermore, this percentage figure is higher in the UK where per-capita aviation emissions are far higher than the global average. In 2019, UK aviation emissions accounted for 8% of the UK's total greenhouse gas emissions [**CD 9.57** pg 3], up from 7% in 2018 [**CD 9.66** pg 5].

3.3. The carbon emissions growth trajectory is also important. When projecting forward, we expect other sectors to decarbonise. This means aviation may produce closer to 25% of global CO2 emissions by 2050 [**Appendix 3** pg 1 BAAN/W2/2 pg 14 (the aviation industry accepts this number) and **CD 9.67** pg 1 (predicting a slightly higher rise)]. This would be a very large share.

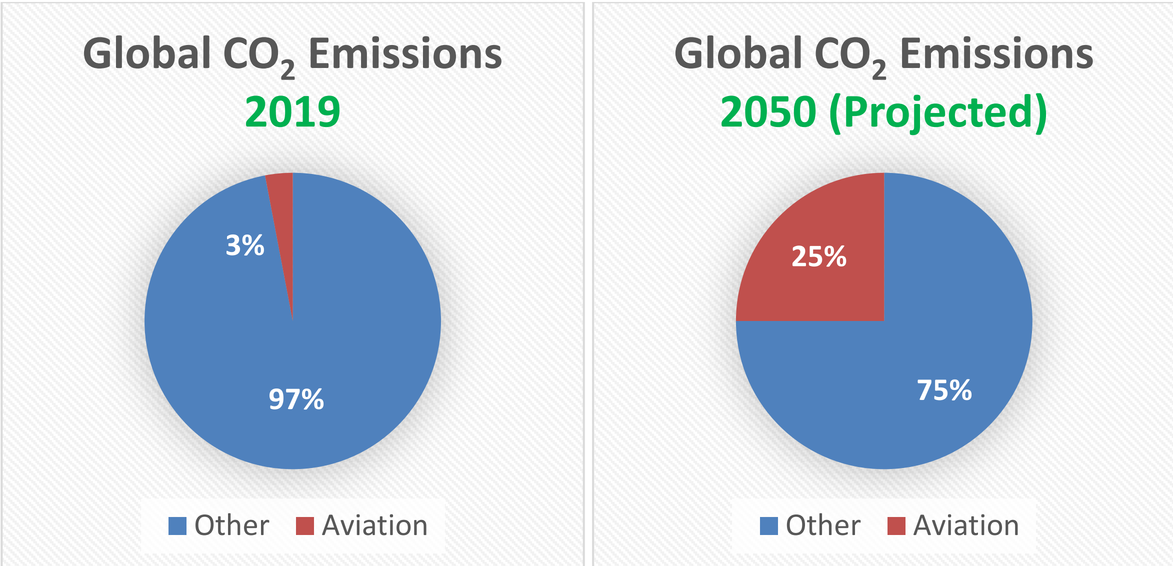

Figure 1: Aviation's Share of Global CO_2 Emissions, 2019 (current) vs. 2050 (projected) [**CD 9.79** pg 2]

3.4. It is also important to understand the effects of non-CO2 emissions such as nitrogen oxides (NOx) and contrail cirrus. Non-CO2 impacts are not accounted for in any existing regulations: whether the national greenhouse gases (GHG) inventory submissions to the UNFCCC, the CORSIA scheme (see Section 8), or the EU (or new UK) Emissions Trading System (ETS). They are currently dismissed by the International Civil Aviation Organization (ICAO) as being too scientifically uncertain to warrant necessary action [**Appendix 4** pg 1 BAAN/W2/2 pg 16]. However, the CCC recognises radiative forcing as one of the drivers of climate change and recommends that the UK report its best estimate of non-CO2 effects. "*as they are a significant part of aviation's impact on the climate*" [**CD 9.34** pg 374, see also pg 422]. The Department of Business Energy and Industrial Strategy recommends a multiplying factor of 1.9 be applied to CO2 emissions from aviation to take into account non-CO2 emissions [see Professor Kevin Anderson's Proof of Evidence [BAAN/W1/1] at para 6.1.2]. This is conservative: the latest science estimates that the non-CO2 impacts from flying have an even greater global warming effect than the CO2 emissions and comprise about 2/3 of aviation's net radiative forcing (the greenhouse effect that traps heat within the Earth's atmosphere). The contribution of these non-CO2 effects mean that aviation is currently warming the climate at approximately three times the rate of that associated with its CO2 emissions alone [**CD 9.60** pg 2].

3.5. Thus: aviation produces a significant amount of CO2 emissions, which are projected to grow considerably, and which are exacerbated by an even greater global warming effect from aviation's non-CO2 emissions. This should dispel any perception that aviation's total climate impact is relatively small.

3.6. The final aspect to understand is the socio-economic distribution of these emissions. It is a very small number of people who fly regularly and produce the vast majority of aviation emissions. It is estimated that only 2% to 4% of the global population flew internationally in 2018, and that 1% of the world's population emits 50% of CO2 from commercial aviation [**CD 9.80** pg 1]. For comparison, a single return flight from Lisbon to New York generates roughly the same level of emissions required to heat the average EU home for an entire year [**Appendix 2** pg 2 BAAN/W2/2 pg 9].

3.7. Focusing on the UK, a recent House of Commons Library Briefing recorded: "***The majority of flights are taken by a small proportion of the population.*** *In 2019 international and domestic flights made up around 12% of emissions from UK households (which also includes energy usage in the home, other forms of transport etc.) but this is unevenly distributed across the population and is growing. A government survey of 1000 UK adults found that in 2013 70% of all flights were taken by only 15% of the population and 52% of people hadn't flown at all over the past year. The National Travel Survey found that from a survey of 18,000 people in England, only 12% had flown three or more times in 2015*." [**CD 9.57** pg 7, emphasis in original]

3.8. Much the same picture emerges from more up-to-date data from 2014 and 2015-2017, which focuses on international flights:

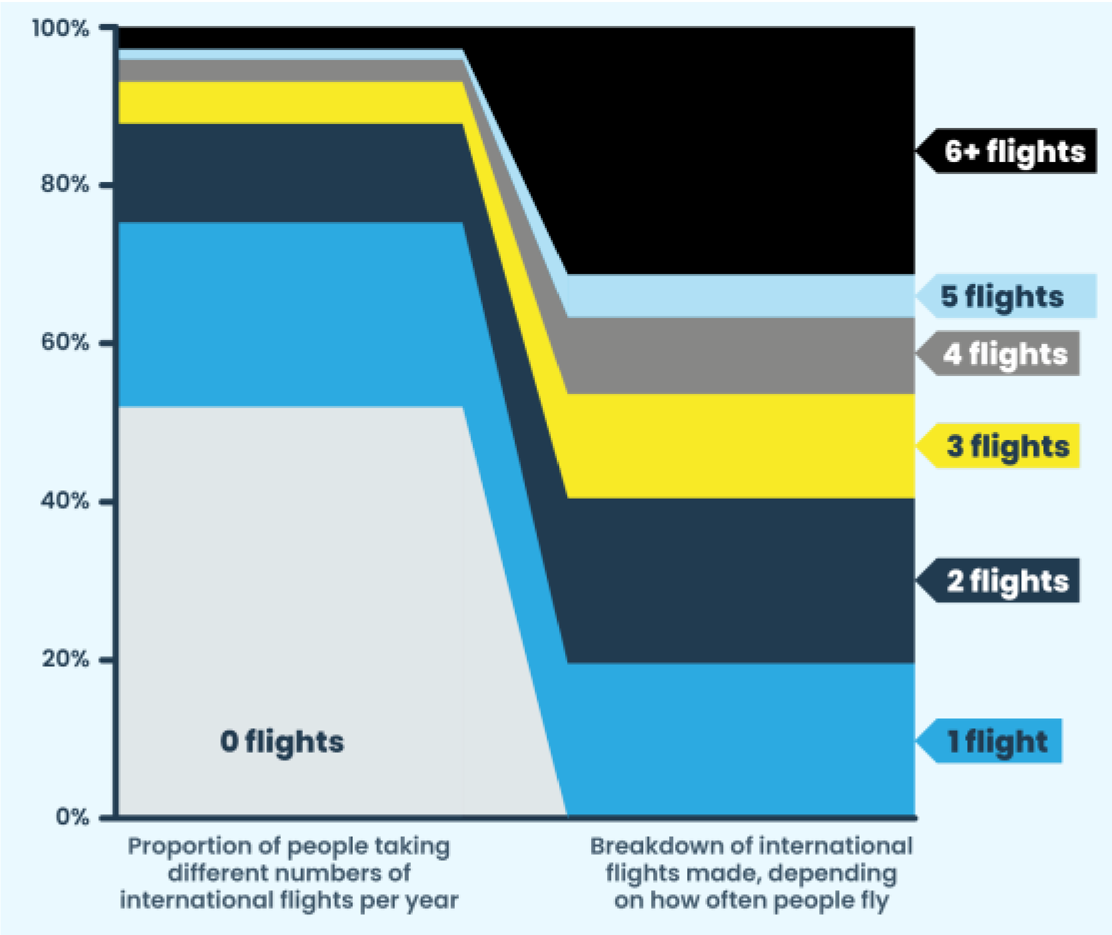

Figure 2: English data from 2015-2017 National Travel Survey on how often people fly and how that related to flight numbers [**CD 9.124** pg 9]

3.9. This socio-economic distribution of emissions is important in light of the principles of equity and fairness introduced by the 2015 Paris Agreement. Given that aviation is an energy- and emissions-intensive activity, which is utilised by a relatively small group of generally high-income individuals and organisations, countries should be slow to encourage further emissions from this industry, because of the inequitable impact.

4. EFFICIENCY

4.1. The next common misconception is that flying can be decarbonised by making aircraft more efficient every year. It is correct that efficiency gains are enabled by improved airline operations, more aerodynamic aircraft wings, use of lighter materials such as carbon fibre, larger engines (for greater propulsive efficiency), and higher temperature and pressure capable materials in the engine cores (for improved thermal efficiency). Unfortunately, these improvements lead to misleading statements from the supporters of the expansion of the aviation industry such as: "*since the advent of jet technology, carbon-dioxide emissions from aviation have reduced by 80%*" [**Appendix 5** pg 2 BAAN/W2/2 pg 19].

4.2. It is correct that these improvements have resulted in emissions reduction **per passenger mile flown**. However, they have also reduced the cost of flying, which has made it more affordable, and contributed to accelerating air traffic growth as airlines simply fly more regularly, further and with larger, less efficient, seat configurations.

4.3. This combination of lower cost flying (enabled by the efficiency gains), coupled with an increased global population who can afford to fly, has resulted in a rapid growth in air travel (doubling every 15 years) that has far outstripped the efficiency savings:

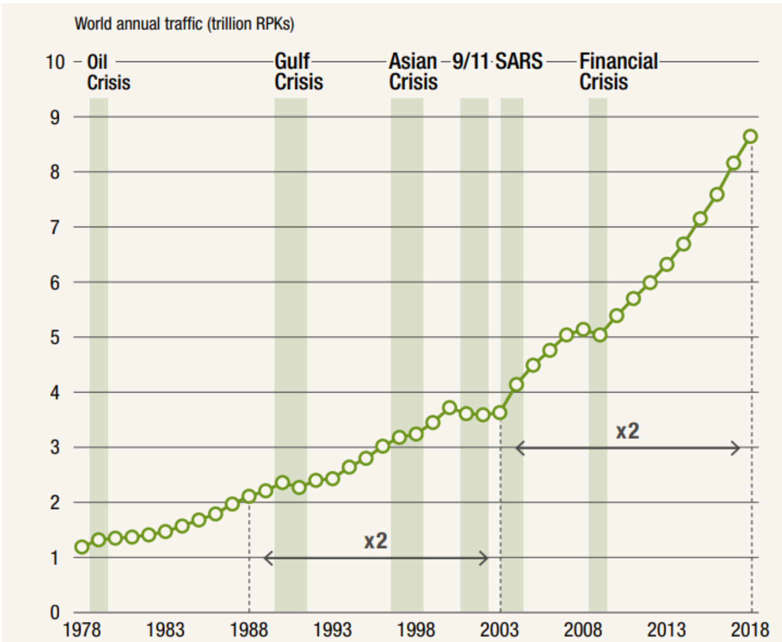

Figure 3: Historic Air Traffic Growth (Revenue Passenger Kilometres = RPK) [**Appendix 6** pg 014 BAAN/W2/2 pg 30]

4.4. Prior to the COVID-19 pandemic, Airbus had projected that air traffic would double from 2018 levels by the mid-2030s, and then again by 2050. This could amount to an **8-times increase** from year 2000 levels:

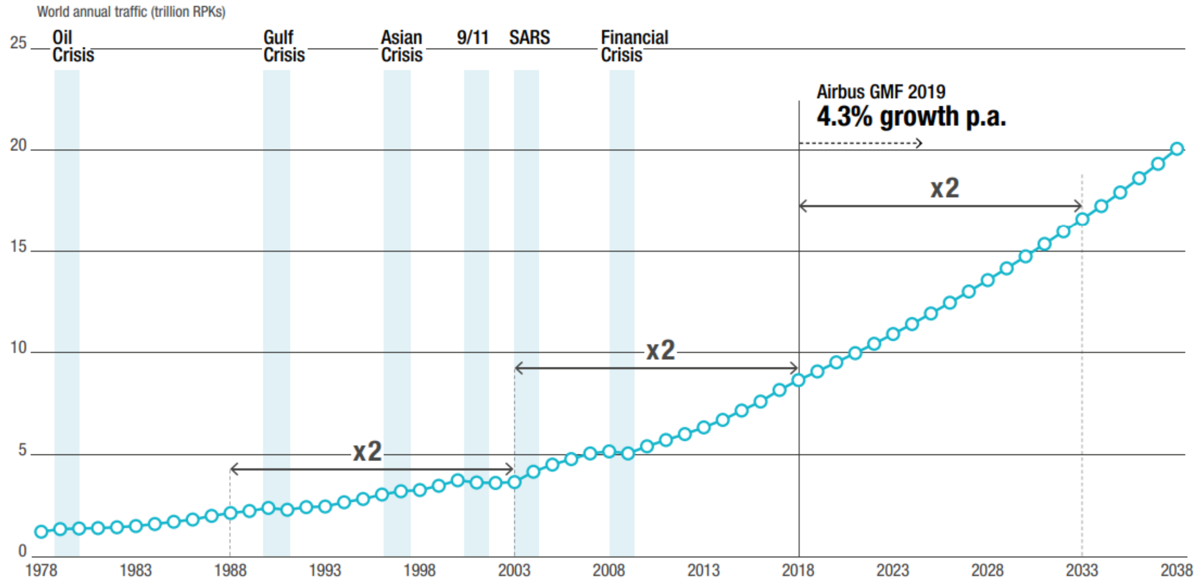

Figure 4: Projected Air Traffic Growth (Revenue Passenger Kilometres = RPK) [**Appendix 6** pgs 010 and 011 BAAN/W2/2 pg 28]

4.5. The key metric for the earth's atmosphere is not emissions **per passenger mile**, but rather **total emissions** produced by aviation. This has been rapidly increasing, rather than decreasing, despite all the historical efficiency improvements to date:

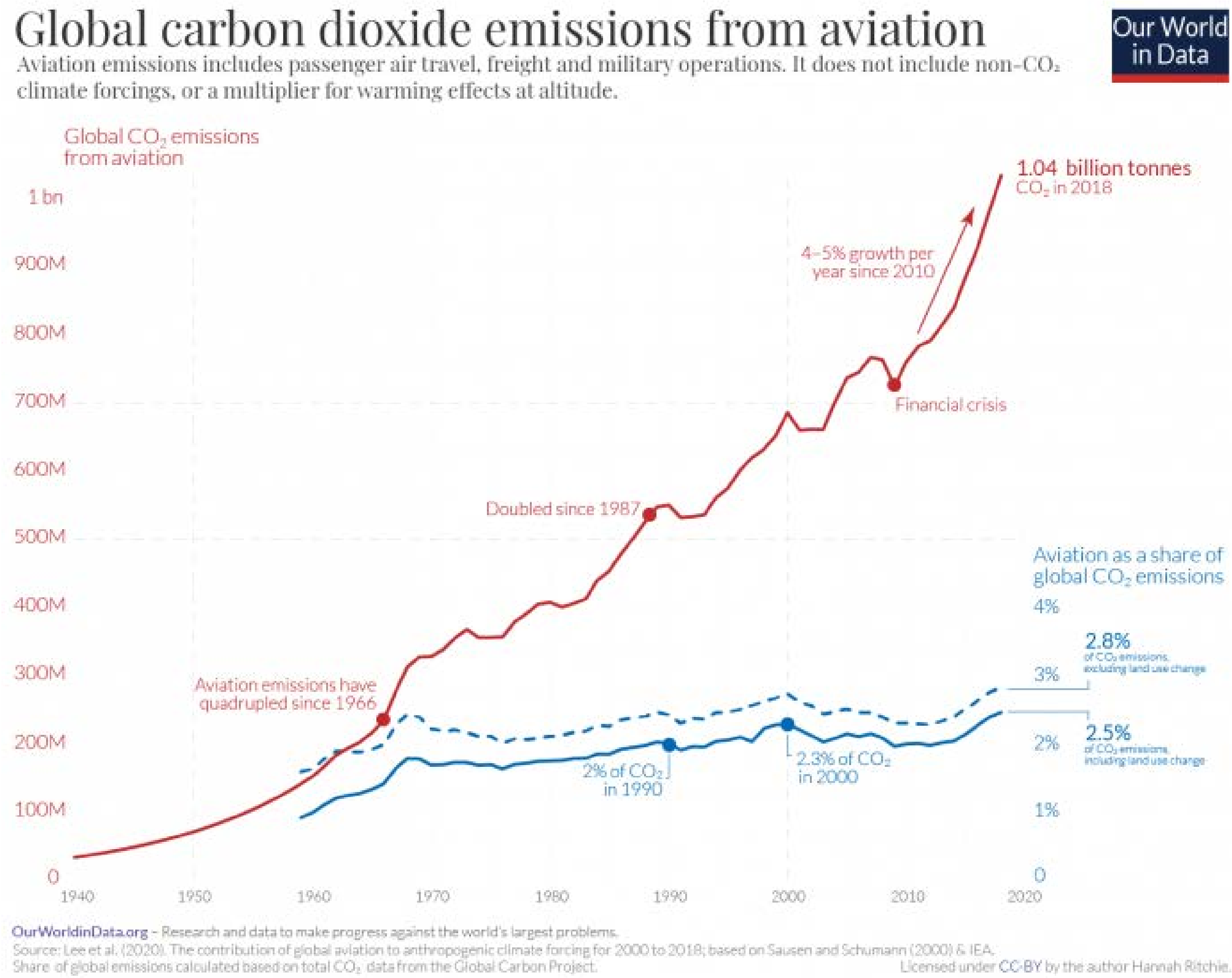

Figure 5: Global CO2 emissions from aviation [**Appendix 7** pg 2 BAAN/W2/2 pg 34][1]

4.6. It would be a reasonable assumption to project that aviation emissions will continue to grow on a similar trajectory if air traffic growth remains unregulated, even if efficiency improvements continue. Unfortunately, aircraft efficiency improvements are also becoming more difficult to achieve, with the rate of improvement decreasing with time. See Figure 6, which shows the rate of aircraft efficiency (kgCO2/passenger-revenue-kilometre) improvements slowing with time (red line), as the rate of air travel (passenger-revenue-kilometres) simultaneously accelerates with time (blue line).

[1] Our World in Data is a scientific online publication, the research team for which is based at the University of Oxford. The red line represents global carbon dioxide emissions from aviation and was taken from Lee et al. (2020) [**CD 9.80**].

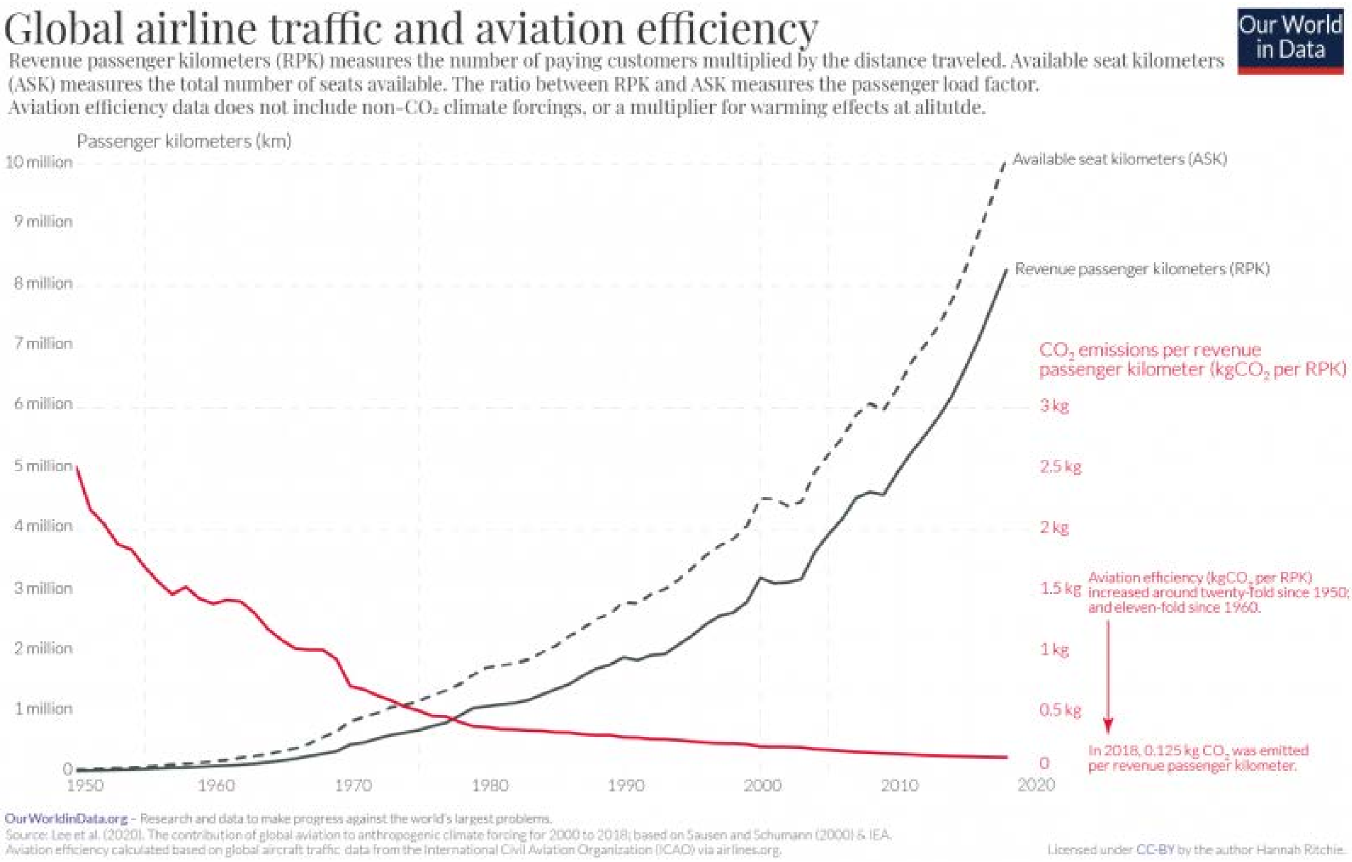

Figure 6: Global airline traffic vs. aviation efficiency. Note: rate of efficiency gains slows with time [**Appendix 7** pg 4]

4.7. This is consistent with my own experience within Rolls-Royce, and my understanding of the other key aircraft engine manufacturers (General Electric and Pratt & Whitney) where the key airframe manufacturers (Boeing and Airbus) have left the airframe largely unchanged and have been seeking efficiency improvements primarily from the engines. This has become more difficult with time, with marginal gains now being achieved, and step-changes in efficiency are not possible unless significant new aircraft and engine architectures are developed – a process which will take decades.

4.8. The key takeaway here is that in a poorly-regulated industry, efficiency improvements may be used to grow the market and increase emissions, not reduce them. Therefore, efficiency gains will not result in **total** emissions or energy consumption reducing, and cannot be relied upon in isolation, without measures to address demand (as emphasised by the CCC) [**CD 9.66** pg 11].

5. ELECTRIC FLIGHT

5.1. Another common misconception encouraged by the aviation industry is that electrification will soon help us to fly whilst producing zero emissions. Electric aircraft propulsion systems typically involve the propulsors (propellor or fan blades) driven by electric motors. In "fully-electric" aircraft, these motors are powered by electrical energy provided directly from batteries. In "hybrid-electric" aircraft, these electric motors act in series, or parallel, with a combustion engine powered by jet fuel.

5.2. As "hybrid-electric" aircraft burn jet fuel, they produce CO2 and other greenhouse gas emissions during operation. They are therefore not zero emissions. These systems unlock potential new aircraft and engine architectures, such as "distributed propulsion" which could provide aircraft-level aerodynamic improvements, although such improvements can often be negated by the additional complexity of the designs. My experience within future programmes at Rolls-Royce was that hybrid-electric studies showed that any theoretical improvement was largely cancelled out by the additional weight of the electrical systems and associated systems such as heat exchangers. For this reason, any likely "electrification" of future engines tended to be confined to the use of electrical auxiliary systems such as oil pumps or fuel pumps for optimising the operation of the jet fuel powered engines. Crucially, if any "hybrid-electric" aircraft are certified for commercial use, they will still burn jet fuel and should be viewed as an aircraft efficiency improvement that may reduce the quantity of fuel burned and emissions produced **per passenger mile**. As shown in Section 4, it is unlikely that such aircraft efficiency improvements alone will result in reduced aviation emissions.

5.3. As "fully-electric" aircraft are powered by batteries, if the batteries are charged using only 'green' renewable electricity, the aircraft can be considered "zero emissions". However, current electrical motor, generator, transmission, and storage technology is far too heavy to displace most aircraft engines and jet fuel. As illustrated by Airbus:

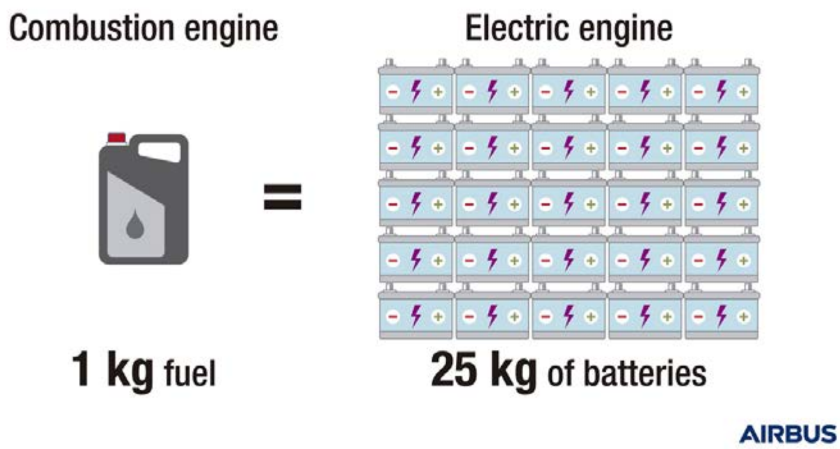

Figure 7: The average efficiency of a motor and thermal engine means that: 1 kg of fuel equals 25 to 30 kg of batteries [**Appendix 8** pg 2 BAAN/W2/2 pg 40]

5.4. In addition, unlike a fuel tank where the weight decreases as fuel is burned during the flight, a battery does not become lighter during the trip. These issues further impact the payload and range capability of the aircraft [**Appendix 8** pg 2].

5.5. Crucially, electric propulsion is not viable for most commercial flights. 80% of aviation emissions come from passenger flights further than 1,500km and electric flight cannot compete at that range. The Chief Technology Officer of Airbus has also stated that "*even assuming huge advances in battery technology, with batteries that are 30 times more efficient and 'energy-dense' than they are today, it would only be possible to fly an A320 airliner for a fifth of its range with just half of its payload*" [**Appendix 9** pg 4 BAAN/W2/2 pg 45]. Such aircraft are typical of those used by airlines operating from Bristol Airport.

5.6. It can therefore be concluded that electric aircraft will not realistically be viable, even by 2050, for anything but very short-haul commercial flights and will not be available for the type of aircraft for which Bristol Airport is predominantly configured and which produce the majority of the associated aviation emissions.

5.7. Any very short-haul commercial flights that do operate from Bristol Airport will likely be domestic aviation. Where infrastructure allows: lower energy- and emissions-intensity ground-based public transport options such as rail, coach, or ferry services should generally be favoured at these short distances. For context, in 2018 UK aviation was responsible for 37.8 MtCO2e of GHG emissions, with domestic aviation accounting for only 1.5 MtCO2e, or less than 4% of the total [CD 9.57 pg 5]. Therefore, even if electric flight is used for some niche cases where ground transport options are poor, it's scope to decarbonise UK aviation emissions is very limited.

5.8. This conclusion is also reflected in the UK CCC's "The Sixth Carbon Budget: Aviation" report, which states that fully-electric aircraft "*have energy storage limitations, and would be most suited for domestic or short-haul flights and/or smaller airplane classes, which make up a relatively small share of UK aviation emissions.*" [**CD 9.66** pg 17].

5.9. It should be noted that the CCC was well aware of the proposals by UK industry lobby group Sustainable Aviation in their "Decarbonisation Road-Map" [**CD 9.14**], which was published on 4 February 2020, the same say as the press release on UK aviation committing to New Zero carbon emissions by 2050, referenced by the CCC in footnote 3 to its "The Sixth Carbon Budget: Aviation" report [**CD 9.66** pg 39]. The CCC therefore did not consider that commitment announced by Sustainable Aviation or the Sustainable Aviation Decarbonisation Road-Map or the Fuel Road-Map [**CD 9.15**] meant that more weight should be given to hybrid-electric or fully electric aircraft than is reflected above. In full knowledge of the industry's commitment to the Sustainable Aviation Decarbonisation and Fuels Road-Maps, the CCC's main recommendation was that air traffic demand management is crucial to achieving a Balanced Net Zero Pathway, through no net expansion of UK airport capacity [**CD 9.66** pgs 11 and 21].

6. HYDROGEN FLIGHT

6.1. Hydrogen aircraft are powered by hydrogen that can be stored as a compressed gas or liquid. The hydrogen can be converted into electricity via a fuel cell, which can be used to power an electric motor driving the aircraft propulsors. Alternatively, the hydrogen can be directly combusted in a gas turbine [**CD 9.75** pgs 24 and 25].

6.2. Hydrogen fuel cells only produce water during operation – no CO2 or other greenhouse gases are produced. However, as just set out, they require electric motors and/or other electrical systems with high associated weight. Therefore, hydrogen fuel cells have similar limitations to fully-electric aircraft and will be limited (once developed – see below on timescales) to very short-haul commercial flights [**CD 9.75** pgs 30 and 31] with limited scope to decarbonise UK aviation emissions. The CCC highlights the same limitations for hydrogen options as for electric options [**CD 9.66** pg 17].

6.3. Hydrogen combustion in a gas turbine produces NOx and water vapour emissions which both have a global warming effect [**CD 9.60** pg 2ff] and is therefore not zero-emissions. Hydrogen combustion aircraft will also be limited in payload and range versus jet fuel combustion aircraft, due to the storage limitations of hydrogen.

6.4. Critically, hydrogen has a lower energy density by volume than jet fuel. It exists as a gas in atmospheric conditions, so needs to be compressed or liquified by cooling it to extremely low temperatures (-253°C) to achieve a reasonable volume. This is energy-intensive, expensive, and results in complex and heavy storage containers [**CD 9.75** pgs 24 and 25]. Even liquified hydrogen has a density of 8 MJ/litre, whereas kerosene has a density of 32 MJ/litre, so the equivalent energy storage requires 4x the volume:

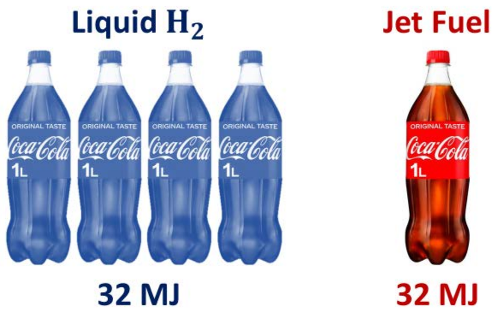

Figure 8: Relative volume required of Liquid Hydrogen for equivalent energy in jet fuel [**CD 9.79** pg 8]

6.5. This size, shape and weight requirements of hydrogen will require a re-design of medium and long-haul aircraft fuselages (the body of the aircraft). For example, the storage tanks must be cylindrical or spherical, which makes it very difficult to store the fuel within the wings as per conventional aircraft design. This will require either:

- Increased aircraft size, increasing drag at a given flight speed; or
- Identical aircraft size, but reduced numbers of passengers.

6.6. Both of these options will increase the cost of flying: as the result is either:

- a loss of aircraft efficiency, increasing the aircraft fuel burn and/or
- flight costs being distributed between fewer paying customers.

6.7. Both options would also require modification to airport infrastructure for compatibility with these new and novel aircraft configurations. Either:

- the size and shape of the aircraft will change, which will affect the layout of the airport gates; or
- the aircraft passenger capacities will change, which will affect the layout of the airport terminals.

6.8. Airline and airport operations would also be significantly affected by differences in aircraft range. As set out below, Airbus has a "moonshot plan" to certify a hydrogen aircraft for commercial use by 2035 (i.e., one aircraft) [**Appendix 10** pg 1 BAAN/W2/2 pg 46], but any certified hydrogen aircraft will only be expected to cover a range of up to 2,000 kilometres at most [**CD 9.75** pg 32]. In reality, such hybrid hydrogen aircraft involving both hydrogen combustion and fuel cells would be technically very complex to develop and certify, and this is very unlikely to happen within the 2030s; certainly not in time to update a significant proportion of the fleet before 2050. This is because demonstrating and certifying technology is only part of the challenge: it will then take decades and huge financial investment to produce and replace aircraft, and to update airport infrastructure. Fuel cell powered commuter or regional aircraft are most likely to happen within the 2030s but will likely be limited to less than 1,000 kilometres of range [**CD 9.75** pgs 30 and 31] and again, are unlikely to be widely utilised within airline operations until later decades. Less than 5% of global aviation emissions are caused by regional and commuter flights [**CD 9.75** pg 16].

6.9. The production of Hydrogen is also an issue. The production methods include:

- Grey Hydrogen = produced from methane or coal (both fossil fuels)
- Blue Hydrogen = Grey Hydrogen with Carbon Capture & Storage (CCS)
- Green Hydrogen = produced (via electrolysis) from renewable electricity

The majority (95%) of hydrogen used today (by refineries and for producing ammonia fertiliser) is "Grey Hydrogen" and therefore still involves fossil fuel and carbon emissions. "Blue Hydrogen" is unproven at scale, is more expensive than Grey Hydrogen, still involves the use of fossil fuel, and cannot capture all carbon emissions. "Green Hydrogen" is the only 'zero-emissions' option, but its production is very energy intensive, making it even more expensive.

6.10. The cost of "Green Hydrogen" is expected to drop with time as production scales. However, even by 2040, the cost of CO2 abatement using Green Hydrogen is expected to be significant. From \$60/tCO2 for commuter, to above \$200/tCO2 for short- to long-range aircraft. As illustrated in the figure below, the short- to long-range sectors produce the majority (95%) of aviation emissions, but those sectors all have a cost of abatement above \$200/tCO2. If hydrogen is applied to these sectors, it will be very costly to achieve emissions reductions:

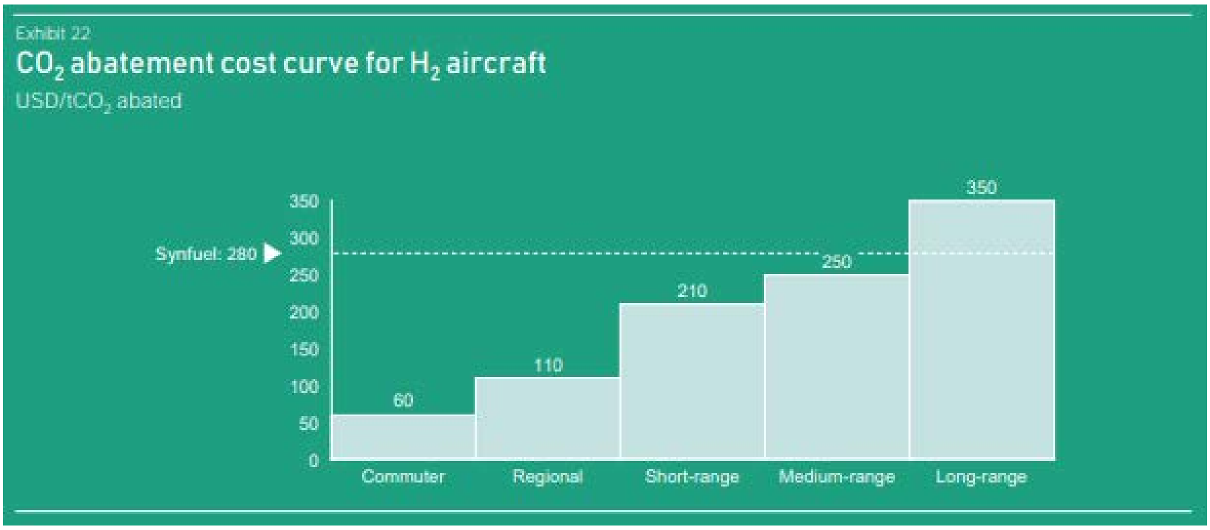

Figure 9: CO2 abatement cost curve for hydrogen aircraft **[CD 9.75** pg 56]

6.11. The energy intensity of "Green Hydrogen", caused by efficiency losses in the electrolysis process, is also an issue in terms of energy consumption. The electrical energy required to produce enough Green Hydrogen to displace the UK's current annual aviation fuel consumption would exceed the UK's current levels of annual renewable energy generation (this is also true when both elements are scaled to the global level). This is clearly not likely to be politically or commercially acceptable. Whilst renewable energy generation is growing every year, the UK needs to use this energy (and green hydrogen) for decarbonising other sectors of the economy.

6.12. The next issue is timescales. If it does happen, hydrogen aircraft and airport infrastructure will take decades to develop. It will then take further decades to update the global fleet from jet fuel to hydrogen powered aircraft. Meanwhile, rapid reductions in greenhouse gas emissions are required. Hydrogen flight will be unable to contribute significantly to this strategy. This conclusion is also reflected in the UK CCC "The Sixth Carbon Budget: Aviation" report which states that "*the time taken to design, build, test, scale-up, certify and manufacture new aircraft propulsion systems (and the new aircraft bodies to accommodate them and their energy stores on-board) is significant – at least several decades. Even if one of these options were commercialised in the 2040s, it would be challenging to immediately achieve a large*

% share of aircraft sales, and given the 20-30 year lifetimes of aircraft, this will not lead to a significant fleet penetration by 2050." [**CD 9.66** pg 17]

6.13. Finally, hydrogen flight is unproven, with many technical and safety aspects yet to be understood. It is not yet clear to the industry whether hydrogen flight is the optimum solution vs. electric flight for short-haul, and vs. alternative jet fuels for long-haul. The comments of the Chief Executive Officers (CEOs) of both major airframers, Airbus and Boeing, reflect this uncertainty, with Boeing's CEO having "*dismissed the potential for hydrogen power to be used at scale in commercial aviation <u>for decades</u>*" (emphasis added) and Airbus calling their hydrogen plans a "*moonshot*" approach, indicating low chance of success [**Appendix 10** pg 1]. It would not be wise to base airport expansion plans on a technology which may never see commercialisation, and until this technology pathway is understood, very little weight can be given to claims that it will play any significant part in decarbonising air travel by 2050.

6.14. In conclusion, the fundamental physics of hydrogen aircraft design and hydrogen fuel production mean that the economics of hydrogen flight contradict, rather than support, the growth plans of the aviation industry. These factors mean that the use of hydrogen in the industry would increase the cost of flying, limit demand, and impact the case for airport expansion by undermining the airport's passenger figures and therefore the need for expansion. They would also mean vastly expensive re-configuration of the airports.

6.15. Finally, even if hydrogen aircraft, airports, and fuel production facilities received generous government subsidies to lower the cost for passengers and enable expansion, the huge quantity of renewable energy required would hinder decarbonisation efforts elsewhere. The timescales required to develop and deploy hydrogen technology and infrastructure also mean that it will not credibly support significant decarbonisation of UK aviation emissions before 2050, and certainly not within the crucial period of the next two decades. Hydrogen flight is as yet unproven, and its continued development is speculative and very uncertain, meaning that no weight can be given to claims that hydrogen flight will help to meet sustainability targets by Bristol Airport in their expansion plans.

6.16. This inability to rely on hydrogen as a means of near-term aviation decarbonisation is underlined by the "Decarbonisation Road-Map: A Path to Net Zero" report [**CD 9.14**] produced by UK aviation industry lobby group 'Sustainable Aviation' (which comprises various aircraft technology manufacturers, airlines, airports, and aviation fuel producers). This report makes little reference to hydrogen aircraft apart from briefly mentioning the ZeroAvia "HyFlyer" project which involves very small aircraft (6-seat and in future, 19-seat aircraft) powered by a hydrogen fuel cell. This will be able to fly up to 300 nautical miles or approximately 500km [**CD 9.14** pg 34]. This demonstrates that even the industry is not viewing hydrogen flight as a significant part of its decarbonisation road map.

7. ALTERNATIVE JET FUELS OR "SUSTAINABLE AVIATION FUELS" (SAF)

7.1. The evidence has now shown that electric or hydrogen powered aircraft are still a long way off for the majority of air travel and that both batteries and hydrogen storage suffer from poor energy density by mass or by volume, relative to conventional jet fuel (kerosene). One solution to this set of problems, presented and hugely promoted by the industry, is to create alternative jet fuels or so-called "Sustainable Aviation Fuels" (SAF). These are produced using carbon taken from the atmosphere, rather than using fossil fuels extracted from deep underground which emit additional carbon to the atmosphere when burned. The industry say that this could allow existing aircraft to be used, whilst reducing the emissions associated with burning the fuel. The UK aviation industry lobby group *Sustainable Aviation* (which comprises various aircraft technology manufacturers, airlines, airports, and aviation fuel producers) claim that "*SAF gives at least 70% life cycle carbon saving compared to using fossil fuel*" [**CD 9.14** pgs 19 & 36; see also **CD 9.15** pg 3]. However, as evidenced below, there are many problems associated with this concept.

7.2. Alternative Jet Fuel can be broadly categorised into two varieties:

- Biofuels
- Synthetic Fuels (Synfuels), also referred to as Power-to-Liquid (PtL), or Electro-Fuels (e-fuels).

7.3. <u>Biofuels</u>

7.3.1. Biofuel production uses biomass for the feedstock: agricultural crops or waste from farms, municipal waste from cities, inedible animal fats, or used cooking oil.

7.3.2. Aviation biofuel is not a sustainable or scalable solution without causing increased global food prices, deforestation, drainage of peatland, loss of biodiversity, and land-use change emissions (the emissions generated when carbon stored in vegetation and soils is released e.g., when forests are converted to agricultural land). The use of large quantities of aviation biofuels will thus exacerbate the climate and ecological emergency.

7.3.3. The future available quantity of sustainable biomass “waste” is also strictly limited and should be considered a precious resource. Global economies will need to use any biomass produced for feeding a growing human population while also decarbonising the grid, domestic heating and ground transport. They are also important for negative emissions (Bioenergy Carbon Capture & Storage or BECCS). The scale of biomass for BECCS assumed in Integrated Assessment Models (IAMs) which are used by the Intergovernmental Panel on Climate Change (IPCC) to inform policy-makers – is typically, one to two times the area of India [**CD 9.68** pg 2]. Therefore, any biomass used for aviation fuel will be competing with other vast global requirements. Combining additional biofuel requirements to this demand will therefore inevitably lead to increased bioenergy impacts: biodiversity loss, food and water scarcity, and land-use change emissions. To illustrate this point, a recent study estimates that the BECCS requirements alone may result in water shortages for 4.5 billion people by 2100 [**Appendix 11** pgs 1-2 BAAN/W2/2 pgs48-49]. It is worth noting that an EU report (contributed to by Airbus, Boeing, BP, Shell, and easyJet [**CD 9.75** pg 11]) states that “*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*” [**CD 9.75** pg 18].

7.3.4. Biofuels have already been scaled to large quantities for road transport. These have resulted in land-use change CO2 emissions which have often been similar to or greater than emissions than if fossil fuels were used:

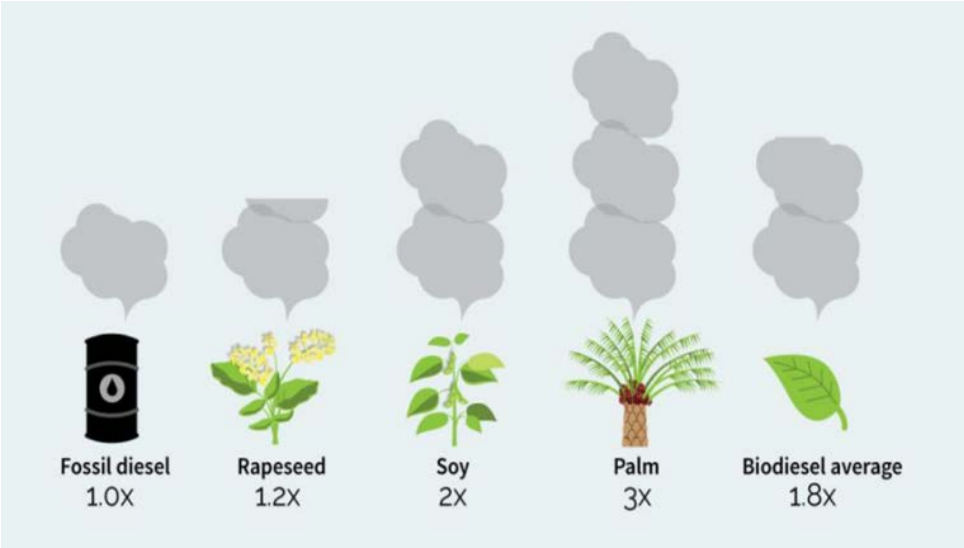

Figure 10: Greenhouse gas emissions linked to biodiesel feedstocks used in EU [**Appendix 12** pg 2 BAAN/W2/2 pg 51]

7.3.5. The most technically feasible and cost competitive aviation biofuel process is HEFA (Hydroprocessed Esters and Fatty Acids), due to its similarity to renewable diesel, a biofuel already produced at commercial scale for the road sector. The most commonly proposed feedstocks for this process are vegetable oils or "waste oils" such as used cooking oil or animal fats [**CD 9.123** pg 4]. However, there are already concerns with illicit markets for such feedstocks, with emissions savings being difficult to verify, and difficulties assessing whether the need for feedstocks is creating additional wastes and/or generating the use of unsustainable virgin materials (palm oil etc.) [**Appendix 13** Executive Summary pgs 4 and 5 BAAN/W2/2 pgs 58-59]. In any case, high near-term demand for HEFA aviation biofuels may only incentivise the diversion of waste oils from existing uses in the road sector. Even then, it could only approach "*approximately 2% of 2030 jet fuel demand from waste oil alone. Moving beyond 2% of SAF deployment will require targeted support for more conversion pathways with more challenging economics and uncertain production timelines*" [**CD 9.123** pg 1].

7.3.6. Without taking into account the political or economic barriers to alternative jet fuel production, it has been estimated that there are only sufficient resources to support approximately 5.5% of projected EU jet fuel demand in 2030 [**CD 9.123** pg 1].

7.3.7. It should be noted that aviation biofuel scale-up has been promised by the industry for more than a decade but this has not materialised. Targets have been routinely missed by significant margins, and then ambition ratcheted-down across successive years (see Figure 11). For example, in 2009, IATA was aiming for 10% biofuels by 2017 [**Appendix 14**, pg 14 BAAN/W2/2 pg 73], and in 2011 ATAG stated that "*We are striving to practically replace 6% of our fuel in 2020 with biofuel. We hope this figure can be higher*" [**Appendix 15**, pg 2 BAAN/W2/2 pg 84]. However, the industry now only predicts "*a sustainable aviation fuel demand within the next 3 years of 650 kt/year, less than 0.5% of current global fossil aviation fuel use*" [**CD 9.15** pg 14]. (Note: global fossil aviation fuel use has already exceeded 300 Mt/year, so 0.5% is an exaggeration).

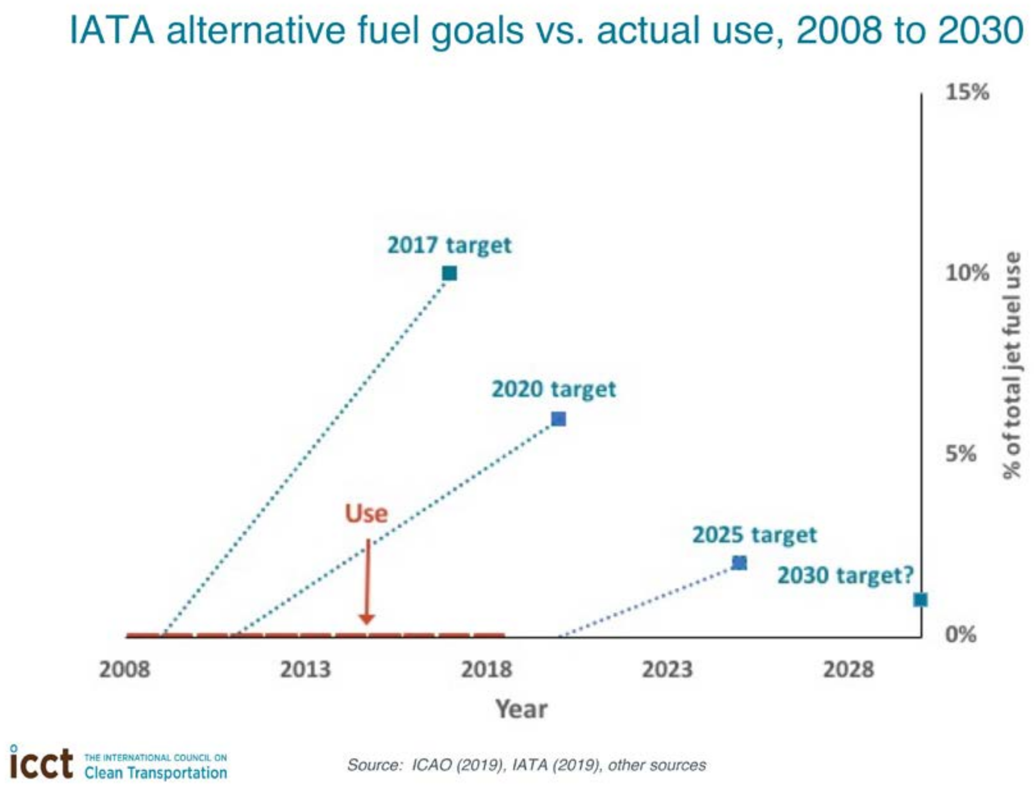

Figure 11: IATA Alternative Fuel Goals vs. Actual Use, 2008 to 2030 [Tweet by Dan Rutherford, Shipping and aviation director at ICCT (6/2/2020), based on **Appendices 14 & 15**]

7.3.8. The key point is that even taking the most optimistic view of the industry, alternative fuels can only be scaled to a small fraction of existing aviation fuel consumption by 2035 or even 2040. UK aviation emission were 39.3 MtCO2e/year in 2018 (CCC), which equates to about 12.5 million tonnes of aviation fuel burned. The UK aviation industry pressure group "Sustainable Aviation" have advocated for the UK Treasury to commit £500m of Government funding towards a set of 14 SAF facilities that could be built across the UK [**CD 9.14, 9.15**]. Even if this large investment was to happen, it would still only put the UK on track to produce 1 million tonnes of alternative fuel in 2035 and 1.6 million tonnes in 2040. This would, at most be around 10% of current UK aviation fuel consumption. It will be even less if UK air traffic grows further, e.g., the 65% growth by 2050 currently planned by the industry, which could grow UK aviation fuel consumption to around 20 million tonnes. Therefore, even the very optimistic stretch target of 4.5 million tonnes per annum by 2050 advocated by the industry might only cover approximately a quarter of fuel consumption if airport expansion and air traffic growth is to continue as planned:

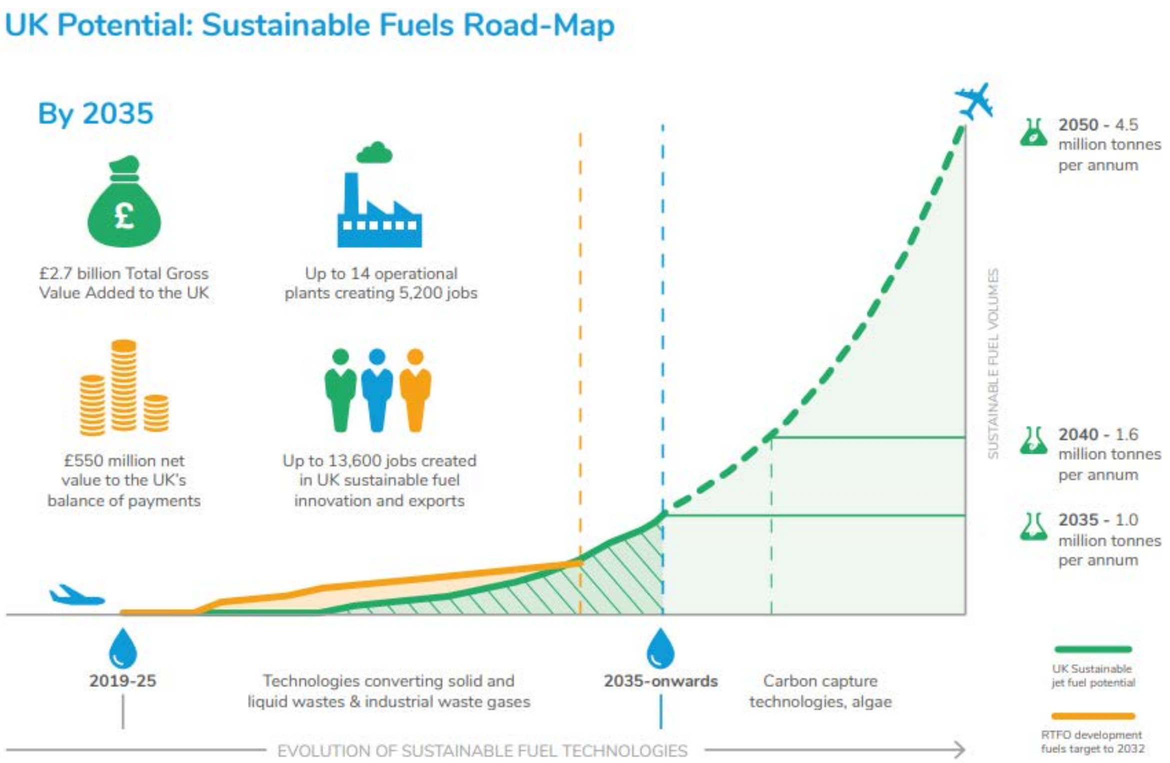

Figure 12: UK Potential: Sustainable Fuels Road-Map [**CD 9.14**, **CD 9.15**]

7.3.9. Another key point is that even if scaled further, aviation biofuels will still cost far more than conventional aviation fuel. HEFA fuels are likely to be the cheapest source of SAF in the near term. The production costs may be as low as €0.88 per litre, but this is "*twice the cost of petroleum-based jet fuel production, while other conversion processes cost as much as eight times the price of petroleum fuel*" [**CD 9.123** pg 4]. These increased costs would undermine the expansion plans of the industry.

7.3.10. Finally, the same point applies to the promotion of and reliance on aviation biofuels by the industry lobby group Sustainable Aviation in its Decarbonisation Road-Map and Fuel Road-Map as was made above in relation to hybrid and electric aircraft: the CCC was well aware of these documents, and the commitments announced by Sustainable Aviation, before it recommended measures for UK aviation within the Sixth Carbon Budget [**CD 9.34**] based on demand control and no net expansion of UK airports [**CD 9.66** pgs 11 and 21].

7.4. <u>Synthetic Fuel</u>

7.4.1. Synthetic Fuels or "Synfuels" are produced from electricity by synthesising hydrogen with carbon to create a liquid hydrocarbon. Hydrogen can be produced from water using electrolysis, and carbon can be extracted from the air using a process called 'Direct Air Capture' (DAC). These can be combined into a hydrocarbon fuel using a process called Fischer-Tropsch (FT) synthesis [**CD 9.73** pgs 7 and 8]. If all of these processes are powered by low-carbon electricity, then this could in theory significantly decrease emissions relative to fossil fuels. It is also known as electro-fuel or "e-fuel".

7.4.2. However, Synthetic fuel technology is still in its infancy and the production processes involved (Hydrogen electrolysis, DAC, and FT) are fundamentally inefficient. Even if these processes are improved, the fuel produced will likely remain 3-5 times the price of conventional untaxed fossil fuel over the next few decades, which would undermine the expansion plans of the industry if used in large quantities:

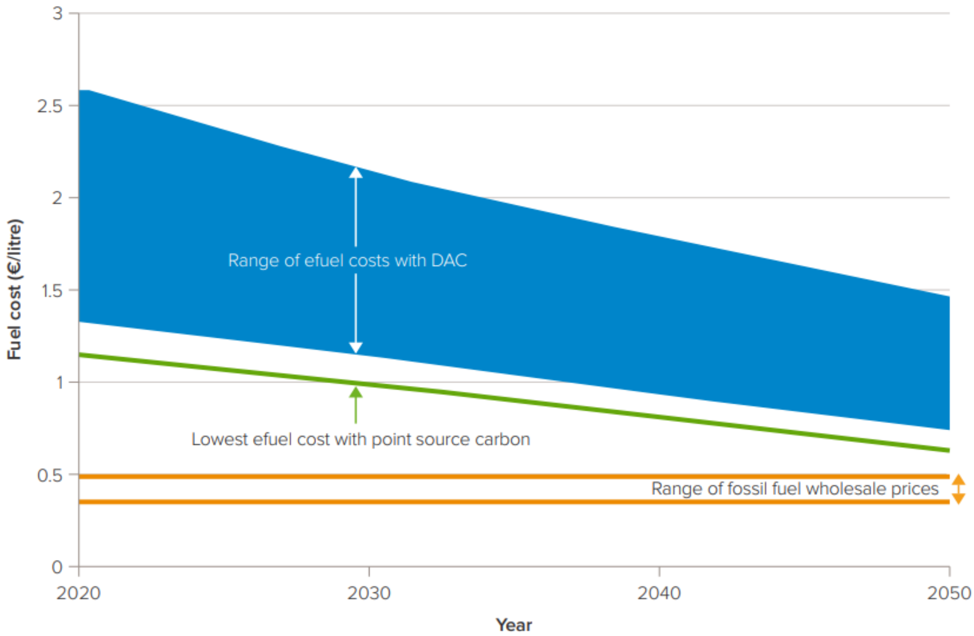

Figure 13: E-fuel (Synfuel) cost forecasts [**CD 9.73** pg 29]

Note: Figure 13 shows the "lowest e-fuel cost with point source carbon", however this would involve using carbon captured from e.g., the exhaust of a fossil fuel power station to synthesise the fuel, rather than DAC. This still involves burning fossil fuels and emitting greenhouse gas to the atmosphere, so cannot be considered zero emissions.

7.4.3. The most advanced roadmap for synthetic fuels is in Germany, where they have committed to an "*annual production of 200,000 tonnes of green kerosene by 2030*", which will only be a tiny fraction (0.7%) of their annual jet fuel consumption [**Appendix 16** BAAN/W2/2 pg 101].

7.4.4. Even if Synfuel production is funded and scaled, the inefficiency of the processes involved would require huge quantities of renewable energy. The electrical energy required to produce enough Synfuel to displace current worldwide annual aviation fuel consumption would exceed the entirety of global renewable energy generated today [**Appendix 17** BAAN/W2/2 pg 103]. For context, the EU defines two aviation scenarios in 2050 called

"Maximum decarbonization" = 60% hydrogen + 40% synfuel, and "Efficient decarbonization" = 40% hydrogen + 60% synfuel. These scenarios would consume 21 PWh and 28 PWh of electricity respectively. This would require 3 or 4 times the renewable energy produced globally today [**CD 9.75** pg 44]. Whilst renewable energy generation is growing every year, this electricity is also needed for decarbonising other sectors of the economy. The following diagram illustrates this choice, demonstrating that 1kWh of renewable electricity can replace more fossil fuel, and provide higher levels of carbon abatement, if used for other purposes:

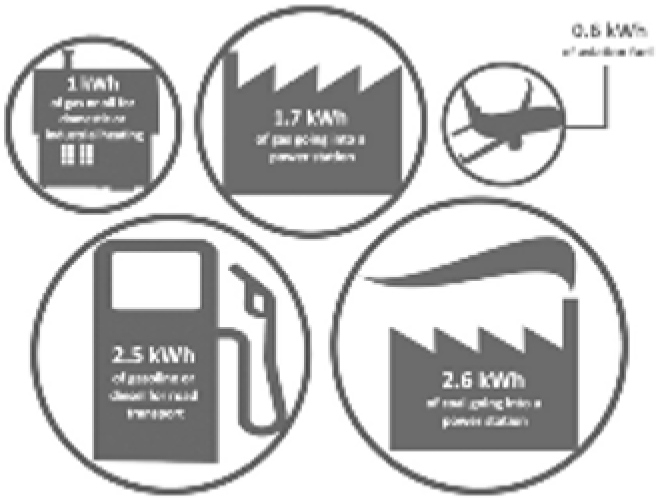

Figure 3.9. The amount of fossil fuel that 1 kWh (kilowatt hour) of renewable electricity can replace depends greatly on what we want to use it for. (The circles are to scale by area.)

Figure 14: Fossil fuel displacement achieved with 1kWh (kilowatt hour) of renewable electricity [**Appendix 18** pg 86 BAAN/W2/2 pg 112]

7.4.5. The same point made above about biofuels falls to be made about the promotion of and reliance on synfuels by the industry lobby group Sustainable Aviation in its Decarbonisation Road-Map and Fuel Road-Map [**CD 9.14**, **9.15**]: the CCC was well aware of these documents, and the commitments announced by Sustainable Aviation, before it recommended the Sixth Carbon Budget [**CD 9.34**] based on demand control and no net expansion of UK airports [**CD 9.66** pgs 11 and 21].

7.5. General

7.5.1. Aviation also produces non-CO2 emissions which have a global warming effect and will not be eradicated by the use of alternative fuels. As such, even synfuel produced from “green” hydrogen and DAC cannot be considered zero emissions:

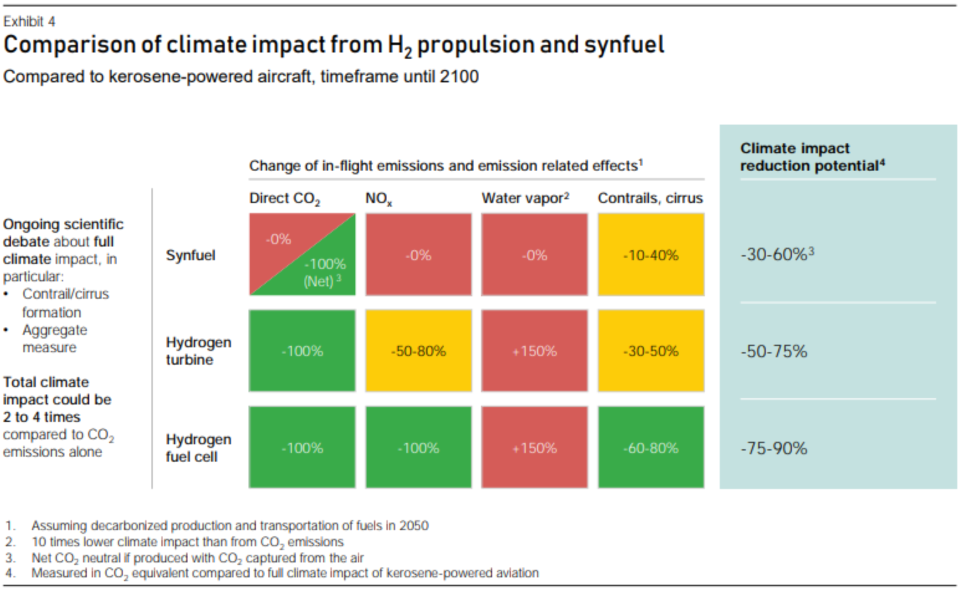

Figure 15: Comparison of climate impact from H2 propulsion and synfuel. [**CD 9.75** pg 21]

7.5.2. It should be noted that the UK does not yet have a detailed roadmap set by Government, and there are no mandates in place for specific quantities of biofuel or synthetic fuel use by UK airlines. Although the Ten Point Plan signalled the Government’s intention to consult on a Sustainable Aviation Fuel mandate [**CD 8.8** pg 22], this has not happened and no plans to conduct the consultation have yet been announced. Any alternative fuels supplied to the UK aviation sector can receive credits under the UK Renewable Transport Fuel Obligation (RTFO) [**CD 9.99**]. However, there are no binding targets or mandates on the aviation industry in the RTFO. Therefore, there are currently no assurances that UK airlines will be mandated to use specific quantities of specific alternative fuels across a specific timeline. This means that there is currently no requirement that flights operating from Bristol Airport will be obliged to use a certain quantity of biofuel or synthetic fuel.

7.6. In conclusion, alternative jet fuels such as biofuel and synfuel cannot be relied upon to decarbonise aviation emissions. They face problems of scale, cost, and use of precious energy resources which mean they cannot contribute a significant percentage towards total aviation fuel consumption in a sustainable manner. Future air traffic and jet fuel consumption growth will further compound this issue and lower the potential contribution of alternative jet fuels. Even where they are used, they will be more expensive than conventional jet fuel and will undermine the case for airport expansion. They will also not completely eradicate the climate impact of flying.

7.7. Taken together, all the evidence in this section shows that little weight can be given to claims that the development and use of alternative jet fuels such as biofuel and synfuel will significantly reduce the carbon impact of the proposed expansion of Bristol Airport. Measures to address demand for flying (as emphasised by the CCC) [**CD 9.66** pg 11] are required in order to give the UK a chance of achieving Net Zero by 2050.

8. CARBON OFFSETTING AND EMISSIONS PRICING

8.1. **Domestic aviation** is subject to the European Union Emissions Trading Scheme (EU ETS) scheme which will soon be replaced by the UK ETS scheme within the UK. Under these schemes, polluters surrender a number of permits equivalent to the amount of CO2 they emitted during the year. Polluters acquire permits through an annual allocation system and some are issued by member states for free. If polluters do not have enough allowances to acquit their previous year's emissions, they can buy additional permits at auction or from other companies which have a surplus. The EU puts a maximum cap on the CO2 emissions that can be emitted by restricting the number of permits available on the market. As issued permits become scarcer due to progressive reductions in the cap, the permit price goes up, providing emitters with an incentive to reduce their emissions where that is cheaper than buying permits. However, the EU ETS has always been limited to intra-EU flights only and until recently the ETS suffered from a gross over-allocation of permits, causing the price of allowances to crash. This gave airlines effectively unlimited access to cheap ETS credits, the cost of which hardly impacted on growth [**CD 9.122** pgs 1-2].

8.2. In future, the CORSIA scheme will replace the ETS for international aviation emissions (see below), so the UK and EU ETS will only apply to domestic aviation. Domestic aviation contributes less than 4% of total UK aviation emissions [**CD 9.57** pg 5] and can more readily be decarbonised through a switch to ground transport, so is not the primary focus for increased regulations.

8.3. **International aviation** and shipping are the only two sectors that are not covered by the emissions reduction targets, set out in the 2015 Paris Agreement. Instead, in 2016 the "*Carbon Offsetting and Reduction Scheme for International Aviation*" (CORSIA) was devised which ICAO claim would enable 'carbon neutral growth' from 2020, through the use of offset credits [**Appendix 19** pg 207 BAAN/W2/2 pg 113]. The idea is that airlines will have to buy credits when they emit carbon, and those credits will then go towards reducing carbon elsewhere. However, the CORSIA scheme has numerous weaknesses [**CD 9.70**; **CD 9.74** and **CD 9.82**]:

8.3.1. CORSIA is voluntary from 2020, and only becomes mandatory after 2027.

8.3.2. The scheme is not legally binding: there are no enforcement mechanisms to ensure compliance.

8.3.3. It only applies to CO_2 and ignores non-CO_2 emissions, despite the significant climate impact of such emissions [**CD 9.60**].

8.3.4. It only applies to emissions in excess of 2019 levels, so for the considerable future, the majority of carbon emissions will not be offset:

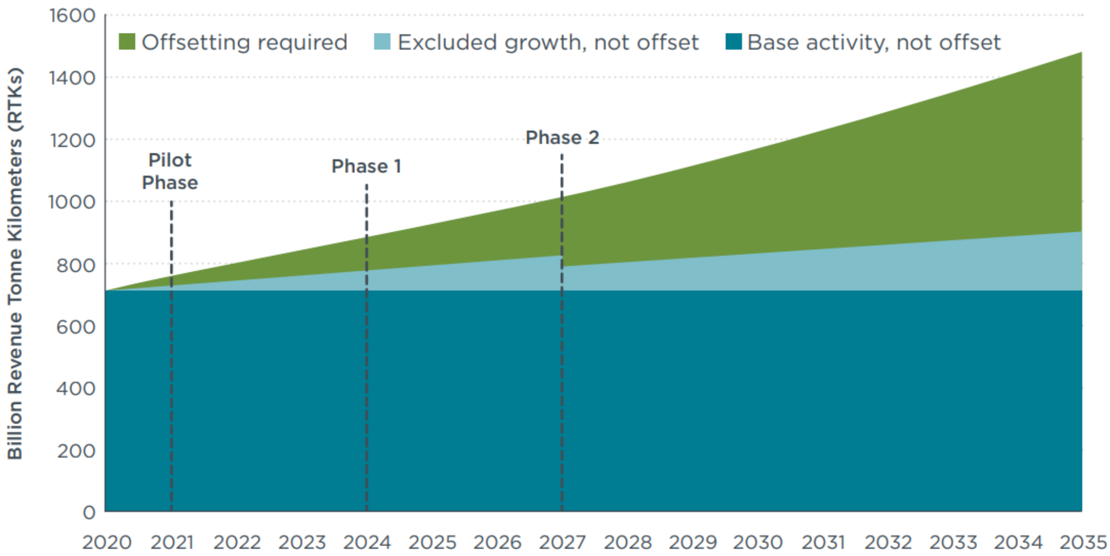

Figure 16: Aviation Revenue Tonne Kilometres (RTK) coverage of CORSIA based on current commitments [**CD 9.74**]

8.3.5. CO_2 emissions are offset using types of schemes which have so far proven very ineffective. An analysis of similar EU offset schemes found that up to 85% of the projects covered had a low likelihood that emission reductions were additional (would not have occurred anyway) and not-overestimated [**Appendix 20** pg 11 BAAN/W2/2 pg 127]. A recent investigative study also found that projects used by major airlines to offset their emissions tended to "*overestimate their climate benefit by miscalculating the level of deforestation that would occur if they didn't exist*" [**Appendix 21** pg 3 BAAN/W2/2 pg 138].

8.3.6. The offset credits are simply far too cheap to purchase per tonne of CO2. For example, they cost less than $1 per tonne of CO2 (tCO2) today, and will only cost up to $12/tCO2 by 2035. This means that offset credits would make up less than 1% of airlines' 2019 operating costs by 2035 [CD 9.82]. As a comparison, industrial CO2 capture is currently closer to $1000/tCO2 [**Appendix 22** BAAN/W2/2 pg 143 (one tonne CO2 = 1000kgs)] and is projected to (best case) reduce to $100/tCO2 over the next few decades [**Appendix 23** BAAN/W2/2 pg 144]. This does not even include the costs of then storing the carbon after it is captured: deep underground or under the sea.

8.3.7. Airlines can reduce their offsetting obligation through the purchasing of "CORSIA eligible fuels", which are alternative fuels which have lower associated greenhouse gas emissions. However, ICAO's rules only require that any alternative fuels used deliver a minimum emission reduction of 10% compared to kerosene. Other sustainability criteria such as criteria on water rights, biodiversity and food security, were rejected by the ICAO Council, and only criteria linked to GHG reduction remains. The ICAO Council have also approved the crediting of 'lower carbon aviation fuel'. This is fossil kerosene produced in a manner which is supposed to deliver emission savings relative to the average measures of producing kerosene, but it is still a fossil fuel [**CD 9.74** pgs 4 and 5]. Even the UK industry lobby group Sustainable Aviation "*does not consider these fuels fall under the definition of sustainable fuels*" and does not include them in their analysis in their "Sustainable Aviation Fuels Road-Map" [**CD 9.15** pg 10]. However, CORSIA is the only existing policy mechanism in place today – so there is nothing to prevent airlines simply purchasing such 'lower carbon aviation fuel' under CORSIA, in preference to carbon offsets or alternative fuels with higher emissions savings.

8.3.8. In conclusion: the CORSIA terms are weak, and the majority of emissions (pre-2019 levels of CO2 and all non-CO2) will not be offset. For the emissions that are offset, the offset credits are far too cheap. Airlines can also choose to purchase alternative fuel instead of offsets, which have very weak sustainability criteria and emissions reduction guarantees. Even the United Airlines CEO, Scott Kirby appeared to agree when he said: "*While they may offer customers some peace of mind, traditional carbon offsets do almost nothing to tackle the emissions from flying*" [**CD 9.82** pg 4].

8.3.9. With regards to the CORSIA scheme the UK CCC state that "*The current level of ambition under CORSIA is an insufficient contribution to the goals of the Paris Agreement*" and that "*In order for operation of CORSIA to be compatible with the UK's Net Zero commitment, there would need to be appropriate governance for offset credits and sustainable fuels, as well as an appropriate cap"* [**CD 9.34** pg 425]. As has been shown, there is insufficient evidence that CORSIA will lead to additional emissions reductions, will have suitable sustainability criteria defined for alternative fuels, and will not cap emissions, so these conditions have not currently been met.

8.4. It has been shown that the only carbon pricing schemes currently in operation (ETS) and proposed (CORSIA) will not be effective in reducing emissions. It is therefore clear that little weight can be placed on them to address the additional aviation emissions that will be caused by the proposed expansion of Bristol Airport. If such carbon pricing schemes were at some point in the future to result in higher pricing of aviation emissions, due to the economics of climate change and reliance on expensive negative emissions technologies [**Appendix 22** and **Appendix 23**], that would also not support the proposed expansion, as it would simply increase the cost of flying, undermining the commercial viability of the proposed expansion.

9. REVIEW OF BAL'S PROPOSALS

9.1. BAL relies on a number of claims about sustainable aviation to make its case. Below I draw out some of the main references and give my response:

	Reference	BAL's case	Response
1.	Draft Carbon and Climate Change Action Plan (May 2021) **CD 9.48** pg 14	"BAL's first step to achieving carbon neutral Scope 1 and 2 emissions, and guiding Scope 3 emissions utilises offsetting schemes. Offsetting is not intended to replace efforts to reduce GHG emissions, but rather to complement continued advancement in mitigating and adapting to the impacts of climate change. BAL's action plan for reducing GHG emissions enables a reduced dependency on offsetting over time."	I show in Section 8 that the only carbon pricing schemes currently in operation (ETS) and proposed (CORSIA) will not be effective in reducing emissions. ETS will only apply to domestic aviation, which contributes less than 4% of total UK aviation emissions. The CORSIA terms are weak, and the majority of emissions (pre-2019 levels of CO2 and all non-CO2) will not be offset. For the emissions that are offset, the offset credits are far too cheap. Airlines can also choose to purchase alternative fuel instead of offsets, which have very weak sustainability criteria and emissions reduction guarantees.
2.	Draft Carbon and Climate Change Action Plan (May 2021) pg 23	"Growth to 12mppa affords us with an even greater opportunity to reduce emissions. This includes delivering a zero-emission fleet across the airport where practicable, an extended Aviation Carbon Transition (ACT) Programme for Bristol Airport and for the south-west of England, and third party installation of a mobility hub on-site providing electrical vehicle charging infrastructure. Ultimately growth of Bristol Airport will enable BAL to invest in the future of sustainable aviation through partnerships with key third party stakeholders and	I show in Section 4 that efficiency improvements may be used to increase air traffic and increase emissions, not reduce them. Therefore, efficiency gains will not result in total emissions or energy consumption reducing, and cannot be relied upon in isolation, without measures to address demand. Clearly emissions reductions would be more easily achieved if revenue-passenger-kilometres from the airport are constrained. There is nothing stopping airlines operating from Bristol Airport from using the most efficient technology, regardless of airport capacity. In fact, capacity limits will mean it's more likely older aircraft will be retired sooner, which will reduce the average age of the fleet and improve average fleet efficiency. In Section 5 and 6 I show that there is limited scope for "zero-

		through investment in tomorrow's technology."	emissions" electric or hydrogen aircraft decarbonising aviation emissions before 2050.
3.	Draft Carbon and Climate Change Action Plan (May 2021) pgs 34-35	"**Aviation Carbon Transition (ACT) Programme:** We will put in place an Aviation Carbon Transition (ACT) Programme with funding of £250k available in 2021 for enabling sustainable aviation fuel (SAF) and other sustainable flight solutions to enable decarbonisation at Bristol Airport. This fund will be used to work with our key strategic partners to develop the innovations and technologies required to fast-track the reduction of GHG emissions from aviation. Consideration to non-CO2 effects of aviation will be considered as part of programmes that receive funding through the ACT Programme. If approval is granted for increased capacity at Bristol Airport, this fund will continue." (emphasis in original)	The ACT Programme for Bristol Airport has no specific commitments associated with it apart from towards research which may not achieve any results. The £250k of funding should also be placed in context of the £500m of government funding being requested by the UK Sustainable Aviation group to scale-up alternative fuel production in the UK. Bristol Airport has not committed to any % use of any sort of alternative fuel. It also fails to account for the non-CO2 effects of aircraft operating from the airport, despite acknowledging significance of them here. Therefore, little weight can be placed on the assertion that this programme will provide emissions reduction.
4.	Draft Carbon and Climate Change Action Plan (May 2021) pg 35	"**Infrastructure change:** We are committed to supporting airlines utilise best-in-class technology and will install and provide infrastructure to enable introduction of SAF at scale when it is commercially viable. In the short- to medium-term we will explore the best method to provide SAF infrastructure." (emphasis in original)	This is vague, without any reference to particular SAF quantity or sustainability criteria. No weight can be placed on the suggestion that this will provide any emissions reduction.
5.	Draft Carbon and Climate Change	"**Strategic action for long-term system change:** Bristol Airport is a founding member of Sustainable	Sustainable Aviation is a UK aviation industry lobby group which advocates for the continued growth of air traffic, despite demand

	Action Plan (May 2021) pg 35	Aviation and will actively support the goal of net zero UK aviation GHG emissions by 2050 through a regional leadership approach on SAFs and the introduction of next-generation zero-low carbon aircraft." (emphasis in original)	reduction being the most effective way of reducing future emissions. In Section 5 and 6 I show that there is limited scope for "zero-emissions" electric or hydrogen aircraft decarbonising aviation emissions before 2050; so, no weight can safely be put on claims that such aircraft will assist in reaching net zero by 2050. In Section 7 I show there are real sustainability concerns around scaling up SAF to large quantities, and even then, the cost of SAF would undermine the growth plans of the industry, such that little weight can be put on claims that SAF will assist in reaching net zero. Rather than fund the development of SAF themselves, the industry is campaigning for huge government subsidies.
6.	Draft Carbon and Climate Change Action Plan (May 2021) pg 35	Table 8.1 Short term actions to guide and influence reductions in aviation emissions (Scope 3)	ACT Programme: little weight can be placed on the assertion that this programme will provide any emissions reduction - see comments above. Feasibility study on SAF infrastructure: no weight can be placed on the suggestion this study will provide any emissions reduction – see comments above. Encourage quieter and greener fleets through a league table: this is tokenistic and there is no evidence this sort of approach works; it is also weak as it is not designed to achieve TOTAL (not relative between airlines) emissions reductions. Support long-term policy developments for Sustainable Flight: this is via an industry lobby group "Sustainable Aviation" which actively campaigns for unsustainable growth of the sector and opposes demand reduction measures. Membership is

			therefore detrimental to emissions reductions. Encourage airlines to use continuous descent approaches (CDAs): this is common practice for airlines to save fuel, and should be happening as a matter of course, regardless of airport expansion – airport expansion does not facilitate this. Work across the aviation sector to push for sustainability metrics within aircraft slot allocation guidelines: this is via an industry lobby group "Sustainable Aviation" which actively campaigns for unsustainable growth of the sector and opposes demand reduction measures. Restriction of airport growth would be the fastest way to phase out older, less-efficient aircraft.
7.	Draft Carbon and Climate Change Action Plan (May 2021) pg 36	Table 8.2 Medium term actions to guide and influence reductions in aviation emissions (Scope 3)	Support SAF research and development: see above regarding vagueness of the proposal, coupled with the lack of any acknowledgment of the sustainability concerns around scaling up SAF to large quantities; little weight can be placed on this providing any emissions reduction. Single-engine taxiing and Autonomous aircraft taxing/ parking: this is common practice for airlines to save fuel, and should be happening as a matter of course, regardless of airport expansion – airport expansion does not facilitate this. Airspace modernisation: this will improve efficiency of some flights due to more efficient routing in the air, but airport expansion does not facilitate this. In fact, more aircraft in

			the sky clearly makes optimised air traffic control more difficult. Development of new airside power and distribution methods: this can and should happen as a matter of course regardless of expansion to improve emissions and air quality of ground operations. It does not affect the main source of emissions though, which is aircraft emissions, which will increase if the airport expands. Support customer offsetting of flights to / from Bristol Airport via an online platform: voluntary carbon offset schemes are a wholly ineffective way of mitigating emissions and no weight can be placed on them to address the increased carbon emissions. Such schemes only serve to confuse and gaslight consumers, both by promoting meaningless or even detrimental offsetting schemes (e.g. **Appendix 21**) and by shifting the blame for emissions/the responsibility for addressing emissions to passengers. I deal with the weakness of non-voluntary offset schemes in Section 8. Review of landing charge structure to incentivise low-carbon flights: In Section 5 and 6 I show that there is limited scope for “zero-emissions” electric or hydrogen aircraft decarbonising aviation emissions before 2050, so no weight can be placed on their “incentivisation”. The electric vertical take-off and landing (eVTOL) aircraft mentioned here are a particularly inefficient mode of transport due to high power requirements to take-off/land vertically and poor aerodynamic efficiency in forward flight. They are thus very constrained on passenger

			payload and range. No weight can be placed on their incentivisation either.
8.	SOC (Sept 2020) **CD 2.18** para 7.1 pg 18 See also pg 35	"[A]ligned with its Carbon Roadmap to become a 'net zero' airport by 2050, BAL will submit a Carbon and Climate Change Action Plan (CCCAP) that will demonstrate the approaches by which it will minimise greenhouse gas emissions in its efforts to become an exemplar airport for sustainable aviation growth across the industry. This includes a commitment to offset greenhouse gas emissions from all surface access journeys to and from the airport, effective from 2020 onwards, and to prepare a CCCAP."	See above comments. In addition: offsetting is not a sufficient alternative to actual emissions reductions, and greenhouse gas emissions from all surface access journeys to and from the airport contribute a relatively small amount towards total emissions from all airport operations.
9.	SOC para 7.6 pg 19	"The CCCAP will identify opportunities to achieve emissions reductions from aviation by, for example, accelerating the adoption of newer, more fuel-efficient lower carbon aircraft."	I show in Section 4 that efficiency improvements may be used to increase air traffic and increase emissions, not reduce them. Therefore, efficiency gains will not result in total emissions or energy consumption reducing, so little weight can be placed on this measure. Clearly emissions reductions would be more easily achieved if revenue-passenger-kilometres from the airport are constrained. There is nothing stopping airlines operating from Bristol Airport from using the most efficient technology, regardless of airport capacity. In fact, capacity limits will mean it is more likely older aircraft will be retired sooner, which will reduce the average age of the fleet and improve average fleet efficiency.
10.	ES Addendum Nov 2020	"The Ten Point Plan for a Green Industrial Revolution" "The plan also includes commitments to	The plan does not set requirements for SAF quantity, nor does it impose sustainability criteria. Little weight can presently be put on the Ten

	CD 2.20.1 Table 10.1 pg 145	take '*steps to drive the uptake of sustainable aviation fuel, investment in R&D to develop zero-emission aircraft and developing the infrastructure of the future at our airports*'. Consultation on the Aviation Decarbonisation Strategy is planned for 2021."	Point Plan as actually achieving any emissions reduction. In Section 7 I show there are real sustainability concerns around scaling up SAF to large quantities, and even then, the cost of SAF would undermine the growth plans of the industry. Rather than fund the development of SAF themselves, the industry is campaigning for huge government subsidies.
11.	ES Addendum Nov 2020 Table 10.2 pg 149	"Committee on Climate Change Letter on International Aviation and Shipping and Net Zero (2019)" "For international aviation, the CCC advise a primary policy approach of international framing while still setting domestic targets. It is recognised that '*Zero-carbon aviation is highly unlikely to be feasible by 2050*' yet reduced emissions are suggested through *'a combination of fuel efficiency improvements, limited use of sustainable biofuels, and by managing demand growth*'. It is acknowledged that the use of GHG removal offsets (e.g. CORSIA) will be essential for reducing emissions in the IAS sectors. The CCC's 'Future Ambition' case was based on a scenario for achieving net-zero by 2050 that kept GHG emissions from international aviation to around 30 MtCO2 in 2050"	This fails to mention the CCC also suggest "limiting demand growth to at most 25% above current levels." And that "There is potential to reduce emissions further with lower levels of demand." The letter also states that: "The ICAO's current carbon policy, CORSIA, has an end date of 2035 and will need to be based on robust rules that deliver genuine emission reductions. A new long-term goal for global international aviation emissions consistent with the Paris Agreement would provide a strong and early signal to incentivise the investment in new, cleaner, technologies that will be required for the sector to play its role in meeting long-term targets." It has been shown in Section 8 that the CORSIA scheme is not based on robust rules that will deliver genuine emission reductions. The letter also mentions "Getting to net-zero emissions will require reducing IAS emissions as far as possible and using scalable GGRs [greenhouse gas removals] (e.g. BECCS or DACCS) to offset remaining emissions" which I show in Section 8 would require a cost per tonne of CO2 far higher than that imposed by the CORSIA scheme.

			The letter also states that "Our scenario has a 10% uptake of sustainable fuels in 2050. It is not appropriate to plan for higher levels of uptake at this stage, given the range of competing potential uses for biomass across the economy". This figure is inconsistent with the higher levels of biofuel use assumed by Sustainable Aviation in 2050, but is consistent with the points I make in Section 7.3 related to the sustainability issues of scaling biofuels, and competing requirements.
12.	ES Addendum Nov 2020 Table 10.2 pg 149	"Sustainable Aviation Carbon Road-Map: A Path to Net Zero" "Sustainable Aviation is a group of UK airlines, airports, aerospace manufacturers and air navigation service providers which aim to set out a collective and long term strategy to ensure a sustainable future for UK aviation. In 2020, the group published the Sustainable Aviation Carbon Road-Map: A Path to Net Zero, to which Bristol Airport is a signatory. This report sets out how the UK '*can accommodate a 70% growth in passengers by 2050 whilst reducing net carbon emissions levels from just over 30 million tonnes of CO2 year down to zero through smarter flight operations, new aircraft and engine technology, modernising our airspace, the use of sustainable aviation fuels and significant investment in carbon reductions through smart market-based policy measures*'. Bristol Airport is aligned to the goals of	"Sustainable Aviation" is an industry lobby group which actively campaigns for unsustainable growth of the sector and opposes demand reduction measures. The 70% growth quoted here contrasts with the advice of the CCC of 25% growth maximum by 2050 (within current airport capacity), and the high levels of biofuel use also contrasts with the CCC advice of 10% biofuel maximum by 2050 (also assuming a lower total fuel consumption too, due to more limited growth). I set out above the evidence showing that little weight can be put on the benefits claimed from: - Aircraft and engine technology in Section 4-6 - the use of alternative fuels in Section 7 - existing market-based policy measures in Section 8

		Sustainable Aviation and achieving the road-map, as demonstrated in the Bristol Airport Carbon Roadmap.”	
13.	**CD 3.11.1** Letter regarding sustainable aviation 7/2/20	“The published Roadmap shows a route through which UK aviation can cut net carbon emissions to zero, whilst meeting anticipated growth in passenger demand up to 2050. Road-Map analysis shows that through the introduction of known and new, more efficient aircraft (saving 23.5 MtCO2/yr by 2050), better air traffic management and operating procedures (saving 3.1 MtCO2/yr), the use of sustainable aviation fuels (saving 14.4 MtCO2/yr) and the global deployment of effective Market Based Measures (saving 25.8 MtCO2/yr), aviation can cut emissions to net zero. A further 4.3 MtCO2/yr is saved due to the carbon pricing impact on demand resulting from the use of global Market Based Measures.”	See row above. In light of the evidence set out above, little to no weight can be put on the suggested measures achieving the emissions reductions claimed. The most effective way to reduce emissions is to limit air traffic demand and growth by limiting airport capacity and applying a high price to aviation emissions, via an emissions-based levy or increased aviation fuel taxation. As identified by the CCC, scalable GGR [greenhouse gas removal] technology will be required, and as I identify in Section 8 here, the price for such removals is in the multiples of £100 per tCO2. This, or the use of scalable alternative jet fuels such as synfuel, will greatly increase the cost of flying and undermine the growth envisaged by the Sustainable Aviation roadmap.

9.2. The Appellant’s proposals are not in any event consistent with the uptake of sustainable aviation measures.

9.2.1. An increase in the use of smaller electric or hydrogen powered aircraft would significantly affect Bristol Airport’s operations, whereas the planning proposal involved simply increasing existing operations. Electric or hydrogen propulsion will not be viable, any time soon, for the type of aircraft for which Bristol Airport is predominantly configured.

9.2.2. For such aircraft, the use of alternative jet fuels is the only option for reducing emissions. These are only available in low quantities, and are far more expensive than conventional fossil-based fuels. Where fossil-based fuels are used, it is also highly likely that future emissions pricing will be applied that will increase the cost of those fuels too. This all points to an increased cost of flying, and reduced demand for air travel, which undermines Bristol Airport's expansion plans.

10. CONCLUSION

10.1. There are a number of misconceptions relating to the potential for "sustainable aviation", all of which have been deployed by the Appellant in its justification for the proposal:

- Aviation contributes only a small % to global emissions and global warming
- Aircraft efficiency improvements are reducing emissions from the sector
- Electric aircraft will soon be a viable alternative to jet fuel powered flight
- Hydrogen aircraft will soon be a viable alternative to jet fuel powered flight
- Alternative jet fuels such as biofuel, or synfuel/electro-fuel can be scaled ecologically and economically – without affecting the price of air travel and undermining the business case for airline/airport expansion plans
- Existing carbon offset schemes will be effective in reducing emissions.

10.2. In my evidence I have addressed each of these in detail, and have shown that very little to no weight can safely be put on the Appellant's claims that they will deliver emissions reductions or that there are credible reasons why the climate change impact of expanding Bristol Airport will not be significant.

10.3. **Environmental Impact**: The aviation industry is eager to highlight that flying only produces 2-3% of global CO2 emissions, but this is not small: if aviation was a country, it would rank amongst the top 10 emitters in the world, ahead of nations like Brazil, Mexico, and the UK. UK aviation already produces a significant amount of CO2 emissions and the UK's per-capita aviation emissions are far higher than the global average. However, these are not even distributed across the population: surveys show that more than half the UK population do not fly in any given year, and only 15% of the population is responsible for 70% of all flights taken. Despite this, the UK's aviation emissions are projected to grow considerably, and are exacerbated by an even greater global warming effect from aviation's non-CO2 emissions.

10.4. **Aircraft Efficiency**: History has shown that efficiency improvements will not result in overall reduced total emissions or energy consumption because of increased number of flights. Over the period that aircraft have become more efficient and CO2 emissions **per passenger mile flown** have dropped significantly, air travel has grown rapidly and the total emissions produced by aviation has increased very steeply. Global aviation emissions have quadrupled since 1966; they have doubled since 1987 and have grown 4-5% a year since 2010 (i.e., after recovery from the global financial crisis). In 2018, the UK's aviation emissions were 88% above 1990 levels [**CD 9.66** pg 5]. In an industry like aviation, efficiency improvements grow the market and increase emissions, rather than reducing them. Efficiency gains will not result in **total** emissions or energy consumption reducing and cannot be relied upon in isolation, without measures to address demand, as the UK CCC has emphasised.

10.5. **Electric Flight**: Electric aircraft, whether hybrid-electric or fully-electric, will not realistically be viable for anything but very short-haul commercial flights, even by 2050, and will not be available for the type of aircraft for which Bristol Airport is predominantly configured.

10.6. **Hydrogen Flight**: The associated costs and timescales required to develop and deploy hydrogen technology and infrastructure mean that it will not credibly support significant decarbonisation of Bristol Airport in the foreseeable future. Hydrogen flight is also as yet unproven, and its continued development is uncertain, meaning that it should not be relied on to meet airport sustainability targets.

10.7. **Alternative Jet Fuels**:

10.7.1. **Biofuels**: Aviation biofuel is not a sustainable or scalable solution without causing increased global food prices, water shortages, deforestation, drainage of peatland, loss of biodiversity, and land-use change emissions. The use of large quantities of aviation biofuels will thus exacerbate the climate and ecological emergency. It will also transfer any sources of sustainable biomass away from other sectors. Without taking into account the political or economic barriers to alternative jet fuel production, it has been estimated that there are only sufficient resources to support approximately 5.5% of projected EU jet fuel demand in 2030. Alternative fuels can only be scaled to a small fraction of existing aviation fuel consumption by 2035 or even 2040. Finally, aviation biofuel scale-up has been promised by the industry for more than a decade but has not materialised. Even optimistic targets from the industry show a low percentage uptake of biofuel over the coming decades and the industry has a history of missing these targets.

10.7.2. **Synfuels**: Aviation synthetic fuels produced from electricity by synthesising hydrogen with carbon to create a liquid hydrocarbon, face problems of scale, cost, and use of renewable energy resources which mean they cannot contribute a significant percentage towards total aviation fuel consumption in a sustainable manner. Existing targets e.g., in Germany, for synfuel are even lower than those for biofuel.

10.7.3. **General**: Future air traffic and jet fuel consumption growth will in fact lower the potential contribution of alternative jet fuels, because of the small scale on which such fuels are capable of being produced. Even where they are used, they will be more expensive than conventional jet fuel and so will undermine the case for airport expansion, because they will drive up prices, resulting in reduced demand for flying. They also will not eradicate the climate impact of flying. This highlights the necessity of demand control, given the aviation emissions that cannot be mitigated with alternative jet fuels.

10.8. The UK CCC has given very clear advice on aviation. Its Sixth Carbon Budget Reports consider aircraft efficiency improvements, the potential for electric or hydrogen aircraft and significant use of alternative jet fuels, but still conclude that air traffic demand management is crucial to achieving a "Balanced Net Zero Pathway". The CCC has recommended no net expansion of UK airports and stated: "*Airport expansion could still occur under the Balanced Pathway, but would require capacity restrictions elsewhere in the UK (i.e. effectively a reallocation of airport capacity).*" [**CD 9.66** pg 11]

10.9. **Carbon Offsetting and Emissions Pricing**: The only carbon pricing schemes currently proposed will not be effective in reducing emissions. The UK/EU ETS scheme is applicable only to domestic aviation emissions which only contribute 4% of total UK aviation emissions, while international aviation emissions are covered by the CORSIA scheme. The CORSIA terms are weak and the majority of emissions (pre-2019 levels of CO2 and all non-CO2) will not be offset. For the emissions that are offset, the offset credits are far too cheap. Airlines can also choose to purchase alternative fuel instead of offsets, which have very weak sustainability criteria and emissions reduction guarantees. Future higher pricing of aviation emissions is inevitable due to the economics of climate change and reliance on expensive negative emissions technologies. This will increase the cost of flying, which will undermine the expansion plans of the industry. The CCC has also advised that CORSIA is not currently compatible with the UK's Net Zero commitment and has thus advised that "CORSIA should not contribute to meeting the carbon budgets" [**CD 9.34** pg 425].

10.10. The Appellant's Draft Carbon and Climate Change Action Plan (CCCAP, May 2021) relies predominantly on offsetting emissions, which for the reasons already given is not a credible approach. It also relies on efficiency improvements, which it is claim expansion will deliver, however, as shown, efficiency improvements may be used to increase air traffic and increase emissions, not reduce them. Therefore, efficiency gains will not result in total emissions or energy consumption reducing, and cannot be relied upon in isolation, without measures to address demand. Such commitments present in the Draft CCCAP to enable "sustainable flight solutions" and sustainable aviation fuel use are vague and, in any event, do not address the difficulties I have evidenced on timescales, costs and adverse impacts. Very little weight can be placed on the Draft CCCAP.

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