Written evidence from Chikage Miyoshi, Cranfield University

a. About Cranfield

As a specialist postgraduate university, our world-class expertise, large-scale facilities and unrivalled industry partnerships create leaders in technology and management globally. We have links with government departments and mutually beneficial relationships with around 1,500 companies and organisations, including many of the largest and most successful global aviation businesses such as Airbus, AWE, BAE Systems, Boeing, Lockheed Martin, Qinetiq, Rolls-Royce, Saab, Thales and the UK Civil Aviation Authority. According to the Research Excellence Framework 2014, 81% of our research is classed as world-leading or internationally excellent. Cranfield is the largest provider of accredited aerospace degree courses, helping our graduates to qualify as Chartered Engineers (Royal Aeronautical Society). Integrated capabilities across the aerospace research and development spectrum at our global research airport allow us to offer analysis of the whole system to design, build and fly aircraft. Our history and heritage in aircraft research and design over the last 70 years is extending into the future with specialisation in aircraft electrification, autonomous vehicle technology and urban mobility, along with ground-breaking manufacturing techniques and research into the wider transportation ecosystem.

Cranfield established its Green Aviation Initiative linking academic research and business interests for reducing the impact on the environment from aviation including those in the Future Flight Challage projects having Global Research Airport and Urban Observatory. The Facility for Airborne Atmospheric Measurements (FAAM) – a specially modified research aircraft dedicated to the advancement of atmospheric science and the largest of its type in Europe – run by the Natural Environment Research Council (NERC), is also based at Cranfield. We submitted our response to the Jet Zero Council Consultation in September 2021[1].

b. Key points

1. The immediate need is for investment into the Sustanable Aviation Fuels (SAFs) production for increasing the domestic supply and lowering the price to achive the UK Government‘ mandate in 2030.

2. All SAF should be truly net zero in terms of Life Cycle CO_2, and ensure its maximum benefit. The substantial research and investment are required to develop SAF usage (production, operation and supply chain), and mitigate other factors such as non-CO_2 GHG emissions and particularly reducing the contrail-cirrus formed.

3. For the long term, other feedstock incl. agri-based SAF should be investigated considering the true land use changes as the possible options for the wider economy.

4. The SAF usage in the domestic market is important both for life cycle CO_2 and the positive impact on the whole society in the UK. Hence, the specific scheme is required to promote it since the CORSIA covers only the international flights. Airlines might be in favour of use in the international fights in the end.

5. While the new technologies can help in the long term, economic instruments such as MBM, travel behaviour change to control demand and/or demand curtailment are the most practical and realistic solutions to reduce CO_2 by using the existing fossil fuelled aircraft in the next 5-20 years for linking to the net zero target in 2050.

6. It is important to understand the market situation for assessing the level of market recovery quantitatively after the COVID pandemic by comparing the updated data. The frequent and specific (detail) assessment of market competition level in terms of traffic volume, fare level, price elasticity by route (e.g., domestic and international) and period with robust data are imperative for the environmental policymakers.

7. An effective MBM can be established in terms of incentives and disincentives, considering its impact across the entire travel system, including the response of each component (flight, travel to airport, etc) of transport.

8. Then the scheme can be effective for leading to significant behavioural changes in travel or operational efficiencies. It should actively encourage greener technologies like fuel efficient aircraft or electric cars in the wider economy.

9. The shift from short haul air travel to alternative transport (e.g., high speed rail, electrified car), or the improvement of efficiencies in all cases through better through-ticketing systems may offer significant "demand control" related gains.

10. The transparent and reliable information regarding the carbon footprint by travel mode should be presented to the users, and it should be easily accessible to the public.

11. The UK Government is required to apply people-centred value design aspects, explicitly focusing on the period between pre-COVID-19 and 2025. A clear understanding of the key determinants for decarbonisation and its quantitative evidence obtained in this period (2015-2025) bring the realistic and efficient decarbonising policy and review and its implementation from 2030 for the next decades by taking a suitable direction to achieve the stringent target in 2050.

12. With innovative technology for greener flights, such as drones, electrified aircraft, and an automated new mode of travel, the third revolution in aviation can deliver safer, comfortable, better mobility, greater connectivity, or access to goods and services by reducing congestion, improving the value of travel time for everyone.

13. New and novel technology faces challenges and risks due to its uncertainty. The risk perception of new technology is challenging in terms of safety, finance, performance, physical, psychological, societal, and (travel) time. Due to a lack of existing data and evidence for risk assessment about the novel techonologies (e.g., electrified and hydrogen aircraft, air travel fueled by SAF) , much of the judgement of risk is generally perceptual and vulnerable to predefined prejudice. We need to quantitatively understand the user's perception of their willingness to use and pay for the novel technology transport.

14. The UK has one of the most developed and mature aviation markets in the world. Its international role, responsibility and impact are significantly large. There is a need to reassess the impact of each MBM (UK ETS, EU ETS, CORSIA and APD) in terms of how it works as one overall system (accounting for carbon leakage, the impact of pricing, competition). It has the capability to be an intellectual and market leader in the use of these measures.

15. The definition and boundary of MBM are important which should be established along with other MBMs. Therefore, an international organisation like ICAO should take the initiative to lead its legislation. Open and wider discussion are required for the evidence based policy. Therefore, we need to assess the comprehensive impact and effectiveness quantitively as one system considering other transport modes, and other MBMs (EU ETS, UK ETS, APD, CORSIA).

16. The implementation of new technology and environmental policy and measurement establishment often brings up issues of equity (e.g., the different impact according to the socio economic background groups). The distribution of service by the new technology always vary among these groups. We need to consider the socio economic aspects as well as the novel technology development by analysing the difference among users, regions and countries and how to compensate the cost for fair distribution.

17. The scientifically estimated key data and its evidence will contribute internationally largely by driving the society and economy in an efficient and productive way as a whole. It is imperative to consider the agenda as one eco-system including the nature based carbon capture solution and biodiversity consideration. This system supports the third revolution in our aviation industry, which the UK has the opportunity to become a global leader in developing innovative technology and its system.

c. **Responses to committee**

Q2. How close are zero carbon fuels to commercialisation for aviation / shipping? How effective will the Jet Zero Council be in catalysing zero emissions technologies? What role should transitional fuels such as alternative hydrocarbon fuels play?

Q3. What new technologies are there to reduce emissions from aircraft / shipping vessels and how close to commercialisation are they?

Q4. How should the Government's net zero aviation strategy support UK industry in the development and uptake of technologies, fuels and infrastructure to deliver net zero shipping and aviation?

1.1 The immediate need is for investment into making Sustainable Aviation Fuels (SAFs) a viable option for industry-wide use, and for those to be produced to standards that provide a transparent and accepted level of 'sustainability. These standards should become stricter to be 100% carbon zero, i.e. go beyond the current focus on reduced CO2 emissions and by about 60%.

1.2 The production and storage of these fuels still needs substantial research and development, at the basic science and optimisation level where significant challenges remain, and ivestment at the industrialisation stage of the production process to supply higher volumes.

1.3 All SAFs should become truly net zero. Reduced carbon emissions via SAFs should only be acceptable as an interim measure. However, SAF will be the main fuel for the long haul flight even after 2040, considering the technological advance. Furthermore, the possible agri based SAF should be considered as one of long term feedstock options for facilitating the comprehensive benefit for the UK society itself in a long run.

1.4 To ensure that the maximum benefit is derived from the development of SAFs, a very high priority should be placed on fuel formulations that minimise contrail formation. Achieving this would greatly enhance (by approx. 2-3 fold) the short-term climate benefits gained from reducing the net-CO2 emissions [2] . Early studies have shown this to be possible [3,4].

1.5 Materials development to ensure the use of SAFs aboard aircraft and particularly within gas turbine powertrains is safe and reliable long-term is essential. The coupling of the two activities (fuel and materials development) is highly desirable to facilitate the safe uptake of the technology. All of these areas are being actively investigated and developed across multi-disciplinary teams at Cranfield. This research must aim to improve fuel efficiency (with current fuels and SAF) and minimize contrail-cirrus formation. The Jet Zero

Council can take strong leadership to deliver and accelerate the speed of novel technology in the wider research area.

1.6 Creating sustainable aviation operations is a global issue that will depend on global collaboration, shared adoption of new technologies and business models and the integration of systems and standards. Accordingly, the UK must continue to be part of European Union initiatives such as Clean Sky 2, the SESAR Joint Undertaking and Horizon Europe in order to facilitate an international, global approach to research and innovation.

1.7 At the same time, however, the UK has significant opportunities to demonstrate its leadership in aviation technologies and wider approaches that provide the necessary combination of dynamism and pragmatism for an era of transformational change to be made possible internationally. In this context, Cranfield agrees with the need to pursue the net zero target for domestic aviation by 2040.

Demand management and effective market based mechanism (MBM)

Q5. What is the most equitable way to reduce aircraft passenger numbers (e.g. reforming air passenger duty and taxes, frequent flyer levies, bans on domestic flights where trains are available, restrictions on airport capacity)? Are there any policy mechanisms that could reduce our reliance on shipping?

Q7. How effective will the global offsetting scheme for international airlines (ICAO's CORSIA) and the UK and EU ETS be at stimulating technology improvement and/ or behaviour change to reduce emissions from aviation / shipping?

Efficient MBM system and quantitative assessment as the air transport system

2.1 While the new technologies can help in the long term, economic instruments such as MBM, travel behaviour change to control demand and/or demand curtailment are the most practical and realistic solutions to reduce CO_2 by using the existing fossil fuelled aircraft in the next 5-20 years for linking to the net zero target in 2050. Indeed, these measures have been tried since the EU ETS (Emission Trading Scheme) included aviation. However, the effect of ETS and airport passenger duty was limited by the low CO_2 price and carbon leakage out of the system.

2.2 The UK government's net zero target includes both the domestic routes for air transport, and international aviation (>90% of 38MTCO2) [5, 6]. In addition, another MBM, the first global carbon offset scheme by ICAO, CORSIA (Carbon Offset Carbon Offsetting and Reduction Scheme for International Aviation) is implemented in 2021. Complicatedly, the first phase of UK ETS also starts from 2021 due to Brexit. However, no explicit demand management policies for aviation are currently planned in the UK. We would require robust data on passenger behaviour and decision-making [5]. It is crucial to evaluate those 'demand control tools' which provide the quantitative key parameters to assess R&D other decarbonising measures such as sustainable aviation fuels (SAFs) and new technology aircraft.

2.3 Emissions produced by air transport activity are based on the traffic volume – which, in turn, is controlled by the users (travellers and operators). After COVID-19, these factors may have changed considerably; we might expect either much lower traffic demand equilibrium or a larger rebound effect.

2.4 Furthermore, most previous studies about the impact of MBM, traffic demand and CO2 price were forecast based on the historical record. The excess cost of EU ETS was estimated between zero to €2.51/passenger, which is either negligible or very limited (€20 per CO2T). Significant absolute reductions can only be reached by a more restrictive system, or a higher price for CO2 (e.g., more than (€85 per tonne) [7,8]. However, these values may have changed by the stronger decarbonising policy environment, and evolving travellers' perception due to COVID-19.

2.5 An illustrative example is the pre COVID air transport market situation. The level of competition in the air transport was severe with the introduction of the basic economy class fare family along with the Long Haul Low Cost Carriers (LH LCCs) in the North Atlantic market, where the UK has a key position.

2.6 Figure 1 presents the fare evolution in the North Atlantic market from 2015 to 2019. Our recent study [9] estimates a 9-13.3% fare reduction on the routes where LH LCC operated during 2015-2019 compared to 8-11% on the overall markets. The price elasticity was lower than unity on some markets from 2017 (Table 1), which implies a very competitive situation, similar to the intra-European Market with strong LCCs [10]. However, the COVID pandemic changed the environment by dropping the traffic volume and raising the fare significantly.

2.7 It is important to understand the market situation for assessing the level of market recovery quantitatively after the COVID pandemic by comparing the updated data. The frequent and specific (detail) assessment of market competition level in terms of traffic volume, fare level, price elasticity by route (e.g., domestic and international) and period with robust data are imperative for the environmental policymakers. Since these parameters can be used to measure the effectiveness of economic instruments such as market-based mechanisms.

Figure 1 The ticket price evolution (USD) on the North Atlantic routes pre COVID pandemic

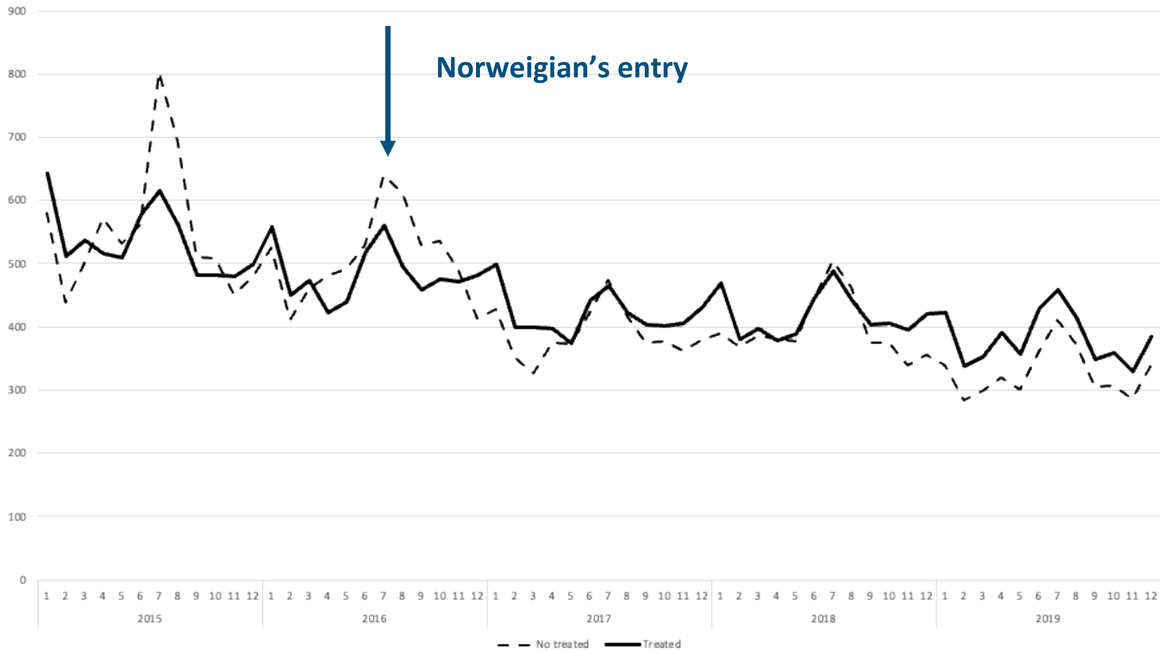


Table 1 Price elasticity examples: pre-COVID competitive market by year

(Paris-New York and London-New York)

CDG-JFK	2015	2016	2017	2018	2019
Price elasticity	-1.771	-0.912	-0.783	-0.800	-0.766
No. of observations	133,864	128,260	208,932	228,974	261,358
No. of carriers	4	5	5	5	5
Average fare	USD518	USD468	USD407	USD407	USD379
Average number of days purchased before departure	57days	62days	69days	75days	81days
LHR-JFK	2015	2016	2017	2018	2019
Price elasticity	-2.675	-1.651	-1.137	-1.036	-0.885
No. of observations	533,668	520,549	559,800	536,189	635,478
No. of carriers	4	4	4	4	4
Average fare	USD465	USD430	USD392	USD405	USD336
Average number of days purchased before departure	65days	70days	71days	72days	79days

2.8 Furthermore, the decarbonising instrument and demand control should be assessed across the entire air transport service system (traveller's decision, flight & travel to airport). Currently, the impact of MBM is assessed only for the flight and surface transport separately.

2.9 An effective MBM can be established in terms of incentives and disincentives, considering its impact across the entire travel system, including the response of each component (flight, travel to airport, etc) of transport. Then the scheme is effective for leading to significant behavioural changes in travel or operational efficiencies. It should actively encourage greener technologies like fuel efficient aircraft or electric cars in the wider economy [11].

2.10 The UK government should take a system approach for a transformative air transport model, which is a combination of top-down and bottom-up models incorporating the reaction of 'travellers', 'airlines', 'and travel to/from airport' as one air transport service system. It aims to assess the decarbonisation instruments (e.g., MBM, carbon charge, and other abatement measures) and a possible travel behaviour change for greener travel options by reflecting the mutual influence of each measure and CO2 cost as a single entire air travel system.

2.11 In addition, in order for aviation to grow sustainably, there needs to be better integration of ground-air infrastructure and a more joined up approach for passengers between flights and getting to and from airports.

2.12 Short-haul flights have the most competition in terms of other modes of transport (especially road and rail). The domestic air transport market produced more than 1 Mt CO_2 in 2019 while 67Mt CO_2 from passenger cars. (see Figure 2). The main players are British Airways, EasyJet, and airports in London and Scotland. Their roles and responsibilities in this market are large. The technology option for reduce emissions from passengers' car is available by electrification, however, it takes time for zero emission aircraft.

2.13 The amount of CO2 from domestic flight dropped by more than 61% in 2020 due to the COVID pandemic. The pre-COVID historical traffic record indicated the growing trend in the UK domestic market. Nevertheless, this large reduction could be the best opportunity to establish the demand management policy for a greener recovery.

2.14 The emission reduction in the domestic market is also less efficient in terms of its carbon footprint and contribute significantly to poor local air quality when airports are located in major cities. The amount of CO_2 from the automobile could be reduced by the electrified car in the short term under the UK government policy.

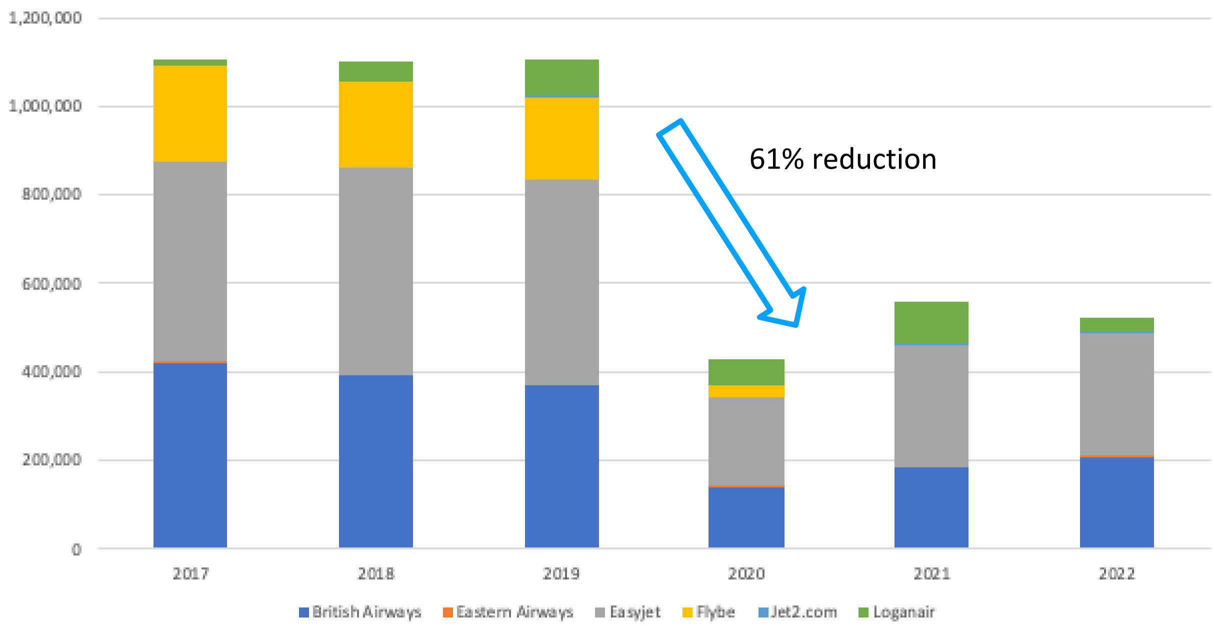
2.15 However, the commercialisation of zero emission aircraft (e.g., electrified or hydrogen aircraft) takes time by 2040-2050 even for a short haul makret. SAF usage in the domestic market is important both for life cycle CO_2 and the positive impact on the whole society in the UK. Hence, the specific scheme is required to promote it since CORSIA covers only the international flights.

2.16 The shift from short haul air travel to alternative transport (e.g., high speed rail, electrified car), or the improvement of efficiencies in all cases through better through-ticketing systems may offer significant "demand control" related gains.

2.17 Understanding the users (people) and providing them with transparent information is key to affecting their travel behaviour and perception and understanding their needs. Therefore, we should consider the topic from the standpoint of a single, comprehensive air transport system, including users' perspectives, airlines' activity, and airport surface access (ASA) how to travel to/from airport.

2.18 The UK Government should apply people-centred value design aspects, explicitly focusing on the period between pre-COVID-19 and 2025. A clear understanding of the key determinants for decarbonisation and its quantitative evidence obtained in this period (2015-2025) bring the realistic and efficient decarbonising policy and its implementation from 2030 for the next decades by taking a suitable direction to achieve the stringent target in 2050.

Figure 2 The total CO2 emissions (tonnes) produced by air carrier in the UK domestic market



Notes: it is estimated by Cranfield air transport carbon calculator with OAG data [12]

Understanding users and economic and social cost and benefit

3.1 With innovative technology for greener flights, such as drones, electrified aircraft, and an automated new mode of travel. The third revolution in aviation will deliver safer, comfortable, better mobility, greater connectivity, or access to goods and services by reducing congestion, improving the value of travel time for everyone.

3.2 Climate change and its impacts are products of human interaction with the environment around us. Inequalities and regional economic challenges are centrally social science issues, but they, in turn, are often products of wider scientific, technological developments or processes [13]. Cleaner growth with improved future mobility which fits our aging society can be achieved by building up new technology and data economy [14]

3.3 New and novel technology faces challenges and risks due to its uncertainty. According to perceived risk theory [15, 16], the risk perception of new technology is challenging in terms of safety, finance, performance, physical, psychological, societal, and (travel) time.

3.4 Therefore, it should be investigated quantitatively in a systematic approach. The risk perception could be largely different according to the type of users, situation and the environment, even for the same person. Due to a lack of existing data and evidence for risk assessment about the novel techonologies (e.g., electrified and hydrogen aircraft, air travel fueled by SAF), much of the judgement of risk is generally perceptual and vulnerable to predefined prejudice.

3.5 New technology is often created from the designer's perspective. A combination of the upstream and downstream design concepts is required for a new technology system by incorporating the user's standpoint and understanding the underlying customers' needs.

3.6 Furthermore, understanding the users and the market response is crucial for controlling air transport demand and managing the efficient use of resources, including human power, energies and managing positive and negative externalities (e.g., waste, CO_2, other GHGs, noise) [17].

3.7 Of course, business derived from the new technology should be sustainable and feasible, driving technology investment to the UK by increasing UK manufacturing and service opportunities. Therefore, it is crucial to consider the topic of new technology in a systematic way to identify a mechanism to address benefits and challenges by applying people-centred value design aspects.

Q6. What further action is needed by the International Civil Aviation Organization and International Maritime Organization to drive emissions reductions? What can the UK Government do to drive international action on emissions?

Q8. How should the UK define its ownership of international aviation and shipping emissions (i.e. arrivals, departures or both) in order to include them in legislative targets?

4.1 The UK has one of the most developed and mature aviation markets in the world. Its international role and impact are significantly large. We support the use of MBMs, including the UK ETS. However, there is a need to reassess the impact of each MBM (UK ETS, EU ETS, CORSIA and APD) in terms of how it works as one overall system (accounting for carbon leakage, the impact of pricing, competition).

4.2 Misuse of these tools — including over or underpricing — could cause both Market (traffic) and carbon leakage. MBMs need to be designed on the basis of quantitative evidence, particularly when it comes to price elasticity (a factor that will be very different in the post-Covid-19 context).

4.3 MBMs and encouraging travel behaviour changes can be practical approaches for the short term. However, to make this effective, there is a need for transparency and clarity: information relating to the level of emissions, the extra charging, and the different available options. There also needs to be explicit communication of how the finances from additional charges are invested into greener travel systems and their benefits to the environment.

4.4 The definition and boundary of MBM are important which should be established along with other MBMs. Therefore, an international organisation like ICAO should take the initiative to lead its legislation. The open and wider discussion are required for the evidence based policy. Therefore, we need to assess the comprehensive impact and effectiveness quantitively as one system considering other transport modes, and other MBMs (EU ETS, UK APD, CORSIA).

4.5 Then we are able to propose the most efficient options. In addition, the place-based solution is important (e.g. self decarbonisation at airport, self sustainable city or airport) for more efficient options using carbon capture, usage, and storage (CCUS)). We need to find the solution and measures which fit the local or regional environment.

4.6 The implementation of new technology and environmental policy and measurement establishment often brings up issues of equity, which is the matter of 'rich or poor, 'larger or small, and 'urban or rural [8,11]. The distribution of service by the new technology is always different among these groups [11]. We need to consider the socio-economic aspects as well as the novel technology development by analysing the difference among users, regions and countries and how to compensate the cost for fair distribution.

4.7 The scientifically estimated key data and its evidence will contribute internationally largely by driving the society and economy in an efficient and productive way as a whole. It is imperative to consider the agenda as one eco-system including nature-based carbon capture solution and biodiversity consideration. This system supports the third revolution in our aviation industry, which the UK has the opportunity to become a global leader in developing innovative technology and its system.

References

1. Sumission from Cranfield University to the Jet Zero Council Consulation September 2021.
2. Lee, D.S., D.W. Fahey, A. Skowron, M.R. Allen, U. Burkhardt, Q. Chen, S.J. Doherty, S. Freeman, P.M. Forster J. Fuglestvedt, A. Gettelman, R.R. De Leo n, L.L. Lim, M.T. Lund, R.J. Millar, B. Owen, J.E. Penner, G. Pitari, M.J. Prather, R. Sausen, L.J. Wilcox, The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018, Atmospheric Environment, 244, 2021, 117834
3. Moore, R., Thornhill, K., Weinzierl, B. et al. Biofuel blending reduces particle emissions from aircraft engines at cruise conditions. Nature 543, 411–415 (2017). https://doi.org/10.1038/nature21420
4. Voigt, C., Kleine, J., Sauer, D. *et al.* Cleaner burning aviation fuels can reduce contrail cloudiness. *Commun Earth Environ* **2,** 114 (2021). https://doi.org/10.1038/s43247-021-00174-y
5. UK Parliament, 2020. UK Parliament post note. No.615. Climate change and aviation.
6. UK Parliament, 2021. Press release. UK enshrines new target in law to slash emissions by 78% by 2035. https://www.gov.uk/government/news/uk-enshrines-new-target-in-law-to-slash-emissions-by-78-by-2035
7. ATA, 2018. Understanding the potential and costs for reducing UK aviation emissions, London.
8. Miyoshi and Ibanez, 2016. Are fuel-efficient aircraft worth investing in for non-Annex country airlines? An empirical analysis of Kenya Airways with an aircraft appraisal cost-benefit analysis model. Transport Policy. 47, 41-54.
9. Miyoshi and Rubio, 2021. Measuring the impact of long-haul low-cost carriers on lowering fares: a quasi-experimental design to assess the pre COVID market.Transport Policy under the review.
10. Morlotti et al., 2017. Morlotti, C., Cattaneo, M., Malighetti, P., Redondi, R., 2017. Multi-dimensional price elasticity for leisure and business destinations in the low-cost air transport market: Evidence from EasyJet. Tourism Management 61, 23–34.
11. Miyoshi and Rietvelt (2015) Measuring equity effects of carbon charge on car commuters: A case study of Manchester Airport. Transportation Research Part D. 35, 23-39.
12. Miyoshi, C., Mason, K., 2009. The carbon emissions of selected airlines and aircraft types in three geographic markets. Journal of Air Transport Management. 15, 138-147
13. Rubin, J., 2021. UK Research and Innovation and the future of the social sciences. https://esrc.ukri.org/research/future-of-social-science-insights-opportunities-and-expectations/uk-research-and-innovation-and-the-future-of-the-social-sciences/
14. Department for Business, Energy, and Industry Strategy. 2017. Industry Strategy: building a Britain fit for the future. London.
15. Mitchel, V. 1992. Understanding Consumers' Behaviour: Can Perceived Risk Theory Help?", *Management Decision*, Vol. 30 No. 3.
16. Ramseyer et al., 2014. Using Phenomenology to Assess Risk Perception of a New Technology in Public Transportation The case of the autonomous vehicles as Mobility as a Service (MaaS) in Switzerland. IEEE.
17. Miyoshi, C., Torrell, P., 2019. Flying Economy – The Economic Impact of New Propulsion Technology: A Cost-Benefit Analysis of the Geared Turbo Fan Engine on the London Heathrow and Frankfurt Route. Emerald.