WITNESS STATEMENT

(Criminal Justice Act 1967, Section 9; Magistrates Courts Act, ss5A (3(a)) and 5B; Magistrates Courts Rules, Rule 70)

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This statement (Consisting of 12 Page(s) each signed by me) is true to the best of my knowledge and belief and I make it knowing that, if it is tendered in evidence, I shall be liable to prosecution if I have wilfully stated anything which I know to be false or do not believe to be true.

Brief report on aspects of aviation and climate change for court case. Alice Bows-Larkin, 5 January 2016.

Prof Alice Bows-Larkin is a Professor and expert in climate science and energy policy, with a particular emphasis on the emissions from international transportation, including aviation. She has a First Class degree in physics and PhD climate modelling and has published widely on the topic of aviation and climate change, including a first authored monograph and nine peer reviewed journal articles. See the attached CV for more detail.

1. Impact of aviation on the climate and other aircraft emissions

1.1 Like other modes of transport, aircraft combust fossil fuels, contributing to increasing global carbon dioxide concentrations and releasing a variety of other emissions including nitrous oxides, soot, water vapour and sulphur oxides. However, unlike other transport sectors, the altitude at which aircraft fly, and the sensitivity of this part of the atmosphere to chemical input, means emissions released there contribute additional climate warming. This means that measuring aviation's climate impact based only on the amount of carbon dioxide released by the aircraft, will miss out a large fraction of emissions that contribute to rising global temperatures. *To my knowledge this is an uncontested statement*. In summary additional impacts are caused by:

- 1. The altitude where emissions are released puts water vapour, another greenhouse gas, directly into the stratosphere where it causes warming.

- 2. The nitrogen oxides released at altitude form ozone in the upper troposphere, which leads to warming. However, they also lead to a depletion of methane, which, as another greenhouse gas, thereby having a cooling impact.
- 3. Water vapour and soot released into the troposphere lead to the formation of contrails, which cause warming.
- 4. Sulphur oxides, sulphuric acid and soot lead to an increase in the cirrus cloud cover, again further increasing the climate warming impact of the aircraft.

1.2 The combined effect of these contributions to the amount of warming is uncertain and challenging to ascertain precisely. One of the reasons for this is that some of the emissions become well-mixed globally as they are very long-lived (e.g. the release of CO_2 with a lifetime of >100 years), while others are local and persist for a matter of minutes (e.g. contrails) (IPCC 2014a, Chapter 8). As a result, a metric that can combine these different types of emission, and their impacts is sometimes employed. Radiative forcing is one such metric. Estimates of the historical warming caused by the aviation industry to date (using radiative forcing) suggest that the total warming impact of aviation has been around twice that than would be caused by the CO_2 alone. While there are uncertainties in this value (a two-fold increase), *there is consensus* that additional warming to that from the CO_2 alone has been produced by these other emissions.

However, it is important to be cautious if wishing to express the impact of current or future air travel taking into account all of the emissions and their impacts. There are some attempts to do using an 'uplift factor', where the warming due to CO_2 is multiplied by a particular factor to account for the additional emissions. However, a more reasonable way of assessing future warming would be to consider projected aviation growth, combined with any new technological interventions that may alter the production of each of the gases and any other operational changes that might be feasible. For instance, if aircraft were to fly at a lower altitude to avoid contrail formation, they would not the produce warming-inducing contrails, but they may increase the amount of fuel burnt and hence CO_2 emitted due to flying in a more turbulent part of the atmosphere. Whilst recognising that these other emissions are important, it is also worth noting that the long-lived nature of CO_2 means that if aviation growth were curtailed to zero (i.e. no additional flights each year), then the warming impact induced by the CO_2 from the aircraft increases in importance compared with the sum of all the emissions over time. This is because most of the additional emissions will not accumulate as their lifetimes are so short, whereas CO_2 lasts for >100 years. *Again to my knowledge this is not contested*.

1.3 The aviation industry is aware of these additional climate change impacts, and also recognises that addressing or mitigating one kind of emission can exacerbate another. For example, and as mentioned in 1.2, altering the altitude at which aircraft fly can reduce the formation of contrails and cirrus clouds, but likely increases fuel burn, and hence CO_2 emissions (Williams et al 2003). Similarly, noise restrictions and targets may require additional engine parts, increasing the weight of the aircraft, and again the fuel burn. Although there are always steps being taken to improve the fuel efficiency of aircraft, given an imperative to reduce fuel costs, it is clear that to avoid an increase in CO_2 production from aviation, the growth in the industry needs to be off-set by fuel-efficiency gains or alternative non-carbon emitting fuels. Moreover, the recent Paris Climate Agreement has a legally binding goal of avoiding a temperature rise of 'well below' 2°C. There are discussions on-going around how to achieve this – but mathematically 'well below' 2°C can only be achieved by preventing CO_2 production, to the extent that any sinks that can absorb CO_2 are larger than the CO_2 produced, leading to net zero emissions by 2050 (Gasser et al 2015, Anderson 2015). There is an on-going debate highlighting the limited capacity of the Earth to absorb CO_2 to the extent necessary by 2050. *If it is assumed that these 'negative emission sources' do not materialise in time*, 'well below 2°C' will only be achieved by a wholesale shift away from fossil fuel combustion. This would mean that CO_2 produced by the aviation sector would also need to be reduced to near zero. *This again would be largely uncontested.*

More conventionally, when considering global temperature targets, the timeframe being discussed (decades) tends to lead national governments to consider sources of CO_2 before assuming there will be additional CO_2 sinks (such as burning biomass with carbon capture and storage (CCS)) to off-set these emissions. In the case of the UK, the 2°C target (referenced in the Copenhagen Accord – which will be superseded by the Paris Agreement) was interpreted by the UK Government in its Climate Change Act as an 80% cut in CO_2 by 2050 across all sectors, but excluding international transport. However, at the time that this target was set, we argued that because the UK's CO_2 target was based on a global temperature goal, all sources of CO_2 needed to be included (Bows and Anderson 2007). This was our informed and considered view at the time. *My view on this has not changed*. However, others have argued that these 'international' emissions should be mitigated by international bodies – the International Civil Aviation Authority (ICAO) in the case of aviation. Moreover, others argue that emission cuts could be achieved by trading aviation CO_2 emissions with other sectors – i.e. other sectors make greater cuts and sell 'allowances' to the aviation sector so that it can emit. Either way, mathematically the contribution from aviation CO_2 needs to be recognised in any estimate of the total reduction amount of CO_2 across all sectors commensurate with a set temperature goal. The Committee on Climate Change (CCC) recognise this, by suggesting that all other sectors would need to reduce emissions by 90% to account for aviation's CO_2 emissions in future (page 30, CCC 2009). However, this estimate assumes that other sectors are able to cut emissions by greater than 80% by 2050. To date there is limited evidence that this will be achieved, and *in my view there are no policies* currently in place that incentivise even 80% reductions by 2050, let alone those required to avoid a 'well below 2°C' goal which limits the carbon budget even further.

It is my view that a 'proportionate' response from the aviation sector should be considered. In other words, that aviation deserves no more 'special' status than any other sector (e.g. shipping, road transport, household heating etc.), because other sectors will also struggle to deliver cuts >80% in the timeframe necessary. If the aviation sector had the same CO_2 constraints as other UK sectors at present, it would need to plan for absolute cuts to its own CO_2 emissions in the coming decades (Bows-Larkin 2014). Moreover, if the UK's climate change target were to be strengthened in line with 'well below' 2°C as stated in the Paris Agreement (the existing 80% target is based on a 63% chance of exceeding 2°C, Anderson and Bows 2011), then these constraints would need to reflect complete global decarbonisation by 2050 (assuming negative emission technologies are not widespread). *It is our view that the current policies surrounding the aviation sector in the UK are at odds with the goal within the Paris Agreement*.

2. Contribution Heathrow makes to climate change

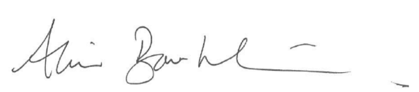
2.1 Heathrow airport is one of the EU's busiest passenger airports, the UK's largest international airport serving all UK residents, as well as being a hub for the majority of transit passengers going through London (Williams and Noland 2006). However, there are challenges in ascertaining the precise contribution of Heathrow's flights to the climate. For example, for an international flight between London Heathrow and New York, is arguably the responsibility of both the US and the UK, thus it is reasonable for international flight CO_2 to be estimated on the basis of a 50:50 split between those two nations. However, there are further uncertainties given that some flights may have interim destinations where some passengers embark and other disembark. It is therefore not straightforward to estimate 'Heathrow's' contribution to CO_2 emissions. CO_2 data for aviation are gathered by the UK Government in terms of total aggregated domestic and international aviation, where 'international aviation' includes around 50% of the CO_2 produced by international flights to and from the UK. Nevertheless, a few studies in the literature have made estimates for Heathrow's CO_2 emissions as summarised below.

2.2 Brooker (2008) (unverified source) use a method to proportionally allocate emissions on the basis of the number of air traffic movements (ATMs) and estimated distance for those movements. They estimate that in 2007, Heathrow contributed to 48.2% of total aviation CO_2 from domestic and international flights associated with the UK. This would amount to 18.7MtCO_2 compared with a total figure of 38.8MtCO_2 for all UK aviation, and 680MtCO_2e for 2007 total UK territorial emissions excluding international aviation and shipping as reported to the UNFCCC. Based on these statistics, Heathrow would contribute around 2.7% of the UK's greenhouse gas emissions for that year.

2.3 Another estimate (unverified) quoted in by the Aviation Environment Federation (AEF) puts the figure at 16.6MtCO2 in 2012 (Fig. 3.2, pp 41, Southgate 2013), highlighting that Heathrow is the airport with the highest CO_2 contribution in the world in terms of combined international and domestic flights.

2.4 UK Government figures from 2011 project total UK domestic and international aviation CO_2 to be 47MtCO_2 with a range of 34.7-52.1MtCO_2 by 2050. The same study estimates that the CO_2 from departing aircraft from Heathrow were 18.8MtCO_2 in 2010, estimated to rise to 21.4MtCO_2 in 2030 and 18.2MtCO_2 in 2050 (Department for Transport 2013).

2.5 The report associated with the Airports Commission Report, makes an estimate for the current two runways at Heathrow, as well as estimates for future Heathrow for departing flights at 20.3MtCO_2 in 2025, 20MtCO_2 in 2030, and 16.6MtCO_2 in 2050, reflecting a slight reduction in ATMs and improvements to aircraft technology (Jacobs 2014). This report states that they are assessing 'do nothing' and 'do something' (i.e. increase runway capacity) scenarios, but only one carbon figure for each year appeared available.



2.6 From the above studies, it can be seen that Heathrow airport is estimated to contribute a little under 50% of the total CO_2 produced by domestic and international flights associated with the UK. The absolute amount of CO_2 is estimated to grow and be higher in 2030 than current levels, but then to decline by 2050 to a level similar to today. This would constitute at best <u>*only a very marginal reduction in the absolute*</u> CO_2 from flights associated with Heathrow by 2050. Moreover, due to the long-lived nature of CO_2, it would also mean *a* *larger cumulative contribution* of CO_2 in the period between 2010 to 2050 than in the previous 40 years (as measured in terms of the area under the curve). Note: *cumulative CO_2 is widely recognised in the scientific community to have a direct relationship with future temperature change* (Summary for Policymakers, page 8, IPCC 2014b). *In my view*, this level of CO_2 production, and absence of absolute and deep CO_2 reduction, would be at odds with the 'well below 2°C' temperature goal in the Paris Agreement, assuming negative emission technologies have not become widespread by 2050.

3 Heathrow into CO_2 and climate context

3.1 Putting Heathrow airport into context: the UK Government, alongside EU partners, is committed to avoiding 'well below' a 2°C temperature rise above pre-industrial levels (UNFCCC 2015). There are a range of published interpretations of what 2°C would mean for industrialised nations, which rely on assumptions regarding the necessary emissions space in industrialising nations, for development to occur. Whilst debate around the scale of change necessary can be had at length, what is clear is that the aggregate of all sectors will need to cut CO_2 emissions significantly over the coming decades, with estimates ranging from total decarbonisation by at least 2050 (Anderson and Bows 2011) to the language of the new Paris Agreement, that states "to undertake rapid reductions…in accordance with the best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century…", (UNFCCC 2015) (see 1.3 above).

3.2 All CO_2 emitting sectors are damaging to human health through contributing to further warming, but particularly concerning are sectors that do not foresee a significant cut in CO_2 going into the future. As noted previously, a growth or absence of CO_2 cut in any sector relies on deeper cuts in other sectors, to remain in line with the 'well below' 2°C goal. Given sectors are already struggling to deliver significant cuts in CO_2 emissions, even greater CO_2 reductions place additional pressure on the need for CO_2 removals by sinks (e.g. land-use change) and the widespread adoption of new unproven technologies (e.g. biomass with CCS).

3.3 For most sectors, CO_2 cuts in line with the 'well below' 2°C goal could feasibly be brought about through a combination technological, operational and demand-side changes (although this would be very demanding to achieve). However, within the aviation sector, *there is a major barrier to any significant technical change in the foreseeable decades that will improve efficiency or carbon intensity to a level that outstrips anticipated growth sufficiently for a proportionate response to the 2°C goal* (Bows et al 2008). *This is a view that is echoed by other academics and many industry sources*. It is also is why the UK Government's own projections for 2050 at best show a 12% reduction in CO_2 from aviation between 2010 and 2050. This represents an absolute growth in CO_2 compared with 1990 levels, which were around 17MtCO_2; aviation growth through the 1990s and 2000s was typically 6% per annum.

Efficiency gains do have some traction in curbing CO_2 production if implemented through a period of flat growth. To put it simply, if growth were 3% per year in terms of passenger-km, this would require fuel efficiency per passenger-km (or carbon intensity) to improve at 3% per year to neutralise CO_2 growth. *This is a point that would be uncontested*. Furthermore, in my view, this would still be insufficient in terms of CO_2 mitigation given the challenge faced by the 'well below' 2°C goal in the Paris Agreement. Moreover, it is my understanding that efficiency gains closer to 1% per year are anticipated, with only a marginal increase (2% overall – not per annum) in the use of biofuel within the sector in the timeframe considered.

It is my considered view that this puts Heathrow expansion at odds with the UK Government's commitment to avoiding a 'well below' 2°C goal, unless an unprecedented global programme of efficiency and biofuel development are implemented in the coming decade, or indeed unless it is assumed that there will be global adoption of unproven negative emission technologies before 2050. Those that contest this statement, are likely assuming that other sectors can reduce emissions by a greater proportion than the constraints put in place by the Committee on Climate Change's short-term carbon budget, and by more than the 80% 2050 target (and by even more if the new Paris Agreement is taken into account) to allow CO_2 from the aviation sector to grow.

4 On the feasibility of the Committee for Climate Change's "planning assumption" that gross CO_2 emissions from aviation will total no more than 37.5MtCO_2 by 2050

4.1 The latest statistics from the Department for Energy & Climate Change put the 2013 CO_2 from international aviation at 32.2MtCO_2e and from domestic aviation 1.8MtCO_2e, which gives a total of 33.2MtCO_2e. The projected 2050 figure of 37.5MtCO_2e by the Committee on Climate Change is on the basis of a 60% increase in demand from 2005 levels by 2050, when emissions were 38MtCO_2e. This implies an approximate 1.05% annual growth in demand, set against a 0.03% annual reduction in emissions, requiring an approximate 1% per year improvement in CO_2 intensity or energy efficiency per unit of passenger demand. This figure is within estimates of potential future efficiency gains. However, annual growth rates of 1% per year in terms of passenger demand are untypical of UK passenger demand.

4.2 Between 1970 and 2010, passenger growth averaged at 5% per year. The UK government projections for 2010 to 2050 average at 1-3% per year. Thus, the CCC's projected 2050 CO_2 emissions would be consistent with the lower growth range, which takes into account: strong market maturity and an increase in video conferencing to reduce business flights. It should be noted that a projection for CO_2 emissions from international and domestic aviation being just 1.2% lower in 2050 than 2005 levels is at odds with a 'fair' or 'proportionate' contribution to avoiding "well below 2°C temperature rise above pre-industrial levels" which is the goal of the 2015 Paris Agreement (see point 3.3 above). Moreover, and as stated previously, the UK's Climate Change Act, and CCC's analysis is based on the UK reducing its CO_2 emissions by 80% from 1990 levels by 2050, in line with the pre-Paris 2°C target enshrined in the Copenhagen Accord. As temperature targets are closely linked to cumulative CO_2 emissions over the 21st century (IPCC, 2014) (*an uncontested point*), it would be logical that the new Paris Agreement now requires nations to revisit their existing targets and goals, given the new language of 'well below' 2°C. It is my view, and likely the view of most other academics in the field, that 'well below' implies a high probability of not exceeding 2°C. This is in contrast to the UK's 80% cut which is premised on a 63% chance of exceeding 2°C, as well as peak CO_2 emissions in some nations that are before those pledged for the 2015 Paris negotiations. Thus, and referring to the assumptions made in points 2.6 and 3.3, *I consider this marginal reduction in CO_2 from the aviation sector by 2050 to be at odds with the 2015 Paris Agreement.*

5. In terms of expansion, a comment on the assumptions made within the Airports Commission Final Report in regard to the environmental impact of the proposed new runway and the feasibility of the suggested mitigation

5.1 The Airports Commission report uses the CCC's CO_2 cap within which to explore the CO_2 impacts of expansion, as well as an alternatively scenario where CO_2 from the aviation sector can be traded, and therefore increase above this limit as a result. It compares Gatwick with Heathrow in this regard, concluding that Heathrow expansion options would have a greater CO_2 impact than expanding Gatwick, given that there are a greater proportion of long-haul flights compared with Gatwick, which have a higher overall absolute CO_2 impact. In the capped scenario, demand in the UK is 61% higher (like CCC) by 2050. In the uncapped one, demand is 104% higher. Focusing in on Heathrow specifically, there would need to be a more substantial package of measures to mitigate emissions than with Gatwick to ensure consistency with the CCC's CO_2 cap and its planning assumption – let alone the Paris Agreement's legal obligation. The report gives an example of overcoming this by having the same carbon price but with significantly higher biofuels usage, plus a range of operational efficiency improvements (practices recognised today but not implemented at scale). This example is rather vague, particularly given the concerns over the sustainability implications of a widespread use of biofuels in general (Adams et al 2013), and specifically within the aviation sector. *In my view, more detail is needed to assess if their scenarios adequately address how these additional CO_2 emissions could be mitigated.* However, it would be my assumption that mitigation is highly unlikely to be commensurate with a proportionate response to 'well below' 2°C.

5.2 There is also a curious statement:
"The more that aviation's 'carbon budget' shrinks, the more important it becomes for that budget to be used as efficiently as possible. The most effective option to achieve this is expansion at Heathrow, which provides the greater benefits to the UK's connectivity and its long-term economic growth", on page 26 of Commission's Report (Airports Commission 2015). This statement would appear to be contradictory – given that expansion of Heathrow would, in my view, lead to an absolute increase in CO_2 emissions after a period of reduction due to easing congestion, that would not have resulted if capacity had remained constrained. In other words, in the time period in question, an option of 'no expansion' would be more likely limit CO_2 emissions from aviation than an option of expansion.

5.3 Included within their report is an assessment of the total CO_2 from all sources associated with the various expansion options. It is worth noting that the flight CO_2 emissions dwarf other contributions (e.g. surface passenger transport) amounting to between 86% and 93% of the total contributions. The options for Heathrow Northwest Runway expansion have the largest CO_2 contributions overall, with 92-93% from the flights. The lowest CO_2 contribution is from Gatwick options.

5.4 To conclude, options for expanding the aviation sector are at odds with the Paris Agreement, given that the language of 'well below 2°C' will require net zero CO_2 emissions from around 2050 (this is taken from the Agreement). This is because, without the widespread global adoption of negative emission technologies that are currently unproven at scale, 'well below 2°C' implies a phasing out of fossil fuels as sources of energy by around 2050. *This is largely uncontested*. What would be contested would be the assumptions around negative emission technologies – but scientific understanding on their development and deployment is only recently starting to emerge.

6. On the weight generally attached to environmental factors when deciding UK aviation policy – and issues with regard to Heathrow in particular

6.1 Given that the evidence suggests that an expansion of airport capacity in general will support an increase in CO_2 emissions, or at least not facilitate their reduction out to 2050, and yet the UK is supportive of the Paris Agreement, a decision to expand Heathrow suggests that CO_2 is a low priority consideration in planning decisions. It is not being considered as a make or break factor. *In my view*, this also implies a misunderstanding by UK Government of the scale of CO_2 mitigation that a 2°C goal relies upon – let alone a 'well below' 2°C target.

7. On the UK government's record generally in compliance with domestic and international obligations in regard to climate change

7.1 The UK has shown leadership within the EU by being the first nation to adopt a legally binding Climate Change Act, with both a 2050 CO_2 target and short-term carbon budgets. To date it has complied with the obligations in these targets. However, where there is some misalignment is with a recommendation from the CCC to the UK Government to explicitly include international aviation (and shipping) emissions within their carbon budgets, or report on why they are not included. This is likely to be revisited in 2016 and in light of the Paris Agreement. As noted in point 1.3, omitting any CO_2 producing sector is at odds with a target based on a global temperature goal (Bows and Anderson 2007).

8. On the impact on human health due to climate change

8.1 The Intergovernmental Panel on Climate Change's 5th Assessment Report (2014) includes 30 chapters on "Impacts, Adaptation and Vulnerability" through the contribution of Working Group II (IPCC 2014a). The report provides an up to date view of the current state of scientific knowledge on Climate Change, explicitly considering the range of scientific evidence and academic opinion and assigning confidence levels and probabilities where appropriate. The Fifth Assessment Report states that the "health of human populations is sensitive to shifts in weather patterns and other aspects of climate change" They categorise this statement as having "very high confidence" (p713)(the highest level of confidence).

They go on to say that "These effects occur directly, due to changes in temperature and precipitation and occurrence of heat waves, floods, droughts, and fires. Indirectly, health may be damaged by ecological disruptions brought on by climate change (crop failures, shifting patterns of disease vectors), or social responses to climate change (such as displacement of populations following prolonged drought). Variability in temperatures is a risk factor in its own right, over and above the influence of average temperatures on heat-related deaths." (p713)

The IPCC state that if climate change continues as projected in line with their Representative Concentration Pathways (RCP), the major negative changes to health compared to a no climate change future will include (inter alia):

- "Greater risk of injury, disease, and death due to more intense heat waves and fires (very high confidence)"
- "Increased risk of undernutrition resulting from diminished food production in poor regions (high confidence)"
- "Increased risks of food- and water-borne diseases (very high confidence) and vector-borne diseases (medium confidence)"(p713)

The World Health Organization (2014), through scenario analysis of future climate impacts, estimate the additional deaths due to climate change across a range of health issues known to be sensitive to climate change (heat-related mortality in elderly people, mortality associated with coastal flooding, mortality associated with diarrhoeal disease in children aged under 15 years, malaria population at risk and mortality, dengue population at risk and mortality, undernutrition (stunting) and associated mortality). Using a medium-high emissions scenario (this would be one that is relatively close to the current emissions track, and not a 'well below 2°C' scenario) they project an additional 250,000 deaths per annum due to climate change across this subset of potential health issues.

It should be noted that there may also be positive impacts on health as a result of climate change. Again, in line with the RCPs, the IPCC state that these positive impacts will be:

- "Modest reductions in cold-related mortality and morbidity in some areas due to fewer cold extremes (low confidence), geographical shifts in food production, and reduced capacity of disease carrying vectors due to exceedance of thermal thresholds (medium confidence)." (p713)

However, the IPCC also note that "These positive effects will be increasingly outweighed, worldwide, by the magnitude and severity of the negative effects of climate change (high confidence)". (p713)

8.2 In the recent Paris Agreement it was recognised that climate change "represents an urgent and potentially irreversible threat to human societies and the planet". In addition, the agreement emphasised the "need to address the significant gap between the aggregate effect of Parties' mitigation pledges in terms of global annual emissions of greenhouse gases by 2020 and aggregate emission pathways consistent with holding the increase in the global average temperature to well below 2 °C above pre- industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre- industrial levels".

Neither the scenario cited above in the World Health Organisation (WHO) report, nor the viable (i.e. have not been out-dated by recent emission levels) RCP scenarios that the IPCC has used to make its projections about impacts on human health listed above, are in line with staying 'well below' the 2 °C threshold without an assumption about widespread deployment of unproven negative emission technologies (Anderson 2015). *<u>This view is largely uncontested</u>*. Where there is a range of opinion, is in regard to how viable this widespread deployment of negative emission technologies could be. This is an area where there is considerable recent debate and concern (Gough and Vaughan 2015, Fuss et al 2014, Anderson 2015). These discussions raise concerns that a reliance on these technologies in most 2°C scenarios could be a dangerous distraction to necessary mitigation of CO_2 emissions (e.g. fossil fuel focused mitigation) and risk giving policy and decision makers a "false sense of security" according to one of the leading experts in the field (Smith 2015).

9. Concluding statement

The aviation sector creates CO_2 emissions through combusting kerosene. The altitude at which aircraft fly also leads to additional warming impacts. One of the greatest challenges for the aviation sector lies in the highly limited opportunities compared with other sectors to reduce CO_2 emissions through technical and operational measures. As a result, any increase in growth in the sector above ~2% per year in terms of passenger-km tends to lead to an increase in absolute CO_2 emissions. Thus without any serious programme of efficiency improvements coupled with rapid biofuel deployment for the sector, demand-side measures (e.g. constraining airport expansion), offer an alternative but also one of the few options to cut its CO_2.

The latest Agreement from the Paris Conference of the Parties in 2015 includes text that…

"aims to strengthen the global response to the threat of climate change by holding the increase in the global average temperature to well below 2 °C above pre-industrial levels".

This level implies a highly constrained amount of CO_2 can be released into the atmosphere in the coming 50 years. Interpretations of what this means will vary – with assumptions around the extent of 'negative emission technologies' being key to this variation. However, with emerging widespread concern over the feasibility of these technologies operating at scale, and within the next 35 years and beyond, the option of phasing out fossil fuels within this period becomes a high priority. This would require all fossil fuel burning sectors to mitigate their CO_2 emissions urgently, in line with a complete phase out by around 2050.

Under less stringent climate constraints than 'well below 2°C', it is reasonable to assume that some sectors will not need to significantly mitigate emissions, and aviation may be a good candidate for being such a sector, given its limited mitigation options. However, the 'well below 2°C' framing of the Paris Agreement, that has been put in place to address concerns over the extent of climate impacts associated with breaching the 2°C threshold, as collated by the IPCC and the WHO, leads to the conclusion that the aviation sector will also need to significantly cut its CO_2 emissions by 2050. Thus, measures that support and encourage CO_2 growth, such as an expansion of airport capacity without mechanisms enforcing increases in efficiency or carbon intensity over and above levels of passenger-km growth, are incompatible with the goals within Paris Agreement. This interpretation would be further underlined, were the Agreement to include an even greater recognition that for many nations world-wide, CO_2 emissions will rise in support of their development for basic energy needs (Lamb et al 2014), leaving even more limited CO_2 space for all CO_2 producing sectors.

There is global agreement that the world needs to limit warming to 'well-below 2°C above pre-industrial levels'. Analysis regarding what this means in terms of mitigation is now being published, with the issue of 'negative emission technologies' leading to the greatest area for debate. Nevertheless, *the vast majority of academics working on climate change mitigation would agree* that a rapid and significant reduction in the combustion of fossil fuels is needed in the coming decades. Air transport is known for both its carbon intensive nature, and its absence of viable technical mitigation options in a timeframe in keeping with avoiding a 2°C temperature rise. As such, there is an expectation that its emissions will continue to grow, or at least not be curbed in a similar way to other sectors, with these other sectors reducing their emissions more to compensate. To date, and from a UK perspective, mitigation measures targeting this sector have been less stringent than for others. However, with the newly published Paris Agreement, most would agree that it is now crucial that targets, goals and pledges be revisited to address the "serious concern" noted in the Agreement that there is a …

"significant gap between the aggregate effect of Parties' mitigation pledges in terms of global annual emissions of greenhouse gases by 2020 and aggregate emission pathways consistent with holding the increase in the global average temperature to well below 2 °C above pre- industrial levels".

Without widespread deployment of highly speculative negative emission technologies, cutting CO_2 emissions in line with 'well below 2°C' will require a transformation in energy systems, and will need to include all CO_2 producing sectors. I am unaware of any analysis that can demonstrate how aviation could be an exception to this.

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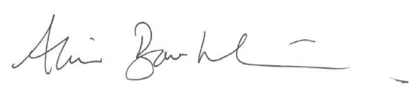

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I confirm that I am aware that an expert's duty is to the court, and I have complied and will continue to comply with that duty.

Signature……….

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Dated……………….5 January……………2016
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