Government airbrushes aviation's non-CO2 greenhouse gas emissions

AirportWatch, June 2015

1. Introduction

While it been recognised for many years that the climate change impacts of aviation extend well beyond those of carbon dioxide (CO_2), this fact is largely ignored by the government and its agencies. Our report examines the reasons for this and proposes an 'index' which will help to ensure that the issue of non-CO_2 gases is properly accounted for.

2. Executive summary

In recent years there has been systematic downplaying of the issue of non-CO_2 gases by the UK government and its associates. This report provides the evidence for that claim.

While 'scientific uncertainty' is claimed as the reason to ignore non-CO_2, the real reason is that aviation emissions are an embarrassment to government and others who want to expand airports and air travel.

In earlier governmental and academic studies a 'Radiative Forcing Index' (RFI) has been used in order to capture non-CO_2 impacts. However, RFI is a 'backward looking metric' and is therefore considered unsuitable for informing aviation policy.

This report argues that instead of just dropping the previously used RFI, it should be replaced by a 'Global Warming Potential' (GWP) index for estimating impacts and developing policy responses.

A rough value for the index of 1.6 is estimated. CO_2 emissions should be multiplied by 1.6 in order to allow for the impact on non-CO_2 GHGs. This is a very conservative figure – the true figure could be much higher, due mainly to cirrus.

The estimate and calculations around it are very approximate. The factor of 1.6 should therefore be regarded very much as an interim, pending a thorough and independent review of the issue of aviation's non-CO_2 emissions.

Although the proposed index is approximate and interim, it should be used forthwith in order to demonstrate impacts and inform policy. Citing scientific uncertainly as a justification for ignoring an issue would not be acceptable in other fields of public policy and should not be accepted when it comes to aviation emissions.

3. Non-CO2 gases

It has been recognised for many years that the climate change impacts of aviation extend well beyond those of carbon dioxide (CO_2). Because they are emitted at altitude, water vapour (H_2O) leading to contrails and nitrogen oxides (NO_x) are greenhouse gases (GHGs) and have a significant additional global warming effect.

The estimates of impacts of H_2O (contrails) and NOx are less precise than for CO_2 (wider confidence limits). However, most authorities recognise the impacts are significant. H_2O can also lead to the formation of cirrus with potentially large effects, but the estimates are less precise again.

The climate effect of non-CO_2 gases can be expressed in terms of 'radiative forcing' (RF) or radiative forcing index (RFI). The best estimate is that a factor of 1.9 should be applied to the effects of CO_2 alone to allow for the non-CO_2 gases (excluding cirrus). That would suggest that the total impact of aviation emissions is almost double that of CO_2 alone.

There has been extensive discussion about the validity of using RFI and various other metrics such as Global Warming Potential (GWP) and Global Temperature Potential (GTP) have been proposed. These metrics give very different results. A key reason for this is the differing lifetime (or residence time) in the atmosphere of the various gases. CO_2 lasts much longer than NOx, for example. See app 1 for further discussion.

Debates about metrics continues, but neither IPCC, CCC nor other authorities and have stated that any specific metrics such as GWP20 or GTP100 should be used in place of RFI.

4. Government forecasting of aviation emissions

The Department for Transport (DfT) published 'UK air passenger demand and CO_2 forecasts' in Nov 2007 and an updated document with the same title in Jan 2009. Later documents of Oct 2011 and Jan 2013 are entitled 'UK aviation forecasts' although they cover the same ground as the previous publications. The change in title may be significant, de-emphasising as it does the non-CO_2 emissions.

In 2007 an RFI of 1.9 was used (see app 2a) and the forecasts were made of CO_2 emissions in absolute terms and as %s of total UK emissions. In 2009 the RFI of 1.9 was again used, but slightly grudgingly (see app 2b). In 2011 non-CO_2 emissions and RFIs were talked down further and no forecasts were made for non-CO_2 emissions and no estimates of aviation's %s even for CO_2 were made (app 2c). In 2013 David Lee's advice was cited as a reason for ignoring non-CO_2 emissions and again there were no forecasts were made for non-CO_2 emissions and no estimates of aviation's %s (app 2d).

The changes between 2007 and 2013 demonstrate an increasing desire by DfT/government to avoid the issue of non-CO_2 GHGs. And, as can be seen from App 2, the government has relied on one scientist's anecdotal and unreferenced advice in order to ignore the impact of non-CO_2 emissions.

5. Committee On Climate Change (CCC)

CCC's report on aviation in 2009 noted that impacts of non-CO_2 GHGs could be significant. It said that use of RFI as a 'multiplier' of CO_2 emissions to determine future effects was inappropriate and discussed other metrics that had been proposed. It showed that if alternative metrics were used, the non-CO_2 impact could still very significant. Because of the large uncertainties, a range of estimates were made with GWPs ranging from 1.3 to 4.3. Even the lowest - 1.3 - is significant, representing a 30% greater impact than CO_2 alone.

In 2012 CCC gave advice on carbon budgets where it said that non-CO_2 effects are important for near-term climate change (near term not defined). But it then says that non-CO_2 does not need to be reflected or included in carbon budgets now, given potential to reduce non-CO_2 emissions before they materially affect the temperature in 2100. It does not explain how non-CO_2 emissions will suddenly disappear. Nor does it explain why only the temperature in 2100 matters; the implication that the next 85 years of climate change do not matter is bizarre.

Finally, CCC argued against the use of a multiplier because it would not provide a direct incentive to reduce the non-CO2 effects. This, too, is bizarre. One could equally apply such an argument to not present evidence on impacts of CO2 or anything else.

These comments demonstrate an increased desire by CCC to avoid the issue of non-CO2 GHGs, despite the fact that its own figures show non-CO2 GHG impacts are far from insignificant. See app 3 for more detail.

6. Airports Commission

The Airport Commission Interim Report mentions uncertainties in non-CO2 impacts and relies largely on what the CCC says. The CCC advice being that "*the target of constraining CO2 emissions from UK aviation to 2005 levels by 2050, consistent with current plans to meet the economy-wide climate target, remains the most appropriate basis for planning future airport capacity*."

The logic of this is very dubious. It seems to be saying that because the Climate Act deals with CO2 and not the other important aircraft emissions, non-CO2 emissions can be ignored generally. See app 4 for more detail.

7. Summary of downplaying

A table summarising this gradual downplaying of non-CO2 emissions follows.

Date	Organisation	Publication	Stance
Nov 2007	DfT	'UK air passenger demand and CO2 forecasts'	Fully recognises non-CO2 issue; applies 1.9 RFI; estimates aviation's % incl RFI.
Nov 2009	DfT	'UK air passenger demand and CO2 forecasts'	Recognises non-CO2 issue; adds warning about RFI; estimates aviation's % incl RFI but derives alternative lower %s where aviation is excluded from the 80% target or is capped at proposed ETS levels.
Dec 2009	CCC	'Meeting the UK aviation target – options for reducing emissions to 2050'	Recognises non-CO2 issue; warns against RFI; estimates GWP20, GWP100 and GTP100 but not RFI; does not propose any specific action to address non-CO2.
Aug 2011	DfT	'UK aviation forecasts ['CO2 forecasts' dropped from title]	Emphasises scientific uncertainties; no estimates at all of aviations %s, with or without any index.
April 2012	CCC	'Scope of carbon budgets - Statutory advice on inclusion of international aviation and shipping'	Effects are important for near-term climate change; do not need to be included in budgets; negligible effect on long term temperature; applying a multiplier would not provide a direct incentive to reduce non-CO2 effects; invents scenarios where contrails and cirrus production suddenly cease, well before the long term.
Jan 2013	DfT	'UK aviation forecasts ['CO2 forecasts' again not in title]	Emphasises scientific uncertainties; cites advice from Lee not to apply a multiplier; no estimates at all of aviations %s, with or without any index.
Dec 2013	Airports Commission		Emphasises uncertainties; says only CO2 is appropriate basis for planning airport capacity.

8. DECC emission factors

DECC publishes guidance on emission factors to be used for company reporting. It recognises there is no good metric, but says there is currently no better way of taking into account the effects of non-CO2 than using a multiplier. A figure of 1.9 based on RFI and GWP100 figure is recommended and this cites, among others, reports by Lee and CCC. See app 5 for more detail.

9. IPPC

IPPC has consistently recognised the significance of non-CO2 emissions since its special report on aviation in 1999. It is neutral about metrics in its most recent report Assessment Report 5, but makes an important point: "*Metrics do not define goals and policy - they are tools that enable evaluation and implementation of multi-component policies (i.e., which emissions to abate). The most appropriate metric will depend on which aspects of climate change are most important to a particular application, and different climate policy goals may lead to different conclusions about what is the most suitable metric with which to implement that policy*."

10. Report by Lee et al

IPCC and CCC refer to an important article 'Aviation and global climate change in the 21st century – Lee et al'. This report estimates RFs at 2005, 2020 and 2050 from which RFIs excluding cirrus can be calculated as 2.0, 2.1 and 2.2 respectively. Including cirrus, RFIs are 3.1, 3.2 and 4.1 respectively.

On metrics, the article points out that the RFI metric is primarily a backward looking metric and says it is therefore inherently unsuitable as an emissions-equivalency metric for policy purposes. However, it does not recommend any specific alternative.

11. Discussion

The material presented above gives clear evidence of a progressive downplaying of the impacts of aviation's non-CO emissions by DfT, CCC and latterly AC. Their documents recognise that non-CO2 emissions are significant but then simply ignore them or give excuses for ignoring them.

There seem to be two main arguments given for ignoring non-CO2 GHGs. Firstly that RFI is an inappropriate metric. Secondly, that the science is uncertain. We examine these below.

It is argued by Lee and others that the use of RFI is inappropriate because it is a 'backward-looking' metric. It tends to over-emphasise the impacts of non-CO2 gases because the residence time of those gases is less than CO2. That RFI is a backward-looking metric and that some 'forward-looking' metric is better is common ground. However, this recognition is nothing new and so does not explain the progressive downplaying of non-CO2 emissions.

Other forward-looking metrics, notably GWP, have been proposed. GTP has also been proposed but, as explained in app 1, we consider the use of GTP inappropriate because it ignores all climate impacts and costs up to the year in which it applies, eg 100 years hence.

While GWP may not be ideal, it is the best there is at present. It therefore makes sense to use it when assessing impacts and developing policy. This principle extends to all area of scientific research and public policy. In our real and imperfect world we have to use the best evidence and the best estimates that are available. To argue that because our knowledge is imperfect, we should ignore an issue is absurd. Such an argument is not applied in other areas of public life. Uncertainly about future terrorist attacks or Ebola outbreaks is not used as a reason to ignore the issues.

The real reason for airbrushing non-CO2 emissions is not hard to find. There is increasing pressure on and from politicians to expand airports and air travel. The climate impacts of such a policy represent a highly 'inconvenient truth'. Given the widespread recognition of the role of CO2, government and its agencies could not hope to ignore CO2 impacts without attracting the severest criticism. But for non-CO2 emissions, about which there is as yet very little public knowledge, government and its servants can hope to ignore the impacts while escaping criticism.

Global Warming Potential (GWP) is noted in the literature as a promising metric. However a period need to be defined over which the effect are integrated. We argue in app 7 that an average of GWP35 and GWP100 should be used.

Including cirrus, GWP35 and GWP100 are 3.69 and 1.9 respectively, giving an average of 2.8. However, the uncertainty around cirrus is especially large. This, leading to possibly misleading high impacts, makes a case for omitting cirrus from an index at present.

Excluding cirrus, GWP35 and GWP100 are 1.92 and 1.4 respectively, giving an average of 1.61, rounded to 1.6. This is a very conservative figure - that is, it is likely to be lower than the true values. (It is conservative because cirrus, although subject to great uncertainty, is nonetheless expected with a fair degree of confidence to add significant radiative forcing. The calculations also assume a 'low' inpact of NOx.)

Where there are significant uncertainties, it seems appropriate to use conservative values. This will avoid 'overshoot' whereby a high index is initially selected, leading to a particular set of policy responses, only for the index to be reduced in the light of further research, leading to possible differences or even reversals of policy responses.

Based on the foregoing, we propose an index of 1.6, based on GWP calculations. That is, impacts of CO2 alone should be multiplied by 1.6 to allow for non-CO2 impacts. This factor should be applied forthwith in order to inform the debate on the impacts of aviation and policy responses to it.

The data and calculations supporting this are indeed approximate, but there is very strong evidence that non-CO2 impacts are significant. Furthermore, the factor of 1.6 is very conservative. These are compelling reasons to allow for non-CO2 emissions and to apply this factor. Simply citing 'scientific uncertainty' as a reason for ignoring non-CO2 emissions and not applying any factor is not tenable.

Recognising the 'rough and ready' nature of the calculations, the proposed index of 1.6 should be regarded very much as an interim figure. A proper and fully independent study should be undertaken in order to refine this index or, indeed, to devise an alternative approach for addressing non-CO2 impacts.

Appendix 1 – Metrics for assessing the impacts of non-CO2 emissions

H2O and NOx do not have a significant greenhouse effect when emitted at ground level. Thus they are not significant (in climate terms) for non-aviation sectors and have therefore not been part of climate negotiations and agreements such as the Kyoto protocol. [1]

CCC's 2009 report on aviation provides a useful summary of metrics (Box 6.2, page 124): [2]

"Three common metrics are discussed here. They can be grouped into one that measures current effects as a result of past emissions (Radiative Forcing Index) and those that measure future effects arising from present emissions (Global Warming Potential and Global Temperature Potential):

• Radiative Forcing Index (RFI): The Radiative Forcing Index (RFI), introduced by the IPCC in their 1999 report1, describes the relative contribution to radiative forcing (RF, see Box 6.1) of all forcing agents from aviation, compared with that of carbon dioxide alone. RFI is the ratio of the total RF from aviation to the RF from CO2. Because RF measures the effect of activity to date, rather than the future effect of current activity, the RFI is not an appropriate measure of emissions equivalence.

• Global Warming Potential (GWP): Global Warming Potential (GWP) is designed as an emissions equivalence metric. It measures the total RF accumulated over a given time horizon arising from a unit emission of forcing agent, relative to that of CO2. A time horizon of 100 years is used for the international reporting of Kyoto GHG emissions. There are certain theoretical difficulties in producing measures of the GWP of the non-CO2 effects of aviation, particularly in taking into account short-lived effects, and effects that do not relate to emissions in a straightforward way (e.g. the formation of contrails and cirrus cloud coverage only occurs under certain atmospheric conditions). Nevertheless, the GWP is finding some favour as the only current way of formulating a CO2 emissions-equivalence for aviation's non-CO2 effects2 that is consistent with the current policy framework. It is also important to note that GWP varies with time horizon, even for long-lived greenhouse gases, and that the choice of 100 years is a policy selection rather than a scientific one. The overall GWPs for aviation effects have been assigned a 'very low' level of scientific understanding (Box 6.3) simply because of the uncertainties in the input data to these metrics (i.e. not an uncertainty in the concept of the metric itself) – this is illustrated by an overall aviation NOx GWP which ranged from -2.1 to +71.

• Global Temperature Potential (GTP): The GTP may be considered analogous to the GWP in that it considers the equivalence of a unit release of emissions to that of CO2. Rather than calculating the ratio of RFs accumulated over a period of time for that agent and CO2, however, it calculates the ratio of global mean surface temperature responses at some specific future point in time.

Comparing metrics
The RFI is not intended to measure the equivalence of future non-CO2 effects. The GWP and GTP are both suitable metrics for this purpose, and recent research has produced estimates of aviation effects using both these metrics (Box 6.3). However, the convention remains under the United Nations Framework Convention on Climate Change (UNFCCC) to express non-CO2 emissions in

[1] There are 5 GHGs other than CO2 which are included in the Kyoto protocol. They are insignificant in terms of the emissions from aviation, but are not insignificant for some other sectors of the economy. The key aviation non-CO2 GHGs – H2O and NOx - are <u>not</u> in the list of 6 Kyoto GHGs.
[2] http://www.theccc.org.uk/publication/meeting-the-uk-aviation-target-options-for-reducing-emissions-to-2050/

terms of CO2-equivalent using the 100-year GWP metric. A recent workshop of the IPCC3 concluded that it would be inappropriate at the current time to propose replacing the GWP with the GTP as more research was required on the GTP's performance and potential applications."

There is a very good reason why a GTP metric such as GTP100 is inappropriate. It only shows impacts in a single year 100 years hence. But there will be impacts – environmental, social and economic in every one of 99 years following emissions in the current year. GTP ignores all this, whereas GWP100, being an integration of future impacts, takes account of impacts every year up and including year 100.

While GWP is preferred to GPT, this begs the question of what timescale to select. This is considered in app 7.

Appendix 2 - Government forecasting of aviation emissions

a. 2007 forecasts

The Department for Transport (DfT) published 'UK air passenger demand and CO2 forecasts' in Nov 2007. [3]

CO2 emissions from aviation were 37.5 million tonnes (mtCO2) in 2005 and forecast to rise to 60.3 mtCO2 pa by 2050. Aviation's emissions expressed as a % of all sectors was 6.4% in 2005, rising to 20.6% in 2050. To calculate the % in 2050 it was assumed that the target was to cut CO2 emissions in 2050 by 50% compared with 1990 levels. (This was before the Climate Act was passed.)

The issue of non-CO2 emissions was fully recognised: "*In order to recognise the varying scientific views on radiative forcing and to demonstrate the potential magnitude of these other effects, in line with the most recent evidence we propose to apply a multiplier value of 1.9 to the figure for carbon emitted as the central case, with a sensitivity tests to define a range of using a multiplier of 1 and 4.*" (p57)

Equivalent calculations were carried out allowing for the non-CO2 GHGs. Aviation's emissions were 71.2 mtCO2 equivalents (37.5 x 1.9) per annum in 2005 and forecast to rise to 114.6 mtCO2 pa by 2050. Aviation's emissions expressed as a % of all sectors was 9.9% in 2005, rising to 29.0% in 2050.

From the above, the effect of including non-CO2 GHGs is to increase aviation's share of emissions at 20590 from **20.6% to 29.0%.** [4]

b. 2009 forecasts

In Nov 2009 the Department for Transport (DfT) published an update: 'UK air passenger demand and CO2 forecasts'. [5]

---

[3] http://webarchive.nationalarchives.gov.uk/+/http:/www.dft.gov.uk/pgr/aviation/atf/ukairdemandandco2forecasts/airpassdemandfullreport.pdf

[4] There are 5 GHGs other than CO2 which are included in the Kyoto protocol. They are insignificant in terms of the emissions from aviation, but are not insignificant for some other sectors of the economy. The key aviation non-CO2 GHGs – H2O and NOx - are <u>not</u> in the list of 6 Kyoto GHGs. This complexity is allowed for when calculating aviation's share of emissions.

CO_2 emissions from aviation were 37.9 $mtCO_2$ in 2006 and forecast to rise to 59.9 $mtCO_2$ pa by 2050. By this time the Climate Act had been passed, with its target of 80% cuts by 2050 compared with 1990 levels. This led to big increase in aviation's emissions expressed as a % of all sectors, rising from 6.3% in 2005 to 38.1% in 2050.

The issue of non-CO_2 emissions was recognised, but slightly more grudgingly than in 2007: "*a 'radiative forcing factor' of 1.9, by which in-flight carbon emissions are multiplied to account for the warming effect of non-carbon emissions. While a multiplier has significant weaknesses and does not necessarily apply with future technologies, we believe it represents an acceptable tool in this circumstance to ensure that the wider climate impact of aviation is not underestimated*." (p21).

Equivalent calculations were carried out allowing for the non-CO_2 GHGs. Aviation's emissions were 71.2 $mtCO_2$ equivalents per annum in 2005 and forecast to rise to 113.8 $mtCO_2$ pa by 2050. Aviation's emissions expressed as a % of all sectors was 9.8% in 2005, rising to 53.9% in 2050.

From the above, the effect of including non-CO_2 GHGs is to increase aviation's share of emissions at 2050 from **38.1% to 53.9%.**

However, a series of alternative %s were also calculated which assumed one or more of the following:
* international aviation is excluded from the 80% target
* aviation emissions assumed to be at the 'capped' level proposed by ETS, not forecast level

By these means, aviation's % of emissions were reduced to **as little as 19.0%.** As at Nov 2014, aviation <u>has not been</u> excluded from the target and ETS <u>has been</u> all but abandoned (for aviation).

c. 2011 forecasts

In Aug 2011 the Department for Transport (DfT) published an update: 'UK aviation forecasts'. [6] This still covered emissions, especially CO_2, the fact that but the change in title may be significant, de-emphasising as it does the emissions.

CO_2 emissions from aviation were 35.0 $mtCO_2$ in 2009 and forecast to rise to 49.0 $mtCO_2$ pa by 2050. The fall in the 2050 figure compared with the 2009 forecast is due to greatly reduced passenger demand forecasts, resulting from the economic situation. Unlike the 2007 and 2009 forecasts, aviation's % of total emissions was **not shown at all.**

The issue of non-CO_2 emissions was even more grudgingly recognised: "*Although aviation does not emit significant quantities of any other Kyoto greenhouse gases, it results in other emissions that have both cooling and warming effects on the climate. .. A comprehensive updated assessment of aviation emissions was undertaken by Lee et al in 2009. .. once the non-CO2 climate effects of aviation are taken into account, aviation's overall climate effects could be up to double the climate effect of its CO2 emissions. However, whilst scientific advances since the 1999 assessment have reduced key uncertainties, considerable scientific uncertainty still remains*." (p67).

---

[5] http://webarchive.nationalarchives.gov.uk/+/http:/www.dft.gov.uk/pgr/aviation/atf/co2forecasts09/co2forecasts09.pdf

[6] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/4503/uk-aviation-forecasts.pdf

Unlike the 2007 and 2009 publications, no forecasts were made in 2011 allowing for the non-CO2 GHGs. Thus there is no forecast of CO2 equivalents or of aviation's share of total emissions.

The crucial point is that no evidence is presented to show that non-CO2 GHG should now be ignored. Nor that application of an alternative metric to RFI is preferred. Nor that 1.9 is not still the best estimate of RFI.

d. 2013 forecasts

In January 2013 the Department for Transport (DfT) published another update: 'UK aviation forecasts'. [7] As with the 2011 forecast, it still covered emissions, especially CO2, but the continued absence of the word "emissions" in the title may be significant.

CO2 emissions from aviation were 33.3 mtCO2 in 2010 and forecast to rise to 47.0 mtCO2 pa by 2050. The slight fall in the 2050 figure compared with the 2009 forecast is due to further reduced passenger demand forecasts. Like the 2011 forecasts, aviation's % of total emissions was **not shown at all.**

The following is added on non-CO2 emissions (para 6.15, page 88):

"*CCC (2009) summarises the findings of Lee et al (2009), including its estimates of the different climate effects of aviation. For example, the estimated 100-year Global Warming Potentials from Lee et al (2009) indicate that, once the non-CO2 climate effects of aviation are taken into account, aviation's overall climate effects could be up to double the climate effect of its CO2 emissions. However, while scientific advances since the 1999 assessment have reduced key uncertainties, considerable scientific uncertainty still remains. The latest advice from Lee et al has been not to apply a multiplier to the CO2 emission forecasts*."

Clarification of this was sought from DfT. In June 2013 DfT advised as follows: "*It originates from p.126 of the December 09 CCC report which is the footnote immediately adjacent in the text. David Lee was advising the CCC in this area and the p.126 text stated that the multiplier "is now regarded as inappropriate" prior to more work on suitable metrics.*"

In May 2014 DfT gave further clarification: "*Between 2010-2011 David Lee was working on behalf of the DfT as part of the EMRC consortium of consultants developing a Marginal Abatement Cost Curve (MACC) for aviation which produced the report published alongside the Government's Response to the CCC 2009 Report. In discussions during the production of that report, David Lee advised the DfT not to use any form of multiplier due to the significant scientific uncertainty surrounding the additional impact associated with non-CO2 effects."* However, DfT said there was no documentation of this.

Appendix 3 – Committee On Climate Change (CCC)

CCC produced a special report on aviation in 2009. [8] On non-CO2 GHGs it says "*There is high scientific confidence that the total climate warming effect of aviation is more than that from CO2 emissions alone. .. This could have implications for UK economy-wide and aviation emissions targets, and could require additional emissions reduction effort within aviation*." (p120).

[7] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/223839/aviation-forecasts.pdf
[8] http://www.theccc.org.uk/publication/meeting-the-uk-aviation-target-options-for-reducing-emissions-to-2050/

Later it says: "*One approach to quantification has been to use estimates of current radiative forcing of the individual effects relative to that of CO2 (the Radiative Forcing Index, RFI) as a 'multiplier' of CO2 emissions to determine future effects. This is now regarded as inappropriate, however (Box 6.2), and more recent estimates based on suitable metrics such as Global Warming Potential and Global Temperature Potential have been proposed*." (p126). Note they had just been "proposed" - not accepted - as replacements to RFI.

Box 6.3 (p127) shows that even if a non-RFI index is adopted, the impact can be very high. A 20-year GWP metric gives factors from 2.1 or 2.6, according to whether "low" or "high" estimates of NOx are used. If cirrus is included, the factors are an astonishing 4.3 or 4.8.

The factors for GWP100 are lower but still very significant – 1.3 or 1.4 according to whether "low" or "high" estimates of NOx are used. The factors are 1.9 or 2.0 if cirrus is included. There are good reasons for giving weight to GWP20 values and not just to GWP100 – see app 1x.

The factors for GTP100 are much lower, but there are very good reasons why these are not suitable - see app 1x.

A letter from CCC (Lord Turner) in 2009 [9] said: "*The influence of aviation on climate extends beyond that due to CO2 emissions. Although there remain uncertainties regarding the quantifications of these effects, the science is clear that they are highly likely to lead to significant additional warming*." (last page).

In 2012 CCC gave advice on 'Scope of carbon budgets Statutory advice on inclusion of international aviation and shipping', Committee on Climate Change' – Aviation non-CO2" emission and effects' [10] (p31-33). It said: "*These effects are important for near-term climate change. However, they do not need to be reflected or included in carbon budgets now, given potential to reduce them before they materially affect the temperature in 2100 ..* " It does not explain how non-CO2 emissions will suddenly disappear. Nor does it explain why only the temperature in 2100 matters; the implication that the next 85 years of climate change do not matter is bizarre.

It then says: "*Contrails and induced cirrus formed from today's aviation activity have a negligible impact on long-term temperature ..*" (p30). This is irrelevant because nothing can be done to mitigate emissions up to the present. What matters is what happens as a result of current and continuing emissions (this is the rationale for using GWP rather than RFI). Fig 2.7 suggests an increase of global temperature of about 0.07deg in 2050, but the impacts of CO2, according to a very rough calculation (app 6), would be about 0.26deg. So non-CO2 adds some 27% to the CO2 impact. That is hardly "negligible".

It continues: "*Applying a multiplier to aviation CO2 emissions has been suggested in order to reflect total aviation effects on the climate. However this would not provide a direct incentive to reduce the non-CO2 effects ..*" This is an illogical argument. The purpose of an index is to show in a convenient form climatic impacts. This is important evidence, needed to inform debate about actions and policies. To argue against evidence being presented is bizarre.

These comments demonstrate an increasing desire by CCC to avoid the issue of non-CO2 GHGs, despite the fact that their own figures show non-CO2 GHG impacts are far from insignificant.

---

[9] http://www.theccc.org.uk/publication/letter-ccc-advice-on-a-framework-for-reducing-global-aviation-emissions/

[10] http://archive.theccc.org.uk/aws/IA&S/CCC_IAS_Core_ScopeOfBudgets_April2012.pdf

Appendix 4 - Airports Commission (AC)

The Airports Commission Interim Report [11] relies largely on what the CCC says. AC says (box 4a, p115)*: " difficult to compare the effects of NCEs [(non-carbon emissions] with those of CO2, although a number of methods have been developed to enable a comparison of some aspects.*

'Radiative forcing' is one method for doing this. Other approaches include the 'Global Warming Potential' (GWP) and 'Global Temperature-change Potential' (GTP). Despite significant progress in quantifying climate effects for NCEs, climate metrics for these emissions remain more uncertain than for CO2.

As scientific understanding in this area continues to improve, climate policies may need to evolve to take better account of NCEs. However, the implications of this for specific sectors, such as aviation, are not yet clear."

These comments all use scientific uncertainty as a justification for ignoring non-CO2 impacts.

"The CCC's recommendation to the Commission, taking account of all these uncertainties, is that the target of constraining CO2 emissions from UK aviation to 2005 levels by 2050, consistent with current plans to meet the economy-wide climate target, remains the most appropriate basis for planning future airport capacity."

The logic in this paragraph is very dubious. It seems to be saying that because the Climate Act deals with CO2 and not the other important aircraft emissions, the non-C02 emissions can be ignored more generally.

Appendix 5 - DECC emission factors

DECC publishes guidance on emission factors, the latest being '2014 Government GHG Conversion Factors for Company Reporting: Methodology Paper for Emission Factors FINAL July 2014'. [12]

The guidance recognises the difficulties with metrics para 8.33 onwards): "*Currently there is no suitable climate metric to express the relationship between emissions and climate warming effects from aviation .. Nonetheless, it is clear that aviation imposes other effects on the climate which are greater than that implied from simply considering its CO2 emissions alone. The application of a 'multiplier' to take account of non-CO2 effects is a possible way of illustratively taking account of the full climate impact of aviation.*"

But unlike DfT and CCC, it does not play down the issue of non-CO2 GHGs: "*Consideration of the non-CO2 climate change effects of aviation can be important in some cases, and there is currently no better way of taking these effects into account. A multiplier of 1.9 is recommended as a central estimate, based on the best available scientific evidence, as summarised in Table 36 and the*

[11] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/271231/airports-commission-interim-report.pdf

[12] http://www.ukconversionfactorscarbonsmart.co.uk/documents/2014%20Emission%20Factor%20Methodology%20Paper_FINAL-4Jul14.pdf

GWP100 figure (consistent with UNFCCC reporting convention) from the ATTICA research presented in Table 37 below and in analysis by Lee et al (2009) reported on by the Committee on Climate Change (2009)57."

Appendix 6 – Relative impact of global non-CO2 emissions by 2050

As described in app 3, CCC 2012 estimated that aviation contrails and induced cirrus would increase global temperature by 0.07deg in 2050 and claimed this is "negligible".

There do not appear to be a coherent or self-consistent set of figures in the literature that enable the global warming impact of non-CO2 emissions to be compared with CO2 emissions. (Lee et al, looked at RFs but do not convert to metrics such as GWP or GTP.) However, by taking figures from a variety of sources a rough comparison of the impact of contrails plus cirrus can be made.

Total anthropogenic emissions forecasts depend on a variety of assumptions – for a 'business as usual' scenario, Carbon Brief [13] suggests something between the IPCC RCP6.0 and RCP 8.5 scenarios. Van Vuuren in 'The representative concentration pathways: an overview of climatic change (2011) 109:5–31' [14], fig 11 on p25 gives 19 GtCO2 at 2050 for RCP 8.5 and 12 Gt for RCP 6.0. We take an average of 15.5 gT.

Lee 2011 [15] Table 1 gives a forecast of CO2 emissions at 2050 ("central growth scenario") of 2.5 gT CO2 pa. Dividing this by 15.5 for all total CO2, the % of emissions due to aviation is 16%.

IPCC summary for Policymakers Table SPM.2 [16] p23 shows likely ranges of temperature increase for the various scenarios. The increase is for the period 2046-2065 compared with a reference period 1986-2005. The mean of the RCP6.0 and RCP8.5 temperature increases is 1.65 deg. While these periods are different from the commonly used 'spot' dates of 1990 and 2050, the spacing is 60 years in each case and the spot dates lie within the periods. For the purpose of these rough calculations, the periods and spot dates are used interchangeably.

CCC 2012 [17] indicates that contrails plus cirrus could increase temperatures by about 0.07 deg over 60 years (app 3). This can now be compared with impact of aviation CO2. As aviation is forecast to account for 16% of emissions, 16% of the forecast 1.65 deg can be attributed to aviation, ie 0.264 deg. Contrails plus cirrus are therefore 0.07 / 0.264 = 27%. (This calculation ignores the fact that a proportion of the 1.65 deg temperature rise is due to non-CO2 non-aviation emissions. The calculation could be refined if necessary and would increase the figure of 27%. It should also be noted that this figure does not allow for NOx.)

While the above calculations are 'rough and ready' they strongly suggest that claims about non-CO2 being negligible are wrong.

---

[13] Roz Pidcock, pers comm.
[14] http://link.springer.com/article/10.1007%2Fs10584-011-0148-z#page-1
[15] 'Aviation and global climate change in the 21st century – Lee et al'. Not open access online - contact AEF for copy.
[16] https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_SPM_FINAL.pdf
[17] http://archive.theccc.org.uk/aws/IA&S/CCC_IAS_Core_ScopeOfBudgets_April2012.pdf

Appendix 7 – Selection of an interim metric

Global Warming Potential (GWP) is noted in the literature as a promising metric. However, a period need to be defined over which the effects are integrated. Periods of 20 year and 100 years have been mooted, for illustrative purposes rather than as a proposed metric for reporting and policy. Both of these periods seem extreme.

IPCC points out that the most appropriate metric will depend on which aspects of climate change are most important to a particular application. In the current debate about aviation and climate changes, attention is very much focussed on the period up to 2050. The Climate Act is built round a 2050 target and the forecasts of aviation demand and emissions extend to 2050. It seems reasonable, then, to use a metric which reflects that period of interest. GWP35, which would integrate up to 2050 the impact of a pulse of emissions in 2015, would achieve this.

A period of 35 years seems intuitively reasonable because it is long enough for at least the initial climate impacts to be noticed and for policy change to be effected within that period (one to two generations). 20 years is rather too short a period.

Having selected a metric of GWP35, the next question is what value this should take. None of the literature referenced here gives figure for GWP35. However, CCC 2009 report gives figures for GWP20 and GWP100 (app 3). The figure for GWP35 will lie between these extremes. Guidance has not been observed in the literature on how to estimate intermediate GWPs, using other GWPs already calculated. We assume GWP will follow a roughly exponential fall from GWP1 to GWP100 on the grounds that the concentration of gases falls off exponentially and significantly over time. Using the published figures for GWP20 and GWP100 to fix the parameters of the exponential equation, values of GWP35 can be calculated. (In practice, there is little difference between linearly and exponentially interpolated results.)

Using the figures from Box 6.3 of the CCC report, interpolated values of the GWP index are:
Including cirrus – 3.69
Excluding cirrus – 1.92
Recognising that confidence in NOx impact is low, separate GWP figures are quoted by CCC for "low" and "high" impacts. Our interpolated values assume the low impact; they are thus conservative.

Given the particularly low levels of confidence for cirrus, combined with possibly misleading high impacts, there is a case for omitting cirrus. This would suggest an index of 1.92. That is, total impacts are 90% higher than CO2 alone. However, this is a very conservative estimate. While the confidence limits for cirrus are wide, the lower end of the 90% confidence range cirrus is well above zero – about 47% of the 'central' value (see CCC 2012 [18] fig 2.6).

100 years seems a very long time – it is 3 or 4 generations - and relying on GWP100 would encourage 'kicking the ball into the long grass'. Nonetheless, such a long period has merit because it is only in the longer term (well after 2050) that the big changes in climate are expected. We therefore consider that there is some case for using GWP100 and not relying just on GWP35. GWP100, excluding cirrus and again taking the 'low' impact of NOx, gives an index of 1.3.

[18] http://archive.theccc.org.uk/aws/IA&S/CCC_IAS_Core_ScopeOfBudgets_April2012.pdf

As with GWP35, this estimate is very conservative because low NOx is used and cirrus is omitted.

We have not established a case for giving more or less weight to GWP35 than GWP100. We therefore simply take the average of GWP35 and GWP100, the result being 1.61. That is, the (rounded) impact of all GHGs is 1.6 times that of CO_2 alone.

This is recognised to be a very ‘rough and ready’ approach. More sophisticated approaches are possible. For example a ‘discounted GWP’ could be computed. This would overcome the problems of selecting GWPs with a specific time frame such as GWP20, GWP35 or GWP50. The warming potential would be integrated over a long period, but applying a discount factor which weights early years more than later ones. This would reflect standard practice in other fields, where costs and benefits over many years are discounted and summed to give a ‘net present value’.

Nic Ferriday, June 2015