Practicalities of an Airspace Based Emissions Trading System

CAP 1055

INTENTIONALLY LEFT BLANK

CAP 1055

Practicalities of an Airspace Based Emissions Trading System

www.caa.co.uk

3rd July 2013

Contents

Executive Summary

1. The CAA has undertaken a qualitative analysis of three different options identified for an airspace based emissions trading system. These options are: using actual fuel burn data directly correlated to FIR or national airspace boundaries; using actual fuel burn data but modelled apportionment to airspace from either filed flight plan data or using actual routes flown; and using modelled fuel burn and modelled airspace data.

2. These options were judged on four criteria: efficacy in relation to a Cap & Trade Emissions Trading System, practicality, administrative feasibility and qualitative cost estimates. It was felt that the first criteria of efficacy should be given the strongest weighting which means a system based on actual fuel burn and actual route flown is the highest ranked approach. However, this analysis has shown that there are conflicts in scores, with no approach scoring highly on all four criteria. This means that trade-offs will be required because the options most appropriate for a trading system are likely to be far more difficult to implement and incur costs for both regulators and operators.

3. From our initial analysis we feel on balance that a system based on actual fuel burn (option 2b.) which then takes a more modelled approach to apportioning emissions to the actual route flown has the greatest potential. This hybrid version could use a mixture of actuals and modelled data and still score relatively highly for efficacy. However, a more detailed quantitative assessment would be required to appraise the options further which would help to mitigate the risk of unforeseen consequences that could arise from some of the options if they are not fully appraised.

4. There is notable variance between the distances of routes based on the most direct routing (Great Circle Distance), the filed flight plan and the actual route flown. This means any system designed on a modelled or predicted route would incur a degree of inaccuracy in emissions emitted.

5. Over flights should be included in any airspace based system. Without the inclusion of overflights a considerable quantity of emissions occurring within the territory of EU Member States would be lost. However, the paper recognises that this presents significant, though we believe not insurmountable, challenges to the administration of such a system.

6. There would be few flights that would not see an 'emissions loss' if the system was based on national rather than FIR airspace boundaries.

7. Reporting of emissions may be more appropriate through a central reporting entity such as Eurocontrol – especially if a more modelled approach is necessary. The role of individual member state administrators looks less clear.

8. A separate small operator's system could be considered - possibly extended to smaller commercial operators - but careful consideration would be needed to avoid competitive distortion. This would also apply to a system designed on modelled data but with the option for operators reporting 'actuals'.

Glossary

Continuous Climb Operations (CCO)

An operation, enabled by airspace design, procedure design and Air Traffic Control, in which a departing aircraft climbs without interruption, to the greatest possible extent, by employing optimum climb engine thrust, at climb speeds until reaching the cruise flight level (ICAO)

Continuous Descent Approach (CDA)

An operation, enabled by airspace design, procedure design and Air Traffic Control, in which an arriving aircraft descends continuously, to the greatest possible extent, by employing minimum engine thrust, ideally in a low drag configuration, prior to the final approach point. (ICAO)

En-route

From completion of Initial Climb through cruise altitude and completion of controlled descent to the Initial Approach Fix.

Flight Management System (FMS)

Provides pilot and crew with highly accurate and automatic long-range navigation capability.

Performance-based Navigation (PBN)

Represents a shift from sensor-based to performance-based navigation. PBN specifies that aircraft RNP and RNAV systems performance requirements be defined in terms of accuracy, integrity, availability, continuity and functionality required for the proposed operations in the context of a particular airspace when supported by the appropriate navigation infrastructure. (ICAO)

RNAV

A navigation system which permits aircraft operation on any desired flight path within the coverage of station referenced navigation aids or within the limits of the capability of self contained aids, or a combination of these. (ICAO)

RNP

An area navigation system which supports on-board performance monitoring. (ICAO)

SESAR

SESAR - The Single European Sky Air Traffic Management Research (SESAR) programme is a pooling of current research and development efforts, which aims to develop a pan-European system.

Standard Instrument Arrival (STAR)

A designated IFR arrivals route linking a significant point, normally on a designated ATS route, with a point from which a published instrument approach procedure can be commenced (ICAO)

Standard Instrument Departure (SID)

A designated IFR departure route linking the aerodrome or a specified runway of the aerodrome with a specified significant point, normally on a designated ATS route, at which the en-route phase of a flight commences (ICAO)

System Wide Information Management (SWIM)

SWIM will provide a common context for top-down, performance-oriented, secure integration and management of shared information assets across the global Air Traffic Management domain.

Waypoint

A named geographical location used to define routes.

CHAPTER 1

Background

Context

1.1 Under Section 16 of the Civil Aviation Act DfT have asked the CAA to provide advice on the practical implementation of an airspace based emissions trading system to help inform the UK Government's position ahead of the ICAO general assembly in September 2013.

1.2 This report covers the practical implementation of an approach based upon: capturing emissions from a flight based upon actual aircraft emissions, modelled aircraft emissions or a hybrid version of actual and modelled data.

1.3 In examining the practicality of an airspace based system, the CAA has looked at aspects including aircraft capability, airspace feasibility, safety and potential administrative and economic burden.

1.4 The study has not commented or raised issues related to the political implementation of such a system and associated legal issues with the use of sovereign and international airspace.

1.5 This report incorporates phases one and two of the work done for the SoS under his Section 16 request and covers in detail some of the considerations that would need to be given to an airspace based emissions trading system .

Introduction to Airspace

1.6 Although every state has exclusive right of sovereignty to control and manage their airspace, for practical air traffic management purposes aircraft are controlled and managed within Flight Information Regions (FIRs). These are usually smaller sub-divisions of airspace within a State's sovereign national airspace; or can extend beyond this sovereignty to international airspace such as over oceans (known as oceanic FIRs).

1.7 Within these FIRs there is an established network of Air Traffic Service (ATS) routes that aircraft use. Along these routes aircraft will transit from one FIR to another and with modern navigational aids the aircraft can pinpoint its position within these FIRs at any given point in time.

1.8 FIRs are relatively static structures and the current structure of airspace design has not changed significantly in the last 30-40 years. ATS routes still provide a back-bone en-route environment with connectivity then provided between this and the terminal airspace and airport environments where conventional holding patterns, Standard Arrivals (STARs) and Standard Instrument Departure (SIDs) provide the transition to/from the runway. Instrument approach procedures support operations to the runway as either stand-alone procedures or as final approach segments.

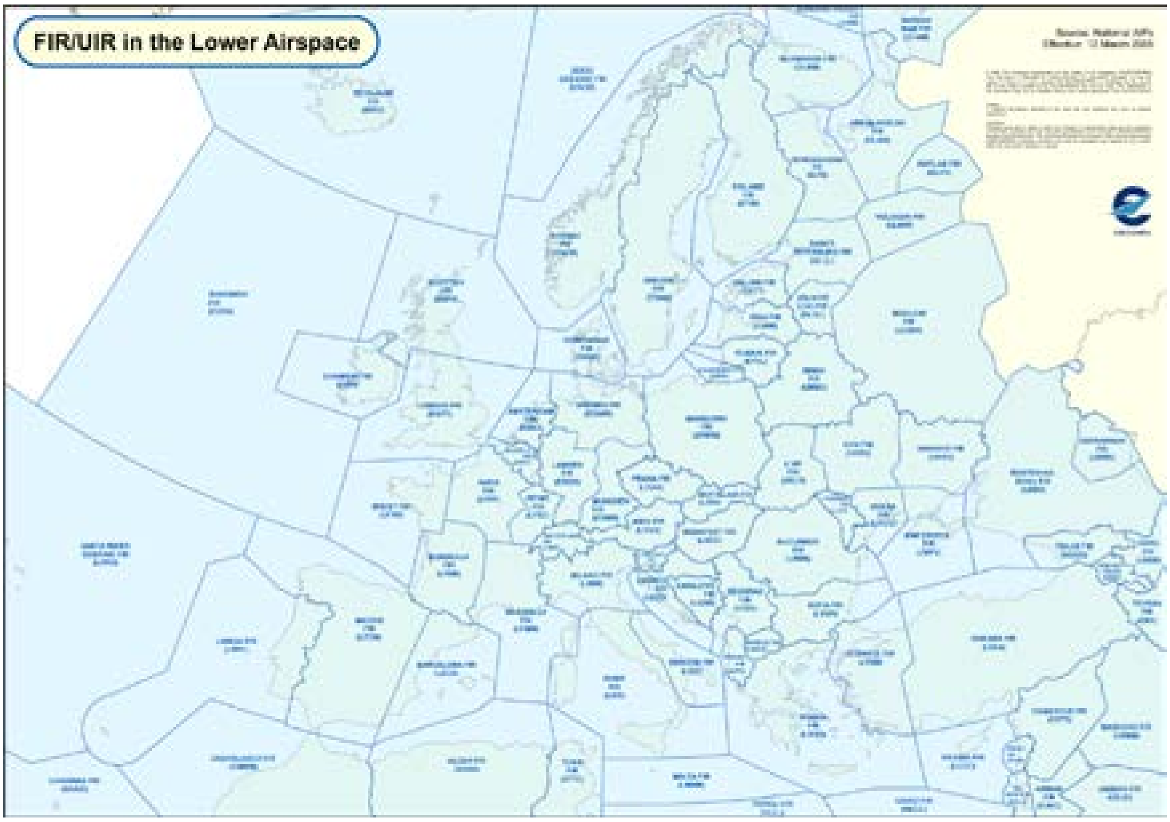
1.9 In the UK, the en-route is predicated on RNAV 5[1] equipment carriage. Terminal airspace procedures are still very much based on conventional, ground based navigation aids although there is a slow uptake of RNAV 1[2] procedures. Instrument approach procedures are largely predicated on use of Instrument Landing Systems (ILS) with Non-Precision Approaches at certain aerodromes and runways providing additional approach capability. Required Navigation Performance (RNP) Approaches are being introduced more widely as a means to provide access at more remote aerodromes, reduce cost of infrastructure and provide resilience to the ILS.

1.10 Although the UK has this defined ATS route and terminal airspace structure, it is rarely operated in this way with a very low systemised use of the current airspace route infrastructure. This will bring challenges to an airspace based emissions trading system; as will future airspace design and operations. The plan is for the future UK airspace structure to align with SESAR concepts and in particular, one based on trajectory operations with Flexible Use and Free Route Airspace (FUA and FRA) being employed.

1.11 More detail on how current and future airspace arrangements could impact upon the operation of an airspace system are provided later in the report.

1 RNAV 5 (formerly European Basic RNAV) has a navigation accuracy of +/- 5 NM, 95% of the flight time.

2 RNAV 1 (formerly European Precision RNAV) has a navigation accuracy of +/- 1 NM, 95% of the flight time.



Measuring CO_2 emissions through airspace

1.12 Under the current EU-ETS, CO_2 emissions are measured by calculating the emissions of an aircraft from the push back at the gate of departure airport, to shut down point at the gate at the arrival airport. This is done by measuring fuel burn – which generates a directly attributable amount of CO_2 emissions. Fuel burn is relatively simple to measure because the consumption of fuel is measured by the difference in quantity between point A and point B. Each aircraft operator is then allocated to an EU member state where they generate the highest amount of emissions, with that state responsible for ensuring compliance with the EU-ETS system.

1.13 Under an airspace based system the fuel burn along the route from departure point to arrival point would need to be apportioned to the different FIRs or sovereign airspace that the aircraft has flown through.

1.14 Therefore, to measure these emissions it would be necessary to devise a system of measuring fuel burn throughout the route; or model the fuel burn using fuel burn models. At face value the former is more favourable because under a 'Cap & Trade' system it should be designed to favour those operators who are most fuel efficient, so the recording of these emissions needs to be as accurate as possible. Using modelled data runs the risk of smoothing out variances in performance between operators and skewing any incentives for improvement.

1.15 The CAA has undertaken an initial analysis of different approaches to measuring emissions in airspace.

CHAPTER 2

Options for applying emissions to airspace

2.1 The CAA consider there are three possible ways of designing an airspace based system for emissions. These are:

1. Using actual fuel burn data directly correlated to FIR or national airspace boundaries.
2. Using actual fuel burn data but modelled apportionment to airspace from either:
   a) filed flight plan data or,
   b) using actual route flown.
3. Using modelled fuel burn data and modelled airspace.

2.2 The CAA has also considered a two tier system of amalgamating the different options e.g a system where modelled data is used as the default reporting mechanism with the option for an aircraft operator to supply actual fuel burn data to improve accuracy of reporting.

2.3 In assessing the feasibility of each option we have considered four evaluation criteria:

- the likely efficacy of any system against meeting the objectives of a cap and trade system,
- the practicality of being able to implement a system,
- the administrative feasibility e.g of being able to use or adapt tools not designed for implementing an emissions system,
- and a qualitative assessment of likely cost of any system.

2.4 It is important to note that this assessment is based solely on applying an airspace option rather than the application of an alternative methodology of emissions capture e.g existing departing/arriving flights system. The CAA is in favour of using a market based measure as a tool to tackle aviation emissions and would advocate a system that provides the most comprehensive coverage of global emissions. It should be noted that an airspace-based system would be inferior in coverage than other alternatives, but is being considered here because of the support for this approach amongst the global aviation community.

2.5 We have considered the options for 3 broad types of aircraft operators and their associated aircraft[3]:

1. Large commercial operators. (e.g. those flying aircraft such as the Airbus families of A320, A330, A350, A380 and Boeing families of 737, 747, 757, 767, 777, 787).
2. Smaller commercial operators (e.g. flying aircraft such as Dash 8s, ATR 72s and the Embraer 145 or 195).
3. Private operators (e.g. flying small corporate jets).

Option 1: Using actual fuel burn data directly correlated to FIR or national airspace boundaries

2.6 This option considers measuring fuel burn using real time data and correlating it to the airspace that the emissions are generated in.

2.7 In order to calculate emissions in airspace the level of fuel burn at the given point in time as the aircraft passes from one airspace to another is required.

2.8 In order to record this level of information aircraft would need to incorporate appropriate technology such as Quick Access Recorders (QARs) which equip many of the major airlines. QARs record flight data for fleet monitoring purposes such as in-flight deterioration and trend analysis to enable airlines to assess operational performance. QARs do have the capability of recording information on thousands of parameters per second. These include engine fuel flow per second and the location of the flight. After each flight an operator would be able to download this data for further processing to enable it to be mapped to FIR boundaries.

2.9 Advanced equipment is most established in the newer and larger parts of the fleet. Therefore, using actual fuel burn does have proportionally increased challenges for smaller operators – including commercial domestic and regional operators. Without significant investment in technology, these operators would find it very difficult to produce actual fuel burn data directly correlated to different portions of airspace.

3 Although for some operators they will operate a mixture of aircraft with differing levels of technology.

2.10 This does provide some justification for exploring the feasibility of a two tier system whereby those who can report actual fuel burn do so and those that can't use a modelled approach. To be successful this relies upon:

1. An assumption that a modelled approach overstates the actual emissions levels - providing an incentive for operators to report 'actuals'.
2. The cost of reporting actual emissions is less than the cost of purchasing allowances for the additional emissions in a modelled rather than actual reported system.
3. That other economic factors in route choice e.g flying a longer route to avoid airspace with higher en-route charges, are not more significant than the incentive to reduce emissions for carbon reporting purposes.

2.11 Just because an aircraft has the technology in place to measure point in time fuel burn, there would still be a requirement to map across that point in time to a FIR or state boundary.

2.12 It's important to note that flight crews do monitor fuel burn as a flight progresses for safety reasons. However, to ask a crew to report fuel burn as they progress from FIR to FIR for administrative purposes, for an emissions trading system, would place a significant burden upon flight crews and would likely create a distraction for personnel whose principle objective is passenger and crew safety. The CAA would therefore regard such an approach as inappropriate and recommend that en-route monitoring is not considered.

2.13 Post flight processing would be a more practical approach. This would require a substantial amount of processing to be undertaken: either directly by an operator or by a central reporting entity such as Eurocontrol which would need to receive the raw data from the operator.

2.14 Central to this post flight mapping to boundaries would be the use of waypoints. Waypoints are used to describe routes and standard arrivals and departures at airports and are a means of describing a particular position on a route for flight planning (FPL) and Air Traffic Control (ATC) purposes. Therefore, they are linked to routes rather than state airspace but are in some cases used to denote the edge of a FIR boundary. This latter point has important implications as to whether FIR or state boundaries are chosen; with the latter harder to calculate because waypoints are rarely mapped to national boundaries. However, some form of demarcation would still be required whether utilising an FIR boundary or sovereign airspace.

2.15 The points are coded into international flight planning systems, state aeronautical information publications and flight management system databases on aircraft. They are used to programme aircraft to fly a particular route or used by air traffic controllers in passing instructions to the pilot, rather than giving a specific heading (ie the pilot, ATC, the aircraft system and ATC/flight planning systems all use the same routes and unique waypoints). Waypoints could be used by both aircraft with or without QARs, although it may be possible for QAR equipped aircraft to use latitude and longitude positional data. There would still be a need for each crossing point to be defined and a system of waypoints established for other non-QAR equipped aircraft. In designing or re-designing routes and airspace, an airspace designer will decide what and where waypoints are required and select a unique 5 letter name code (5LNC) to be associated with the waypoint. These will then be agreed as part of the route or airspace change through the State Regulator.

2.16 In order to use waypoints as a means for measuring emissions as part of an airspace based system, there would be a need to introduce more into the system. The process to add, amend or remove a waypoint is relatively straight forward, in some cases the changes can be agreed in a few days. However, to instigate a large number of changes simultaneously across a number of European States would be a major undertaking and require considerable co-ordination amongst member states. Essentially waypoints' function is navigational; so using them for emissions monitoring would require a fundamental change in their function.

Table 1: CAA initial assessment of using actual fuel burn data directly correlated to airspace boundaries

Evaluation Criteria	Aircraft Operator type	Score	Narrative
Efficacy	Large commercial	***	Uses actual fuel burn data at point in time so would give the most accurate emissions data correlated to airspace boundaries.
	Smaller commercial	***	
	Private	***	
Practicality	Large commercial	**	Would require post flight analysis to be undertaken by the operator (or data sent to a central reporting entity). This would be a substantial piece of processing required.
	Smaller commercial	*	Technology is not in place on many aircraft in this range.
	Private		Technology not in place on majority of aircraft in this range.
Administrative feasibility	Large commercial	*	Waypoints functionality is for navigational purposes – not for administering an emissions trading system. Burden of responsibility in reporting would fall more on the operator.
	Smaller commercial	*	
	Private	*	
Qualitative costs	Large commercial	**	Technology in place. Would require post flight processing which is a cost.
	Smaller commercial	*	Would require investment in technology in some aircraft - a considerable cost.
	Private		Would require investment in technology in some aircraft, and proportionally for passengers travelled very high costs.

Summary	- Provides the most accurate emissions data in relation to airspace, but on practical and cost grounds it would only be feasible for large commercial operators. - With prohibitive costs a two tier system may need to be put in place; with smaller operators operating a more modelled approach. This however could create competitive distortion, potentially penalising those who have invested in more modern technology. - An alternative approach could be developed whereby operators can choose to report under either a modelled system or using actual fuel burn data. However, there are risks to this approach if emissions reduction is not the primary economic incentive for operators when filing a route plan. - Central to all of these issues would be the need to allocate waypoints to airspace boundaries which would be a significant undertaking.

Option 2: Using actual fuel burn but modelled apportionment to airspace

2.17 This option looks at the issues in apportioning actual fuel burn data to the airspace that the emissions are generated in when a direct correlation cannot be made. This option requires a more modelled approach.

2a) Using Filed Flight Plans

2.18 A well established model based on airspace is the Eurocontrol route charges system which is managed by the Central Route Charges Office (CRCO). Route charges are levied on air traffic users for the provision of en-route and terminal air traffic control services provided by member states. The CRCO calculates and then re-distributes these route charges to member states. The charge is calculated using a formula based upon the aircraft weight, the distance flown and the unit charge levied by each member state. The distances flown in airspace are taken from filed flights plans that every operator has to submit prior to take-off. These flight plans are submitted to the Network Management Operations Centre (NMOC). This means that the CRCO has data on the filed distance flown in each FIR or Member State's territory.

2.19 A limitation to using route charging data for emissions calculations is the weight component of the route charge. This is calculated on the certified MTOW of each aircraft (as declared by the operator in an annual fleet declaration). It does not use the actual weight for each individual flight. So the fuel burn calculation would not be an actual figure, but a generic value based on the aircraft type. As an example, the route charge for a given type of aircraft flying a certain route will be the same whether the aircraft is empty with a minimum fuel load, or carrying a full complement of passengers and maximum fuel.

2.20 A model would therefore need to be developed that measures actual fuel burn from point A (departure) to point B (arrival) – which is far easier to measure – and then apportions these total emissions between the different distances travelled between FIRs. Assumptions would need to be made upon the differing fuel burn rates of the flight in order to generate a more accurate calculation as to where in the airspace emissions are occurring. For example, take-off requires higher fuel burn due to:

- Greater amounts of engine thrust required to initiate take-off. In addition to this aircraft often have to take-off in a stepped approach which results in higher fuel burn because the pilot has to increase throttle every time permission is granted to ascend further to the next flight level.
- The aircraft being at its heaviest at point of take-off - so requires higher energy intensity per kilometre travelled.
- Engines burn more fuel at lower altitudes due to the density of the air.

2.21 Once an aircraft reaches its cruising altitude engine power can be reduced to operate at a speed that is closest to optimal fuel efficiency; due to less drag on the airframe because of the lower air density at higher altitudes. For every kilometre travelled the aircraft reduces weight so as it descends for landing it’s at its lightest weight to date in the flight and so this phase would also see lower emissions than the initial take-off.

2.22 Operational procedures also vary between airports, for example using Continuous Climb Operations (CCO) or Continuous Descent Approach (CDA) reduces fuel burn. At the main airports in the UK these operations are being encouraged e.g Gatwick exceeds 90%[4] CDA operations. For accuracy purposes in an emissions trading system these assumptions would need to be factored in, although given that emissions have global effects regardless of the airspace in which they are emitted in is fairly irrelevant from a global perspective. However, this would have implications for States with domestic carbon targets for aviation.

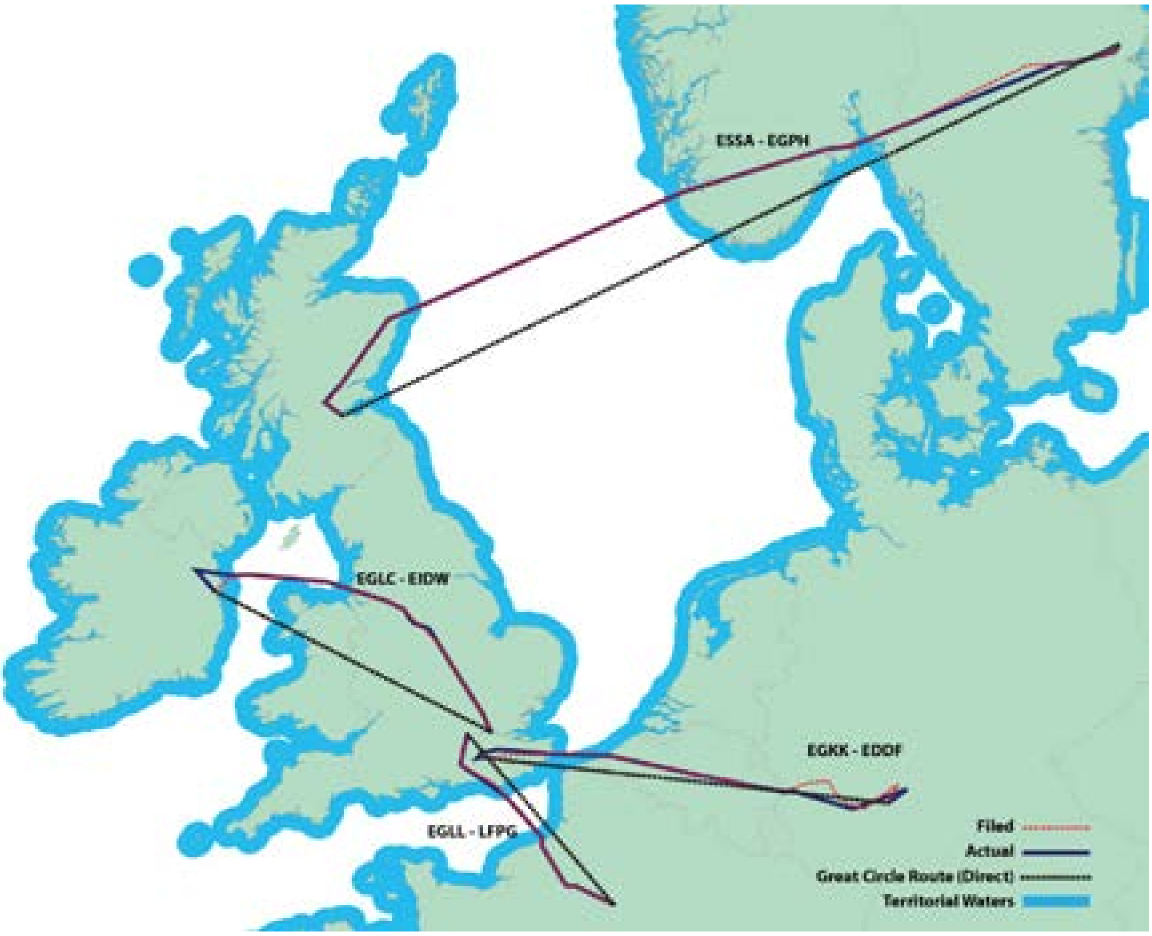
2.23 If this approach was to be adopted existing tools such as Eurocontrol's RSO distance tool - which breaks down the anticipated distance flown in each airspace for a route - could be used or developed to measure emissions.

2.24 For smaller emitters, the submission of fuel burn data after the flight would need to be completed manually (with conventional flight management tools such as Plogs) by pilots or retrieved from onboard systems by aircraft specialists on behalf of the airline. Alternatively, the existing approach that allows small operators to use a modelling/forecast approach to emissions may be a sensible alternative approach.

2.25 Another major drawback to using filed flight plans is that they are not based on the actual route flown. The actual route can vary both horizontally and vertically due to prevailing weather conditions and for managing route flows in busy airspaces to ensure the safe operation of aircraft. Tactical interventions by air traffic control such as stack holding can add significant distances to a flight and varies between routes.

2.26 The CAA sourced the filed flight plan and actual route flown on four random flights: London City (EGLC) to Dublin (EIDW), London Heathrow (EGLL) to Paris Charles De Gaulle (LFPG), Arlanda Stockholm (ESSA) to Edinburgh (EGPH) and London Gatwick (EGKK) to Frankfurt (EDDF) to show the variance of distances.

4 Gatwick Airport: Our Decade of Change 2011 Performance Report



2.27 It shows that for the Stockholm to Edinburgh flight there was a considerable increased distance on the actual route flown, and to a lesser extent on the London City to Dublin route. However, for London Heathrow to Paris and London Gatwick to Frankfurt the actual route flown was marginally shorter than the filed flight plan (see table 2)

Table 2: Route distance and % difference between the Great Circle Distance (direct), filed flight plan and actual route flown distances

Route	Total Distance (nm)	% Difference Actual Route Flown v FPL	% Difference Actual Route Flown v direct
EGLC - EIDW (Filed)	294.47	12.40	-
EGLC - EIDW (Actual)	330.99	-	27.82
EGLC - EIDW (Direct)	258.95	-	-
EGKK - EDDF (Filed)	387.96	1.15	-
EGKK - EDDF (Actual)	392.41	-	14.67
EGKK - EDDF (Direct)	342.21	-	-
EGLL - LFPG (Filed)	208.57	-0.25	-
EGLL - LFPG (Actual)	208.05	-	10.56
EGLL - LFPG (Direct)	188.17	-	-
ESSA - EGPH (Filed)	764.33	-0.25	-
ESSA - EGPH (Actual)	762.43	-	6.14
ESSA - EGPH (Direct)	718.32	-	-

Source: NATS

2.28 These routes also demonstrate that if Great Circle Distance (direct) is chosen as the modelled distance for emissions purposes it would underestimate emissions because the actual distances flown are considerably higher.

2.29 Risks of unforeseen circumstances in using filed flight plans also need to be flagged. Some operators could file misleading flight plans they never intend to fly - to reduce their emissions reporting leading to subsequent increased congestion and worsening of environmental impacts.

2.30 The above analysis has been conducted on only a small selection of flights. To give an indication of the assumptions used to estimate variance between actual, filed and Great Circle Distances, the CAA has researched a number of sources and references:

Table 3: Review of evidence of variances in flight distances

Source	Variance found	Commentary
Variety of carbon calculators	Typically 9%	Most carbon calculators use a 9% uplift factor over the Great Circle Distance
NATS and the Environment 2009	Specific to stackholding - up to 2% of emissions	NATS have identified that in the airspace that they control emissions associated with stackholding are 2%.
Eurocontrol Network Operations Report 2012	4.64% (based on filed flight plan)	The average route extension compared to the latest filed flight plan was 4.64% across Europe.
Flight Efficiency Studies in Europe and the United States: Kettenen, Hustache, Fuller, Howell, Bonn, and Knorr (2005)	10% (Europe); 6%-8% (USA) based on great circle distance	For European flights it found that inefficiencies were higher the shorter the flight due to a higher proportion of inefficiency occurring in the terminal rather than enroute environment.
ATM flight efficiency and its impact on the Environment (EEC/ENV/2003/001): Chesneau, Fuller and Hustache (2003)	9% on great circle distance	Based on a selection of intra European and domestic routes

Dependent on the Dark: Cargo and other Night Flights in European Airspace: Eurocontrol Trends in Air Traffic Volume 5	10% of flights -3% distance of filed flight plan. During deep night (24hr - 05hr) 25% of flights -2% and 10% of flights -6%	Some flights do fly shorter distances than their filed flight plans. This is particularly the case for cargo operators who fly night flights when the skies are less congested. However, fuel efficiency is often affected because fuel upload has to be based on the flight plan so excess fuel is often carried.
EU-ETS	Great Circle Distance + 95km	Under the existing EU-ETS system the calculation for assessing operators tonne kilometre outputs for use in allocating free allowances made an assumption of the great circle distance + 95km. This means that for the shorter the flight, the higher the assumed flight inefficiency. For example, from Edinburgh to London Heathrow this adds on 17.8% greater distance; but for London Heathrow to Athens just 3.3%.

2.31 So, it is fair to say that there is considerable variance between flight distances from the Great Circle Distance, filed flight plans and the actual route flown. This variance is particularly prevalent in UK airspace due to its congested nature. Even though an aircraft will file a flight plan from the departure aerodrome to its destination, almost as soon as an aircraft becomes airborne, ATC will start issuing vectors to provide optimum lateral route and profile information which serves to expedite movement through UK airspace and at the same time, de-conflict aircraft within the same sector. UK ATC operations are therefore very much tactical in nature.

2.32 In the en-route cruise where there is less need to de-conflict traffic and less climbing and descending, the stored flight plan in the aircraft's Flight Management System (FMS) is rarely executed as is. Aircraft frequently receive Direct Routings (DCTs), in order to expedite the flight through an area sector.

2.33 The evolution of future airspace design and operations may have an impact on the degree of variance. The plan is for the future UK airspace structure is to align with SESAR concepts and in particular, one based on trajectory operations. That implies a flight plan filing based on declared capabilities being matched to the desired route and then coordinated through System Wide Information Management (SWIM) to provide the optimum trajectory. Hence, we might envisage a more dynamic system of planning with up-to-date information available to determine the optimum profile and lateral path. The future in this context could be 2030 and between today's arrangements and this future model, there will be an evolution of airspace concepts and structure.

2.34 For terminal airspace the first step is the wider implementation of systemised use of SIDs, STARs and runway transitions utilising Performance-based Navigation (PBN) specifications for RNAV and RNP[5]. In the en-route there will still be a need to provide connectivity to/from the terminal airspace and an ATS Route Network (ARN). This will be in support of Free Route Airspace (FRA) in upper airspace, where the traffic density and complexity allows a more direct track to be flown subject to other traffic and airspace constraints. Examples today include Ireland upper airspace which has no defined routes, just entry and exit waypoints about which DCTs are defined on the day.

2.35 The mix of airspace structures makes the flight plan prediction of the actual route to be flown somewhat difficult. Numerous factors could influence the "actual" route flown as a much more flexible use of the upper airspace is adopted.

2.36 Within terminal airspace there should be less tactical manoeuvring than today as service providers seek to reduce route spacing and sequence traffic flows in such a way as to require intervention only when absolutely necessary.

2.37 Approach operations will remain largely unchanged from today, albeit with a greater reliance on RNAV and RNP procedures supplementing Precision landing systems such as ILS.

5 RNP specifications include onboard performance monitoring and alerting and provide greater integrity of aircraft position. RNP specifications will become the future basis for aircraft equipage and airspace developments.

2.38 It is therefore very difficult to ascertain an accurate allocation of emissions to the route using a modelled approach. An additional complexity - as mentioned in para 2.25 - is that by just having data for horizontal distance flown (even if it is the actual route) does not necessarily equate to a simple emissions per kilometre flown calculation because of the differing rates of fuel burn throughout a flight. An approach that correlates modelled apportionment of emissions to airspace, will not be truly representative of the emissions attributable to that State due to the underlying weaknesses in any modelling approach; and future airspace design and evolution will continue in this vein.

Table 4: Using actual fuel burn but modelled apportionment to airspace (using filed flights plans)

Evaluation Criteria	Aircraft Operator type	Score	Narrative
Efficacy	Large commercial	*	The likely deviation from filed flight plans would make the reporting of emissions very inaccurate and goes against the principles of a Cap & Trade system. It also makes accurate reporting of emissions at State level more difficult. Future airspace designs are likely to see continued dynamic routes flown, rather than adherence to the filed flight plan.
	Smaller commercial	*	
	Private	*	
Practicality	Large commercial	**	Would require a degree of modelling to be undertaken; either by the operator using a tool such as the Eurocontrol RSO distance tool; or centrally by a reporting entity.
	Smaller commercial	**	
	Private	**	
Administrative feasibility	Large commercial	**	Would require a sea change in using Eurocontrol data collected for charging purposes; to use it for emissions charges. Burden of responsibility would fall more on the central (or member) state than the operator. Given the quantity of flights across Europe a substantial model would need to be built. There would be no need for a separate small emitters system.
	Smaller commercial	**	
	Private	**	
Qualitative costs	Large commercial	**	Cost in developing model but not as prohibitive as costs involved in retrofitting or placing new technology on aircraft.
	Smaller commercial	**	
	Private	**	

Summary	- Practically this would be an attractive option because much of the data is already captured and collated. - It would potentially shift the burden of administration more towards the central or member state entity and political acceptance of using flight plan data for emissions monitoring purposes would be required. - The risks of unforeseen circumstances would also need to be understood if filed flight plans are used. - The central reporting entity would need to develop a modelling system to incorporate fuel burn with routes. - Having said all this, the option fails on efficacy with a degree of inaccuracy in the emissions data using filed flight plans because of the variances in actual routes flown and the differing rates of fuel burn throughout a flight.

2b) Using Actual routes flown

2.39 As mentioned in para 2.25 the actual route flown often varies from the optimal shortest route (Great Circle Distance) and the filed flight plan. This highlights the importance of using the actual route flown in any modelled system.

2.40 Eurocontrol's NMOC monitors flight plan compliance for flow and capacity monitoring purposes but this information is not currently shared with CRCO and so does not currently link with Eurocontrol charging data that would record when an aircraft enters a new airspace. Eurocontrol has never formally undertaken work to assess the feasibility of basing charges on the actual route flown, rather than last filed flight plan. The CRCO is currently undertaking a major redevelopment of their IT system which offers scope to explore this further; but the CAA is unaware of any functionality being built in to it at this stage. However, in theory a model could be developed to link these two data sources.

2.41 An alternative way of recording the actual route flown and the deviation from the filed flight plan would be to use technology on the aircraft. ADS-B technology records the entire trajectory of the flight and this is already publically available for the UK FIR at www.flightaware.com. However, although equipage of ADS-B is very high on commercial jet transport, some smaller commercial aircraft – particularly turboprops - are rarely ADS-B capable. The same applies to corporate jets. The CAA undertook a 24 hour 'snap shot' of flights in UK airspace[6] and found that for flights eligible under the current ETS (so excluding military and <5.7 tonnes) only 80% of aircraft were ADS-B capable, leaving 20% incapable of reporting positions via ADS-B. This includes UK operators such as Flybe, BA Cityflyer, BMI Regional and Eastern Airways as well as numerous smaller European commercial airlines. Example aircraft types were Embraer ERJ 145s to 195s, Dash-8s and some Boeing 737s.

2.42 If this ADS-B capability was correlated to total estimated emissions under the EU-ETS for 2012[7] (based on extra and intra EU flights), aircraft without ADS-B capability only accounted for approximately 4%[8] of these emissions. However, if this analysis was undertaken on intra EU flights only - as per Stop the Clock - these non ADS-B capable aircraft would account for a much higher proportion of total emissions. For example, emissions reported under 'Stop the Clock' by some long haul carriers could be less than 1%[9] of what they would have reported under the full EU-ETS system. So, taking a view that an airspace system would only capture intra EU emissions means that the 4% figure has to be treated with a degree of caution until the 2012 data is made publically available - but we would expect it to rise.

2.43 Globally, ADS-B capability is extremely variable with estimations of roughly 60% of all passenger aircraft equipped with ADS-B capability. However, it's as low as 30% in some states such as the USA.[10]

6 The data sample is all flights captured by the CAA ADS-B receiver in a 24 hour period (0800 on 2nd May to 0800 on the 3rd May 2013)

7 Operators with less than 10,000t of CO_2 are excluded

8 For operators that have a mixed fleet of ADS-B and non ADS-B technology an estimation was undertaken of the proportion of the fleet e.g 10% and directly correlated to the emissions e.g 10%. In reality these two percentages wouldn't necessarily be the same because of differences in aircraft size. However, the CAA did not have this next layer of data available for this analysis.

9 EU-ETS Support Facility

10 Source: Flight radar 24

2.44 In the EU under the SES Surveillance Performance Interoperability – Implementing Rule (SPI IR) there will be a requirement for all new aircraft to be ADS-B capable by 2015, and those manufactured before this retrofitted by 2017. However, there will be exemptions for some older aircraft that are impossible to retrofit or the costs are deemed disproportionate.

2.45 There would also still need to be a degree of modelling undertaken to factor in the differing rates of fuel burn during the different stages of a flight. Para 2.46 provides detail about the availability of fuel burn models.

Table 5 Using actual fuel burn but modelled apportionment to airspace (using actual route flown)

Evaluation Criteria	Aircraft Operator type	Score	Narrative
Efficacy	Large commercial	**	Will give more accurate correlation between actual fuel burn and actual route flown so more appropriate for a Cap & Trade system.
	Smaller commercial	**	
	Private	**	
Practicality	Large commercial	**	The technology is in place for reporting positions via ADS-B.
	Smaller commercial		The technology is not currently in place for reporting positions via ADS-B but regulation will mandate this for the majority of aircraft by 2017.
	Private		
Administrative feasibility	Large commercial	**	There would need to be a degree of data processing and modelling undertaken by a central entity. The current Eurocontrol route charging system would be a sensible model to develop further; but this would require substantial investment.
	Smaller commercial	**	
	Private	**	

Qualitative costs on operators	Large commercial	**	Technology already in place so no additional burden on larger commercial operators. Would be a cost to central reporting entity in developing a model.
	Smaller commercial	*	Would require investment in technology (although this will become mandated through regulation); or cost would be passed on to central reporting entity for processing flight plan compliance.
	Private	*	

Summary	-This is a more attractive option for monitoring emissions compared to option 2a because of the higher degree of accuracy in correlating emissions to airspace. -This correlation could be done by a central entity such as Eurocontrol analysing route plan compliance, or by utilising technology on an aircraft. - However, the proportion of the fleet with technology to report these positions is currently only 70%-80% in Europe although under the full EU-ETS system this would equate to approximately 96% of emissions. - A two tier system might need to be developed with the smaller aircraft using modelled data or all flights would need to be modelled using analysis of flight plan compliance. The former option could bring questions of competitive distortion, although in reality with ADS-B technology being mandated by 2017 this risk of distortion could decrease.

Option 3: Using modelled fuel burn and modelled airspace

2.46 If operators are not required to provide fuel burn from point A to point B (assuming that the technology is restricting apportioning it to airspace) the alternative would be to use modelled fuel burn to calculate emissions. Numerous models are already in existence, primarily for use in calculating emissions for carbon offsetting purposes at an individual passenger level. These models have to make assumptions around the weight of the aircraft, the actual route flown, the seating configuration of the aircraft (e.g economy, premium, first) and the quantity of freight on board to estimate emissions and do not tend to differentiate between operators; instead relying on averaging across similar type aircraft. Some also make assumptions and use conversions factors depending upon the type of flight (see table 6 below)

Table 6: CO_2 conversion factors for different types of flights

Type of flight	Conversion factor kg of CO_2 per passenger km
Domestic (463 km)	0.16313
Short haul (1,108 km)	0.09589
Long haul (6,482 km)	0.11037

Source: Defra/DECC GHG conversion factors

2.47 This table assumes that different types of distances flown have higher proportional emissions, with domestic being the least efficient flights and short haul the most efficient. This is due to the proportion of the Landing and Take Off (LTO) cycle within a flight where the fuel burn is at its greatest; and the fact that passenger (load) densities are less on long haul.

2.48 Being based on a number of assumptions these models are not appropriate for an emissions trading system that is designed to reward those operators who operate the most fuel efficient fleets. They are simply too broad and contain too many assumptions.

2.49 Eurocontrol currently operates and maintains an Advanced Emissions Model that is designed to forecast emissions from aircraft activity under different scenarios. It uses a range of data sources such as the ICAO Engine Exhaust Emissions Databank for calculating emissions during the LTO as well as their own Base of Aircraft Database (BADA) for emissions over 3,000 feet. Numerous other data sources are used to provide data for route distances, aircraft weight etc. The model has been verified alongside actual emissions data provided by airlines and has proved to achieve a relatively high degree of accuracy. The model can also be used by other users; so operators could utilise this if required.

2.50 The advantages of using a model based upon actual aircraft specifications would mean that those aircraft and engines that are best in class will yield the lowest emissions levels so will reward those that invest in these. However, it may not necessarily reward those who through their operational procedures such as using the most appropriate range aircraft on the route or when taxiing using fewer engines, reduce emissions during the flight.

2.51 Small operators who currently use the small emitters tool to model fuel burn and emissions could continue to do this – and then these emissions could be apportioned to airspace.

Table 7: Using modelled fuel burn and modelled airspace

Evaluation Criteria	Aircraft Operator type	Score	Narrative
Efficacy	Large commercial	*	Using both modelled fuel burn and modelled routes would increase the uncertainty and accuracy of such a system. This would bring in to question the efficacy of a Cap & Trade system.
	Smaller commercial	*	
	Private	*	
Practicality	Large commercial	***	Once the model is built there are few practical issues - especially for operators.
	Smaller commercial	***	
	Private	***	
Administrative feasibility	Large commercial	**	The central reporting entity would probably need to manage the model and data inputted in to it but it would feasible.
	Smaller commercial	**	
	Private	**	
Qualitative costs	Large commercial	**	Cost burden on operators relatively minor; with the reporting burden likely to be passed more to the State.
	Smaller commercial	**	
	Private	**	

Summary	- A modelling approach would require some investment in the model, but from an operators point of view this would be relatively practical with the burden of administration and reporting passed more on to the central reporting entity. - However, being based solely on modelling, the efficacy of a Cap & Trade system using this approach is questionable.

CHAPTER 3

Policy considerations

3.1 This chapter looks at policy considerations that are relevant across all of the options set out in chapter 2.

Overflights

3.2 Overflights are those flights where an aircraft transits the airspace but does not land. In European airspace the advent of ultra long-haul aircraft has led to the introduction of quite a few non-stop flights from the Middle East and Indian sub-continent to the USA and Canada. Other routes that traverse EU airspace without landing would include flights from Russia, Turkey and Ukraine to the US and Canada, and flights to some North African destinations from the Middle East, Turkey, Russia etc. There would also be other flights that 'clip' the edge of EU airspace, particularly at its eastern and south eastern extremes, although the emissions associated with these flights would be minimal.

3.3 The three largest Gulf State carriers account for a high proportion of overflights, mainly flying from the Gulf States to either North Africa[11] or the US. The table below shows that typically this ranges from 10 - 17% of these operators' total flights that operate in EU airspace, increasing in the summer months.

Table 8: Flights of three Gulf Carriers (March & June 2013)

Carrier	Number of flights into EU airspace		Number of overflights		% of total	
	12th Mar 13	11th Jun 13	12th Mar 13	11th Jun 13	12th Mar 13	11th Jun 13
Emirates	111	136	11	21	10%	15%
Etihad	39	49	6	8	15%	16%
QATAR	83	95	12	16	14%	17%

Source: CFMU system, 12th March 2013 & 11th June 2013

11 For our analysis we have only included overflights transiting through to North Atlantic airspace. A number of flights from the Middle East to North Africa do enter Cypriot airspace for a short period but these have been excluded because the emissions associated with these flights would be negligible.

3.4 The NMOC system also shows that on March 12th that of the 864 flight plans filed[12] for flights entering North Atlantic airspace, 47 (5.4%) would be overflying the EU without landing. On the 11th June there were 1,044 flight plans for flights entering North Atlantic airspace, of which 77 (7.4%) would be overflying without landing.

3.5 So flights that overfly the EU are not that uncommon but nevertheless represent a very small percentage of total flights. However, importantly the emissions of each flight may be quite significant because of the long haul nature of the flight.

3.6 The CAA can see no operational or methodological reason why overflights could not be incorporated in to an airspace based system in all three options identified. The technical difficulty would lie with enforcement if an operator refuses to report over flight data or surrender allowances. However, the current en route charging system recovers over 99% of charges. For the minority who fail to comply enforcement measures can be taken when they land in a European airport. For those solely overflying the EU and never landing in Europe the number is very low.

3.7 Therefore, there are no practical issues as to why overflights should not be included in an airspace based system.

National versus FIR airspace

3.8 Whichever airspace option is chosen, the amount of emissions captured and reported would vary depending upon whether national airspace or FIR airspace boundaries are chosen for reporting purposes.

3.9 This is demonstrated by analysis of our earlier four selected flights (see table 9):

12 Eligible under the existing ETS system, so excluding military flights

Table 9: Proportion of flight distance in National airspace (territorial waters)

Route	Total Distance (nm)	UK & 12nm Territorial Waters	Norway & 12nm Territorial Waters	Sweden & 12nm Territorial Waters	Ireland & 12nm Territorial Waters	France & 12nm Territorial Waters	Belgium & 12nm Territorial Waters	Germany & 12nm Territorial Waters	Outside 12nm Territorial Waters	% Outside Territorial Boundary
EGLC - EIDW (Filed)	294.47	186.59	0	0	23.02	0	0	0	84.86	28.82
EGLC - EIDW (Actual)	330.99	188.53	0	0	57.61	0	0	0	84.86	25.64
EGLC - EIDW (Direct)	258.95	204.82	0	0	20.8	0	0	0	33.33	12.87
EGKK - EDDF (Filed)	387.96	72.22	0	0	0	31.16	151.92	132.66	0	0
EGKK - EDDF (Actual)	392.41	80.6	0	0	0	31.15	151.92	128.73	0	0
EGKK - EDDF (Direct)	342.21	66.55	0	0	0	41.04	145.83	88.78	0	0
EGLL - LFPG (Filed)	208.57	74.31	0	0	0	99.52	0	0	34.74	16.66
EGLL - LFPG (Actual)	208.05	73.79	0	0	0	99.52	0	0	34.74	16.70
EGLL - LFPG (Direct)	188.17	62.44	0	0	0	90.43	0	0	35.3	18.76
ESSA - EGPH (Filed)	764.33	138.05	211.93	194.26	0	0	0	0	220.08	28.79
ESSA - EGPH (Actual)	762.43	137.87	211.93	192.54	0	0	0	0	220.08	28.87
ESSA - EGPH (Direct)	718.32	43.96	157.08	224.36	0	0	0	0	292.91	40.78

Source: NATS

3.10 This analysis highlights that for the majority of flights from the UK there would be a degree of emissions 'loss' if administered solely on national airspace. The route from London to Paris would see no loss but this is due to it crossing the narrow English channel where UK waters join French. Flights to Scandinavia or North East Europe would see emissions loss; as would those traversing towards South West Europe to destinations in Spain and Portugal.

3.11 The analysis also highlights again the variance if modelled rather than actual emissions data is used. For example, on the Stockholm to Edinburgh route the emissions loss under a national airspace system would be around 12% higher if Great Circle Route was used instead of 'actuals'.

Reporting

3.12 The current EU–ETS is managed by allocating an operator to the member state where that operator has the greatest estimated emissions. In reality this is closely correlated to the state with the largest number of departures and landings. It is then up to the member state to administer that operator and if necessary take enforcement action upon operators who fail to comply.

3.13 If the system is based upon actual fuel emissions being submitted by the operator it would make logical sense to continue with the existing approach where this data is submitted to member states. This would provide continuity to the system.

3.14 In a modelled system based on comparing flight plans with NMOC data or with data submitted by operators, the role for member states in administration seems less obvious and could favour central management of the system. However, this would be a large change to the existing system so a hybrid version may need to be explored with a combination of member state and central state administration.

3.15 Under the existing EU- ETS system, operators have to have their emissions data verified which is an essential part of the system to ensure accurate reporting. Any new airspace based system would need to have verification factored in and the degree of difficulty for verifiers would have to be part of the system design.

Emissions coverage

3.16 Moving to an airspace system will see differences in the level of emissions captured and reported. Work by the Manchester Metropolitan University concluded that on an arriving and departing flights basis a national airspace system would only see 22% of global emissions captured (55% if overflights are included). However, the CAA is not aware of any analysis that has been done on an airspace option so has undertaken some initial analysis based on time spent in European airspace.

3.17 As para 2.42 stated, under 'Stop the Clock' some long haul operators may only have to report less than 1% of the emissions that they would have done under the full EU-ETS. However, for an intra EU-ETS airspace system (which includes overflights) this figure would be significantly higher.

Table 10: Time spent in EU airspace for a selection of flights arriving or departing outside of EU airspace

Operator	Type of flight	Total Estimated Flight Times[13] (minutes)	Estimated flight time in European airspace (minutes)	% in EU airspace
Singapore Airlines	Arriving in EU	8,363	1,499	17.9
	Including overflights	8,363	1,690	20.2
South African	Arriving in EU	1,313	250	19.0%
	Including overflights	1,313	250	19.0%
Etihad	Arriving in EU	6,683	2,553	38.2%
	Including overflights	6,683	3,288	49.2%
China Eastern	Arriving in EU	2,078	378	18.2%
	Including overflights	2,078	378	18.2%

Source: CFMU system, 00:01 - 12:00 19th June 2013

13 Total flight times for those flights captured by the existing EU ETS (pre Stop the Clock). This is why this figure does not increase when overflights are taken into account, as overflights are not captured by existing EU ETS.

3.18 Although flight time doesn’t necessarily equate to emissions due to the variances in fuel burn in the landing and take-off cycle and once at cruise altitude, it does provide an alternative illustrative picture of emissions capture under an airspace based system.

3.19 The table shows that the longer the flight time, the greater the proportion of emissions lost under an EU-ETS airspace system. It also shows the additional emissions that could be captured if overflights are included - emissions that are currently not captured under the existing EU-ETS (pre Stop the Clock).

Small operators

3.20 The analysis has identified that small operators are likely to be proportionally more affected by any system that uses actual rather than modelled data. Additionally an airspace based system could impact commercial operators who use older or less sophisticated technology. There could be scope for considering if a smaller operators system could be incorporated to include smaller commercial operators, although risks of competitive distortion would need to be carefully considered.

3.21 If a purely modelled approach is taken by all, then there would in theory not need to be a separate small emitters system. Careful consideration would be required of a system that gave operators the choice of reporting emissions using modelled data or actual data. There could be differing incentives depending upon the size and nature of the operator and a more detailed analysis of risks such as competitive distortion would be required.

Summary of different options

Airspace option	Strong scores	Weak scores
1. Using actual fuel burn data directly correlated to actual airspace boundaries	Efficacy (for all operators)	Practicality (smaller commercial and private) Administrative feasibility Qualitative costs (smaller commercial and private)
2a. Using actual fuel burn but modelled apportionment to airspace from filed flight plans	Practicality Administrative feasibility Qualitative costs	Efficacy
2b. Using actual fuel burn but modelled apportionment to airspace from actual route flown	Efficacy Administrative feasibility	Practicality (smaller commercial and private)
3. Using modelled fuel burn and modelled airspace	Practicality Administrative feasibility Qualitative costs	Efficacy

Summary of policy considerations

Policy Consideration	Summary
Overflights	There are no practical considerations why overflights should not be considered in an airspace based scheme.
National versus FIR airspace	There would be very few flights departing or arriving from UK national airspace that would not see an 'emissions loss' if national rather than FIR airspace boundaries are used to capture emissions.
Reporting	Reporting of emissions may be more appropriate through a central reporting entity - especially if a more modelled approach is chosen. The importance of designing a system that can have the data verified should not be understated.
Emissions Coverage	The longer the flight time, the greater the proportion of emissions lost under an EU-ETS airspace system.
Smaller Operators	Under a scheme that uses actual fuel burn data smaller operators are proportionally more affected.