Manchester: A Certain Future, *CO_2 Monitoring Group*

Manchester International Airport

Estimate of Aviation Emissions

2014-2015 Inventory

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All errors remain my own. Any positions expressed are not necessarily representative of the CO_2 Monitoring Group.

Contents

Executive Summary

- This document provides an **estimation** of **CO_2 emissions** associated with flights **departing** from **Manchester International Airport** in the years **2014 and 2015.**

- Estimated CO_2 emissions for whole flight journeys departing from Manchester International Airport in **2014** were **2,972,431.62 tonnes CO_2.**

- Estimated CO2 emissions for whole flight journeys departing from Manchester International Airport in **2015** were **3,032,528.52 tonnes CO2.**

- Within the confines of this methodology, emissions are estimated to have **risen by 2.02%,** or **60,096.90 tonnes CO_2**, between 2014 and 2015. **Future growth has the potential to negate emissions savings made elsewhere.**

- Aviation is the second most-polluting mode of transport after the diesel car. However, **the growth of aviation makes it of primary concern,** with future aviation growth threatening to make other decarbonisation interventions meaningless. Moreover, **the complex mix of other aviation emissions (including NOx, SOx, H_2O, CO, HC) - and their associated warming potential - compounds the CO_2 emissions reported here.**

- **Flights destined for Europe** (including domestic emissions) comprise **the majority of emissions (60% in 2015).** These are the **journeys that are most easily replaceable by other modes of transport** and, as such, offer a key area of intervention.

- The greatest emissions per passenger, per journey can be attributed to those flying to North America and Asia. However, whilst North America-bound flights retained the highest number of passengers of the two, **emissions from flights bound for Asian destinations overtook those from North America-bound flights in 2015**. This is attributable to the distance - and associated fuel demands - of some popular Asian destinations.

- Moreover, whilst overall emissions of flights departing **for European, North American and African destinations have fallen** slightly, **emissions arising from journeys to Asia have risen 22% 2014-2015, it is this increase that is accountable for the observed rise in CO_2 emissions.** This may partly be due to the introduction of new direct flights to Asian destinations, where previously connecting flights or other airports would have borne some of these additional emissions. Nonetheless, there has been a 17% increase in passengers to the Asian continent, travelling from Manchester International Airport.

- The methodology of this document, and associated spreadsheets, is based upon and furthers previous work conducted by Dan Walker to **make whole-flight emissions easily reportable on an annual basis**.

- It is important, however, to note that there are **assumptions and blind-spots within this model**, the scope of which is outlined in Figure 1.

Scope of Accounting

Emissions Source	Included in the inventory?
All domestic passenger flights departing MIA	✓
All international passenger flights departing MIA	✓
Landing/Take Off (LTO) phase of passenger aircraft	✓
Climb/Cruise/Descent phase of departing passenger aircraft	✓
Connecting flights	✗
Domestic freighter aircraft departing MIA	✗
International freighter aircraft departing MIA	✗
General aviation (non-commercial flights) in Greater Manchester airspace	✗
Surface access, i.e. passenger and freight journeys to and from MIA	✗
Non-aircraft airport sources, e.g. terminal lighting and airfield vehicles	✗
International flights arriving at MIA	✗
Domestic flights arriving at MIA	✗

Table 1 – The scope of the inventory, adapted from Department of Transport (2017, p. 43)

Introduction

On a planetary scale, and with the exception of the diesel motor car, international aviation is the mode of transport causing the greatest amount of CO_2 emissions (Chapman, 2007). However, the projected growth of air transport is a major concern, holding the potential to make other decarbonisation efforts meaningless (Anable & Boardman, 2005). Moreover, the complex mix of other emissions released from aircraft directly in to the troposphere and lower stratosphere means that the overall radiative forcing of aviation is around 2-4 times greater than that of CO_2 alone (Chapman, 2007). As such, whilst aviation contributes to around 2% to 3% of total anthropogenic CO_2 emissions, aviation emissions more broadly considered may contribute to around 5% of radiative forcing (Owen, Lee, & Lim, 2010). Technological improvement alone cannot address this problematic expansion of aviation (Chapman, 2007; Owen et al., 2010). Influencing behavioural practices such as limiting heavy luggage, reducing the weight of facilities on the flight and reducing individuals' inclination to fly are therefore central to reducing aviation emissions (Wood, Bows, & Anderson, 2010). It is integral that both producers and consumers play a role in these efforts (Randles & Bows, 2009). Between 2011 and 2016, Manchester International Airport (MIA) saw the second largest increase in passengers (+7m) within the UK (Department of Transportation, 2017). In 2015 MIA was host to 23 million passengers, forecast to more than double to 56 million per annum by 2050 and, as such, is a critical space of intervention (Department of Transportation, 2017).

The inclusion of aviation within sub-national inventories is useful in developing a baseline for mitigation strategies (Wood, Bows, & Anderson, 2010). Moreover, these inventories also allow the comparison of aviation emissions with other emissions sources (Wood, Bows, & Anderson, 2010). However, as an international mode of transport, operating within and beyond geopolitical boundaries, allocating shares of transboundary aviation emissions to a given national and sub-national entity is invariably a contentious practice. As such, there is no one 'correct', or standardised, way to apportion responsibility for these emissions (Wood, 2011).

This report, therefore, explicitly recognises that conducting aviation emission accounts - and carbon accounts more generally - requires value-based decisions on behalf of the accountant. Mainstream accounting often (implicitly or explicitly) presents accounts as an all-encompassing 'monologic' truth (Brown, 2009). More often than not, carbon-emitting practices that are more difficult to assign territorial responsibility for – such as transboundary transport or consumption - are simply left unaccounted for. In response, this report makes one such inventory, but in doing so recognises the heterogeneity of ways in which aviation emissions might be counted and the different perspectives of responsibility that underpin them. This is what might be termed as a 'dialogic' accounting approach, receptive to "a plural society … that is 'multi-voiced' and attuned to a diversity of stakeholders' values and interests (Brown, 2009, p. 317). To this end, a number (but in no way definitive selection) of perspectives for the City of Manchester's aviation emissions footprint are presented, with assumptions and blind spots highlighted throughout. The following section outlines the emissions inventory for 2015, the revised emissions inventory for 2014 and changes between the two inventory years. Subsequently, recommendations are made. Finally, the methodology is outlined, both to provide an outline of the scope of the inventory and to guide future accounts.

Results and Analysis

2015

Total Departing Passengers	23,092,341
Total International Emissions, 2015 (t CO2)	2,949,923.20
Total Domestic Emissions, 2015 (t CO2)	82,605.32
50% Int / 100% Domestic Emissions for MIA, 2015 (t CO2)	**1,557,566.92**
100% Int & Domestic Emissions for MIA, 2015 (t CO2)	**3,032,528.52**

Table 2 – Total MIA Emissions, 2015

Destination	Overall Emissions	% Emissions	Passengers	% Passengers	Average Emissions Per Passenger, Per Journey (kg CO_2)
Europe (Exc. Domestic)	1,738,081.07	57%	15,544,347	67%	111.81
Africa	136,416.78	4%	756,524	3%	180.32
Asia	591,150.37	19%	2,150,866	9%	274.84
North America	484,274.98	16%	2,259,385	10%	214.33
Domestic	82,605.32	3%	2,381,219	10%	34.69

Table 3 – Geographic Spread of MIA Emissions and Passengers, 2015

Emissions for the whole duration of flights leaving Manchester International Airport in 2015 were around 3 million tonnes CO_2. This figure is given some veracity by the 2017 UK Aviation Forecast which adopts the same scope of accounting, though does not account annually. For departing commercial passenger flights in 2016, they estimate that 3.2 million tonnes of CO_2 were emitted (Department of Transportation, 2017, p. 145). The estimates produced in this report are therefore backed up by the Government's own accounts.

The previous 2014 analysis accounted a 50% responsibility of internationally bound flight emissions. This figure is once again presented above, however the main figure provided now takes a 100% share of these emissions, in line with the Department of Transportation account.

Flights bound for European destinations are the greatest source of emissions (see Figure 1, overleaf), where (including domestic emissions) they account for 60% of the overall carbon footprint of flights departing MIA in 2015. Moreover, over three quarters of all passengers (77%) are bound for European destinations (Figure 2). These are also the most feasible journeys to replace with other, lower carbon, modes of transport and so offer a crucial opportunity for intervention.

Long-haul destinations are unsurprisingly the greatest source of CO_2 emissions per person, per journey, with Asian destinations on average slightly ahead of North American destinations (Figure 3). This is due to the added distance involved with some Asian destinations such as Hong Kong or Thailand. Correspondingly, despite having slightly less passengers overall, the average footprint for Asia-bound journeys was higher than North American counterparts in 2015.

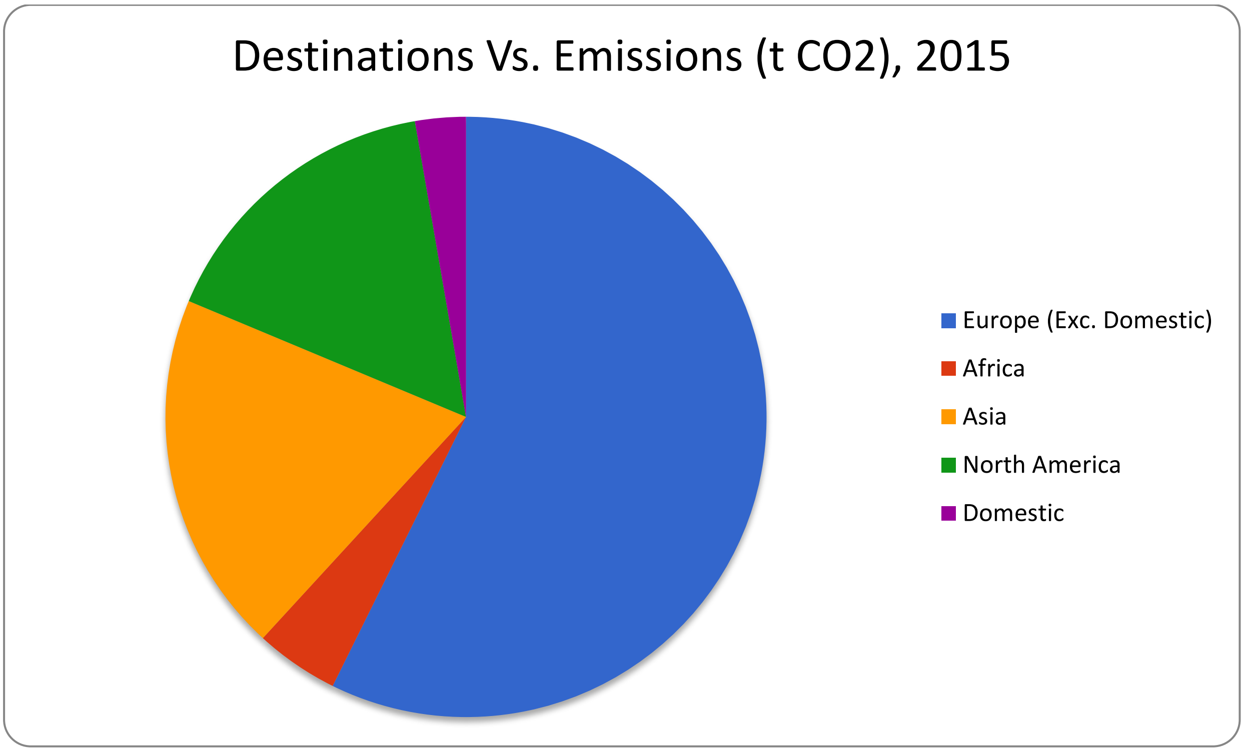

Figure 2 – Geographic Spread of Emissions, 2015

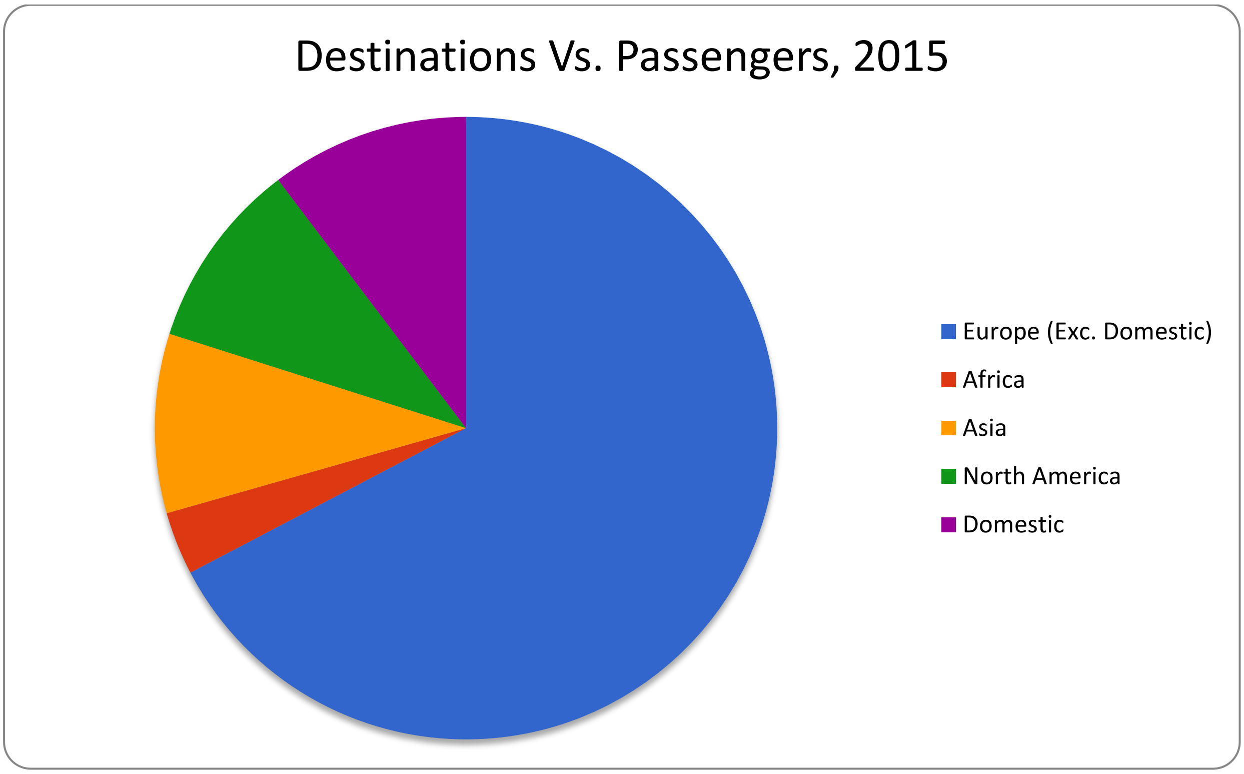

Figure 2 – Spread of Passenger Destinations, 2015

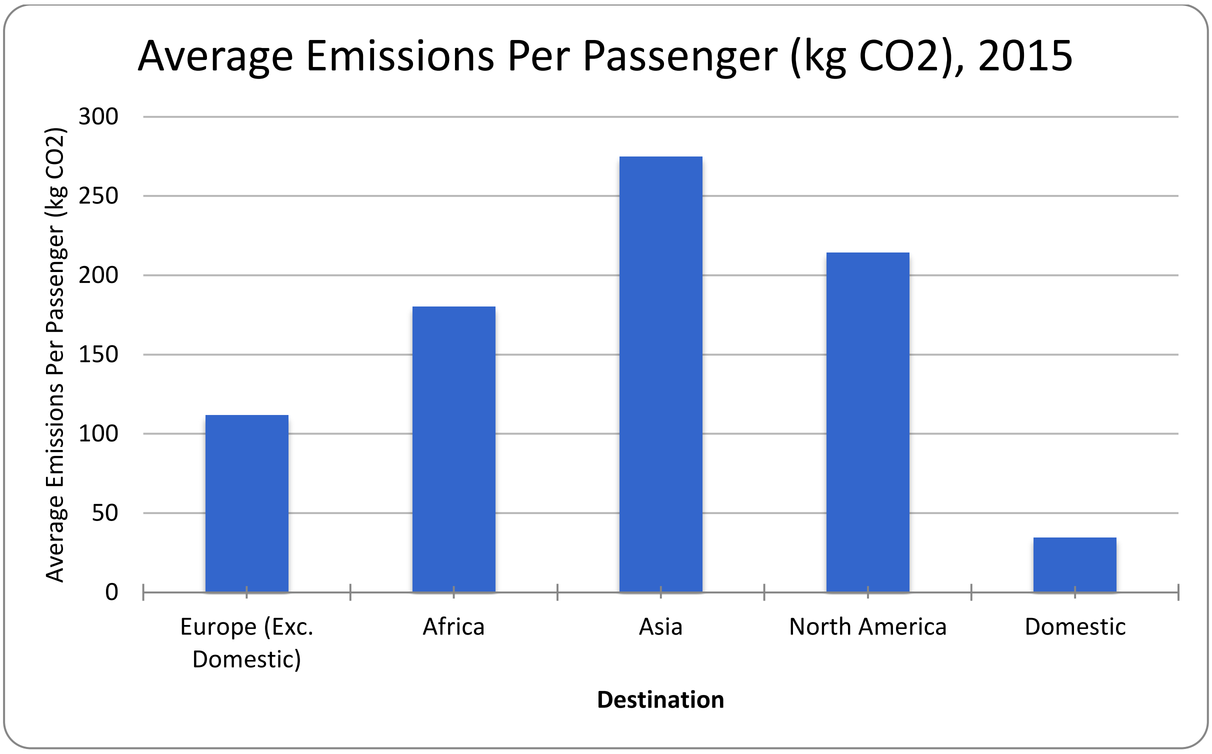

Figure 3 – Average Emissions per Passenger, per Destination, 2015

2014

Total Departing Passengers	
Total International Emissions, 2014 (t CO2)	2,887,082.44
Total Domestic Emissions, 2014 (t CO2)	85,349.18
50% Int / 100% Domestic Emissions for MIA (t CO2)	**1,528,890.40**
100% Int & Domestic Emissions for MIA, 2014 (t CO2)	**2,972,431.62**

Table 4 – Total MIA Emissions, 2014

Destination	Overall Emissions	% Emissions	Passengers	% Passengers	Average Emissions Per Passenger, Per Journey (kg CO_2)
Europe (Exc. Domestic)	1,742,077.12	58.61%	14,661,738	67%	118.82
Africa	153,732.49	5.17%	865,813	4%	177.56
Asia	483,191.21	16.26%	1,840,611	8%	262.52
North America	508,081.62	17.09%	2,106,311	10%	241.22
Domestic	85,349.18	2.87%	2,468,346	11%	34.58

Table 5 – Geographic Spread of MIA Emissions and Passengers, 2014

To allow for an easier updating of the inventory, the EMEP/EEA flight emissions calculator was integrated in to the 2015 methodology (see 'Methodology' section). However, owing to this change the 2015 inventory and the 2014 inventory were not directly comparable due to slight divergences in the calculation of fuel burn. As such, it was necessary to revisit the 2014 figures to allow for comparison. Table 4 lists these revised figures. Moreover, further diverging from the previous inventory that reported a 50% 'share' of international emissions, Table 4 also provides a figure for a 100% share of emissions from all departing journeys.

Table 5 provides a geographic breakdown of the 2014 aviation footprint.

Annual Change

2014 vs. 2015, Percentage Annual Emissions Change (50% International / 100% Domestic perspective)	101.88%
2014 vs. 2015, Annual Emissions Change (+ t CO2) (50% International / 100% Domestic perspective)	28,676.52
2014 vs. 2015, Percentage Annual Emissions Change (100% perspective)	**102.02%**
2014 vs. 2015, Annual Emissions Change (+ t CO2) (100% perspective)	**60,096.90**

Table 6 –Total Annual Change

From the 100% responsibility perspective, emissions from departing flights are estimated to have risen by 2.02%, or 60,096.90 tonnes CO_2, between 2014 and 2015 (Table 6). 2014 to 2015 also saw a 5% increase in passengers departing from MIA (Table 7).

The greatest emissions per passenger, per journey can be attributed to those flying to North America and Asia. However, whilst North America-bound flights retained the highest number of passengers of the two, emissions from flights bound for Asian destinations overtook those from North America-bound flights in 2015.

Moreover, overall emissions from journeys bound for European, North American and African destinations have fallen slightly, but emissions arising from journeys to Asia have risen 22% 2014-2015, it is this increase that is accountable for the observed rise in CO_2 emissions**.** This may partly be due to the introduction of new direct flights to Asian destinations made available in 2015, where previously connecting flights or other airports would have borne some of these additional emissions under this scope of accounting. Nonetheless, MIA has seen a 17% increase in passengers to the Asian continent in 2015 from 2014.

The other notable change has been the fall in emissions from flights bound for Africa, accounting for a difference of -17,315.71 tonnes of CO2, and a 13% decrease in passengers (see Table 7).

Destination Region	2015 Emissions (t CO2)	2014 Emissions (t CO2)	Emissions Change (t CO2)	CO2 Emissions Percentage Change	2015 Spread of Emissions	2014 Spread of Emissions	2015 Passengers	2014 Passengers	% Change in Passengers	2015 Spread of Passengers	2014 Spread of Passengers
Europe (Exc. Domestic)	1,738,081.07	1,742,077.12	-3,996.05	0%	57%	59%	15,544,347	14,661,738	6%	67%	67%
Africa	136,416.78	153,732.49	-17,315.71	-11%	4%	5%	756,524	865,813	-13%	3%	4%
Asia	591,150.37	483,191.21	107,959.16	22%	19%	16%	2,150,866	1,840,611	17%	9%	8%
North America	484,274.98	508,081.62	-23,806.64	-5%	16%	17%	2,259,385	2,106,311	7%	10%	10%
Domestic	82,605.32	85,349.18	-2,743.86	-3%	3%	3%	2,381,219	2,468,346	-4%	10%	11%
Totals	3,032,528.52	2,972,431.62	60,096.90				23,092,341	21,942,819	5%		

Table 7 – Geographic Breakdown, 2014, 2015

Recommendations

The City of Manchester has a responsibility to reduce its carbon emissions and those associated with aviation are key. The projected growth of aviation, the lack of a technological 'fix' and the global warming potential of all aviation emissions make it a vital area for intervention (Anable & Boardman, 2005).

Manchester International Airport is not the responsibility of the City of Manchester alone. In fact, there is a diversity of perspectives as to what its responsibility for MIA emissions should be – and no one perspective is correct. Table 8 outlines a few of these.

Percentage Responsibility	Description	Carbon Emissions (t CO2)
19%	According to the percentage of City of Manchester residents out of the whole Greater Manchester population	576,180.42
35.50%	According to the percentage of the airport that the City of Manchester owns	1,076,547.62
100%	According to the geographic location of the airport in the City of Manchester	3,032,528.52

Table 8 – City of Manchester, Perspectives of Responsibility for MIA Emissions

Nonetheless, and on the basis of this analysis, there are clear areas for intervention.

- Aviation emissions across the board need to be reduced, such that other decarbonisation work is not conducted in vain and, as such, **aviation should form a cornerstone of policy and in particular the work of *Manchester: A Certain Future*.**

- The UK Aviation Forecast predicts that MIA passengers will more than double to 56 million per annum by 2050 (against 23 million per annum in 2015) (Department of Transportation, 2017). Even with some technological advances**, this growth has the potential to negate the savings made by direct emission reductions and as such, the reconcilability of this level of MIA growth with the city's climate change strategy must be questioned.**

- Short-haul journeys within Europe are the source of the majority of aviation emissions. **Alternative means of transport must be advocated – and perhaps incentivised - for European journeys.**
    - Budget Domestic and European flights and the convenience of the short travel time are likely a major factor in why these are so prevalent**. The relative price of rail and ferry journeys** and the social appetite for **'slow travel'** are, therefore, key levers.

- **Long-haul journeys** produce the most emissions per journey and, as such, should be the journeys that citizens decide to make **most cautiously.**

- **Carbon literacy** has a crucial role to play in conveying the importance of reducing flying and the figures presented in this report might go some way in terms of making this ‘visible’.

- Whilst this work provides an insight in to the operations of MIA, **further work would be valuable in understanding the travel (including aviation) habits of Manchester resident**s. Moreover, similar aviation **analyses of nearby airports** would also be beneficial in understanding the ‘full picture’ of travel flows.

- The Global Protocol for Community-Scale GHG Emission Inventories (GPC) analysis is **important to consider this aviation footprint in relation to other CO_2 intensive practices** in the City of Manchester.

Methodology

This model estimates CO_2 emissions arising from both domestic and international passenger flights that depart Manchester International Airport (MIA) for a given year. The model was developed by Dan Walker for the 2014 inventory which estimated that MIA was responsible for a total of 1.7 Mt of CO_2. However, the 2015 inventory introduced a minor alteration to the methodology, in that an EMEP/EEA tool is now used to calculate fuel burn in order for the inventory to be easily updatable. This tool uses a slightly different approach and, as such, required the 2014 figure to be revisited in order to be comparable with 2015 and future inventories. This caveat aside, the methodology remains entirely the same as the previous approach. This section outlines the workings of the model, the scope of its accounting and the sources of data, such that the inventory might be updated in future years.

It is important to stress that the model provides an approximation of CO_2 emissions. The overall amount of CO_2 emissions corresponds to the level of fuel consumed by these aircraft. The factors which affect the energy required for a flight (and hence fuel consumption) include: aerodynamics, aircraft weight, flight length and altitude, atmospheric conditions and the time spent at each stage of flight operation (Wood, Bows, & Anderson, 2010). This model cannot reconstruct these exact circumstances for every flight; instead it draws upon the geographical location of destination airports and passenger data to estimate CO_2 emissions. Table 1 (page 3) explains what emissions the model represents whilst Figure 4 (overleaf) expands on how the model functions.

Overview of Model Working

1

- **User Input**
- Domestic and International Flight Destinations for the given year
- Passenger Data for the given year
- *Aircraft types (optional, but improves data quality if updated).*

2

- **ICAO Code Assignment**
- The model checks the user inputted list of flight destinations (Sheets 'Mia Int flights' and 'MIA dom flights') against a list of airport locations and codes (Sheet 'Airport Codes and Locations') to assign an ICAO code.
- If this cannot be assigned the user must input it manually.

3

- **Calculation of Great Circle Distance**
- For both international and domestic flights (Sheets 'Calcs MIA Int dists' and 'Cacls MIA dom dists') the model calculates the great circle distance (the shortest distance between two points on the surface of a sphere) between MIA and each destination. It does this by refering to the list of airport locations and codes (Sheet 'Airport Codes and Locations') and adding 95km in accordance to Decision 2009/339/EC. of the Commission of the European Community. This is then converted in to nautical miles.

4

- **Estimation of the number of flights per annum, per journey**
- Every journey is categorised in to short (<1500 nm), mid (1500-4000 nm) or long (>3500 nm) range.
- Operational aircraft at MIA are categorised in to these range categories and the average number of passenger seats is taken.
- The number of passengers for each journey is divided by the average number of passengers for an aircraft operating within the respective range.

5

- **Best Aircraft Match**
- For each journey range, the aircraft that most closely matches the average number of passengers is selected. As such, three 'represenative' aircrafts are selected for short-, mid- and long-range flights.

6

- **Average fuel useage using best aircraft match**
- This component requires manual data entry. The overall distance (nm + 95) is inputted in to the '1.A.3.a Aviation - Annex 5 EMEP/EEA Master emissions calculator 2016' . The tool then generates an approximation of jet fuel burn in kg.

7

- **Approximation of CO_2 emissions**
- The fuel burn is multiplied by 3.15 - the emissions factor which denotes that for every 1 kg of jet fuel burned, 3.15kg of CO_2 is produced (ICAO, 2009). This produces the average emissions per flight.
- These emissions per flight are multiplied by the number of flights completing this journey per annum, to give the overall annual emissions from this route.
- The sum of these emissions across all journeys is taken to generate an overall annual figure for emissions associated with departing flights from MIA.

Figure 4- A brief overview of how the model calculates an approximation of annual CO2 emissions

Data Sources

Data is sourced from the Civil Aviation Authority (CAA) website[1]. The CAA provide airport data on a monthly basis, but also provide yearly datasets and it is these that should be drawn upon for the inventory. The CAA's reports are published as a series of tables made available in Microsoft Excel and PDF formats.

The following tables are required for the model, and should be collected in the 'MIA data tables' sheet (of which a blank version has been made available):

Table Name	Notes
Table_10_2_Domestic_Terminal_Pax_Traffic_20xx	Domestic Terminal Passenger Traffic
Table_08_Air_Passengers_by_Type_and_Nat_of_Operator_20xx	Air Passengers by Type and Nationality of Operator
Table_09_Terminal_and_Transit_Pax_20xx	Terminal and Transit Passengers
Table_03_1_Aircraft_Movements_20xx	Aircraft Movements
Table_10_1_EU_and_Other_Intl_Terminal_Pax_Traffic_20xx	EU and Other International Terminal Passenger Traffic
Table_12_1_Intl_Air_Pax_Route_Analysis_20xx	International Air Passenger Traffic to and from UK Reporting Airports
Table_12_3_Dom_Air_Pax_Route_Analysis_by_Each_Reporting_Airport_20xx	Domestic Air Passenger Traffic to and from UK Reporting Airports

Table 9 – Data that should be sourced from the CAA

There is also an option to source updated data on aircraft used for journeys. It is important to check that the aircraft being used as analogues (for instance in the 2014/15 analyses this was the E190, B737 and B77W) are still a fair representation of the 'average' aircraft used for short, medium and long-haul journeys respectively. To remain representative this should be updated at a reasonably frequent interval, or when a case can be made that there has been a significant change in the types of aircrafts being used.

Data Entry and Model Use

The model is made up of seven separate sheets and, whilst partly automated, it requires a certain amount of user input and manipulation. Figure 5 provides an overview of the sheets and the user-input required. Figure 6 overviews the EMEP/EEA tool.

[1] https://www.caa.co.uk/Data-and-analysis/UK-aviation-market/Airports/Datasets/UK-Airport-data/

Sheet Name	Notes
Airport Codes and Locations	This sheet provides a list of airport names, ICAO codes and the geographical co-ordinates of airports. **It does not need updating unless MIA provides flights to new-build airports that are not present in the sheet.**
MIA Int Flights	This sheet takes the **user-inputted list of MIA international flight destinations (sourced from Table_12_1_Intl_Air_Pax_Route_Analysis_20xx)** and assigns the correct ICAO code to them. **If the correct ICAO code is not found, the user must input it manually.**
MIA Dom Flights	This sheet takes the **user-inputted list of MIA domestic flight destinations (sourced from Table_12_3_Dom_Air_Pax_Route_Analysis_by_Each_Reporting _Airport_20xx)** and assigns the correct ICAO code to them. **If the correct ICAO code is not found, the user must input it manually.**
Calcs MIA Int dists	This sheet calculates the great circle distance between MIA and the destination international airport. It also categorizes each journey in to a short, medium or long distance flight and selects an aircraft analogous to the ones that would have been used for that distance. **The user is required to submit this aircraft and the 'nm + 95' distance value in to the EMEP/EEA Aviation Emissions Calculator.** The calculator generates an estimation of fuel burn for LTO and CCD phases and **this figure should be entered in to the 'Average fuel usage per flight using best aircraft match (inc LTO)' field.** On the basis of 3.15 kg of CO2 being released for every kilogram of jet fuel used, the model calculates the average emissions for each journey. **Finally, the user is required to copy in the data on passengers to 'Average 20xx PAX' (from Table_12_1_Intl _Air_Pax_Route_Analysis_20xx),** the model will use this to calculate the expected number of flights that this translates to and will then calculate the overall emissions from international flights.
Calcs MIA Dom dists	This sheet functions very similarly to the international flights calculations. This sheet calculates the great circle distance between MIA and the destination international airport. **All destinations are assumed to be short distance and so the appropriate aircraft is manually noted. The user is required to submit this aircraft and the 'nm + 95' distance value in to the EMEP/EEA Aviation Emissions Calculator.** The calculator generates an estimation of fuel burn for LTO and CCD phases and **this figure should be entered in to the 'Average fuel usage per flight using best aircraft match (inc LTO)' field (See Figure 6).** On the basis of 3.15 kg of CO_2 being released for every kilogram of jet fuel used, the model calculates the average emissions for each journey. **Finally, the user is required to copy in the data on passengers to 'Average 20xx PAX' (from Table_12_1_Intl _Air_Pax_Route_Analysis_20xx)**, the model will use this to calculate the expected number of flights that this translates to and the model will then calculate the overall emissions from domestic flights.
NOx, SOx, H2O, CO, HC Estimates	This sheet provides a very rough approximation of other aviation emissions based on the overall CO_2 emissions. The approximation is based on average short, medium and long range distances that have been processed through the EMEP/EEA calculator and the percentage of flights for each destination length. From this a factor is derived for each gas relative to 1 kg CO2 for the given year. This factor is used to generate a very crude approximation of the overall other gases emitted in a given year. **This sheet only needs updating if the aircraft analogues have been changed – however, some cell ranges may need extending (B,C,D19).**
Output Statistics and Graphs	This sheet provides the output statistics. **Only data locations will need changing if other sheets have been modified.**

Figure 5 – Overview of data calculation sheets, element pertaining to user input are in blue.

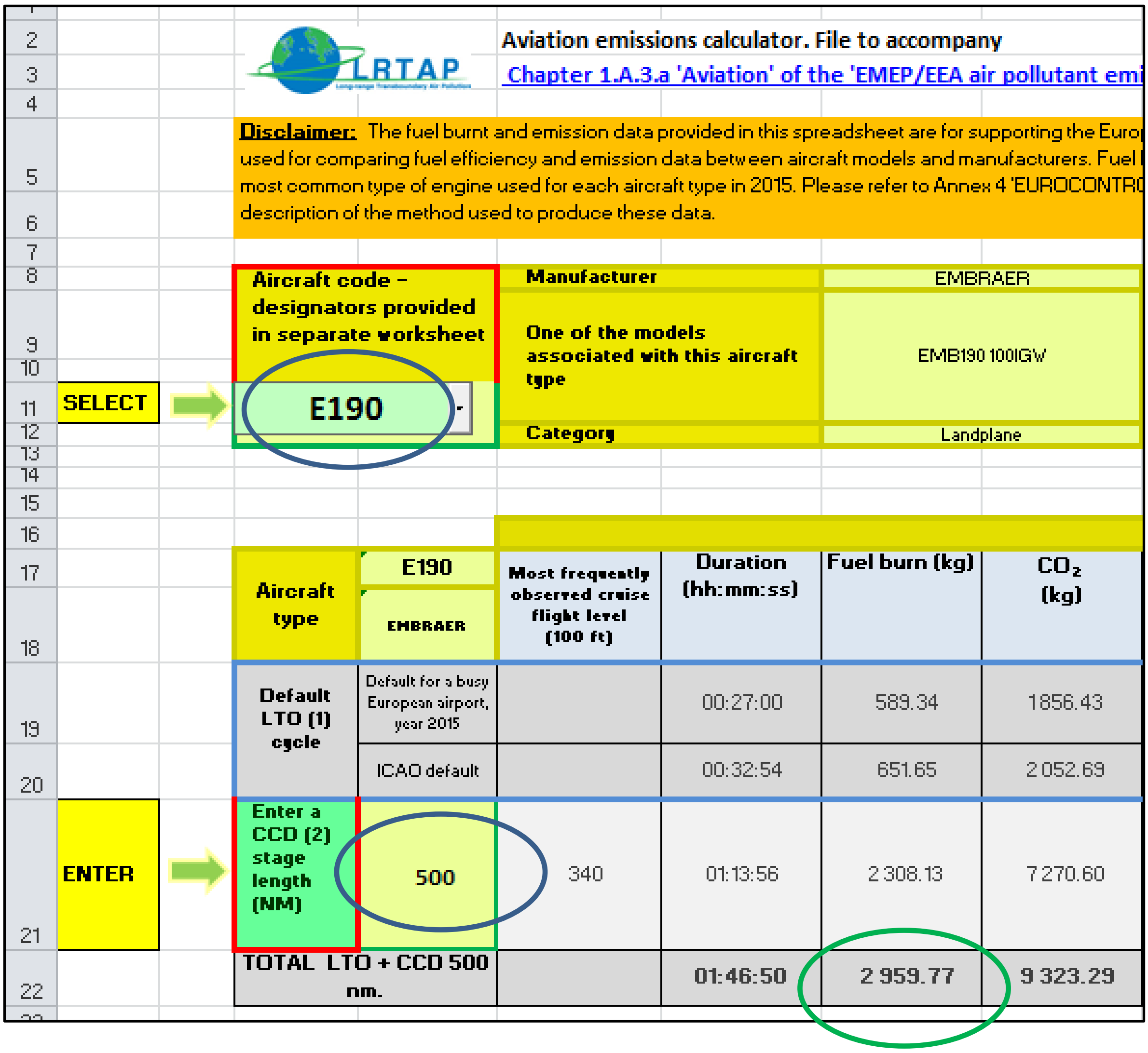

Figure 6 – The EMEP/EEA Emissions Calculator, blue circles indicate where user input is required. The green circle indicates the fuel burn figure that should be noted.

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