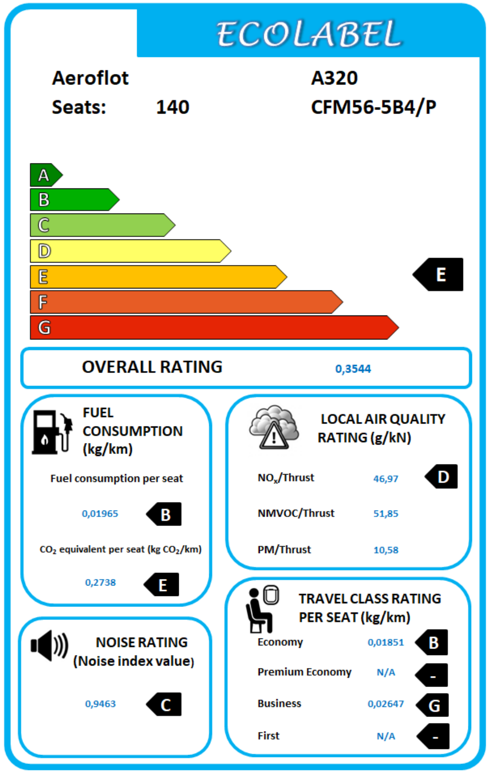
Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

AIRCRAFT DESIGN AND SYSTEMS GROUP (AERO)

An Ecolabel for Aircraft

Dieter Scholz Hamburg University of Applied Sciences

https://doi.org/10.5281/zenodo.4072826



Deutscher Luft- und Raumfahrtkongress 2017

German Aerospace Congress 2017

Munich, Germany, 05.-07.09.2017 **DLRK 2017**

AN ECOLABEL FOR AIRCRAFT

including work of:

- **Tim Haß** (Bachelor Thesis)
- **Lynn Van Endert** (Master Thesis)
- ...

Abstract

In attempting to increase the environmental awareness in the aviation sector and to eliminate the green washing phenomenon, an investigation was done into the development and definition of an ecolabel for aircraft. Based on life cycle assessment it was found that aviation affects the environment most with the impact categories resource depletion and global warming (both due to fuel consumption), local air pollution (due to the nitrogen oxide emissions in the vicinity of airports) and noise pollution. For each impact category a calculation method was developed based solely on official, certified and publicly available data to meet the stated requirements of the ISO standards about environmental labeling. To ensure that every parameter is evaluated independent on aircraft size, which allows comparison between different aircraft, normalizing factors such as number of seats, rated thrust and noise level limits are used. Additionally, a travel class weighting factor is derived in order to account for the space occupied per seat in first class, business class and economy class. To finalize the ecolabel, the overall environmental impact is determined by weighting the contribution of each impact category. For each category a rating scale from A to G is developed to compare the performance of the aircraft with that of others. The harmonization of the scientific and environmental information, presented in an easy understandable label, enables the traveling customers to make a well informed and educated choice when booking a flight, selecting among airline offers with different types of aircraft and seating arrangements.

Table of Content

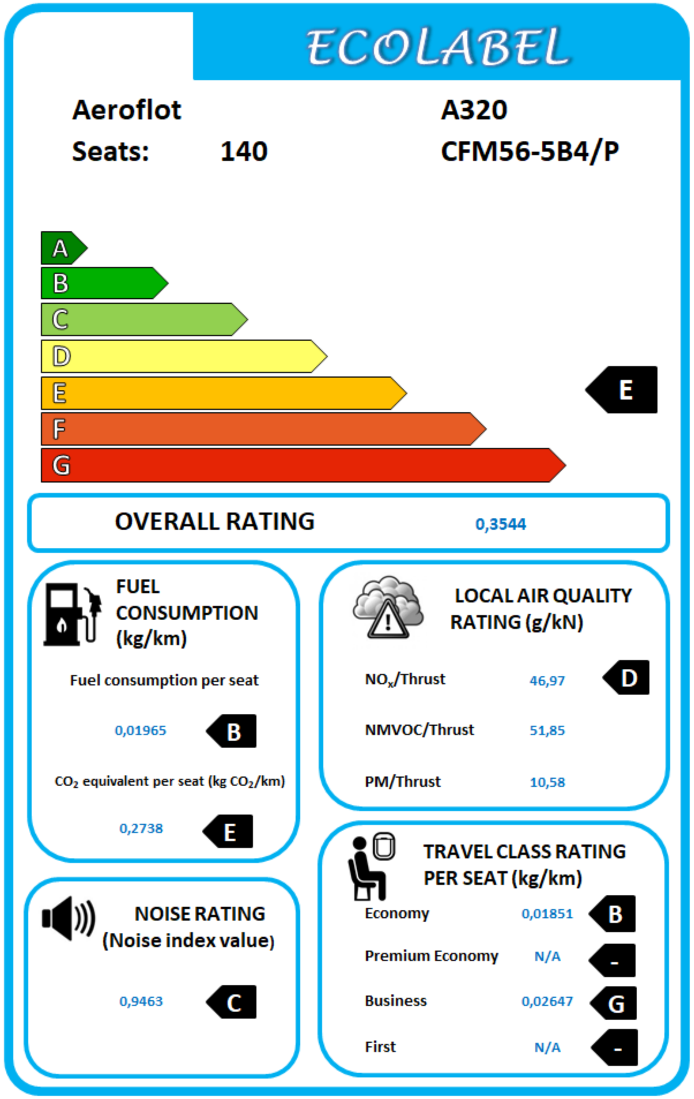
Idea / Goal & ...

- **The travelling public should make an informed choice when selecting a flight**
  - o **Price**
    - – ticket price (basic fare, baggage, seat selection, ..., payment fees)
  - o **Time**
    - – useful time & wasted time
  - o **Comfort**
    - – travel class (=> seat pitch, seat width, ...)
    - – number of transfers
  - o **Environmental footprint** => **Ecolabel for Aircraft**
    (**simplified** Life Cycle Assessment, **LCA**)
    - – **Resource depletion** (fuel burn)
    - – **Global warming** (fuel burn)
    - – **Local air quality** (NOx)
      - + **Ozone** formation potential (NMVOC: NOx, SO2, CO, HC)
      - + **Particulate matter** formation (PM: NOx, PM)
    - – **Noise**

... the Ecolabel for Aircraft

- Information: airline, aircraft, number of seats, engine
- Overall Rating (average rating on <u>airline</u> level)
  - o Metric <u>scaled</u> between 0 and 1 (90% of aircraft)
  - o category: A to G
- Fuel consumption

  (from manufacturer's payload & range diagram)
  - o resource depletion:
    fuel per seat-km (kg/km) & A to G
  - o global warming (depending on altitude):
    CO2-equivalent per seat-km (kg/km) & A to G
- Local air quality (ICAO LTO cycle)
  - o NOx (g/kN) & A to G
  - o NMVOC (g/kN) – for information only
  - o PM-equivalent (g/kN) – for information only
- Noise (from NoisedB database; ICAO & DGAC)
- Rating according to passenger travel class



Background

- **My presentation at the German Aerospace Conference 2012*:**
  - o Eco-efficiency: Create more with less waste and pollution.
  - o Aviation growth does not (and will never) be met by aviation's efficiency gain!
  - o Jevson's Paradox: "Fuel Can Not Be Saved from Efficiency Increase!"
  - o **ACARE goals** (fuel burn reduction, NOx, ...)
    - – are unrealistic and will not be met
    - – this without any consequences (see "Vision 2020")
  - o **IATA** / ATAG goal: "**carbon-neutral growth from 2020**"
    - – would need massive & effective compensation scheme. CORSIA?
    - – Why 2020 and not today?
  - o CO_2 is not the (major) problem. **The major problem is water!**
  - o It is already too late to safe the world. **We need resilience!**
    - – Do not bother about aviation, rather increase height of the dikes (Hamburg)

* http://www.fzt.haw-hamburg.de/pers/Scholz/Airport2030/Airport2030_PRE_DLRK_2012_EcoEfficiencyOffCourse_2012-09-10.pdf

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Hamburg University of Applied Sciences

Aero

AERO – AIRCRAFT DESIGN AND SYSTEMS GROUP

Eco-Efficiency in Aviation – Flying Off Course?

Dieter Scholz

Hamburg University of Applied Sciences

https://doi.org/10.5281/zenodo.4067014

Deutscher Luft- und Raumfahrtkongress 2012
German Aerospace Congress 2012
Berlin, Germany, 10.-12.09.2012

resilience

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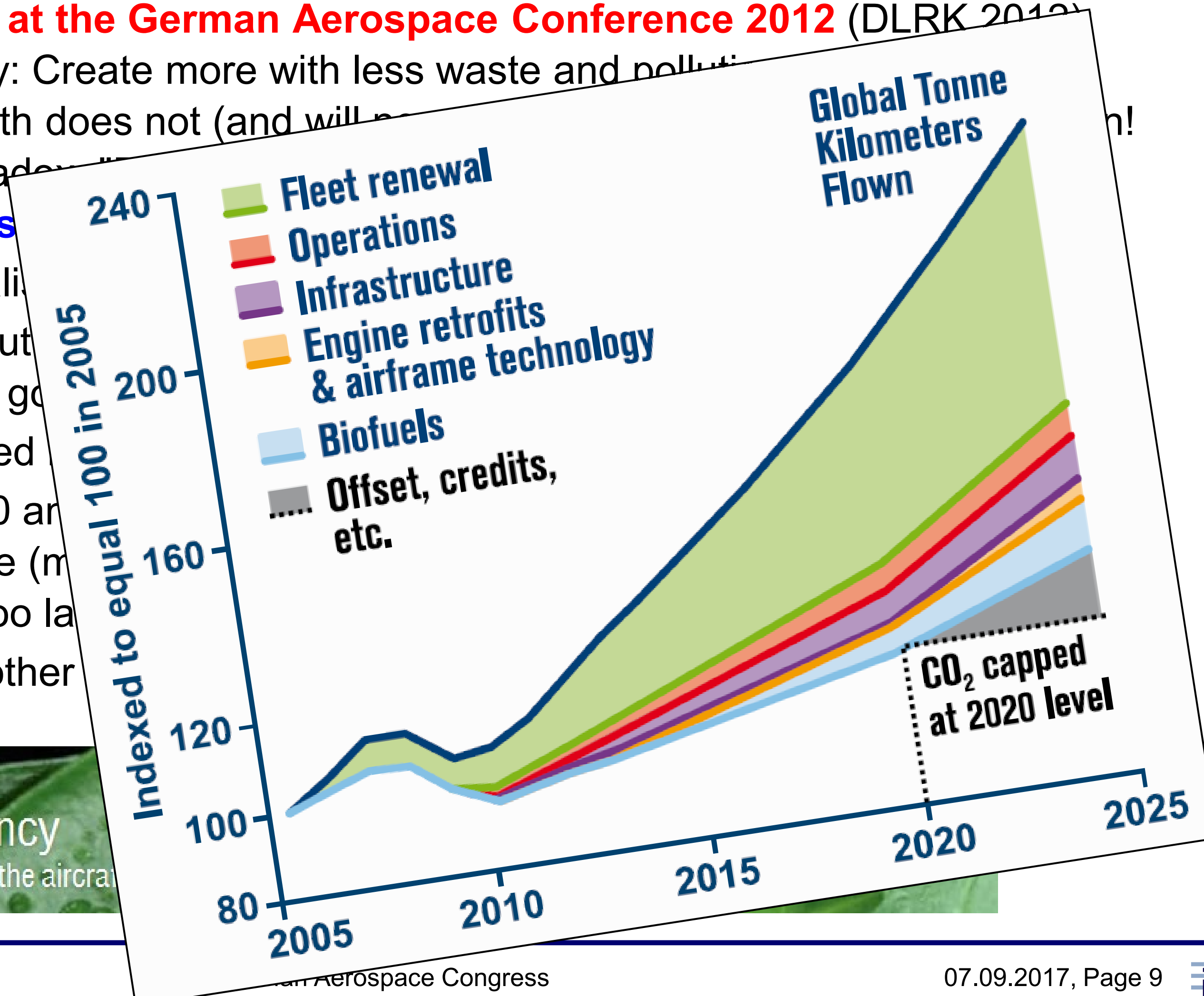
    - – Do not bother…



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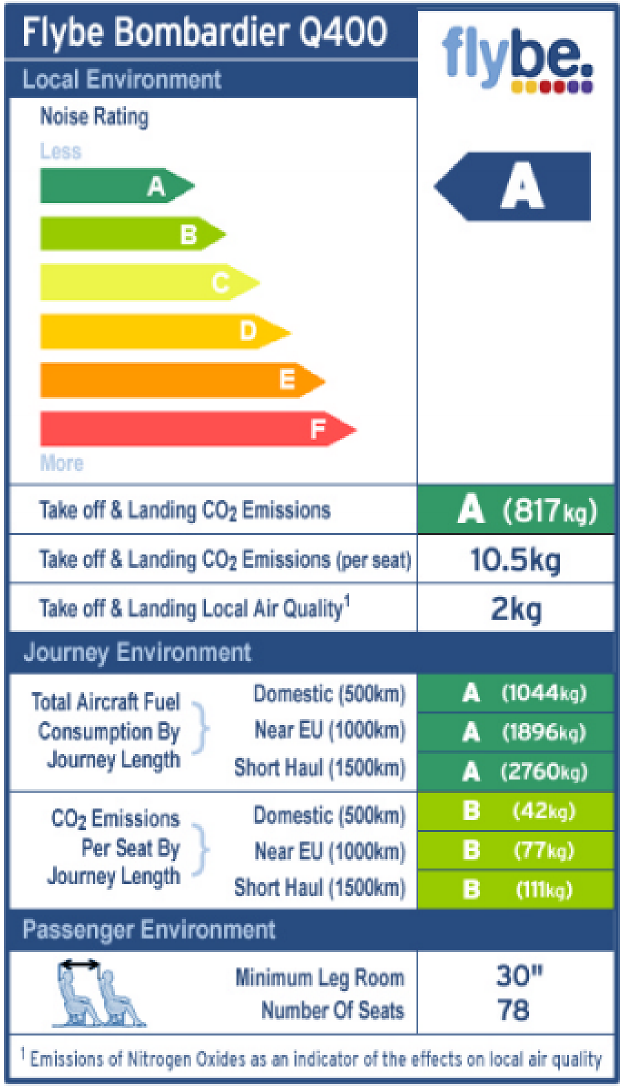
Background

- **Let's get priorities right** to protect the **environment**:
  1. **Avoid to travel** (do something else instead)
  2. For each trip select the **best mode of transportation** (aircraft, train, bus?)
  3. Select the **shortest route**
  4. Select the **best vehicle/airline** (**get info from the Ecolable for the Aircraft**)
  5. Make sure the **vehicle is full** and you select an **economy seat**, unless ...
  6. **Compensate** (... or maybe just do not compensate, if you do not like the idea)

think • go climate conscious
atmosfair

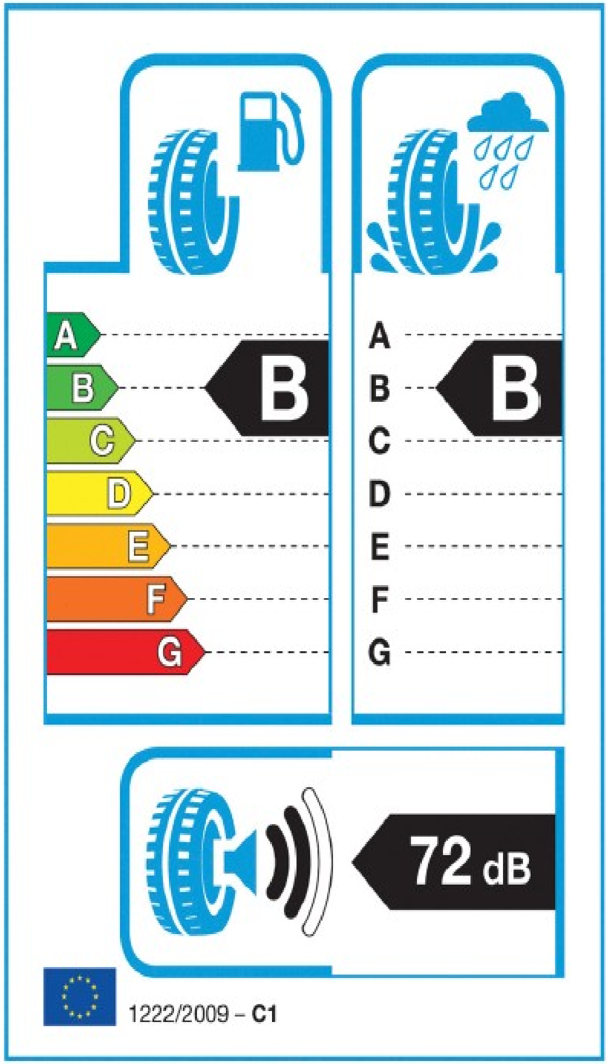
Background

- **Flybe's Ecolable** (2007):
  - o Label not used anymore by Flybe
  - o Never used by other airlines (as intended)
  - o Detail design shows **many deficiencies**.



Background

- **Labelling of Tyres** (2009):
  - o "Regulation (EC) No 1222/2009 on the labelling of tyres" *
  - o An example to learn from



* http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32009R1222

Background

- **Other schemes**

  1. **ICAO Emission Calculator**

http://www.icao.int/env

  2. **Atmosfair Emission Calculator**
  3. **Atmosfair Airline Index**

http://www.atmosfair.de

Background

- **ISO 14020 Series: Environmental labels and declarations**

ISO 14020:2000 Environmental labels and declarations –
General principles
ISO 14021:2016 Environmental labels and declarations –
Self-declared environmental claims (Type II environmental labelling)
ISO 14024:1999 Environmental labels and declarations –
Type I environmental labelling -- Principles and procedures
ISO 14025:2006 Environmental labels and declarations –
Type III environmental declarations -- Principles and procedures
ISO/TS 14027:2017 Environmental labels and declarations –
Development of product category rules

Type II Used for the **travelling public** => **Ecolabel for Aircraft**
Type III Used for the **experts** => **Full Report for Experts**

http://www.iso.org

Background

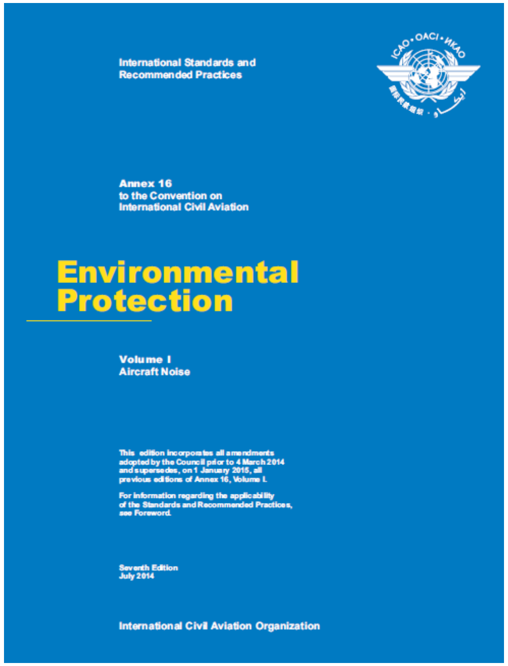
- **ISO 14025 (Type III) for Experts => Full Report**

  - **The label has to be** voluntary
  - The label has to be **life cycle based**
  - The label has to be verifiable
  - The label has to be open for interested parties
  - The label has to be **transparent**
  - The label has to be flexible
  - The label **allows comparing** different offers
  - The label can be calculated by anyone

- **ISO 14021 (Type II) for the Travelling Public => Ecolabel derived from Report**

Background

- **ICAO-Regulations**



ICAO Annex 16 - Volume 1: Environmental Protection –
Aircraft Noise

http://cockpitdata.com/Software/ICAO Annex 16 Volume 1

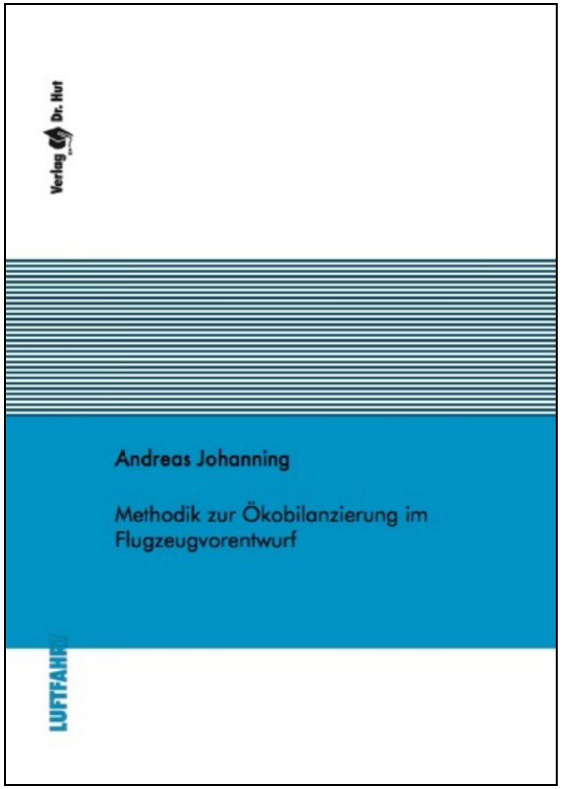
ICAO Annex 16 - Volume 2: Aircraft Engine Emissions –
Aircraft Engine Emissions

http://cockpitdata.com/Software/ICAO Annex 16 Volume 2

ICAO Annex 16 - Volume 3: Aircraft Engine Emissions –
CO2 Certification Requirement

http://www.fzt.haw-hamburg.de/pers/Scholz/materialFM1/ICAO-2017_Annex16_Volume3_CO2CertificationRequirement.pdf

Life Cycle Assessment (LCA)



Johanning (2017):
Life Cycle Assessment in Aircraft Design

ISO 14040:2006
Environmental Management -- Life Cycle Assessment

National Institute for Public Health and the Environment
Ministry of Health, Welfare and Sport

NL

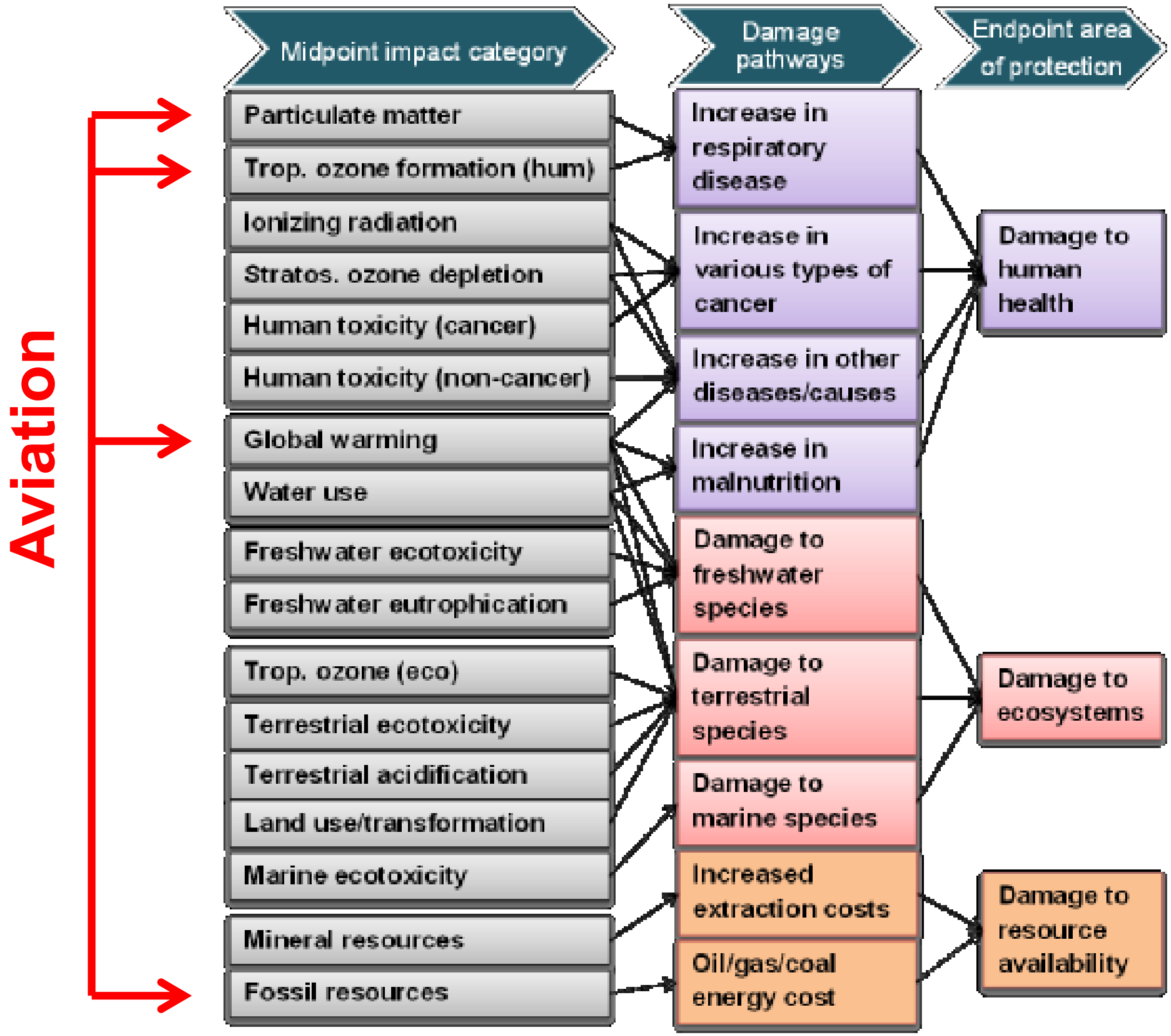
http://www.lcia-recipe.net

ReCiPe

ReCiPe is a method for the impact assessment in a **Life Cycle Assessment** LCA. LCA translates emissions and resource extractions into a limited number of environmental impact scores by means of so-called characterization factors. There are two ways to derive **characterization factors**, i.e. at midpoint level and at endpoint level. ReCiPe calculates:

- **18 Midpoint Indicators**
- **3 Endpoint Indicators**
- **1 Single Score**

http://www.fzt.haw-hamburg.de/pers/Scholz/Airport2030/JOHANNING_DISS_Methodik_zur_Oekobilanzierung_im_Flugzeugvorentwurf_2017.pdf



ReCiPe

It was added to the basic Method:

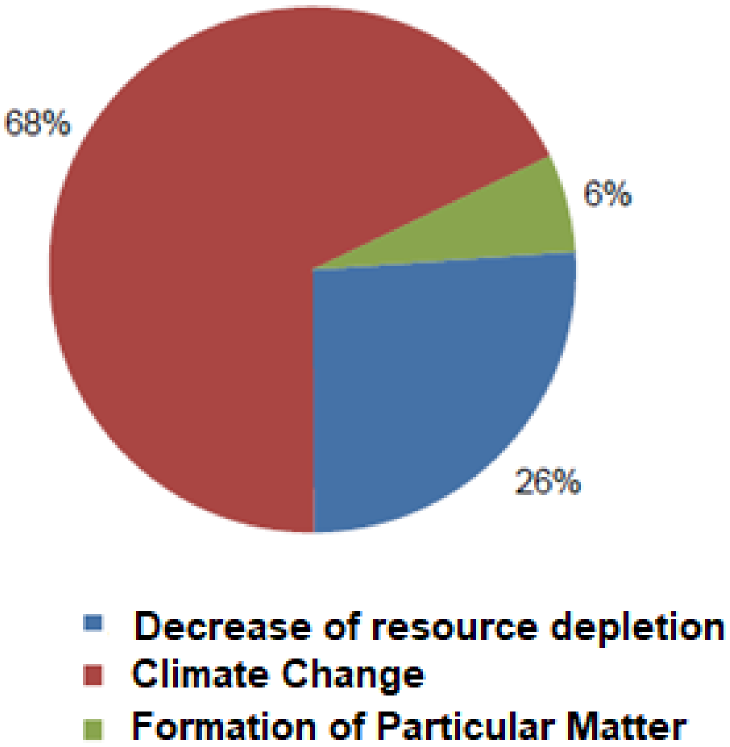
1.) by Johanning:
Altitude Dependency

2.) here:
Noice

Life Cycle Assessment (LCA)

ReCiPe – Result (A320):

Johanning (2017)



Ecolabel for Aircraft

Overall Rating:

$$R_{overall} = 0.4 R_{warming} + 0.2 R_{depletion} + 0.2 R_{localAir} + 0.2 R_{noice}$$

Fuel Consumption

Table 1: Summary of candidate metrics

	Full Mission Metrics				
Single parameter metric	Block Fuel ---------------- Range				
Two-parameter metric	Block Fuel ---------------- **Payload** * Range	Block Fuel ---------------- **Useful Load** * R	Block Fuel ---------------- **MTOW** * Range	Block Fuel ---------------- **Floor Area** * R	Block Fuel ---------------- **Av. Seats** * R
Three-parameter metric	Block Fuel ---------------- **Payload** * R.*Speed	Block Fuel ---------------- **Useful Load** * R.*Speed	Block Fuel ---------------- **MTOW** * R. *Speed	Block Fuel ---------------- **Floor Area***R.*Speed	Block Fuel ---------------- **Av. Seats** * R. *Speed
	Block Fuel ---------------- **Payload** * R./Time	Block Fuel ---------------- **Useful Load***R./Time	Block Fuel ---------------- **MTOW** * R./Time	Block Fuel ---------------- **Floor Area***R./Time	Block Fuel ---------------- **Av. Seats** * R./Time
	Instantaneous Performance Metrics				
Single parameter metric	1 ---------------- **Specific Air Range** = 1 ----- **SAR**				
Two-parameter metric	1 ---------------- SAR * **Payload**	1 ---------------- SAR * **Useful Load**	1 ---------------- SAR * **MTOW**	1 ---------------- SAR * **Floor Area**	1 ---------------- SAR * **Av. Seats**
Three-parameter metric	1 ---------------- SAR * **Payload** * Speed	1 ---------------- SAR * **Useful Load** * Speed	1 ---------------- SAR * **MTOW** *Speed	1 ---------------- SAR * **Floor Area*** Speed	1 ---------------- SAR * **Av. Seats** * Speed

Note: R = Range

PARTNER
Partnership for Air Transportation Noise and Emissions Reduction

Selecting a Fuel Metric:

$$1/(SAR \cdot n_{seat})$$

http://partner.mit.edu/projects/metrics-aviation-co2-standard

Fuel Consumption

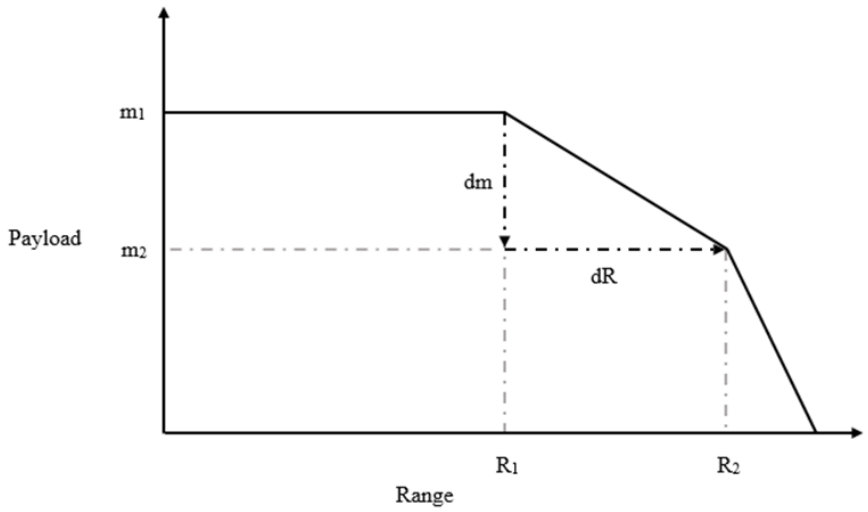
measured $$SAR = -\frac{dR}{dm} = \frac{V_{TAS}}{C_{gross}}$$

calculated $$SAR = -\frac{dR}{dm} = \frac{V \cdot E}{c \cdot g}$$

Here taken from:

Payload-Range-Diagram available from: "Documents for Airport Planning"

See: http://links.ProfScholz.de



$$SAR = -\frac{dR}{dm}$$

$$SAR = \frac{R_2 - R_1}{m_1 - m_2}$$

Fuel Consumption

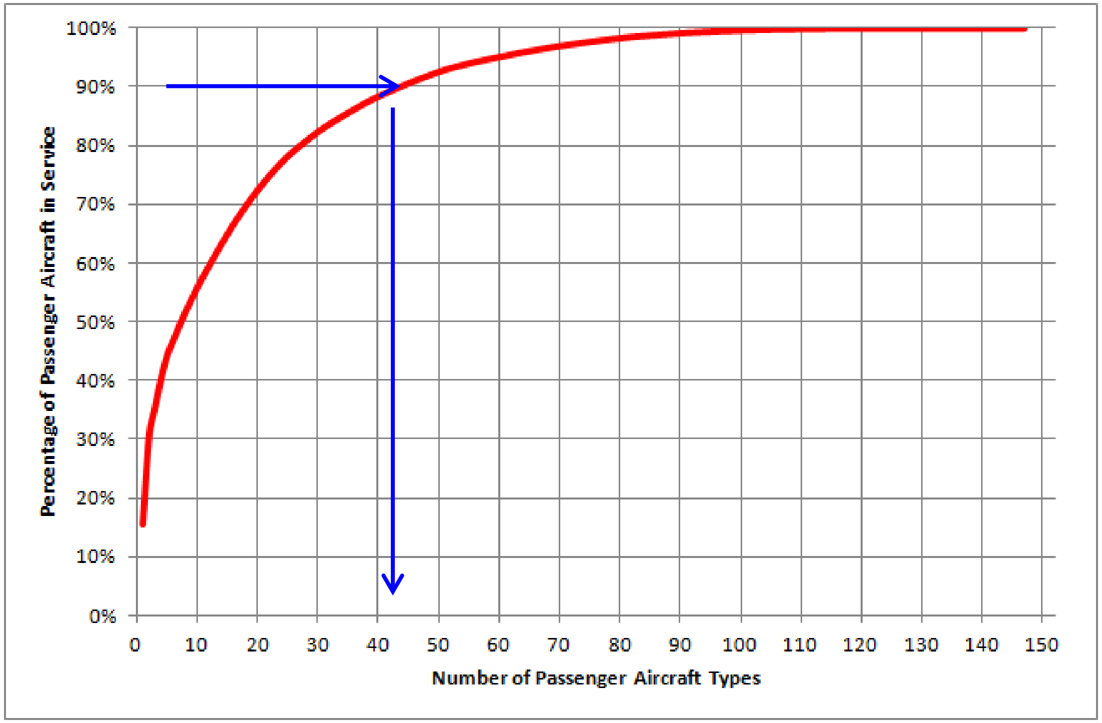
Global airliner fleet by type and operator

Airbus A300	**Total 210**
Africa	**Total 3**
Egyptair (600)	2
Egyptair (B)	1
Asia Pacific & Middle East	**Total 47**
Air Hong Kong (600)	10
Global Charter Services (B)	4
Iran Air (600)	3
Iran Air (B)	4
Mahan Air (600)	14
Mahan Air (B)	1
Meraj Air (600)	2
Qeshm Airlines (600)	4
Silk Road Cargo Business (600)	1
Unique Air (600)	2
Uni-top Airlines (600)	2
Turkish Airlines	3
North/South America	**Total 17**
Air Transat	9
FedEx	8
Airbus A318	**Total 43**
Europe	**Total 24**
Air France	18
British Airways	2
TAROM	4
North/South America	**Total 19**
Avianca	10
Avianca Brazil	9
Airbus A319	**Total 1,327 (6)**
Africa	**Total 34**
Afriqiyah Airways	2
Air Côte d'Ivoire	4
Druk Air	3
Etihad Airways	2
Lucky Air	3
Mihin Lanka	1
Myanmar Airways International	3
R Airlines	1
Rotana Jet	1
Royal Jordanian	4
Safi Airways	2
Saudia	4
Shenzhen Airlines	5
Sichuan Airlines	23
SilkAir	4
Tibet Airlines	14
Tigerair	2
West Air (China)	4
Dart Airlines	1
EasyJet	133
EasyJet Switzerland	11
Ellinair	2
Finnair	9
Germania	8
Germania Flug	2
Germanwings	43
Hamburg International	(2)
Helvetic Airways	1
Iberia	16
Lufthansa	30
Niki	5
Rossiya	26
S7 Airlines	20
SAS	4

147 different aircraft types and
26000 aircraft in database

https://www.flightglobal.com/asset/12798

Fuel Consumption



$$\left(\frac{n}{n_{max}}\right)_{in\_service} = 1 - a \cdot e^{b\left(\frac{n}{n_{max}}\right)_{type}}$$

$$a = 0.748$$

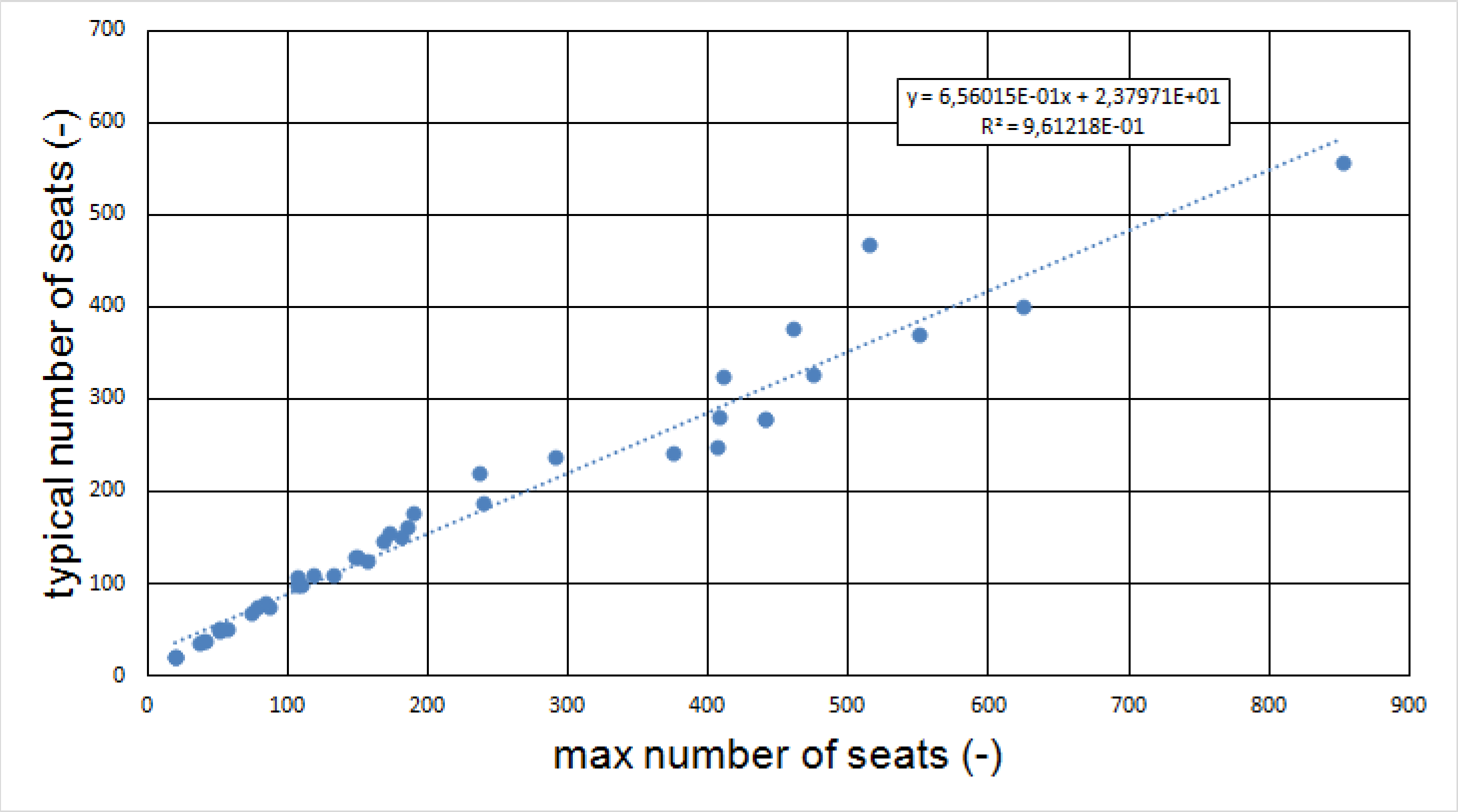
$$b = -0.0480$$

Some of the most operated 49 types where selected to describe 90% of all passenger aircraft (n_{seat} > 14).

49 payload-range diagrams evaluated

Method to quickly determine cruise altitude from basic data

Fuel Consumption



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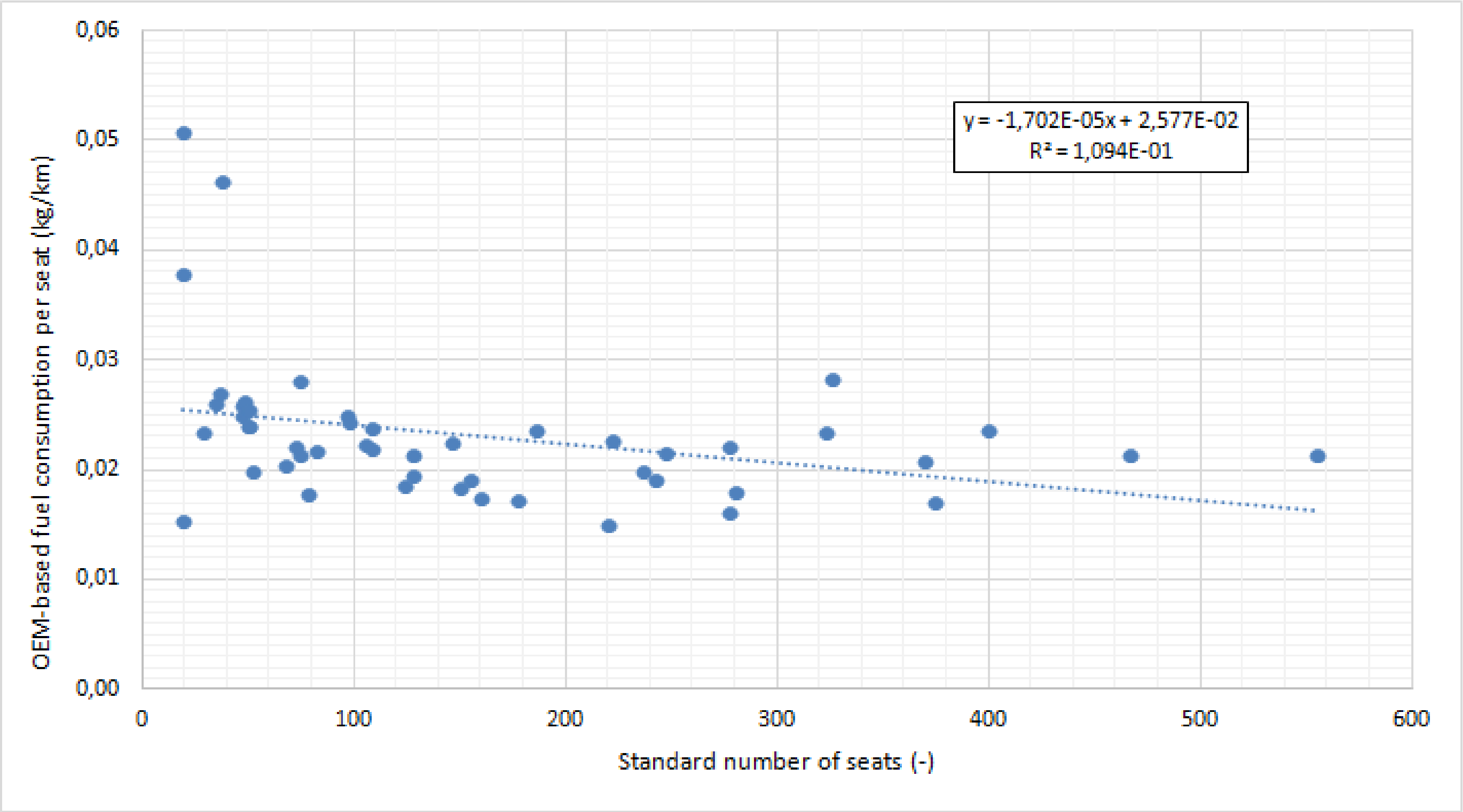

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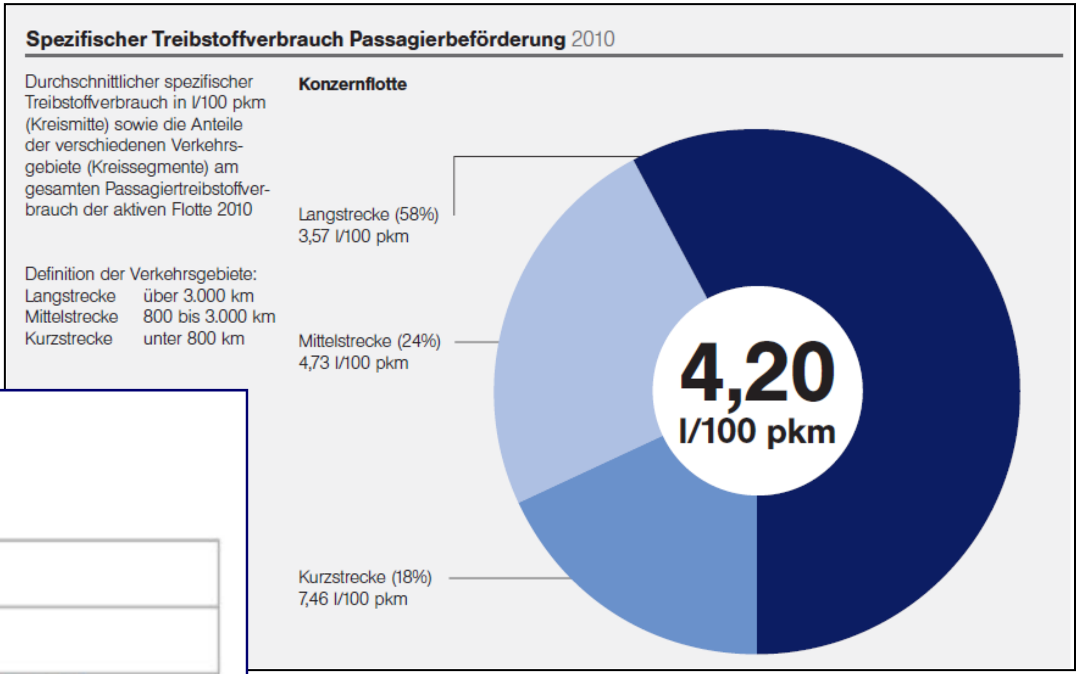
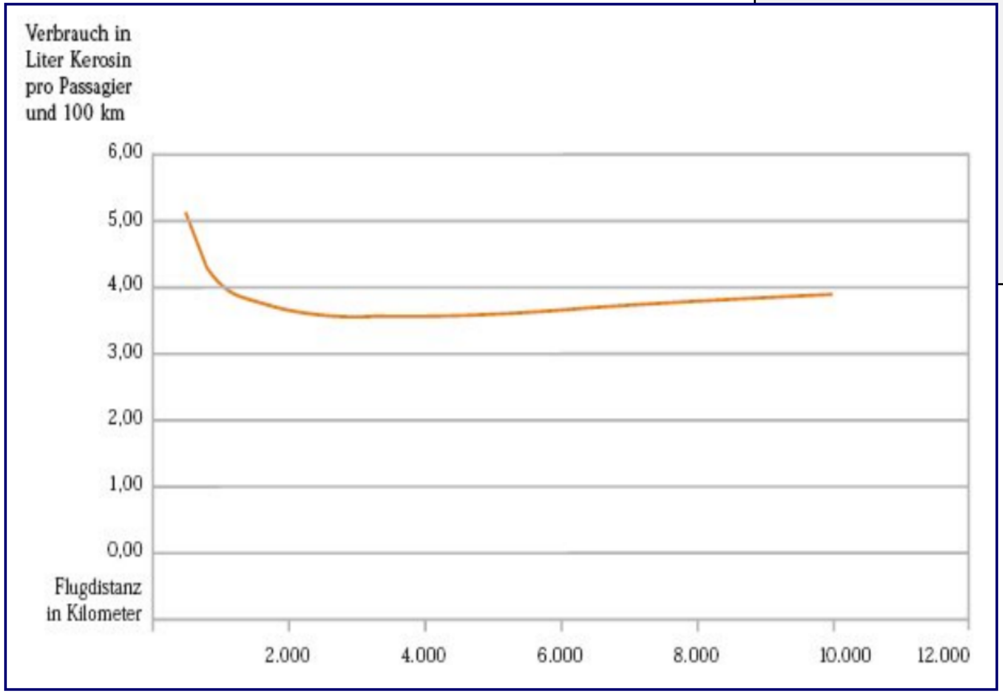


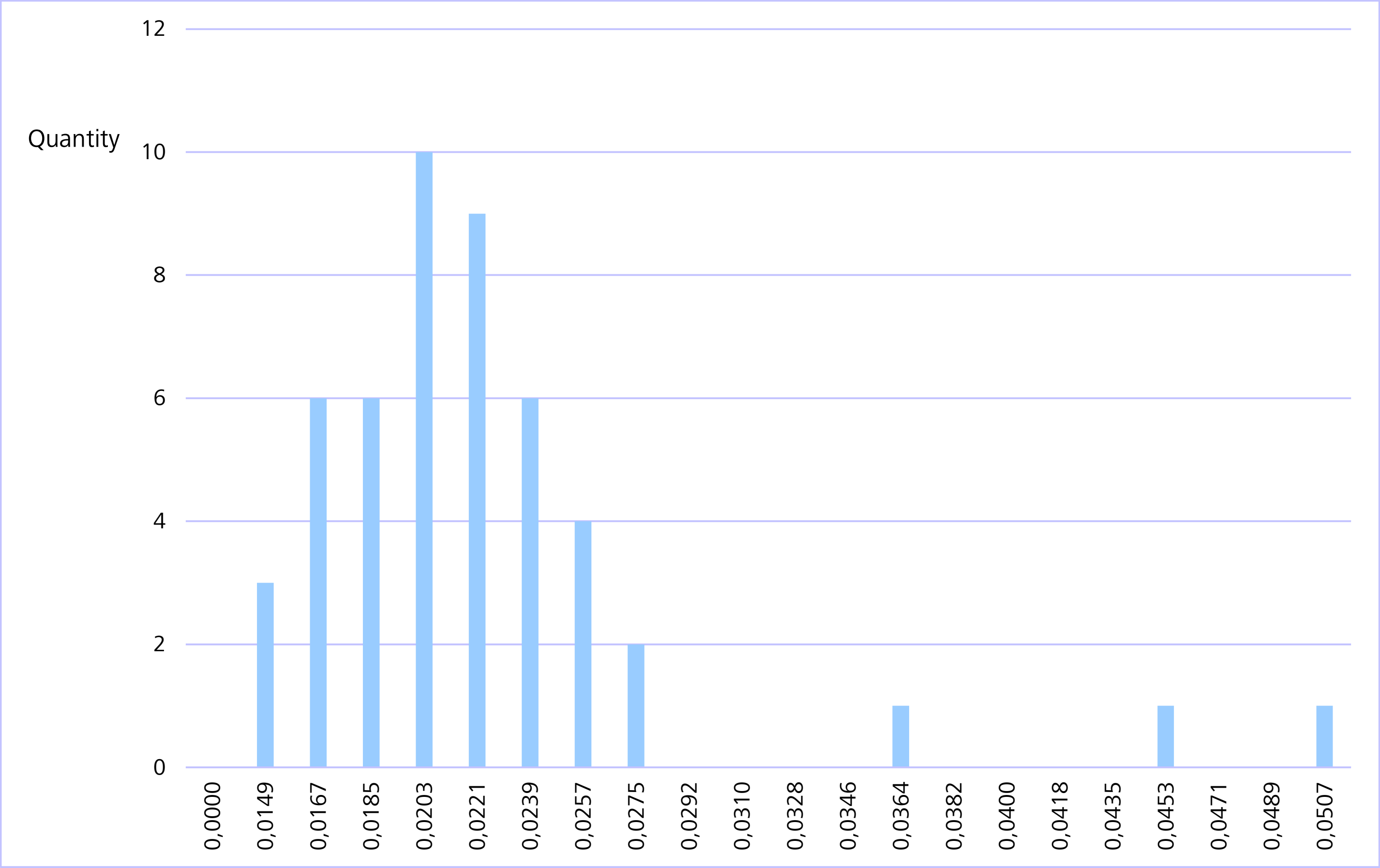
Lufthansa 2010



DLR 2000

Fuel Consumption

21 equal intervals



Normalized OEM-based fuel consumption per seat (kg/km)

Fuel Consumption

Rating scale for the fuel consumption per seat (kg/km)

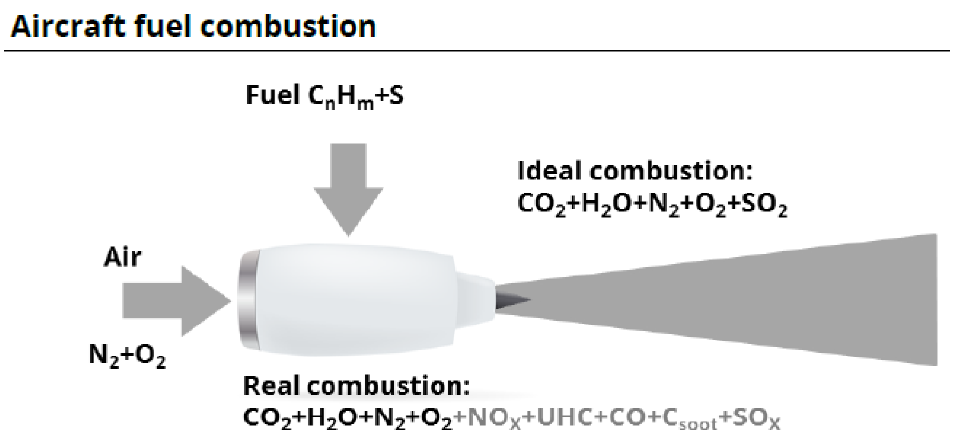
Rating	Range		Normalized to 0-1	
	min	max	min	max
A	0,01493	0,01772	0	0,0781
B	0,01772	0,01983	0,0781	0,1370
C	0,01983	0,02131	0,1370	0,1783
D	0,02131	0,02246	0,1783	0,2106
E	0,02246	0,02392	0,2106	0,2514
F	0,02392	0,02602	0,2514	0,3099
G	0,02602	0,05070	0,3099	1,000

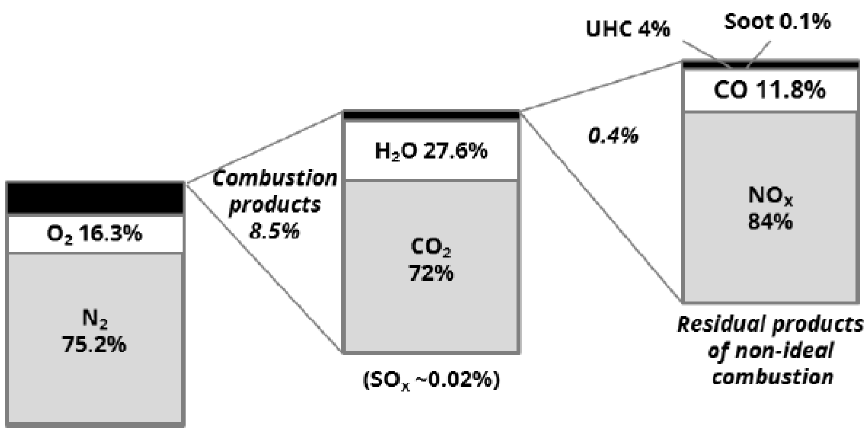
7 unequally spaced intervals for categories A to G with the same number of aircraft in each category

Global Warming

Species	Emission Index (kg/kg fuel)
CO_2	3,16
H_2O	1,23
SO_2	$2{,}00 \cdot 10^{-4}$
Soot	$4{,}00 \cdot 10^{-5}$

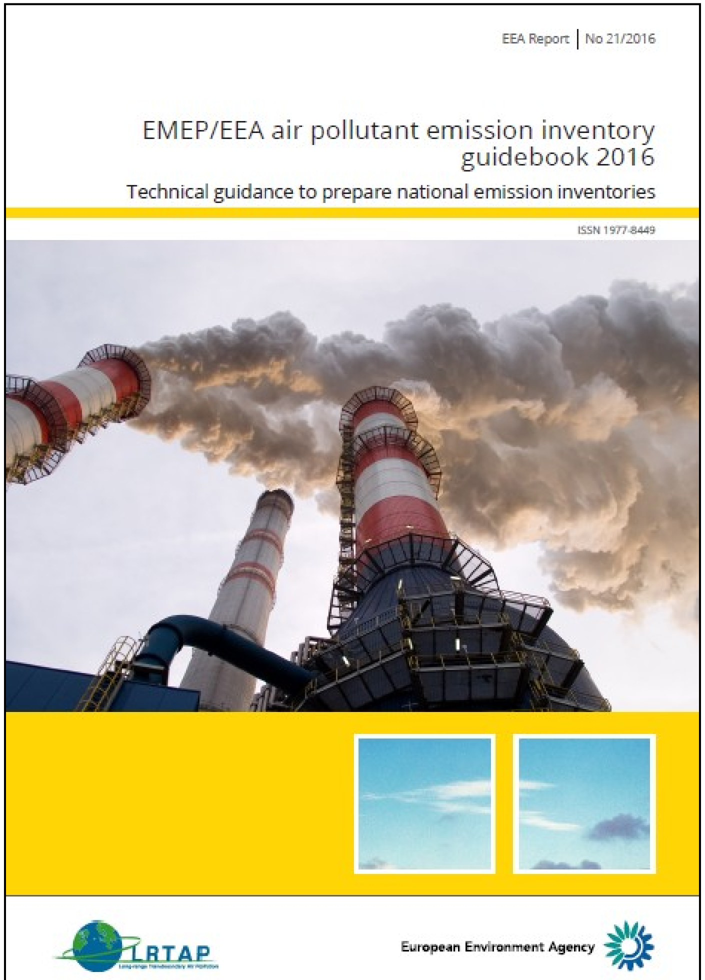
IPCC1999
http://www.ipcc.ch/ipccreports/sres/aviation/





EEA 2016
http://www.eea.europa.eu/publications/emep-eea-guidebook-2016

Global Warming



European Environment Agency

European Monitoring and Evaluation Program (EMEP)
http://www.emep.int

European Environment Agency
http://www.eea.europa.eu/publications/emep-eea-guidebook-2016

Users will find two Excel files:
- Master emission calculator
- LTO emission calculator

Height (feet)	Fuel burnt	NO_x, UHCs and CO	CO_2, H_2O and SO_x	VOCs
> 3 000 CCD	BADA	BFFM2	Proportional to the mass of fuel burnt	Proportional to the mass of UHCs generated
≤ 3 000	AEED and other databases			

Global Warming

Aviation emissions calculator. File to accompany
Chapter 1.A.3.a 'Aviation' of the 'EMEP/EEA air pollutant emission inventory guidebook 2016'

European Environment Agency

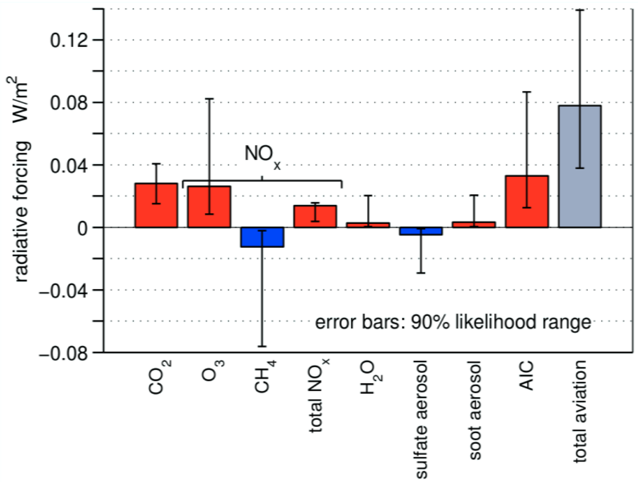
Disclaimer: The fuel burnt and emission data provided in this spreadsheet are for supporting the European Union and EU Member States in the maintenance and provision of European and national emission inventories. These data should not be used for comparing fuel efficiency and emission data between aircraft models and manufacturers. Fuel burn and emission data in this spreadsheet are modelled estimates and not 'absolute' values. The engine associated to each aircraft type is the most common type of engine used for each aircraft type in 2015. Please refer to Annex 4 'EUROCONTROL fuel burn and emissions inventory system' in the aviation chapter of the 'EMEP/EEA air pollutant emission inventory guidebook 2016' for a description of the method used to produce these data.

Aircraft code - designators provided in separate worksheet	
SELECT	A320
Manufacturer	AIRBUS INDUSTRIE
One of the models associated with this aircraft type	A320 233
Category	Landplane
Engine type	Jet
The most common engine ID in 2015 used for modelling this aircraft type	3CM026
Number of engines	2

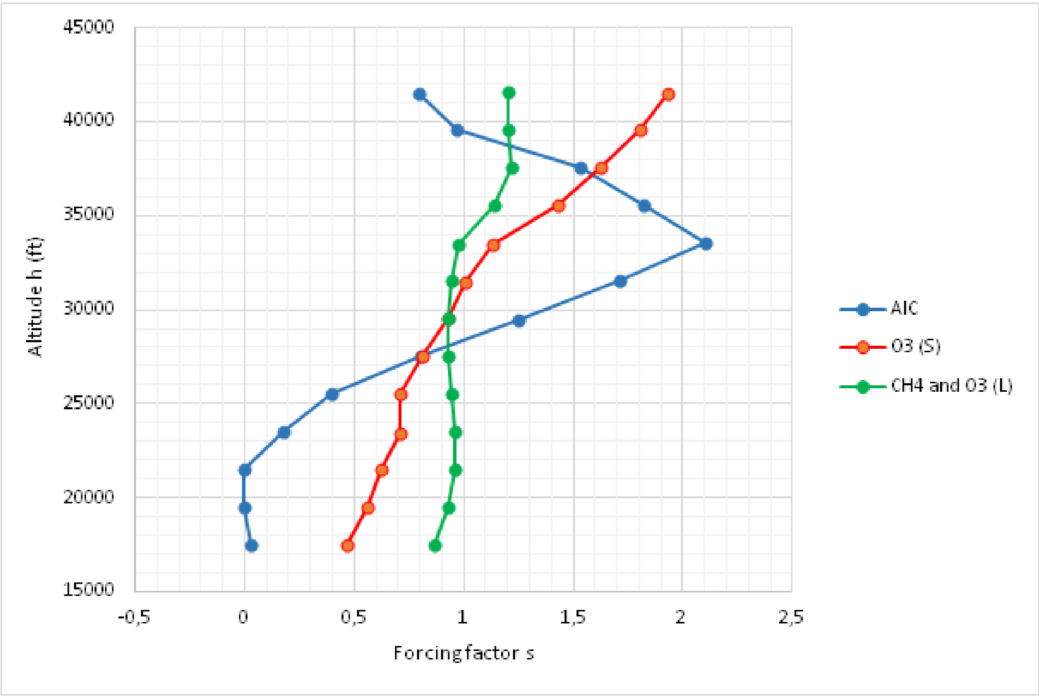
Default LTO (1) cycle (hh:mm:ss)		
Phases	ICAO default	Default for a busy European airport, year 2015
Taxi	00:26:00	00:20:06
Take off	00:00:42	00:00:42
Climb out	00:02:12	00:02:12
Approach	00:04:00	00:04:00
TOTAL	**00:32:54**	**00:27:00**

		Estimated parameters (based on year 2015)											
Aircraft type	A320 AIRBUS INDUSTRIE	Most frequently observed cruise flight level (100 ft)	Duration (hh:mm:ss)	Fuel burn (kg)	CO_2 (kg)	NO_x (kg)	SO_x (kg)	H_2O (kg)	CO (kg)	HC (kg)	PM non volatile (kg)	PM volatile (organic + sulphurous) (kg)	PM TOTAL (kg) (3)
Default LTO (1) cycle	Default for a busy European airport, year 2015		00:27:00	742,54	2 338,99	10,97	0,62	913,32	6,52	1,30	0,0066	0,0536	0,0602
	ICAO default		00:32:54	816,17	2 570,93	11,28	0,69	1 003,89	8,25	1,64	0,0067	0,0593	0,0661
ENTER: Enter a CCD (2) stage length (NM)	300	280	00:44:21	1 907,10	6 007,38	33,60	1,60	2 345,74	5,48	1,14	0,0250	0,1912	0,2163
TOTAL LTO + CCD 300 nm.			**01:17:15**	**2 723,27**	**8 578,31**	**44,88**	**2,29**	**3 349,63**	**13,72**	**2,77**	**0,0318**	**0,2505**	**0,2823**

Global Warming



IPCC 1999



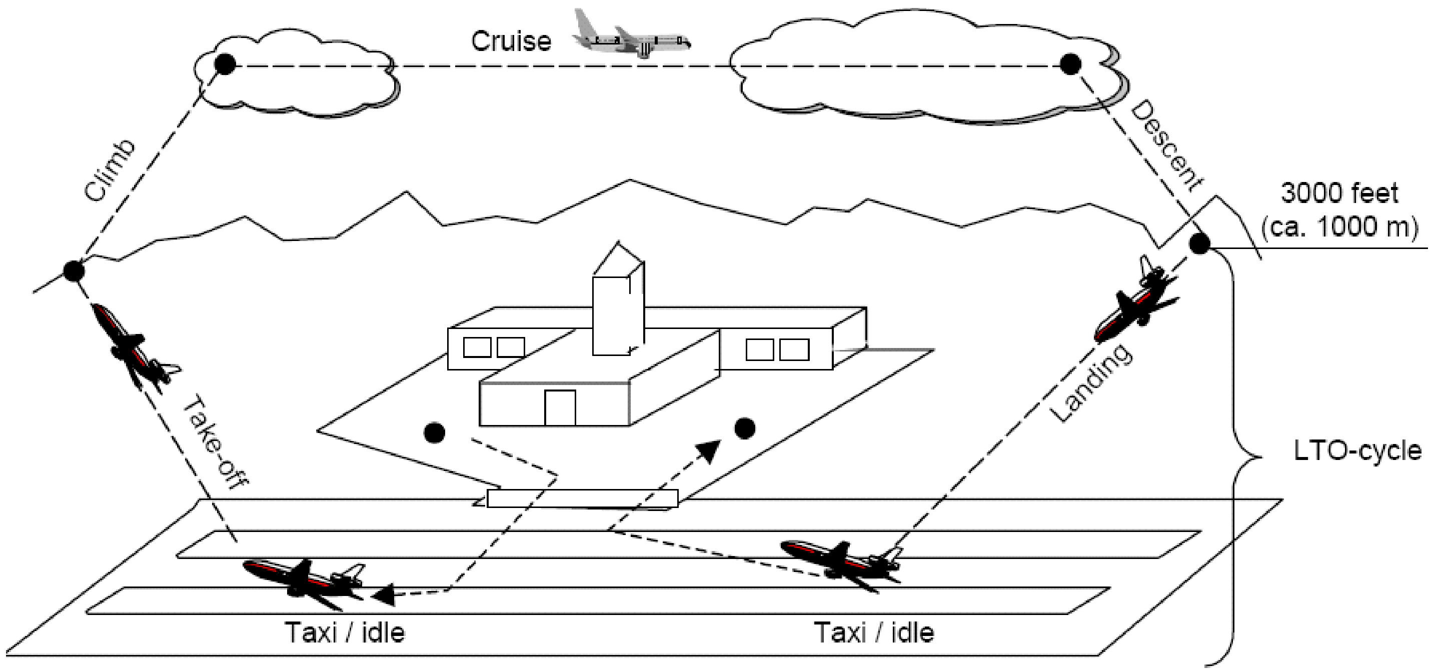
Schwartz 2009

http://www.enu.kz/repository/2009/AIAA-2009-1261.pdf

... more details ...

This added to
ReCiPe
to include the
Altitude Dependency

Local Air Quality



Definition of the landing and take-off cycle (LTO)

Hochschule für Angewandte
Wissenschaften Hamburg
Hamburg University of Applied Sciences

Local Air Quality

LRTAP

Aviation LTO emissions calculator. File to accompany:
Chapter 1.A.3.a 'Aviation' of the 'EMEP/EEA Air Pollutant Emission Inventory Gu

European Environment Agency

Disclaimer: The fuel burnt and emission data provided in this spreadsheet are for supporting the European Union and the Member States of the European Environment Agency in the maintenance and provision of European and national emission inventories. These data should not be used for comparing fuel efficiency and emission data between aircraft types and/or manufacturers. Fuel burn and emission data in this spreadsheet are modelled estimates and not "absolute" values. Where only one type of engine is associated with a particular aircraft type, it is the most common type of engine (as seen in Europe), or the best equivalent type of engine, for that aircraft type. Where several types of engine are associated with a particular aircraft type, the most-common type of engine is marked with "*". Please refer to Annex 4 'EUROCONTROL fuel burn and emissions inventory system' in the aviation chapter of the 'EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016' for a description of the method used to produce these data.

Enter aircraft and airport details here (using the drop-down menus in the dark blue boxes)

1) Type of aircraft: A320 (Airbus A-320) with 1CM008 engines

2) Airport
a) Country: United_Kingdom
b) Airport: LXGB (Gibraltar International Airport, GIBRALTAR)
c) Year: 2009

=>

See general engine details here:

Engine type code: 1CM008
Engine type name: CFM56-5-A1
Type of engine: Turbofan/turbojet

Number of engines: 2

See airport annual average taxi times here

Taxi out time (s): 712
Taxi in time (s): 324

=>

See engine fuel burn and emissions data here

	Engine thrust setting (% of maximum thrust)			
	7	30	85	100
Rate of fuel burn (kg/s/engine)	0.1011	0.2910	0.8620	1.051
Rate of emission of CO[2] (kg/s/engine)	0.001779	0.0007275	0.0007758	0.0009459
Rate of emission of HC[3] (kg/s/engine)	0.0001415	0.0001164	0.0001983	0.0002417
Rate of emission of NOX[4] (kg/s/engine)	0.0004044	0.002328	0.01690	0.02585

1 There are no turboprop-engined aircraft.
2 CO is carbon monoxide.
3 HC is unburnt hydrocarbons.
4 NOX are mono-nitrogen oxides (NO and NO_2)

See LTO cycle fuel burnt and emissions totals here

	LTO cycle total												
	Departure phase total						Arrival phase total						
	Taxi out			Take off	Climb out		Approach+landin	Taxi in					
	Average taxi-out time for the selected airport and	ICAO default taxi-out time (=1140 s)	Average taxi-out time for the 25 busiest airports in					Average taxi-in time for the selected airport and	ICAO default taxi-in time (=420 s)	Average taxi-in time for the 25 busiest airports in			
	[7% thrust]			[100% thrust]	[85% thrust]		[30% thrust]	[7% thrust]					
Mass of fuel burnt (kg)	143,941	230,500	165,020	88,284	227,568	459,793	139,680	65,518	84,324	78,870	205,198	664,991	Mass of fuel burnt (kg)
Mass of CO emitted (kg)	2,533	4,056	2,904	0,079	0,205	2,817	0,349	1,153	1,434	1,374	1,502	4,319	Mass of CO emitted (kg)
Mass of HC emitted (kg)	0,201	0,329	0,231	0,020	0,052	0,274	0,056	0,092	0,113	0,103	0,148	0,422	Mass of HC emitted (kg)
Mass of NOX emitted (kg)	0,576	0,922	0,660	2,171	4,462	7,209	1,117	0,262	0,340	0,312	1,380	8,588	Mass of NOX emitted (kg)
Mass of CO_2 emitted (kg)	453,415	726,400	519,037	278,095	716,839	1448,348	439,992	206,382	267,544	245,320	646,374	2094,723	Mass of CO2 emitted (kg)

Local Air Quality

Characterization factors of ReCiPe

Midpoint category	NO_x	SO_2	PM	CO	HC
Photochemical oxidant formation (ozone)	1	0,081	-	0,046	0,476
Particulate matter formation	0,22	0,20	1	-	-

... more details ...

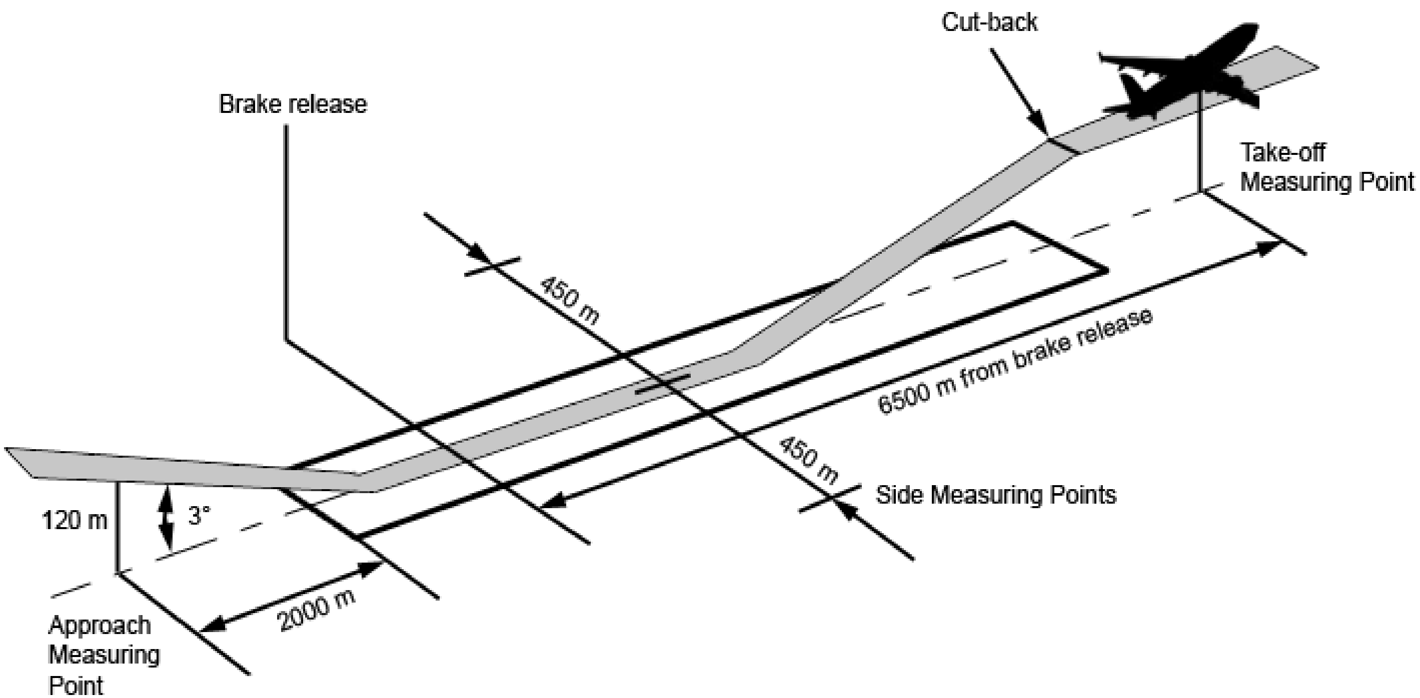
Ozone : $$NMVOC_{LTO} = 1 \cdot (NO_x)_{LTO} + 0{,}081 \cdot (SO_2)_{LTO} + 0{,}046 \cdot (CO)_{LTO} + 0{,}476 \cdot (HC)_{LTO}$$

PM : $$(PM_{equivalents})_{LTO} = 0{,}22 \cdot (NO_x)_{LTO} + 0{,}20 \cdot (SO_2)_{LTO} + 1 \cdot (PM)_{LTO}$$

$(PM)_{LTO}$ calculated from "smoke number"

But: Only NOx enters the overall rating

Noice



Reference points for the noise measurement

Noice

Noise Certification Database

Run | Init | All Data | Home | Help | More items

Manufacturer	All		
Commercial name	All		
Type	All		
Version	All		
Production aircraft	All		
Chapter/Stage	All		
Engine	All		
ID	All		
	Operator	X	Y
MTOM(kg)	All		
MLM(kg)	All		

Noise Certification Database

... more details ...

http://noisedb.stac.aviation-civile.gouv.fr

The Tool

General Information	
Aircraft type	A320
Airline	Aeroflot
Engine type	CFM56-5B4/P
Thrust (kN)	120,1
MTOW (kg)	75500
Amount of Seats	140

Travel Class Rating			
Class	Pitch (in)	Width (in)	Seats
Economy	31	18	120
premium economy	0	0	0
Business	38	21	20
First	0	0	0
Total amount of seats			140
S_{EC} (in²)			558
S_{PEC} (in²)			0
S_{BC} (in²)			798

Noise Rating Jets			
	Lateral	Flyover	Approach
Noise Level (EPNdB)	93,5	84,7	95,5
Noise Limit (EPNdB)	96,9	91,6	100,6
Level/Limit	0,964912281	0,924672489	0,949304175
Average	0,9463		
Normalized 0-1	0,7040		

... more details ...

Local Air Quality Rating	
Fuel LTO cycle (kg)	408
LTO NO_x (g)	5641
LTO SO_x (g)	81,6
LTO HC (g)	818
LTO CO (g)	4123
Smoke number T/O	5,4
Smoke number C/O	4,1
Smoke number App	0,2
Smoke number Idle	0,5
Fuel Flow T/O (kg/sec)	1,132
Fuel Flow C/O (kg/sec)	0,935
Fuel Flow App (kg/sec)	0,312

... more details ...

Fuel Consumption Rating	
R_1 (km)	3882
m_1 (kg)	19750
R_2 (km)	5200
m_2 (kg)	16125
dr (km)	1318
dm (kg)	3625
1/SAR (kg/km)	2,750379363
Fuel consumption (kg/km/seat)	0,01965
Normalized 0-1	0,1318

Summary & What Next?

Summary

- An "**Ecolabel for Aircraft**" has been **defined** (ISO, ICAO, ...)
- **Based on simplified Life Cycle Assessment (LCA)**
- **Fuel Consumption**
  - o Source of Information: Payload & Range Diagram (directly from OEM)
- **Global Warming**
- **Local Air Quality**
- **Noise**

What Next?

- Final check; final ideas; finalizing the method
- More Examples
- "Governing Body" ???
- To go "massive" public ???

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