HKIA long-term traffic and emission forecasts

Emissions Forecasting Report
Version 3

21 January 2014

Preface

- This Study was commissioned by Mott MacDonald (MM) on behalf of the Airport Authority of Hong Kong (AAHK)
- IATA Consulting is providing the present preliminary findings to the best of our understanding of the issues based on information and data from AAHK, IATA database and public as well as private sources.

Content

Summary of the main updates since the delivery of the Emissions Forecasting Report - Version 1

VERSION 2

- Schedules have been updated
- Changes have been introduced in the calculation of the emissions
  - In line with the outcomes of the HKIA survey, a reduced thrust has been considered for take-off, resulting in lower emissions
  - APU emissions have been added for 2012 and 2013
  - For aircraft with several possible engines, an average of emissions of each engine type has been considered
- Adjustments have been made to the emissions of future engines
  - Updates based on OEMs' feedback resulting in lower long-term emissions

VERSION 2.5

- **Interim version including APU emissions until 2038**
- **Update of take-off thrust to match ICAO value at 100%**

Updated

Summary of the main updates since the delivery of the Emissions Forecasting Report - Version 1 (cont'd)

VERSION 3

- Fleet evolutions have been fine-tuned to factor in additional inputs from the airlines
- Schedules have been fine-tuned
- Present report based on the constrained schedules v8

Content

Approach to Forecast Aircraft Emissions et HKIA

Main constituents of the HKIA emission forecast

Busy Day Schedule
- Number of ATM
- Aircraft sub-type
- Engine type
- APU type

Engine / APU Characteristics
- Fuel burn
- Gaseous emissions

Flight and ground Operations
- Time-in-mode
- APU usage policy

HKIA emissions

- Scope: Emissions are assessed during the landing and take-off (LTO) cycle below 3,000 feet
- Busy day schedules: come from HKIA constrained traffic forecast
- Engine/APU characteristics: Combine actual ICAO data and estimates for future engines made by IATA and reviewed by OEMs
- Flight and ground operations: Include standard as well as airline or airport specific assumptions
- HKIA emissions: forecast on a yearly basis from 2012 until 2038

Approach to Forecast Aircraft Emissions et HKIA
Data sources

- Certified engines: LTO fuel burn and emissions have been supplied from ICAO
- Future engines: A methodology has been developed by IATA based on OEM inputs to estimate the following characteristics:
  - Engine specifications (thrust, by-pass ratio)
  - Fuel burn
  - CO, HC and NOx emissions
- APU: Fuel burn and emissions have been supplied from FAA EDMS and various publications
- Regulation: Current and future regulation has been obtained from and discussed with ICAO

Approach to Forecast Aircraft Emissions et HKIA
Considerations for Deriving Future Engine Emissions

- Engine manufacturers (OEM) usually announce well in advance the new technologies they are developing or the improvement they are bringing to existing engines
- These announcements are not always specific, except for key design considerations that are driving engine development:
  - Thrust and by-pass ratio
  - Fuel efficiency targets
  - Emission reduction, in particular for NOx where rigorous stringency levels are being enforced by ICAO's Committee on Aviation Environmental Protection (CAEP) on engine manufacturers
- These high-level assumptions have been essential to estimate future emissions

Approach to Forecast Aircraft Emissions et HKIA

Methodology for Deriving Future Engine Emissions

1 Future Engine Specifications

- Collection of information on future regulation
- Collection of information on future technologies
- Collection of available information on the main engine specifications
  - Thrust
  - Bypass ratio
  - Fuel efficiency
  - NOx emission reduction

2 Engine Comparison Baseline

- Identification of a baseline engine
  - for which the ICAO emissions profile exists
  - from which the new engine is being or will be developed
- The new engine will have a similar rated output to the baseline engine, albeit with an improved bypass ratio

3 Future Emissions Estimates

- Assumed publicly announced fuel efficiency improvements will be met by OEMS. These enabled computation of fuel flow in the LTO cycle
- Assumed the medium and long-term CAEP stringency goals will be met by OEMs.
- Estimates for HC and CO emissions based on the most advanced combustor technology

4 Validation with OEMs

- Future estimates for the LTO total emissions have been submitted to the OEMs for their review

Note: Three major OEM manufacturers have been consulted (GE, Pratt & Whitney and Rolls Royce). Two of them provided their feedback.

Content

New aircraft will be introduced within the forecasting horizon triggering the introduction of new engines

Example of New Aircraft	Estimated Entry In-Service at HKIA	Engine Type	Comments
Airbus A350-900	Late 2015	Trent XWB-79	▪ Only one selected engine so far
Airbus A350-1000	Late 2017	Trent XWB-97	▪ Rolls Royce given the monopoly on this aircraft sub-type
Airbus A320neo	2018	CFMI Leap-1A PW1127G	
Boeing 777-9X	2020	GE9X9	▪ GE given the monopoly on this aircraft
Boeing 737-MAX	2022	CFMI Leap-1B	▪ CFMI given the monopoly on this aircraft
Airbus A350 Freighter	2025	Trent XWB-84	▪ Only one selected engine so far
Airbus A380neo	2026	GEnx-1B70 Trent XWB-74 RR Advance 3	

Future Engine Emissions
Historical trends

- Engine manufacturers (OEM) are committed to improve their engine performance, improve fuel efficiency and decrease emissions
  - Regulation imposes more and more stringent standards for engine emissions
  - Fuel savings need to be achieved in order to compensate for the high price of oil and hence improve airlines' economics

- Engine manufacturers work along two ways to satisfy regulation and airlines
  - Continuous improvement: OEM optimize their engines all throughout their life cycle. New models are released every 2-4 years with optimized performance resulting in **incremental gains over the first 10 years**
  - Technology breakthrough: New engine families are designed to meet new mission or regulation challenges. Performance is drastically improved by the use of new technologies. Successful engine families usually last 25 to 30 years.

Content

Aircraft engines are required to meet the environmental certification standards adopted by the Council of ICAO

Emissions

- Limits for NOx, CO, HC and smoke emissions
- Gradual tightening of the NOx emissions standards
- *Limits for CO_2 emissions under development*
- *Limits for non-volatile PM emissions under development*
- *No ICAO standards related to aircraft APU at present*

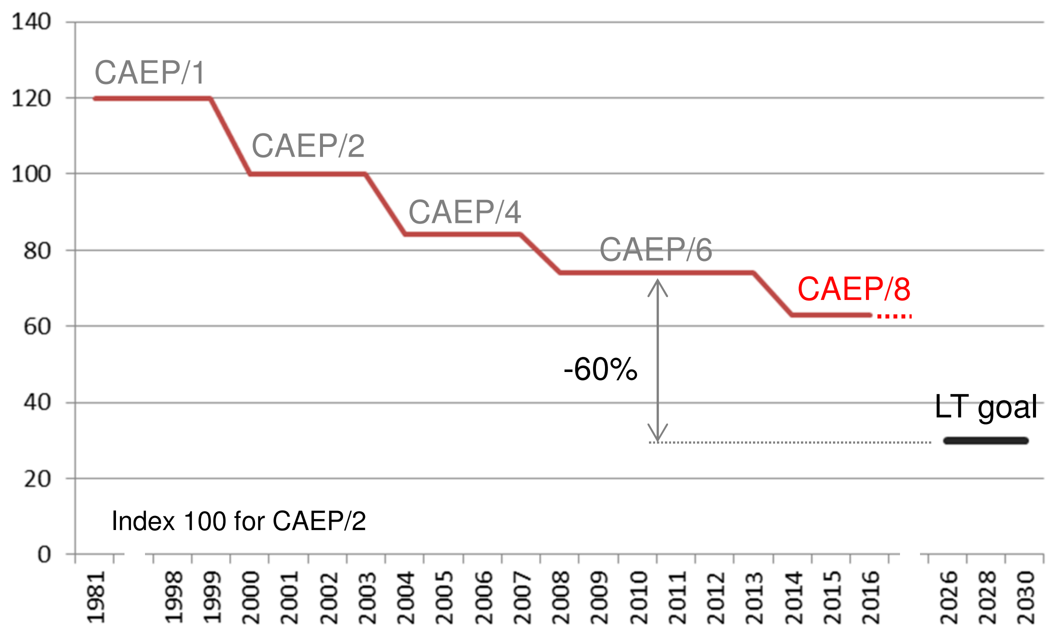
Noise

- Noise certification standards for sub-sonic aircraft

Regulatory Framework

ICAO regulation keeps tightening the limits for NOx emissions

CAEP NOx stringency levels relative to CAEP/2

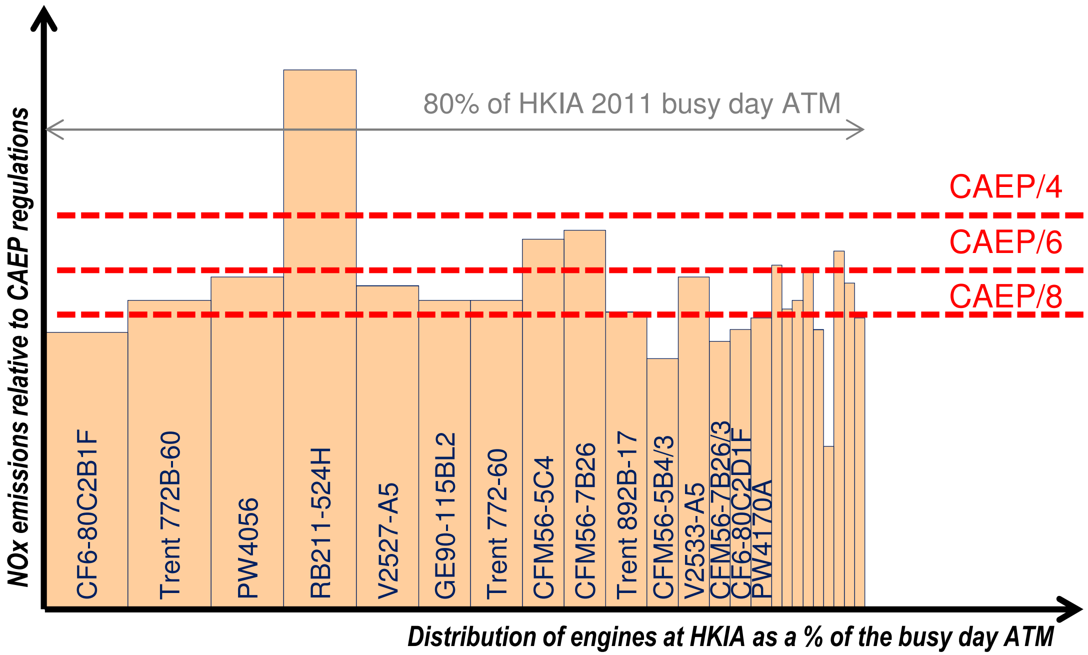


- CAEP regulations define in particular:
  - NOx maximum emissions for new engines to be certified
  - Production cut-off dates for old engine above the NOx maximum
- CAEP doesn't impose phasing out the aircraft with engines not meeting the standards
- CAEP/8 enforced as of 31/12/2013
- Since the NOx standard was adopted in 1981, it has been made 50% more stringent
- The long-term ICAO objective for 2026 is to be at 60% (+/- 5%) below CAEP/6

Source: ICAO CAEP

With regard to NOx emissions, current situation at HKIA shows a sizeable room for improvement

Comparison of HKIA 2011 busy day ATM with the CAEP NOx stringency levels

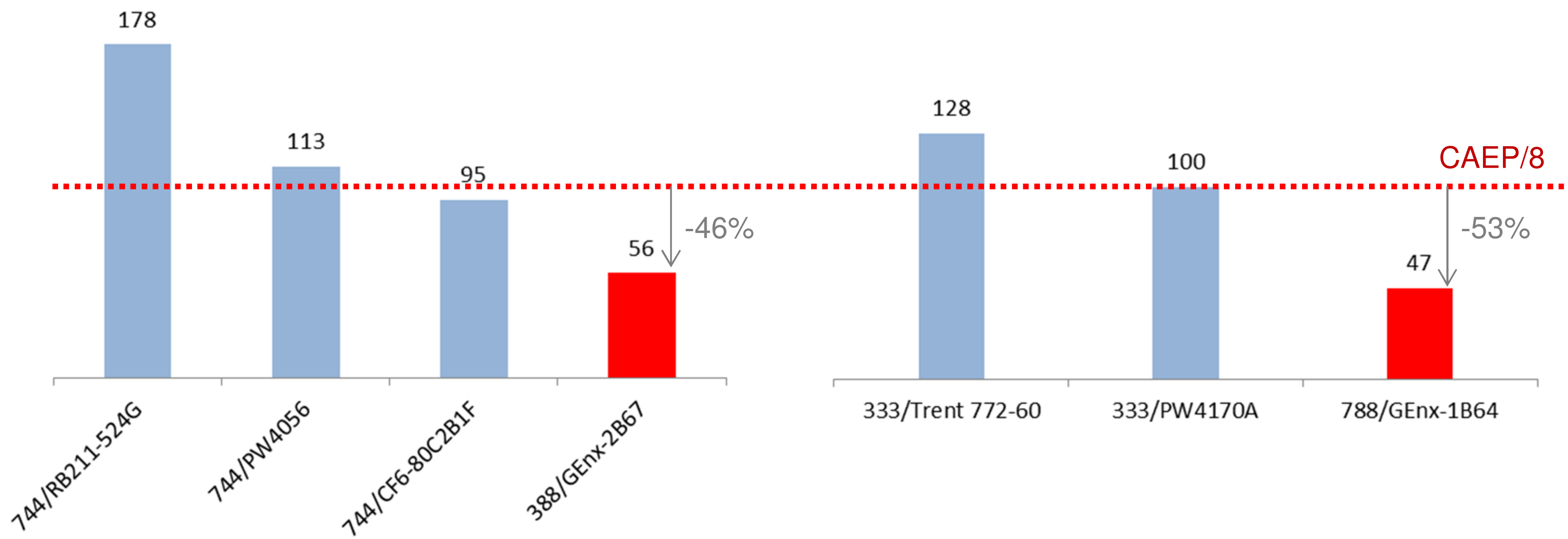


Source: ICAO engine emission database

- On average, HKIA 2011 busy day ATM engine NOx emissions were:
  - 3% below the CAEP/6 standards
  - 13% above CAEP/8
- From this analysis we conclude that the current engines operating at HKIA have maxed out with respect to current CAEP NOx standards and will not meet the standards imposed to new engines
- This means that HKIA will fully benefit from the introduction of new aircraft / engines that should stand between 30% to 50% below CAEP/8 requirements

Modern aircraft being deployed at HKIA illustrate the potential for a decrease in the NOx emissions

Comparison of selected aircraft / engine combinations operating at HKIA against CAEP/8 NOx stringency levels



Source: ICAO engine emission database

Content

With regard to continuous improvement on engines already in-service, IATA considered the following assumptions

Emission	Evolution	Effect duration	Comments
NOx	-0.5% p.a.	10 years after entry-in-service	
CO_2	-0.5% p.a.	10 years after entry-in-service	Reduction obtained through an improvement of the fuel flow
CO	0	N/A	
HC	0	N/A	

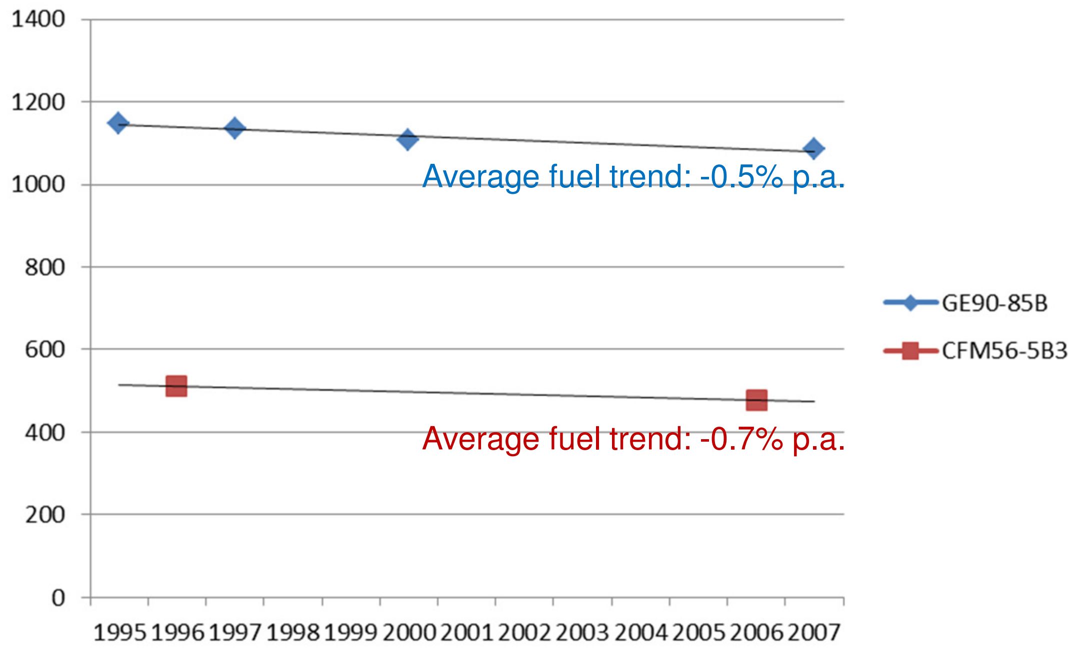
Source: IATA analysis and estimates

Note: Justifications are detailed in the next pages

Continuous improvement

An annual 0.5% decrease in fuel flow is observed across engine models

LTO Fuel Consumption for successive engine models
in kg



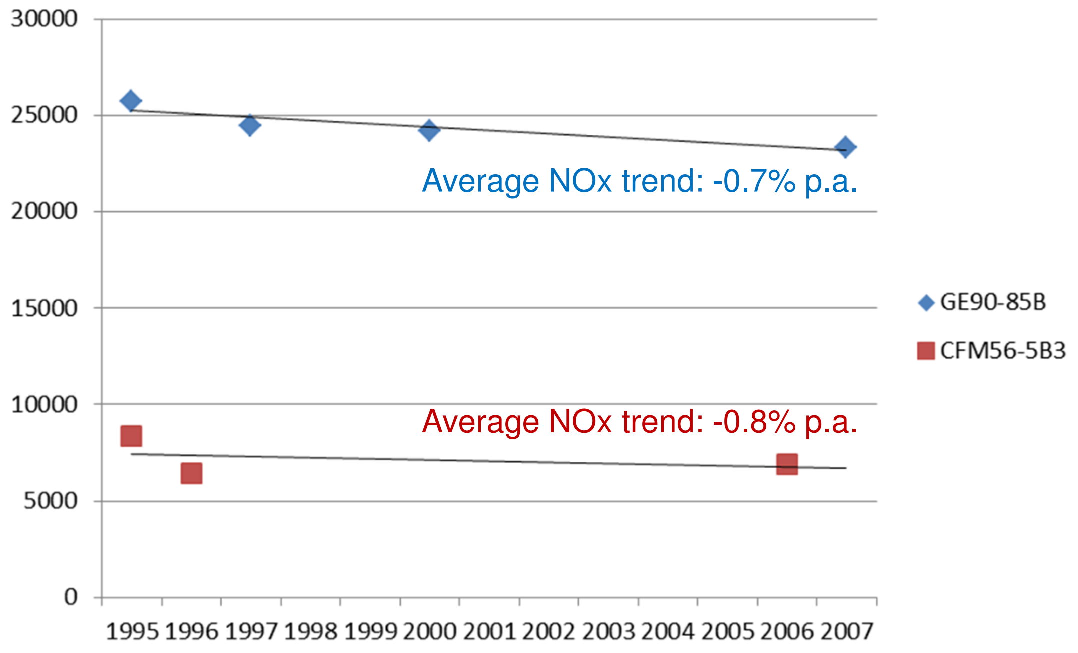
Source: ICAO engine emission database

- Between 1995 and 2007, four successive models of the GE90-85B have been released resulting in an average decrease of 0.5% p.a.
- Over the same period the CFM56-5B3 engine achieved a 0.7% decrease in fuel consumption
- **For the purpose of forecasting emissions, IATA have considered a steady improvement of fuel consumption of 0.5% p.a.as a result of continuous improvement. This decrease is applied for 10 years following the engine entry-in-service**

Continuous improvement

Similarly an steady decrease in NOx is observed across engine models

LTO NOx emissions for successive engine models
in kg



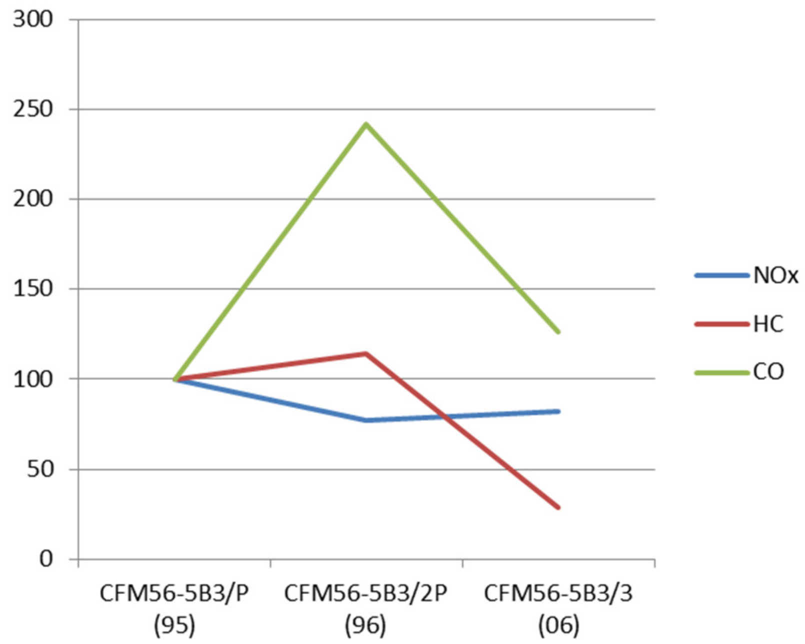
Source: ICAO engine emission database

- Between 1995 and 2007, four successive models of the GE90-85B have been released resulting in an average 0.7% reduction in NOx emissions
- The CFM56-5B3 family showed an average annual decrease in NOx emissions of 0.8%
- **For the purpose of forecasting emissions, IATA have considered a 0.5% annual decrease of NOx emissions of 0.5%. This decrease is applied for 10 years following the engine entry-in-service and factored in through the reduction of the fuel flow.**

Continuous improvement

No clear historical trend could be observed for HC and CO emissions

LTO NOx, HC and CO emissions for successive CFM56-5B3 models
in index



Source: ICAO engine emission database

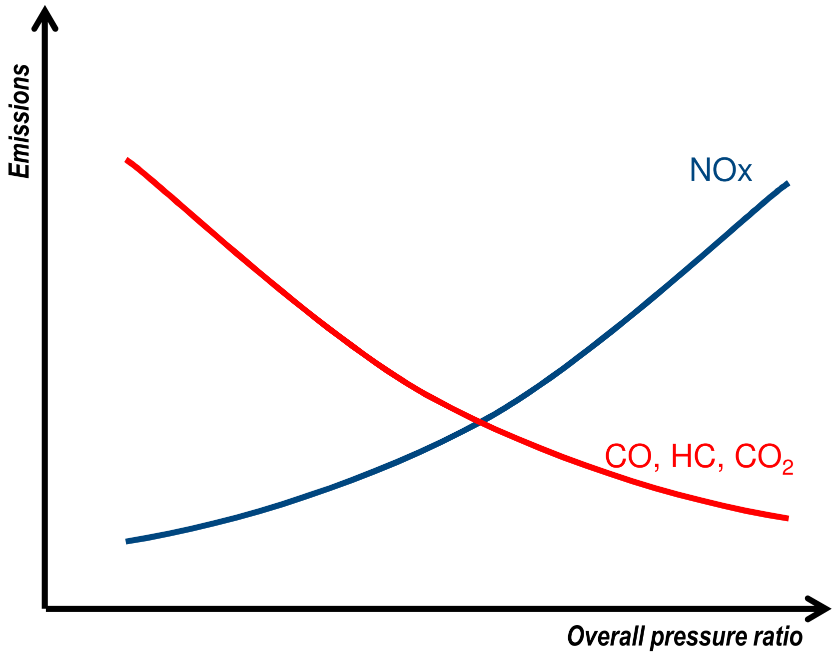
- As illustrated by the CFM56-5B, NOx emissions and HC/CO emissions often follow opposite trends
  - A decrease in NOx may have a negative impact on CO and HC
  - A decrease in HC and CO may trigger an increase in NOx emissions
- On the other hand the decrease in fuel consumption drives CO and HC emissions down
- Engine manufacturers are reportedly working on new combustor technologies to improve the HC/CO emissions without deteriorating the NOx emissions
- **For the purpose of forecasting HC and CO emissions, IATA in consultation with OEMs assumed combustor technology yielding lowest emission indices for the new engines**

Content

2 Emissions of Future Engines

Technologies are being developed to further reduce NOx emissions without compromising the other gaseous emissions

CO_2 / NOx trade



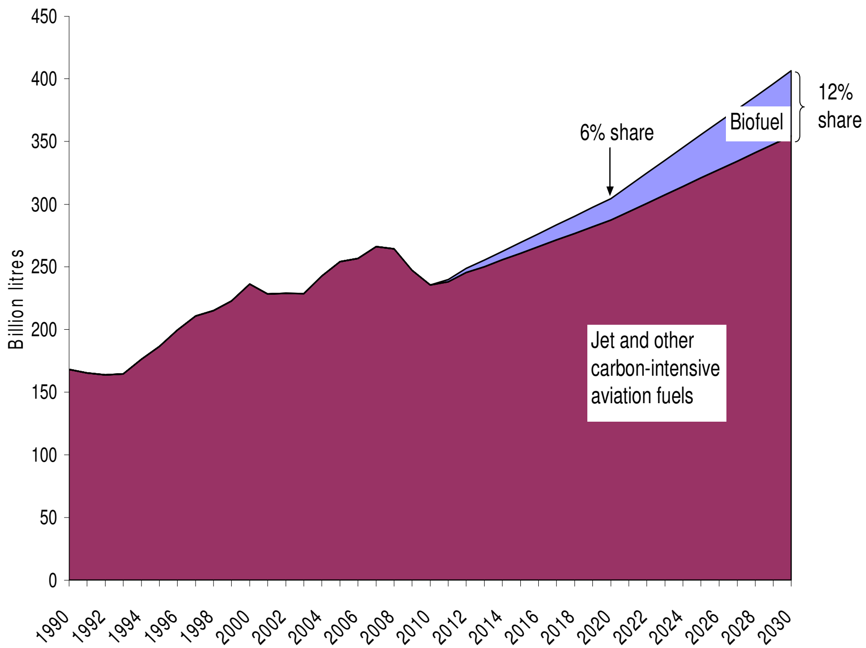
Source: General Electric

- Higher engine pressure ratio and by-pass ratio reduce CO, HC and CO_2 emissions
- Higher pressure ratio requires higher flame temperature and therefore increases NOx formation
- CFMI, RR and GE are developing new designs for combustors to meet ICAO long-term NOx emission goal without increasing the other gaseous emissions
- Advanced combustors can be categorized into two broad types:
  - RQL (Rich burn, Quick quench, Lean burn) that controls Nox production through adjustment of the air to fuel ratio
  - Staged-DLI (Direct Lean Injection) that controls NOx by staging the combustion
- These technologies allow the elimination of unburnt HC from the exhaust stream

Content

Alternative Fuels
Assumptions

Commercial fuel burn
in billion liters

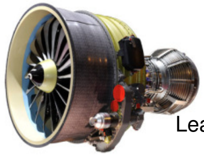


Source: EASA

- Alternative fuels have been successfully tested and are already in use on a limited scale on certain commercial routes.
- LTO emissions in terms of NOx , HC and CO will not be significantly impacted. Engine certification data with alternative fuels not available
- Smoke will reduce by 50% on account of lower aromatics content
- The industry is aiming at replacing 6% of current fossil fuel by 2020 growing to 12% by 2030. (EASA, 2011). The IEA forecasts a 30% substitution by 2050
- Expect a 5-10% use of alternative fuels at HKIA by 2038
- However, in the absence of a concrete plan for HKIA to offer such alternative fuels, the potential reduction was not factored in our baseline emission forecast

Content

New Engines
Narrow-Body – Leap 1A



LEAP-1A Rated Output: 124.7 kN Bypass Ratio: 10
Based on **CFM56-5B**
Certification: 2015 EIS: **2016**

Mode	Power setting	Time	Fuel Flow	HC	CO	Nox	Smoke No
T/O	100	0.7	0.971	0.02	0.36	17.4	7.32
Climb out	85	2.2	0.798	0.02	1.55	14.11	6.55
Approach	30	4	0.269	0.08	4.18	7.16	1.15
Idle	7	26	0.087	1.34	26.1	3.47	1.52
LTO Total			346	190	3990	3129	

- LEAP-1A is the planned replacement engine for the CFM56-5B
- CFM56-5B4 variant has the closest rated output to the estimated LEAP-1A output at 120kN.
- Fuel LTO was obtained by factoring in a 15% saving on the LTO Fuel flow of the most recent CFM56-5B (CFM56-5B4/3) (Source CFMI)
- NOx indices were calculated to match an LTO NOx value equal to 50% of CAEP/6 regulations. LEAP also includes the only lean burning combustor (TAPS) in aviation that will reduce total engine NOx emissions 50%.
- The HC and CO indices were taken from the GEnx-1B54 which shares the same improved combustor technology (TAPS).as the LEAP-1A

Source: IATA estimates, ICAO emission database, OEM inputs

New Engines
Narrow-Body – Leap 1B


Leap-1B


B737MAX8

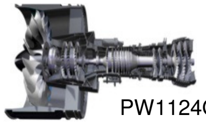
LEAP-1B Rated Output: 106.9kN By-pass Ratio: 10
Based on **CFM56-7B24**
Certification: 2016 EIS: **2017**

Mode	Power setting	Time	Fuel Flow	HC	CO	Nox	Smoke No.
T/O	100	0.7	0.935	0.02	0.36	15.16	9.38
Climb out	85	2.2	0.765	0.02	1.55	12.16	7.37
Approach	30	4	0.255	0.08	4.18	6.83	1.23
Idle	7	26	0.085	1.34	26.1	3.19	1.23
LTO Total			338	185	3887	2664	

- LEAP-1B is the planned replacement engine for the CFM56-7B estimated at 107kN; It is the exclusive powerplant for the new Boeing 737 MAX aircraft family
- LTO Fuel Flow was derived using 15% reduction in LTO fuel from the most recent CFM56-7B24E (2005).(Source CFMI)
- NOx indices were calculated to match an LTO NOx value equal to 50% of CAEP/6 regulations. LEAP also includes the only lean burning combustor (TAPS) in aviation that will reduce total engine NOx emissions 50%.
- The HC and CO indices were taken from the GEnx-1B54 which shares the same improved combustor technology (TAPS).as the LEAP-1A

Source: IATA estimates, ICAO emission database, OEM inputs

New Engines
Narrow-Body – PW1124G


PW1124G


A319neo

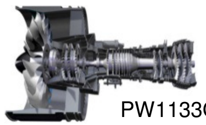
PW1124G Rated Output: 106.7 kN Bypass Ratio: 12
Based on **PW6124A**
Certification: 2014 EIS: **2015**

Mode	Power setting	Time	Fuel Flow	HC	CO	Nox	Smoke No
T/O	100	0.7	0.993	0	0.68	14.12	5.16
Climb out	85	2.2	0.798	0.002	0.81	11.2	4.71
Approach	30	4	0.276	0.001	3.69	5.73	1.32
Idle	7	26	0.097	0.002	25.19	2.73	1.51
LTO Total			365	1	4169	2561	

- PW has one current engine of the same thrust category PW6124A
- PWC announced an increase in fuel efficiency by 15% over current engines in the market
- Fuel LTO was obtained by factoring in a 15% saving on the LTO Fuel flow of the PW6124A
- PWC targets a reduction of NOx emissions by 50% over the CAEP/6 standards; NOx indices were estimated accordingly
- HC and CO index for the respective time in modes were taken to be the same as PW6124A resulting in a lower LTO total for HC and CO because of the reduced fuel flow

Source: IATA estimates, ICAO emission database, OEM inputs

New Engines
Narrow-Body – PW1133G



PW1133G

A321neo

PW1133G Rated Output: 147 kN Bypass Ratio: 12
Based on **CFM56-5B3**
Certification: 2014 EIS: **2015**

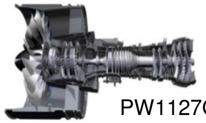
Mode	Power setting	Time	Fuel Flow	HC	CO	Nox	Smoke No
T/O	100	0.7	1.243	0.05	0.54	22.75	7.06
Climb out	85	2.2	0.98	0.02	0.25	16.08	6.27
Approach	30	4	0.314	0.05	2.14	7.05	0.93
Idle	7	26	0.096	1.1	25.59	3.39	1.63
LTO Total			406	174	4054	4307	

- PWC announced an increase in fuel efficiency by 15% and a NOx reduction by 50% over current engines in the market
- A comparable current engine on the market was found to be CFM56-5B3
- A reduction of 15% LTO fuel on CFM56-5B3 was applied to get the LTO fuel for PW1133G
- NOx was derived from the CFM56-5B3 to obtain 50% CAEP/6 which = (6875x50)/80= 4307 g
- HC and CO index for the respective time in modes were taken to be the same as CFM56-5B3 resulting in a lower LTO total for HC and CO because of the reduced fuel flow

Source: IATA estimates, ICAO emission database, OEM inputs

New Engines

Narrow-Body – PW1127G


PW1127G


A320neo

PW1133G Rated Output: 124.7 kN Bypass Ratio: 12

Based on **PW1124G and PW1133G**

Certification: 2014 EIS: **2015**

Mode	Power setting	Time	Fuel Flow	HC	CO	Nox	Smoke No
T/O	100	0.7	1.076	0.02	0.67	17.12	7.32
Climb out	85	2.2	0.858	0.007	0.81	13.14	6.55
Approach	30	4	0.288	0.002	4.63	6.29	1.15
Idle	7	26	0.097	0.36	25.78	2.94	1.52
LTO Total			378	56	4343	3142	

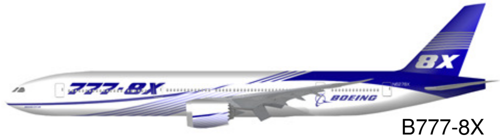
- PWC announced an increase in fuel efficiency by 15% and a NOx reduction by 50% over current engines in the market
- As PW does not currently have a comparable engine, the emissions for PW1127G were deducted by trend analysis from the two other PW1100G engines

Source: IATA estimates, ICAO emission database, OEM inputs

New Engines

Wide-Body – GE9X @ 392.4kN

GE90-115B



B777-8X

GE9X 777-8x Rated Output :392.4 kN Bypass Ratio: 10
Based on **GE90-85B and GEnX-1B70**
Certification: 2018 EIS: **2019**

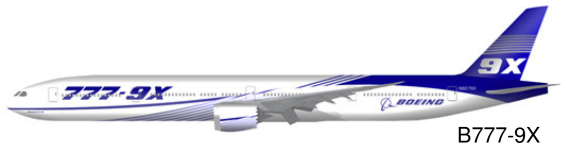
Mode	Power setting	Time	Fuel Flow	HC	CO	Nox	Smoke No.
T/O	100	0.7	2.818	0.02	0.17	37.9	1.71
Climb out	85	2.2	2.298	0.02	0.24	30.3	1.24
Approach	30	4	0.724	0.06	2.49	12.4	1.53
Idle	7	26	0.244	0.63	19.68	4.42	3.77
LTO Total			976	259	8017	17513	

Source: IATA estimates, ICAO emission database, OEM inputs

- GE9X derives from the GE90 family. The forecasted rated output for the 777-8X is of 390-400kN
- GE90-85B was used as a proxy as it is the closest variant in the current GE90 family
- Fuel Flow was calculated from a 10% reduction on the LTO Fuel of the latest certified GE90-85B (2007) engine (source GE)
- It is also expected that GE9X will generate 25% less NOx due to the combustion temperature being lower compared to GE90 (source GE); the LTO NOx of the latest GE90-85 B (2007) was reduced by 25% and the emissions indices were scaled down (across the modes) accordingly.
- GE states that the GE9X will feature an improvement of the TAPS combustor technology currently found in the GEnX series
- The HC and CO emission indexes for GE9X were taken from the GEnX-1B70 engine because the latter will have a similar/improved combustor technology

New Engines
Wide-Body – GE9X @ 431kN


GE90-115B



B777-9X

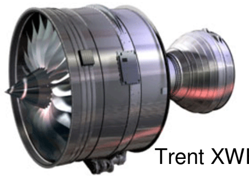
GE9X 777-9x Rated Output : 431 kN Bypass Ratio: 10
Based on **GE90-94B** and **GEnX-1B70**
Certification: 2018 EIS: **2019**

Mode	Power setting	Time	Fuel Flow	HC	CO	Nox	Smoke No.
T/O	100	0.7	3.161	0.02	0.17	41.8	3.37
Climb out	85	2.2	2.547	0.02	0.24	33.8	1.96
Approach	30	4	0.788	0.06	2.49	13.7	2.07
Idle	7	26	0.256	0.63	19.68	4.76	1.66
LTO Total			1058	272	8434	21405	

- GE9X derives from the GE90 family. The forecasted rated output for the 777-9X is of 430-440kN
- GE90-94B was used as a proxy as it is the closest variant in the current GE90 family
- Fuel Flow was calculated from a 10% reduction on the LTO Fuel of the latest certified GE90-94B (2007) engine (source GE)
- It is also expected that GE9X will generate 25% less NOx due to the combustion temperature being lower compared to GE90 (source GE); the LTO NOx of the latest GE90-94 B (2007) was reduced by 25% and the emissions indices were scaled down (across the modes) accordingly.
- GE states that the GE9X will feature an improvement of the TAPS combustor technology currently found in the GEnX series
- The HC and CO emission indexes for GE9X were taken from the GEnX-1B70 engine because the latter will have a similar/improved combustor technology

Source: IATA estimates, ICAO emission database, OEM inputs

New Engines
Wide-Body – Trent XWB-75


Trent XWB-74


A350-800

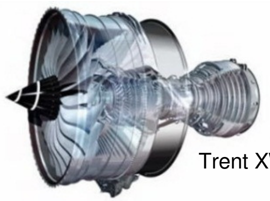
RR Trent XWB-75 A 350-800 Rated Output: 334kN
Comparable to **Trent 970** & **Trent 1000-C** Bypass Ratio: 9.3
Certification: 2013 EIS: **2015**
Formerly Trent XWB-74

Mode	Power setting	Time	Fuel Flow	HC	CO	Nox	Smoke No.
T/O	100	0.7	2.21	0	0.51	35.06	3
Climb out	85	2.2	1.87	0	0.48	19.11	3.8
Approach	30	4	0.595	0	0.68	9.71	3.1
Idle	7	26	0.255	0.04	7.66	4.37	0.6
LTO Total			833	16	3310	11095	

- Rolls Royce have not specified the reduction in fuel consumption and emissions the Trent XWB-75 will bring
- RR Trent XWB is announced to be an improvement on the Trent 900 and 1000 series; Trent 970-84 and Trent-1000-C were found to be comparable engines
- Similar engines to enter in service in a few years are announced with a 15% reduction in fuel consumption and NOx figures to match 50% of CAEP/6 standards
- 15% Fuel reduction on the Trent 970-84 was taken for the Trent XWB-75. (Trent-1000C entered into service after the 15% fuel reduction statement was made)
- NOx LTO emissions were calculated to match 50% CAEP/6 Regulations
- The HC and CO emissions indices are taken from the Trent 1000-C as recommended by Rolls Royce

Source: IATA estimates, ICAO emission database, OEM inputs

New Engines
Wide-Body – Trent XWB-97



Trent XWB-97

A350-1000

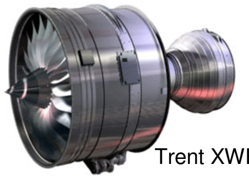
RR Trent XWB-97 A350-1000 Rated Output: 431kN
Based on the **GE90-94B** Bypass Ratio: 9.3
Certification: 2015 EIS: **2017**

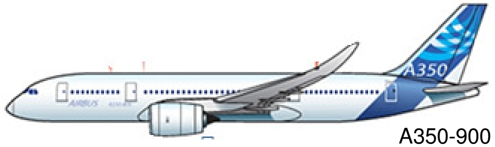
Mode	Power setting	Time	Fuel Flow	HC	CO	Nox	Smoke No.
T/O	100	0.7	3.161	0	0.51	41.8	3
Climb out	85	2.2	2.547	0	0.48	33.8	3.8
Approach	30	4	0.788	0	0.68	13.7	3.1
Idle	7	26	0.256	0.04	7.66	4.76	0.6
LTO Total			1058	16	3417	21405	

- Rolls Royce have not specified the reduction in fuel consumption and emissions the Trent XWB-75 will bring
- Similar engines to enter in service in a few years are announced with a 15% reduction in fuel consumption and 25% reduction in NOx over current engines
- A similar engine on the market was found to be the GE90-94B (also used as a comparable for GE9X)
- LTO Fuel flow for Trent XWB-97 was calculated based on a 10% reduction from the LTO Fuel flow of the GE90-94B
- LTO Nox figures were based on a 25% reduction on Nox figures of the GE90-94B
- The HC and CO emissions indices were taken from the Trent 1000-C as recommended by Rolls Royce. Their new lean burn combustor technology to be incorporated in the XWB-97 will be an improvement on the rich burn combustor technology found in the Trent 1000 series

Source: IATA estimates, ICAO emission database, OEM inputs

New Engines
Wide-Body – Trent XWB-79





RR Trent XWB-79 A350-900 Rated Output: 351kN

Based on the **Trent XWB-75** & **XWB-97** Bypass Ratio: 9.3

Certification: 2015 EIS: **2017**

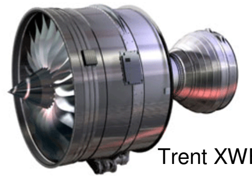
Formerly Trent XWB-83

Mode	Power setting	Time	Fuel Flow	HC	CO	Nox	Smoke No.
T/O	100	0.7	2.38	0	0.51	36.27	3.37
Climb out	85	2.2	1.99	0	0.48	21.75	1.96
Approach	30	4	0.629	0	0.68	10.42	2.07
Idle	7	26	0.255	0.04	7.66	4.44	1.66
LTO Total			874	16	3327	12678	

- Having calculated the LTO emissions and fuel flow for the RR Trent XWB-75 and RR Trent XWB-97, a trend based on rated output was used to derive the LTO totals for XWB-79

Source: IATA estimates, ICAO emission database, OEM inputs

New Engines
Wide-Body – Trent XWB-84


Trent XWB-74

RR Trent XWB-84 A350F Rated Output: 374kN
Based on the **Trent XWB-75** & **XWB-97** Bypass Ratio: 9.3
Certification: 2015 EIS: **2017**
Formerly Trent XWB-94

Mode	Power setting	Time	Fuel Flow	HC	CO	Nox	Smoke No.
T/O	100	0.7	2.599	0	0.51	37.82	3.37
Climb out	85	2.2	2.15	0	0.48	25.13	1.96
Approach	30	4	0.674	0	0.68	11.34	2.07
Idle	7	26	0.255	0.04	7.66	4.53	1.66
LTO Total			925	16	3349	14897	

- Having calculated the LTO emissions and fuel flow for the RR Trent XWB-75 and RR Trent XWB-97, a trend based on rated output was used to derive the LTO totals for XWB-84

Source: IATA estimates, ICAO emission database, OEM inputs

New Engines

Wide-Body – Rolls Royce Advance3

Trent-1000

No specified aircraft

RR Advance 3 250-seat Rated Output: 334.7kN

Based on the **Trent-1000C** Bypass Ratio: ~15

Certification: 2017 EIS: **2018**

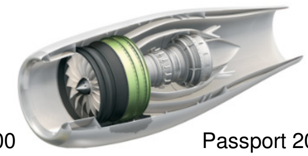
Mode	Power setting	Time	Fuel Flow	HC	CO	Nox	Smoke No.
T/O	100	0.7	2.132	0	0.51	41.3	3.6
Climb out	85	2.2	1.741	0	0.48	31.1	4.3
Approach	30	4	0.567	0	0.68	10.52	2.8
Idle	7	26	0.209	0.04	7.66	4.27	0.7
LTO Total			781	13	2746	13670	

Source: IATA estimates, ICAO emission database, OEM inputs

- Advance3 planned to deliver 15-20% lower fuel consumption, 10-20% less CO2, 50% lower emissions over current engines
- Advance3 is based around the Trent 1000 Environmentally Friendly Engine core technology demonstrator
- A reduction of 15% LTO Fuel was made on the Trent 1000-C to estimate LTO fuel for the Advance3
- NOx was derived from the trent-1000 to equal 50% of CAEP6/ today's standards
- As Bypass ratio and pressure ratio is expected to be higher than the Trent-1000, it was safe to assume that HC and CO would be same or lower
- However, the LTO values for the HC and CO emissions are lower than the Trent 1000-C because of the 15% in fuel reduction

New Engines
Small Jets – GE Passport 20 & PW800


PW800


Passport 20


Bombardier Global 8000

GE Passport 20 and PW800 Rated Outputs: 72.06kN
Based on Rolls Royce **BR725** Bypass Ratio: 10
Certification: 2015 EIS: **2016**

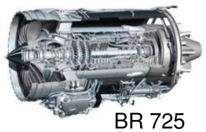
Mode	Power setting	Time	Fuel Flow	HC	CO	NOx	Smoke No.
T/O	100	0.7	0.684	0	0.293	12.37	4.26
Climb out	85	2.2	0.566	0	0.232	10.34	4.42
Approach	30	4	0.195	0	4.96	6.24	0
Idle	7	26	0.08	2.75	27.34	2.81	0.1
LTO Total			275	343	3670	1770	

- GE compares its new Passport 20 engine to the already existing Rolls Royce BR 725 so the latter was taken as a baseline
- GE states passport 20 will provide 8% fuel savings over BR725
- Emissions for the Passport 20 are not specified however Passport 20 is expected to have a similar design to PW800; rated outputs are similar
- PWC states that PW800 will exceed ICAO CAEP/6 standards for NOx by 50% and CO by 35%. Passport 20 was assumed to be on par.
- Same HC and CO indexes were taken from the BR725 for the Passport 20, however the LTO totals for HC and CO are lower due to the reduction in specific fuel flow indexes

Source: IATA estimates, ICAO emission database, OEM inputs

New Engines

Small Jets – Rolls Royce Advance2



BR 725

No specified aircraft

RR Advance 2 150-seat Rated Output: 72kN
Based on the **BR 725** Bypass Ratio: NC
Certification: 2017 EIS: **2018**

Mode	Power setting	Time	Fuel Flow	HC	CO	Nox	Smoke No.
T/O	100	0.7	0.6	0	0.4	12.37	4.26
Climb out	85	2.2	0.497	0	0.3	10.34	4.42
Approach	30	4	0.17	0	6.61	6.24	0
Idle	7	26	0.072	2.75	41	2.81	0.1
LTO Total			244	309	4904	1560	

- Advance2 is aimed at the lower thrust segment of the market, 60kN-112kN. RR currently has the BR725 engine in the 72kN category, therefore this engine was taken as a baseline for the planned Advance2 engine
- Based on RR stated, Advance2 is designed to reduce fuel-burn by 15% compared to similar engines in service and to achieve NOx emission levels up to 60% lower than current CAEP/6 regulations.
- LTO Fuel for Advance2 was calculated by taking a 15% reduction in fuel flow from BR725. An additional 5% reduction was factored in on account of current improvement work on BR 725 as per RR.
- LTO Nox for advance2 was calculated to be 50% of CAEP/6 regulations.
- No specific reduction in HC or CO emissions were stated, therefore the same indices as BR725 for each specific mode was taken for the Advance2

Source: IATA estimates, GE, ICAO emission database, OEM inputs

Content

Updated

Engine Emissions Forecast
Assumptions used to assess future engine emissions

- Schedules: Optimized constrained schedules V8
- Emissions for current engines
  - Sourced from the ICAO emissions database
  - When multiple versions (hence emission indices) were available for a same model of engine, IATA has selected the version that was still in production (if possible) and with the most recent date of certification.
- Future engine emissions
  - Estimated by IATA
  - Taking into consideration the inputs of the OEMs (see section 2.6)
- Continuous improvement: in line with previous trends (see section 2.3)

Engine Emissions Forecast

Assumptions used to assess future engine emissions (cont'd)

- Time-in mode considered constant throughout the forecasting horizon at the ICAO specified thrust levels
  - Take-Off: 0.7 min
  - Climb-Out: 2.2 min
  - Approach: 4 min
  - Taxi/Idle: In: 7 min; Out: 19 min
- Fuel sulfur concentration as per ICAO
- For aircraft with several engine options, an average of the emissions of each engine has been considered
- No-single engine taxi-in and taxi-out
- Partial introduction of alternative fuels not taken into account

Updated

APU Emissions Forecast
Assumptions used to assess future APU emissions

- Schedules: Optimized constrained schedules V8
- Emissions for current APU
  - Sourced from FAA EDMS and various publications
- Future APU emissions
  - Estimated by IATA based on press releases from OEMs
  - For future aircraft with no designated APU (A320neo, 737MAX, B777X, A380neo and future small jets), IATA has picked the most recent APU models matching the type of aircraft
- Continuous improvement: none

APU Emissions Forecast
Assumptions used to assess future APU emissions (cont'd)

- Time-in mode as per the results of the survey of HKIA Airlines for 2012 and 2013
  - Start-up (no load):
    - 2 minutes for Passenger aircraft
    - 3 minutes for Freighters
  - Aircraft preparation, crew and passenger boarding (normal running):
    - 25 minutes for Passenger aircraft
    - 28 minutes for Freighters
  - Main engine start (high load): 5 minutes for Passenger aircraft and Freighters
  - Passenger disembarkation and aircraft shutdown:
    - 7 minutes for Passenger aircraft
    - 12 minutes for Freighters

Source: HKIA Airlines survey administered by IATA on behalf of AAHK, November 2012

APU Emissions Forecast
Assumptions used to assess future APU emissions (cont'd)

- Time-in mode for 2014 and beyond
  - As of 2014 HKIA gates will be equipped with Ground Power Units (GPU), Air Conditioning equipment (ACU). Air Start Units (ASU) won't be available at the gates
  - At gate parking stands, APU will be used to start the aircraft engines (and only for that) for an estimated five minutes before being shut down
  - At remote parking stands, it is assumed that mobile GPU and ACU will be used. Similarly to the gate parking stands, APU will be used to start up the engine for about 5 minutes
  - The above assumptions apply to both passenger aircraft and freighters

Emissions Forecast

Emissions calculation methodology for NOx, CO and HC

- To determine the NOx, CO or HC emissions, the following formula is used

$$Eij = \Sigma\ (TIMjk * 60) * (FFjk) * (Eiijk) * (Nej)$$

- where:
  - Eij = total emissions of pollutant i (e.g. NOx, CO or HC), in grams, produced by aircraft type j for one LTO cycle;
  - Eiijk = emission index for pollutant i (e.g. NOx, CO or HC), in grams per pollutant per kilogram of fuel(g/kg of fuel), in mode k (e.g. take-off, climb-out, idle and approach) for each engine used on aircraft type j;
  - FFjk = fuel flow for mode k (e.g. take-off, climb-out, idle and approach), in kilograms per second (kg/s), for each engine used on aircraft type j;
  - TIMjk = time-in-mode for mode k (e.g. idle, approach, climb-out and take-off), in minutes, for aircraft type j;
  - Nej = number of engines used on aircraft type j.

Source: ICAO Airport Air Quality Manual)

Emissions Forecast

Emission calculation methodology for NOx, CO and HC - Illustration

GE9X 777-8x Rated Output :392.4 kN Bypass Ratio: 10
Based on **GE90-85B**

Mode	Power setting		Time		Fuel Flow	HC	CO		Nox	Smoke No.
T/O	100		0.7	x	2.818	0.05	0.163	x	37.9	1.71
Climb out	85	+	2.2	x	2.298	0.043	0.18	x	30.3	1.24
Approach	30	+	4	x	0.724	0.425	7.47	x	12.4	1.53
Idle	7	+	26	x	0.244	1.69	24.24	x	4.42	3.77
LTO Total						736	10599	=	17514	

Note: CO_2 emissions from aviation fuel are 3.15 grams per gram of fuel

Source: ICAO Airport Air Quality Manual)

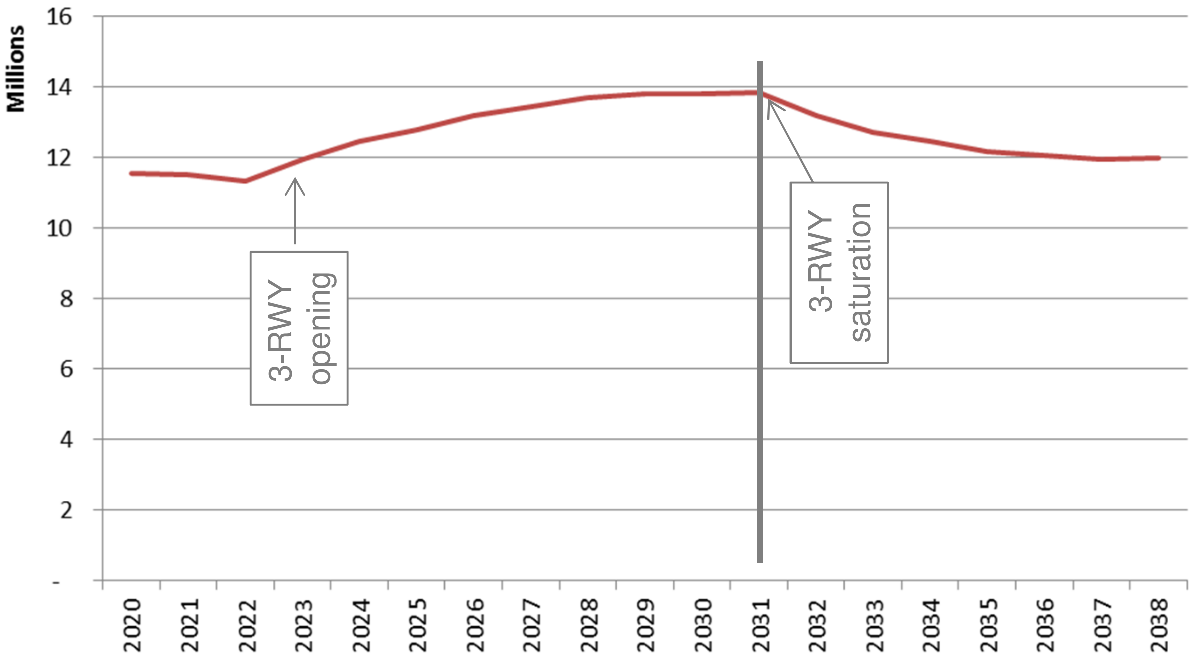
Content

Updated

Constrained Future Schedule – 3 runways as of 2023

After 3rd runway opening, CO emissions will reach their highest point in 2031

Aircraft CO Emissions
in grams – 2020 to 2038 ATM busy day



Source: IATA modelling and estimates

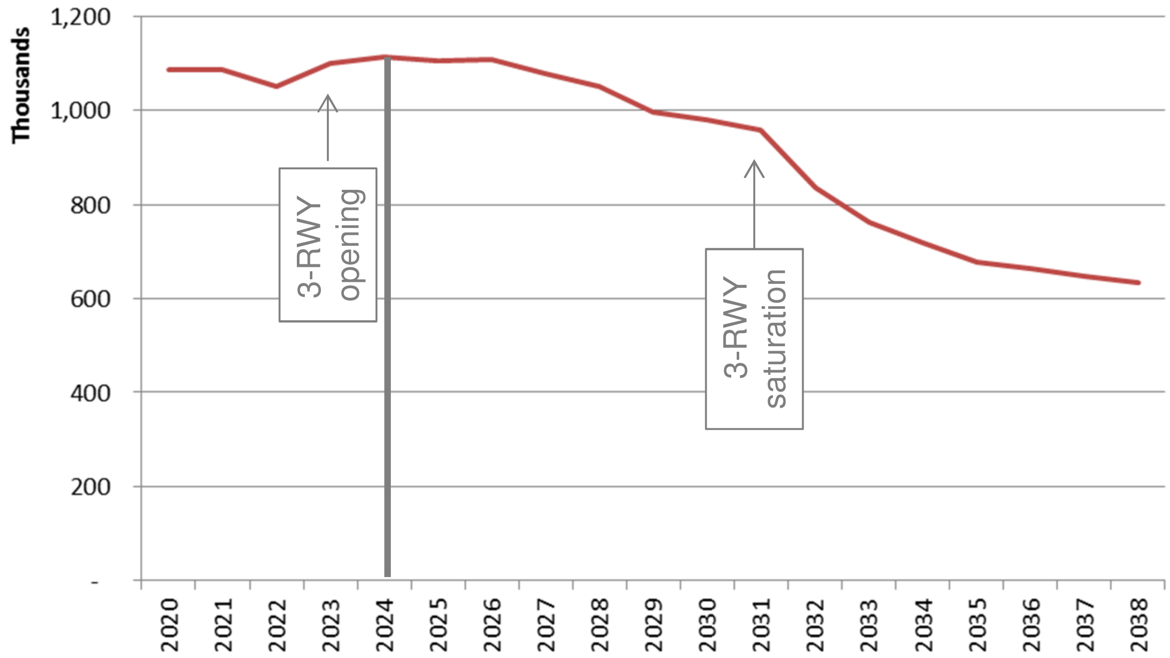
- Over the period 2020-2022, while the two-runway system is saturated, CO emissions are slightly decreasing
- Over the period 2022-2031, it is anticipated that CO emissions will increase by 22.1% and reach their peak in 2031
- Over the same period, the combined passenger and cargo traffic is expected to grow by 46.6%
- The slower increase in CO emissions (in comparison to passengers and cargo) results from the introduction of new engines

Constrained Future Schedule – 3 runways as of 2023

After 3rd runway opening, HC emissions will reach their highest point in 2024

Aircraft HC Emissions

in grams – 2020 to 2038 ATM busy day



- Over the period 2020-2022, while the two-runway system is saturated, HC emissions are decreasing
- Over the period 2022-2031, it is anticipated that HC emissions will reach their highest in 2024
- New combustor technologies allow the HC emissions to record a steady decrease despite the increase in traffic

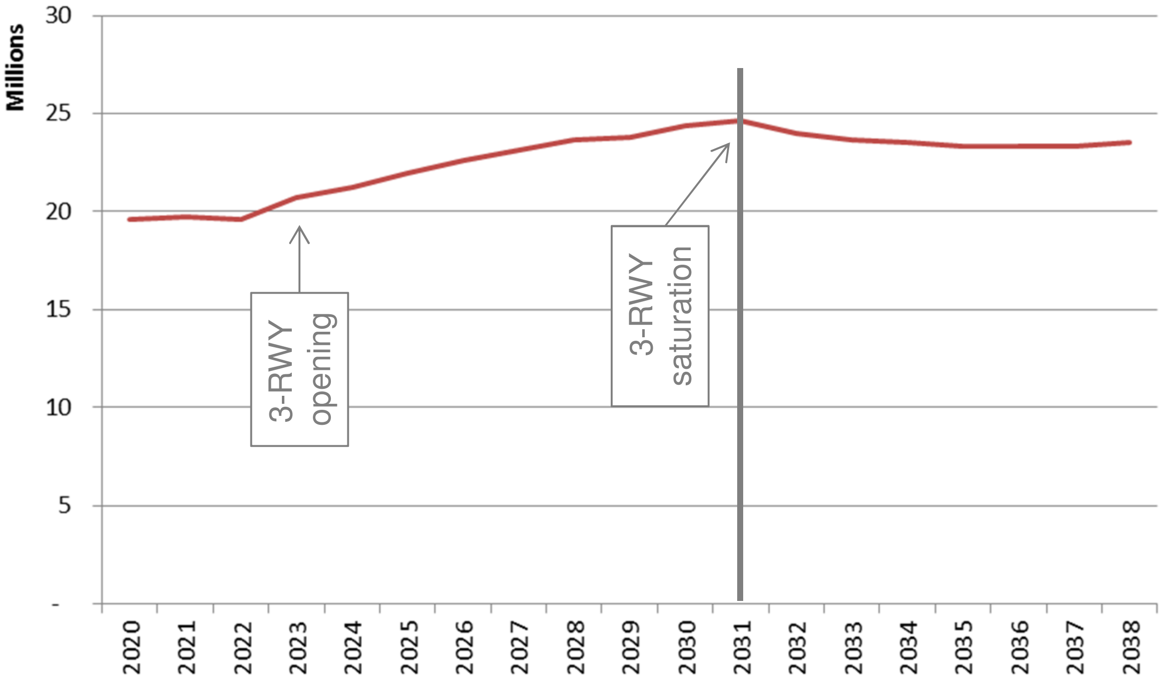
Source: IATA modelling and estimates

Constrained Future Schedule – 3 runways as of 2023

After 3rd runway opening, NOx emissions will reach their highest in 2031

Aircraft NOx Emissions

in grams – 2020 to 2038 ATM busy day



Source: IATA modelling and estimates

- Over the period 2020-2022, while the two-runway system is saturated, NOx emissions are stable
- Over the period 2022-2031, it is anticipated that NOx emissions will increase by 25.8% and reach their peak in 2031
- Over the same period, the combined passenger and cargo traffic is expected to grow by 46.6%
- The slower increase in NOx emissions (in comparison to passengers and cargo) results from the introduction of new engines and more stringent regulations

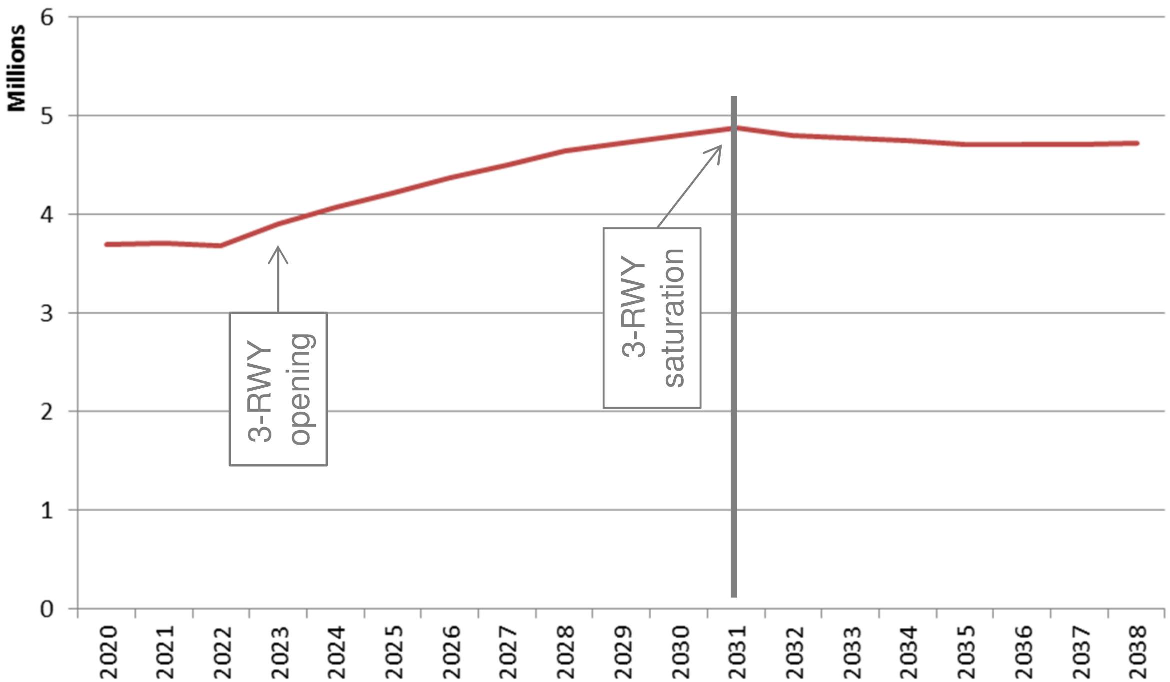
Updated

Constrained Future Schedule – 3 runways as of 2023

After 3rd runway opening, CO_2 emissions will reach their peak in 2031

Aircraft CO_2 Emissions

in kg – 2020 to 2038 ATM busy day

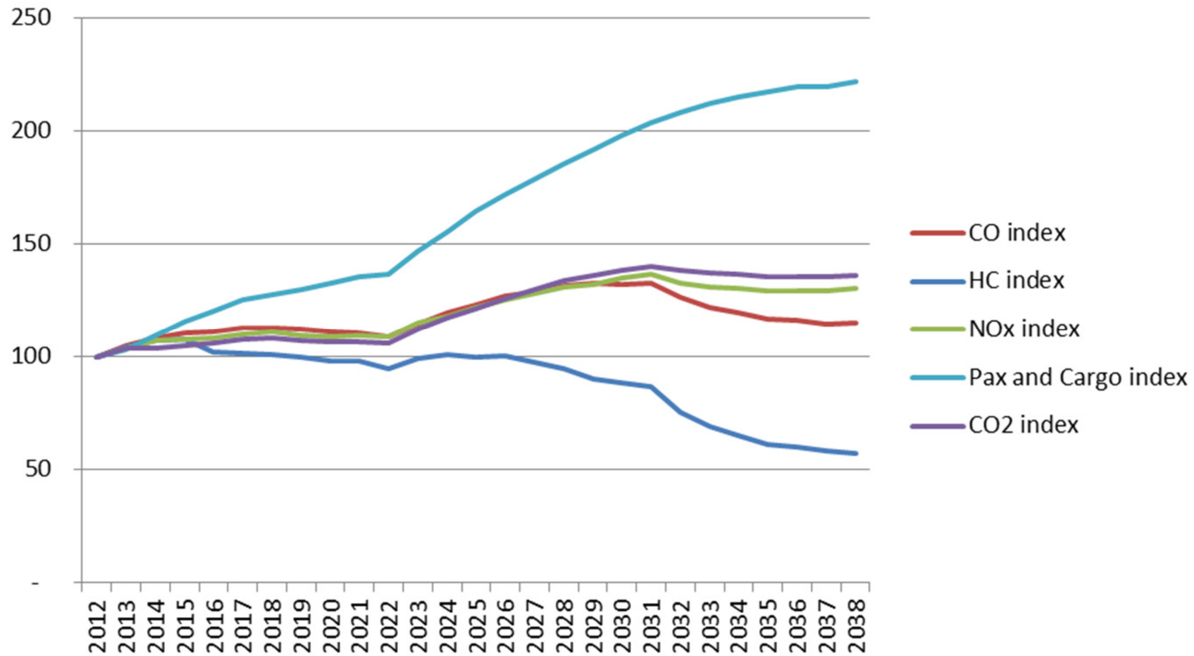


Source: IATA modelling and estimates

- CO_2 emissions are directly proportionate to the fuel consumption
- Over the period 2020-2022, while the two-runway system is saturated, CO_2 emissions are stable
- Over the period 2022-2031, it is anticipated that CO_2 emissions will increase by 32.3% and reach their peak in 2031
- Over the same period, combined passenger and cargo traffic is expected to grow by 46.6%
- The slower increase in CO_2 emissions (in comparison to passengers and cargo) results from the lower consumption

Constrained Future Schedule – 3 runways as of 2023
Compared evolutions of emissions and airport workload

CO, HC, CO_2 and NOx aircraft emissions index compared to the airport workload
Index 100 in 2012– 2012 to 2038



- 1 workload unit = 1 pax or 100kg of freight

Source: IATA modelling and estimates

Content

Identification of the Critical Year in terms of Emissions
Brief Specification

- The Study Brief specifies under Clause 5(iv) in Appendix A that "the air pollution impacts of the future air traffic shall be calculated based on the highest aircraft emissions, due specifically to aircraft LTO cycles, within the period when the project commences operation to the year the project reaches and operates at full capacity. The Applicant shall demonstrate that the **selected year of assessment** represents the highest aircraft emission scenario, taking into consideration the number of landing take-off cycles and the corresponding aircraft engine emission factors for the selected year"

- As per the above specification, the critical year is to be sought within the **2023 – 2032** period

Identification of the critical year in terms of emissions
2031 appears to be the most appropriate critical year

- It is anticipated that 2031 will see the **highest aircraft emissions for CO, NOx and CO_2**

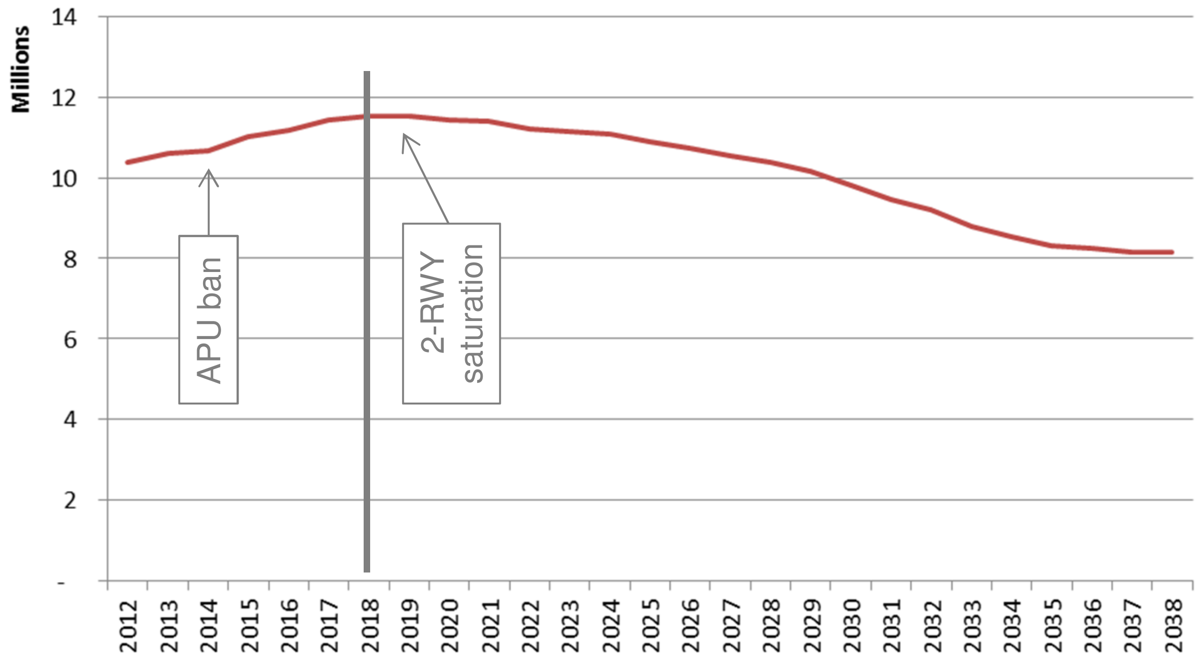
- HC emissions will reach their peak in 2024.
- Sensitivity to the assumptions made for this assessment:
  - Alternative fuels: A progressive deployment of alternative fuels at HKIA – along the worldwide trend – would result in a reduction in smoke and SOx
  - Most airlines use derated or flexible thrust procedure for take-off .This would reduce emissions, in particular NOx
  - Taxi-time: Taxi-time may increase as the runway system is close to its capacity (between 2030 and 2032). It may result in an increase in emissions for those years amplifying the emission peak in 2031

Content

Constrained Future Schedule – 2 runways

Without the 3rd runway, CO emissions will reach their highest in 2018/2019

Aircraft CO Emissions – 2-runway scenario
in grams – 2012 to 2038 ATM busy day



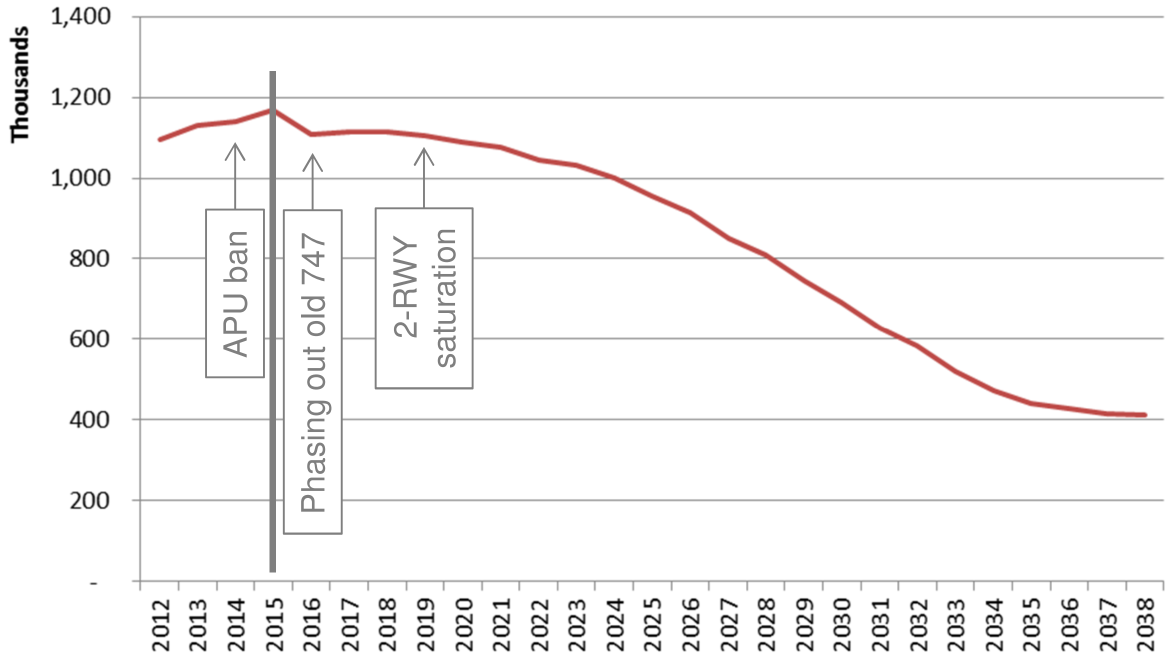
- Over the relevant period, 2018 and 2019 should see the highest level of CO emissions
- Combined passenger and cargo traffic in 2018 / 2019 is 28% higher than in 2012
- CO Emissions in 2018 / 2019 are estimated to be 11% higher in 2012
- The slower increase in CO emissions (in comparison to passengers and cargo) results from the introduction of new engines

Source: IATA modelling and estimates

Constrained Future Schedule – 2 runways

Without the 3rd runway, HC emissions will reach their highest in 2015

Aircraft HC Emissions – 2-runway scenario
in grams – 2012 to 2038 ATM busy day

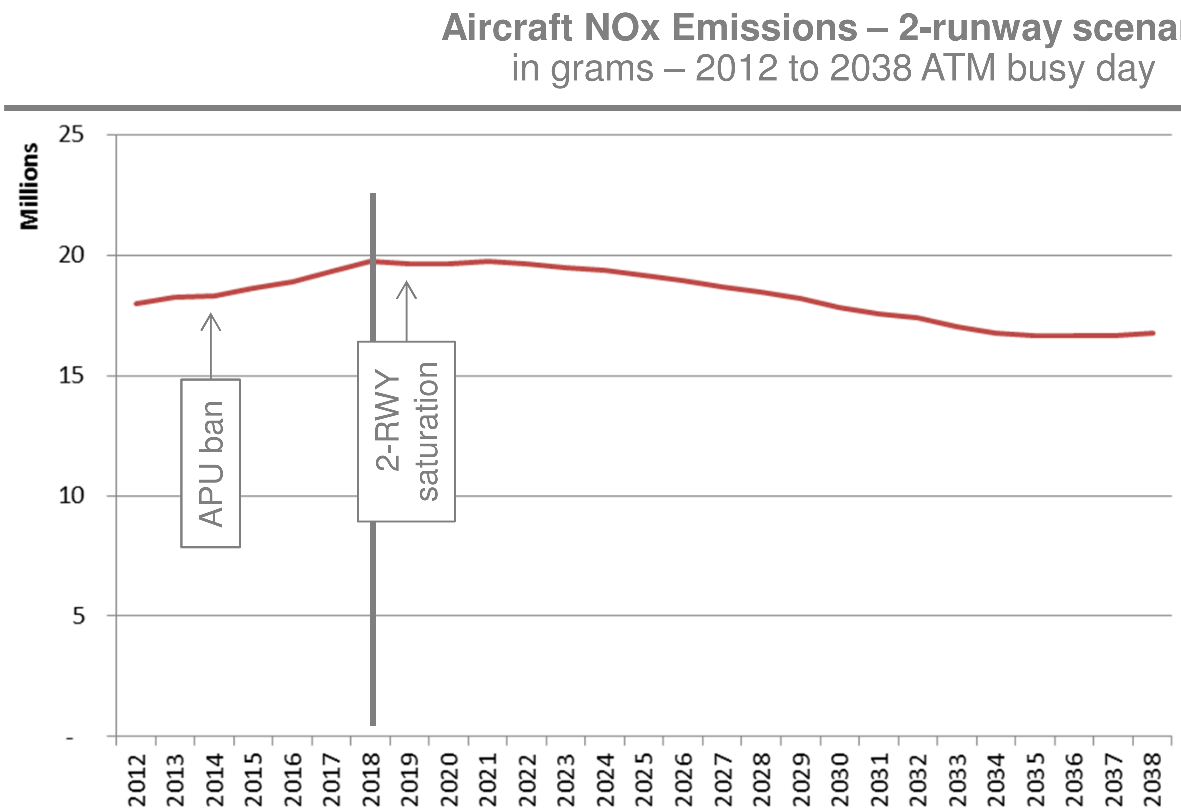


- Over the relevant period, 2015 should see the highest level of HC emissions
- HC emissions in 2015 are estimated to be 6.7% higher than in 2012
- New combustor technologies allow the HC emissions to decrease despite the increase in ATM. This can be observed in 2016 with the introduction of the A350 in replacement of old B747

Source: IATA modelling and estimates

Constrained Future Schedule – 2 runways

Without the 3rd runway, NOx emissions will reach their highest in 2018



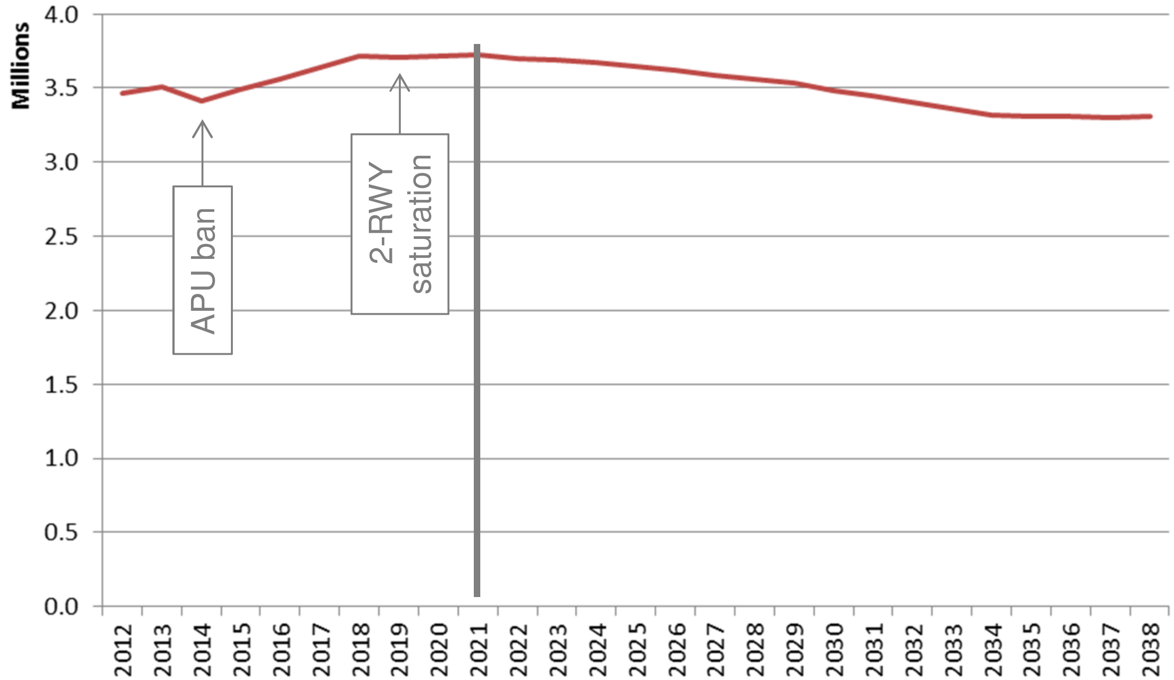
Source: IATA modelling and estimates

- Over the relevant period, 2018 should see the highest level of NOx emissions
- Combined passenger and cargo traffic in 2018 is 26% higher than in 2012
- NOx emissions in 2018 are estimated to be 11% higher than in 2012
- The slower increase in NOx emissions (in comparison to passengers and cargo) results from the introduction of new engines and more stringent regulations

Constrained Future Schedule – 2 runways

Without the 3rd runway, CO_2 emissions will reach their highest point in 2021

Aircraft CO_2 Emissions – 2-runway scenario
in kg – 2012 to 2038 ATM busy day



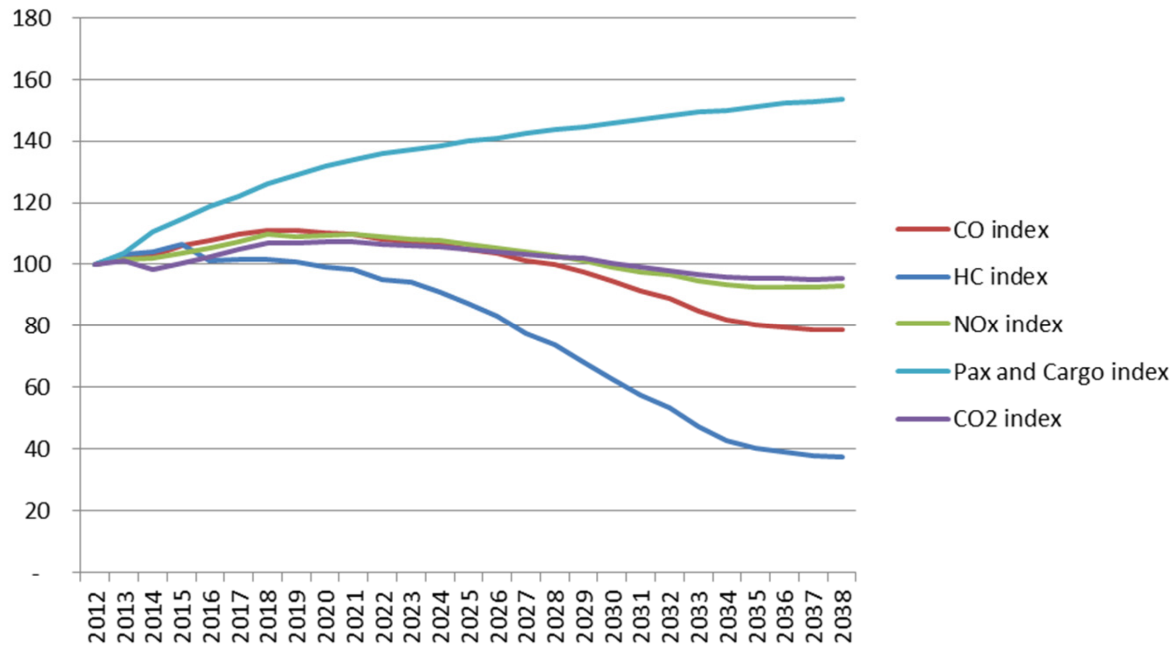
Source: IATA modelling and estimates

- CO_2 emissions are directly proportionate to the fuel consumption
- Over the relevant period, 2021 should see the highest level of CO_2 emissions
- CO_2 emissions in 2021 are estimated to be 7.3% higher than in 2012 in comparison to 33% for traffic
- The slower increase in CO_2 emissions (in comparison to passengers and cargo) results from the lower consumption

Constrained Future Schedule – 2 runways

Compared evolutions of emissions and airport workload

Aircraft CO, HC, CO_2 and NOx emissions index compared to the airport workload
2-runway scenario - Index 100 in 2012– 2012 to 2038



- 1 workload unit = 1 pax or 100kg of freight

Source: IATA modelling and estimates

Content

Engine Emissions Database (1/5)

Engine Type	EIS	Bypass Ratio	Rated Engine Output (kN)	Unadjusted Fuel Flow - Takeoff	Unadjusted Fuel Flow - Climbout	Unadjusted Fuel Flow - Approach	Unadjusted Fuel Flow - Idle	CO Raw Emission Index - Takeoff	CO Raw Emission Index - Climbout	CO Raw Emission Index - Approach	CO Raw Emission Index - Idle	HC Raw Emission Index - Takeoff	HC Raw Emission Index - Climbout	HC Raw Emission Index - Approach	HC Raw Emission Index - Idle	NOx Raw Emission Index - Takeoff	NOx Raw Emission Index - Climbout	NOx Raw Emission Index - Approach	NOx Raw Emission Index - Idle	Smoke Number - Takeoff	Smoke Number - Climbout	Smoke Number - Approach	Smoke Number - Idle	LTO CO	LTO HC	LTO Nox
BR710A1-10	1996	4.2	65.61	0.594	0.594	0.214	0.089	0.93	0.93	4.78	27.82	0.02	0.02	0.05	1.09	15.07	15.07	7.68	4.69	13.99	11.92	0.29	0.56	4,204	156	2,603
BR710A2-20	1996	4.19	65.61	0.595	0.595	0.214	0.089	0.93	0.93	4.81	28	0.02	0.02	0.05	1.12	15.03	15.03	7.67	4.67	13.96	11.87	0.27	0.57	4,231	160	2,598
CF34-10E5A1	2009	5.09	83.7	0.717	0.717	0.239	0.088	0.77	0.77	4.02	41.73	0.09	0.09	0.1	4.02	16.22	16.22	7.94	3.69	12.74	6.91	0.1	0.5	6,055	569	2,986
CF34-3B	1991	6.25	41.01	0.3288	0.3288	0.116	0.0489	0.000001	0.000001	1.88	47.59	0.05	0.05	0.13	4.69	9.68	9.68	6.63	3.72	18.3	9.2	3.1	3.1	3,683	364	1,022
CF34-3B1	1991	6.25	41.01	0.3288	0.3288	0.116	0.0489	0.000001	0.000001	1.88	47.59	0.05	0.05	0.13	4.69	9.68	9.68	6.63	3.72	18.3	9.2	3.1	3.1	3,683	364	1,022
CF6-50E2	1987	4.3	230.4	1.94	1.94	0.663	0.163	0.45	0.45	3.71	24.04	0.15	0.15	0.28	2.72	25.5	25.5	10.16	3.4	10.95	11.72	1.62	1.4	6,855	787	11,089
CF6-80C2A5F	1995	5.1	271.88	2.106	2.106	0.691	0.22	0.04	0.04	1.92	16.96	0.04	0.04	0.11	1.18	21.27	21.27	12.64	4.9	7.4	5.2	0	0	6,154	438	11,572
CF6-80C2B1F	1995	5.1	254.26	1.983	1.983	0.65	0.199	0.04	0.04	2.13	19.23	0.05	0.05	0.11	1.54	19.72	19.72	12.47	4.73	6.9	4.5	0	0	6,316	512	10,218
CF6-80C2B5F	1995	5.1	272.53	2.162	2.162	0.697	0.206	0.04	0.04	1.83	17.45	0.05	0.05	0.11	1.31	21.76	21.76	12.74	4.91	7.4	5.2	0	0	5,929	458	11,895
CF6-80C2B6F	1995	5.1	267.03	2.104	2.104	0.682	0.203	0.04	0.04	1.93	18.42	0.05	0.05	0.11	1.43	21.05	21.05	12.63	4.81	6.9	5.3	0	0	6,164	489	11,297
CF6-80C2B7F	1995	5.1	267.03	2.104	2.104	0.682	0.203	0.04	0.04	1.93	18.42	0.05	0.05	0.11	1.43	21.05	21.05	12.63	4.81	6.9	5.3	0	0	6,164	489	11,297
CF6-80C2D1F	1995	5.1	269.96	2.126	2.126	0.688	0.205	0.04	0.04	1.9	18.02	0.05	0.05	0.11	1.38	21.3	21.3	12.66	4.85	7	5.5	0	0	6,091	478	11,521
CF6-80E1A2	1992	5.1	287.04	2.245	2.245	0.724	0.228	0.34	0.34	1.61	42.67	0.07	0.07	0.14	9.37	28.02	28.02	9.91	4.53	9.9	7.2	0	0	15,589	3,384	14,279
CF6-80E1A3	1995	5.1	304.8	2.387	2.387	0.755	0.227	0.31	0.31	1.23	37.02	0.07	0.07	0.18	9.53	31.74	31.74	10.29	4.69	10.1	8.6	0	0	13,461	3,436	16,708
CF6-80E1A4	1995	5.1	297.44	2.337	2.337	0.744	0.227	0.3	0.3	1.33	38.09	0.07	0.07	0.18	10.35	30.3	30.3	10.13	4.62	10.09	8.06	0	0	13,848	3,726	15,766
CF6-80E1A4B	1995	5.1	297.44	2.337	2.337	0.744	0.227	0.3	0.3	1.33	38.09	0.07	0.07	0.18	10.35	30.3	30.3	10.13	4.62	10.09	8.06	0	0	13,848	3,726	15,766
CFM LEAP-1B	2018	10	106.9	0.765	0.765	0.255	0.085	1.55	1.55	4.18	26.1	0.02	0.02	0.08	1.34	12.16	12.16	6.83	3.19	9.38	7.37	1.23	1.23	3,923	185	2,460
CFM56-3B1	1983	5.1	89.41	0.792	0.792	0.29	0.114	0.95	0.95	3.8	34.4	0.05	0.05	0.08	2.28	15.5	15.5	8.3	3.9	4	2.5	2.5	2.2	6,513	418	3,407
CFM56-3C1	1983	5.1	104.6	0.954	0.954	0.336	0.124	0.9	0.9	3.1	26.8	0.04	0.04	0.07	1.42	17.8	17.8	9.1	4.3	7.7	3.9	2.5	2.3	5,584	287	4,520
CFM56-5B2/3	2006	5.5	137.9	1.107	1.107	0.358	0.111	0.23	0.23	2.33	26.72	0.02	0.02	0.05	1.22	20.76	20.76	9.42	4.53	15.5	13.1	2.1	2.1	4,871	219	5,593
CFM56-5B3/P	1995	5.6	142.4	1.15	1.15	0.4	0.13	1.3	1.3	19.9	34.5	0.1	0.1	2.9	2.5	18.6	18.6	7.8	4.3	0.5	0.3	0.5	2.3	9,167	805	5,343
CFM56-5B4/3	2006	5.7	120.1	0.939	0.939	0.316	0.102	0.16	0.16	3.24	32.07	0.02	0.02	0.05	1.92	17.23	17.23	8.85	4.22	13.4	9.9	2.1	2.1	5,375	313	4,158
CFM56-5B4/P	1995	5.9	120.11	0.935	0.935	0.312	0.104	0.9	0.9	2.3	23.4	0.2	0.2	0.5	4.6	23.2	23.2	10	4.3	5.4	4.1	0.2	0.5	4,115	816	5,221
CFM56-5B5/P	1995	5.9	97.89	0.742	0.742	0.26	0.094	1	1	3.4	30	0.2	0.2	0.7	6.2	18.5	18.5	8.7	3.8	5.4	1.6	0.3	0.6	4,740	979	3,489

Engine Emissions Database (2/5)

Engine Type	EIS	Bypass Ratio	Rated Engine Output (kN)	Unadjusted Fuel Flow - Takeoff	Unadjusted Fuel Flow - Climbout	Unadjusted Fuel Flow - Approach	Unadjusted Fuel Flow - Idle	CO Raw Emission Index - Takeoff	CO Raw Emission Index - Climbout	CO Raw Emission Index - Approach	CO Raw Emission Index - Idle	HC Raw Emission Index - Takeoff	HC Raw Emission Index - Climbout	HC Raw Emission Index - Approach	HC Raw Emission Index - Idle	NOx Raw Emission Index - Takeoff	NOx Raw Emission Index - Climbout	NOx Raw Emission Index - Approach	NOx Raw Emission Index - Idle	Smoke Number - Takeoff	Smoke Number - Climbout	Smoke Number - Approach	Smoke Number - Idle	LTO CO	LTO HC	LTO Nox
CFM56-5B6/3	2006	5.9	104.5	0.8	0.8	0.279	0.095	0.17	0.17	4.35	38.39	0.03	0.03	0.07	2.93	14.88	14.88	8.29	3.94	11.3	8.4	2.1	2.1	6,004	443	3,210
CFM56-5B6/P	1995	6	104.53	0.799	0.799	0.275	0.097	1	1	2.9	27.7	0.2	0.2	0.6	5.5	19.6	19.6	9.2	4	5.4	2.2	0.3	0.6	4,522	900	3,937
CFM56-5B7/P	1995	5.9	120.11	0.935	0.935	0.312	0.104	0.9	0.9	2.3	23.4	0.2	0.2	0.5	4.6	23.2	23.2	10	4.3	5.4	4.1	0.2	0.5	4,115	816	5,221
CFM56-5B8/P	1995	5.9	94.7	0.729	0.729	0.262	0.094	0.8	0.8	3.9	32.9	0.1	0.1	0.9	6.5	16.7	16.7	8.4	3.4	5.4	1.5	0.3	0.6	5,171	1,022	3,145
CFM56-5C3/F	1991	5.6	142.4	1.131	1.131	0.37	0.1203	0.82	0.82	1.57	32.6	0.008	0.008	0.074	5.35	27.1	27.1	10.4	4.26	11.8	9.1	1	1.1	6,419	1,012	7,056
CFM56-5C4	1991	6.6	151.25	1.195	1.195	0.386	0.124	0.85	0.85	1.4	30.93	0.008	0.008	0.065	5	29.05	29.05	10.67	4.28	12.6	9.8	1	1.1	6,290	975	7,857
CFM56-5C4/P	1991	6.6	149.9	1.143	1.143	0.37	0.115	0.7	0.7	1.6	31.6	0.000001	0.000001	0.000001	5	26.7	26.7	9.9	4.1	12	9.6	1	1.1	5,950	897	6,925
CFM56-7B22	1996	5.3	100.97	0.844	0.844	0.298	0.105	0.6	0.6	2.5	22.8	0.1	0.1	0.1	2.5	19	19	10	4.5	12	10.5	0	0	4,002	431	4,243
CFM56-7B24	1996	5.2	107.65	0.91	0.91	0.316	0.109	0.6	0.6	2.2	22	0.1	0.1	0.1	2.4	20.5	20.5	10.1	4.4	12.6	11.4	0	0	4,003	432	4,760
CFM56-7B24/3	2006	5.3	107.6	0.895	0.895	0.308	0.103	0.15	0.15	3.68	34.71	0.03	0.03	0.06	2.3	15.6	15.6	8.6	4.09	12.1	8.7	2.1	2.1	5,873	379	3,722
CFM56-7B26	1996	5.1	116.99	0.999	0.999	0.338	0.113	0.6	0.6	1.6	18.8	0.1	0.1	0.1	1.9	22.5	22.5	10.8	4.7	14.7	11.9	0	0	3,548	360	5,616
CFM56-7B26E	2006	5.1	116.99	1	1	0.3	0.1	0.2	0.2	3.1	30.9	0	0	0.1	1.8	17.1	17.1	8.9	4.3	13.1	9.8	2.1	2.1	5,078	288	4,287
CFM56-7B26/3	2006	5.1	117	0.986	0.986	0.331	0.108	0.16	0.16	3.07	30.94	0.02	0.02	0.05	1.75	17.08	17.08	8.93	4.27	13.1	9.8	2.1	2.1	5,484	302	4,359
CFM56-7B26/E	2006	5.1	117	1	1	0.3	0.1	0.2	0.2	3.1	30.9	0	0	0.1	1.8	17.1	17.1	8.9	4.3	13.1	9.8	2.1	2.1	5,078	288	4,287
CFM56-7B27/E	2006	5.1	121.4	1	1	0.3	0.1	0.2	0.2	2.8	29.4	0	0	0.1	1.5	17.9	17.9	9.1	4.4	13.4	11.2	2.1	2.1	4,823	241	4,456
CFMI Leap-1A	2017	10	124.7	0.798	0.798	0.269	0.087	1.55	1.55	4.18	26.1	0.02	0.02	0.08	1.34	14.11	14.11	7.16	3.47	7.32	6.55	1.15	1.52	4,027	190	2,892
GE90-110B1	2003	7.34	492.6	3.47	3.47	1.08	0.37	0.07	0.07	2.29	40.59	0.03	0.03	0.06	4.55	33.85	33.85	15.78	5.11	3.58	2.25	1.42	0.96	24,064	2,660	27,478
GE90-115B	2003	7.08	513.9	3.67	3.67	1.13	0.38	0.07	0.07	1.98	39.11	0.03	0.03	0.06	4.24	35.98	35.98	16.5	5.19	4.1	2.5	1.45	0.87	23,766	2,549	30,528
GE90-115BL2	2003	7.08	513.9	3.67	3.67	1.13	0.38	0.07	0.07	1.98	39.11	0.03	0.03	0.06	4.24	35.98	35.98	16.5	5.19	4.1	2.5	1.45	0.87	23,766	2,549	30,528
GE90-90B	2007	8.36	418.1	2.735	2.735	0.852	0.28	0.31	0.31	1.88	29.89	0.03	0.03	0.06	2.59	39.07	39.07	15.44	5.48	2.42	0.82	1	0.95	13,588	1,158	24,144
GE90-94B	2007	8.33	432.8	2.831	2.831	0.876	0.284	0.31	0.31	1.74	29.23	0.03	0.03	0.06	2.49	40.63	40.63	15.81	5.55	3.04	1.01	0.95	0.81	13,469	1,131	25,797
GE9X8	2020	10	392.4	2.298	2.298	0.724	0.244	0.24	0.24	2.49	19.68	0.02	0.02	0.06	0.63	30.3	30.3	12.4	4.42	1.71	1.24	1.53	3.77	8,020	258	15,953
GE9X9	2020	10	431	2.547	2.547	0.788	0.256	0.24	0.24	2.49	19.68	0.02	0.02	0.06	0.63	33.8	33.8	13.7	4.76	3.37	1.96	2.07	1.66	8,437	272	19,471
GEnx-1B64	2009	9	298	1.861	1.861	0.604	0.199	0.38	0.38	2.99	21.62	0.02	0.02	0.06	0.81	14.61	14.61	9.03	4.24	0	0	5.54	0.05	7,268	267	7,356
GEnx-1B70	2009	8.8	321.6	2.037	2.037	0.65	0.208	0.24	0.24	2.49	19.68	0.02	0.02	0.06	0.63	18.48	18.48	9.63	4.37	0	0	5.54	0.05	6,859	221	9,470

Engine Emissions Database (3/5)

Engine Type	EIS	Bypass Ratio	Rated Engine Output (kN)	Unadjusted Fuel Flow - Takeoff	Unadjusted Fuel Flow - Climbout	Unadjusted Fuel Flow - Approach	Unadjusted Fuel Flow - Idle	CO Raw Emission Index - Takeoff	CO Raw Emission Index - Climbout	CO Raw Emission Index - Approach	CO Raw Emission Index - Idle	HC Raw Emission Index - Takeoff	HC Raw Emission Index - Climbout	HC Raw Emission Index - Approach	HC Raw Emission Index - Idle	NOx Raw Emission Index - Takeoff	NOx Raw Emission Index - Climbout	NOx Raw Emission Index - Approach	NOx Raw Emission Index - Idle	Smoke Number - Takeoff	Smoke Number - Climbout	Smoke Number - Approach	Smoke Number - Idle	LTO CO	LTO HC	LTO Nox
GEnx-2B67	2009	8	299.8	2.012	2.012	0.701	0.216	0.28	0.28	2.53	18.95	0.02	0.02	0.06	0.57	17.94	17.94	9.58	4.43	0	0	5.54	0.05	6,909	209	9,385
GE Passport 2(	2017	10	72.06	0.566	0.566	0.195	0.08	0.232	0.232	4.96	27.34	0	0	0	2.75	10.34	10.34	6.24	2.81	4.26	4.42	0	0.1	3,667	343	1,661
GP7270	2005	8.71	332.39	2.169	2.169	0.711	0.234	0.09	0.09	1.27	33.58	0.03	0.03	0.07	4.04	31.37	31.37	12.9	5.24	4.06	3.87	2.2	3.08	12,509	1,498	15,953
JT8D-15	1980	1.03	68.94	0.945	0.945	0.3403	0.1477	1	1	9.6	35.2	0.25	0.25	1.65	11	15	15	5.9	3	23.8	21.4	7.1	7.1	9,059	2,710	3,640
JT8D-217	1999	1.73	92.74	1.078	1.078	0.3833	0.1372	0.47	0.47	3.54	15.31	0.000001	0.000001	0.000001	0	13.54	13.54	7.66	4.57	6.1	5.5	1.8	1.8	3,691	0	4,223
PW800	2017	10	72.06	0.566	0.566	0.195	0.08	0.232	0.232	4.96	27.34	0	0	0	2.75	10.34	10.34	6.24	2.81	4.26	4.42	0	0.1	3,667	343	1,661
PW1000G	2011	12	124.7	0.798	0.798	0.269	0.087	1.62	1.62	12.91	31.1	0.1	0.1	3.98	2.9	10.16	10.16	5.16	2.5	7.32	6.55	1.15	1.52	5,279	664	2,083
PW1124G	2016	12	106.7	0.798	0.798	0.276	0.097	0.81	0.81	3.69	25.19	0.002	0.002	0.001	0.002	11.2	11.2	5.73	2.73	5.16	4.71	1.32	1.51	4,169	1	2,348
PW1127G	2016	12	124.7	0.858	0.858	0.288	0.097	0.81	0.81	4.63	25.78	0.007	0.007	0.002	0.36	13.14	13.14	6.29	2.94	7.32	6.55	1.15	1.52	4,342	56	2,841
PW1133G	2016	12	147	0.98	0.98	0.314	0.096	0.25	0.25	2.14	25.59	0.02	0.02	0.05	1.1	16.08	16.08	7.05	3.39	7.06	6.27	0.93	1.63	4,036	172	3,781
PW1524G	2015	12	106.7	0.765	0.765	0.255	0.085	1.31	1.31	9.87	33.5	0.05	0.05	1.57	3.38	12.16	12.16	6.83	3.19	9.38	7.37	1.23	1.23	5,221	551	2,460
PW306A	2000	4.5	26.87	0.2641	0.2641	0.0974	0.0422	2.51	2.51	7.11	36.35	0.000001	0.000001	0.000001	4.36	19.26	19.26	11.87	4.26	2.6	0.8	0	0.2	2,675	287	1,443
PW307A	2007	4.2	28.49	0.274	0.274	0.102	0.045	0.72	0.72	3.37	39.6	0	0	0	3.24	13.67	13.67	6.78	2.39	0.4	0.33	0	1.57	2,897	227	985
PW308C	2001	4.1	31.15	0.3047	0.3047	0.1237	0.0448	0.97	0.97	5.23	42.3	0.1	0.1	0.14	5.94	15.99	15.99	7.83	3.63	4.8	3.9	1.4	1.3	3,163	425	1,334
PW4056	1987	4.7	252.4	1.93	1.93	0.658	0.208	0.57	0.57	2	21.86	0.01	0.01	0.13	1.92	22.9	22.9	11.6	4.8	7.8	-	-	-	7,600	647	11,080
PW4060	1987	4.5	266.9	2.085	2.085	0.703	0.213	0.51	0.51	1.78	20.32	0.03	0.03	0.14	1.66	24.7	24.7	12	4.9	8.3	7.5	2.5	2.5	7,237	586	12,614
PW4062	1993	4.5	266.9	2.166	2.166	0.708	0.223	0.51	0.51	1.68	23.96	0.08	0.08	0.15	3.26	27.55	27.55	12.78	4.14	10.1	7.4	0.7	0	8,813	1,190	13,995
PW4062A	1993	4.5	266.9	2.166	2.166	0.708	0.223	0.51	0.51	1.68	23.96	0.08	0.08	0.15	3.26	27.55	27.55	12.78	4.14	10.1	7.4	0.7	0	8,813	1,190	13,995
PW4077	1994	6.7	343	2.452	2.452	0.816	0.232	0.1	0.1	0.4	20.2	0.1	0.1	0.2	3	32.5	32.5	11.3	4.2	7.4	3	0.6	0	7,432	1,168	17,599
PW4077D	2010	6.6	355.7	2.562	2.562	0.892	0.31	0.34	0.34	0.86	24.8	0.02	0.02	0.04	2.82	34.05	34.05	11.63	3.81	4.9	2.57	0.66	0.34	12,329	1,381	19,511
PW4084	1994	6.4	369.6	2.689	2.689	0.875	0.242	0.1	0.1	0.4	18.73	0.1	0.1	0.2	2.7	35.5	35.5	12	4.4	10.5	4.8	0.8	0	7,202	1,108	20,791
PW4090	2010	6.1	395	2.996	2.996	0.979	0.338	0.31	0.31	0.55	11.94	0.02	0.02	0.04	0.69	41.17	41.17	12.74	4.48	10.51	4.29	0.7	0.37	6,587	384	26,818
PW4152	1987	4.9	231.3	1.785	1.785	0.593	0.177	0.17	0.17	1.09	12.76	0.16	0.16	0.15	0.74	22.7	22.7	11.1	4.9	12.7	11.4	3.8	3.8	3,731	275	9,983
PW4164	2000	5.2	284.68	2.2	2.2	0.766	0.24	0.18	0.18	2.84	17.73	0	0	0	0.37	18.66	18.66	11.88	4.99	12.5	10.5	0.6	0	7,229	139	11,195
PW4168	2000	5.1	302.48	2.363	2.363	0.809	0.25	0.2	0.2	2.4	15.9	0	0	0	0.2	20.2	20.2	12.1	5.2	12.7	11	0.6	0	6,749	78	12,683

Engine Emissions Database (4/5)

Engine Type	EIS	Bypass Ratio	Rated Engine Output (kN)	Unadjusted Fuel Flow - Takeoff	Unadjusted Fuel Flow - Climbout	Unadjusted Fuel Flow - Approach	Unadjusted Fuel Flow - Idle	CO Raw Emission Index - Takeoff	CO Raw Emission Index - Climbout	CO Raw Emission Index - Approach	CO Raw Emission Index - Idle	HC Raw Emission Index - Takeoff	HC Raw Emission Index - Climbout	HC Raw Emission Index - Approach	HC Raw Emission Index - Idle	NOx Raw Emission Index - Takeoff	NOx Raw Emission Index - Climbout	NOx Raw Emission Index - Approach	NOx Raw Emission Index - Idle	Smoke Number - Takeoff	Smoke Number - Climbout	Smoke Number - Approach	Smoke Number - Idle	LTO CO	LTO HC	LTO Nox
PW4168A	2000	5.1	302.48	2.363	2.363	0.809	0.25	0.2	0.2	2.4	15.9	0	0	0	0.2	20.2	20.2	12.1	5.2	12.7	11	0.6	0	6,749	78	12,683
PW4170A	2008	4.86	311.4	2.45	2.45	0.833	0.255	0.18	0.18	1.17	14.04	0.000001	0.000001	0.05	0.83	22.84	22.84	12.49	4.18	5.6	5.6	0.2	0	5,896	340	13,896
PW4462	1993	4.5	266.9	2.085	2.085	0.703	0.213	0.51	0.51	1.78	20.32	0.03	0.03	0.14	1.66	24.7	24.7	12	4.9	8.3				7,237	586	12,614
RB211-524C2	1986	4.5	224.8	2.02	2.02	0.74	0.3	1.63	1.63	18.9	81	0.22	0.22	4.42	54.2	32.3	32.3	10.4	3.37	14.5	10.9	2.2	0.7	41,838	26,228	14,777
RB211-524G	1992	4.25	253	2.08	2.08	0.7	0.26	0.43	0.43	1.01	13.74	0.27	0.27	0.37	0.89	40.54	40.54	9.56	4.63	3.03	3.62	1.82	0.21	5,898	521	18,156
RB211-524GH-	1994	4.2	264	2.22	2.22	0.77	0.26	0.14	0.14	1.05	26.17	0.02	0.02	0.000001	3.31	23.19	23.19	9.91	4.16	5.2	5.27	1.83	0.53	10,863	1,350	12,476
RB211-524H	1987	4.2	264.4	2.17	2.17	0.71	0.26	0.38	0.38	0.99	11.75	0.33	0.33	0.36	0.74	46.31	46.31	10.26	4.78	3.03	3.62	1.82	0.21	5,078	486	21,173
RB211-535E4	1999	4.1	178.4	1.5	1.5	0.52	0.18	0.29	0.29	2.72	20.33	0	0	0.04	0.27	17.56	17.56	8.38	4.4	7.3	6.8	0.6	0.46	6,124	81	6,865
TPE331-14GR	1976	0	1250	0.079	0.079	0.045	0.025	1.8	1.8	4.8	24.5	0.08	0.08	0.22	2.94	11.2	11.2	8.8	5	0	0	0	0	1,032	118	444
Trent 1000-A	2011	9.47	310.9	1.877	1.877	0.625	0.237	0.45	0.45	0.77	8.73	0	0	0	0.06	35.87	35.87	13.29	5.4	3.3	4.1	2.9	0.6	3,490	22	15,705
Trent 556-61	2005	7.5	263.9	1.83	1.83	0.62	0.23	0.38	0.38	0.54	9.96	0.01	0.01	0.04	0.13	33.25	33.25	11.68	6.09	4.34	4.17	2.05	0.93	3,775	56	14,511
Trent 556A2-6	2005	7.5	263.9	1.83	1.83	0.62	0.23	0.38	0.38	0.54	9.96	0.01	0.01	0.04	0.13	33.25	33.25	11.68	6.09	4.34	4.17	2.05	0.93	3,775	56	14,511
Trent 772-60	1994	5.03	315.9	2.58	2.58	0.85	0.28	0.16	0.16	0.89	17.94	0	0	0.01	1.46	26.44	26.44	10.3	4.71	1.9	2	0.7	0.2	8,090	640	16,028
Trent 772B-60	1994	5.03	315.9	2.58	2.58	0.85	0.28	0.16	0.16	0.89	17.94	0	0	0.01	1.46	26.44	26.44	10.3	4.71	1.9	2	0.7	0.2	8,090	640	16,028
Trent 772C-60	1994	5.03	315.9	2.58	2.58	0.85	0.28	0.16	0.16	0.89	17.94	0	0	0.01	1.46	26.44	26.44	10.3	4.71	1.9	2	0.7	0.2	8,090	640	16,028
Trent 875-17	1994	6.08	351.85	2.57	2.57	0.88	0.28	0.16	0.16	0.86	19.66	0.000001	0.000001	0.000001	1.78	26.55	26.55	10.43	4.64	4.86	5.26	2.2	0.5	8,841	778	16,102
Trent 884	1994	5.87	390.1	2.89	2.89	0.97	0.31	0.18	0.18	0.65	15.19	0.000001	0.000001	0.000001	1	30.63	30.63	11.07	5.04	4.37	5.1	2.53	0.5	7,588	484	20,417
Trent 884-17	1994	5.87	390.1	2.89	2.89	0.97	0.31	0.18	0.18	0.65	15.19	0.000001	0.000001	0.000001	1	30.63	30.63	11.07	5.04	4.37	5.1	2.53	0.5	7,588	484	20,417
Trent 892B-17	1994	5.7	411.48	3.1	3.1	1	0.3	0.2	0.2	0.57	13.07	0.000001	0.000001	0.000001	0.7	33.3	33.3	11.58	5.33	4	4.9	2.76	0.53	6,361	328	23,236
Trent 895	1994	5.7	413.05	3.19	3.19	1.05	0.33	0.19	0.19	0.54	14.71	0.000001	0.000001	0.000001	0.89	34.29	34.29	11.39	5.11	4	4.9	2.6	0.5	7,814	458	24,534
Trent 970-84	2006	7.5	334.7	2.2	2.2	0.7	0.3	0.2	0.2	1.4	15.1	0.000001	0.000001	0.000001	0.2	29.1	29.1	11.4	5.1	4.1	4.7	2.6	0.7	7,379	94	15,441
Trent 972-84	2006	7.5	345.9	2.23	2.23	0.75	0.27	0.3	0.3	1.4	15.94	0.000001	0.000001	0.000001	0.24	29.6	29.6	11.8	5	4.1	4.8	2.6	0.8	7,082	101	15,715
Trent XWB-74	2016	9.3	334	1.87	1.87	0.595	0.255	0.48	0.48	0.68	7.66	0	0	0	0.04	19.11	19.11	9.71	4.37	3	3.8	3.1	0.6	3,300	16	9,343
Trent XWB-83	2018	9.3	351	1.99	1.99	0.629	0.255	0.48	0.48	0.68	7.66	0	0	0	0.04	21.75	21.75	10.42	4.44	3.37	1.96	2.07	1.66	3,316	16	10,870
Trent XWB-93	2018	9.3	374	2.15	2.15	0.674	0.255	0.48	0.48	0.68	7.66	0	0	0	0.04	25.13	25.13	11.34	4.53	3.37	1.96	2.07	1.66	3,337	16	13,038

Engine Emissions Database (5/5)

Engine Type	EIS	Bypass Ratio	Rated Engine Output (kN)	Unadjusted Fuel Flow - Takeoff	Unadjusted Fuel Flow - Climbout	Unadjusted Fuel Flow - Approach	Unadjusted Fuel Flow - Idle	CO Raw Emission Index - Takeoff	CO Raw Emission Index - Climbout	CO Raw Emission Index - Approach	CO Raw Emission Index - Idle	HC Raw Emission Index - Takeoff	HC Raw Emission Index - Climbout	HC Raw Emission Index - Approach	HC Raw Emission Index - Idle	NOx Raw Emission Index - Takeoff	NOx Raw Emission Index - Climbout	NOx Raw Emission Index - Approach	NOx Raw Emission Index - Idle	Smoke Number - Takeoff	Smoke Number - Climbout	Smoke Number - Approach	Smoke Number - Idle	LTO CO	LTO HC	LTO Nox
Trent XWB-97	2018	9.3	431	2.547	2.547	0.788	0.256	0.48	0.48	0.68	7.66	0	0	0	0.04	33.8	33.8	13.7	4.76	3	3.8	3.1	0.6	3,400	16	19,471
V2524-A5	2009	4.81	109.06	0.867	0.867	0.326	0.133	0.44	0.44	2.28	12.03	0.04	0.04	0.07	0.14	19.25	19.25	9.69	5.18	7	7.8	3.7	1.7	2,741	41	4,737
V2527-A5	2009	4.82	111.2	0.873	0.873	0.328	0.134	0.44	0.44	2.25	11.96	0.03	0.03	0.07	0.14	19.36	19.36	9.74	5.19	6.9	7.7	3.8	1.6	2,744	39	4,792
V2530-A5	2009	4.54	133.4	1.078	1.078	0.387	0.145	0.41	0.41	1.65	10.45	0.03	0.03	0.06	0.12	23.92	23.92	10.92	5.52	3.7	6.6	5.7	1.4	2,594	38	6,750
V2533-A5	2009	4.46	140.56	1.142	1.142	0.405	0.147	0.41	0.41	1.54	10.12	0.02	0.02	0.06	0.12	25.65	25.65	11.24	5.6	2	5.8	6.4	1.3	2,552	37	7,474
RR Advance2	2018	NC	72	0.497	0.497	0.17	0.072	0.3	0.3	6.61	41	0	0	0	2.75	10.34	10.34	6.24	2.81	4.26	4.42	0	0.1	4,901	309	1,464
RR Advance3	2018	15	334.7	1.741	1.741	0.567	0.209	0.48	0.48	0.68	7.66	0	0	0	0.04	31.1	31.1	10.52	4.27	3.6	4.3	2.8	0.7	2,735	13	12,245

Note: Take-Off indices are provided for a thrust of 85%

Source:
- *ICAO Emissions Database*
- *OEM inputs*
- *IATA estimates*

Content

A	**Appendices**

APU Emissions Database

APU	Fuel Flow (kg/hr)	CO (kg/hr)	HC (kg/hr)	NOx (kg/hr)
GTCP131-9A	125	0.56	0.04	0.77
GTCP131-9B	125	0.56	0.04	0.77
GTCP331-350	192	0.38	0.05	2.03
PW901A	392	6.57	0.59	1.23
GTCP331-600	290	0.46	0.05	2.77
PW980A	470	6.57	0.59	1.23
GTCP331-500B	244	0.46	0.05	2.77
GTCP36-300-4	128	0.21	0.02	1.01
GTCP331-200	122	0.50	0.05	1.16
APS3200	125	0.56	0.04	0.77
GTCP85-129	107	1.92	0.11	0.51
GTCP331-250H	122	0.64	0.07	1.56
GTCP331-350C	192	0.38	0.05	2.03
APS2300	107	1.92	0.11	0.51
PW901C	232	6.57	0.59	1.23
GTCP331-250	122	0.64	0.07	1.56
APS2000	68	0.44	0.04	0.31
TSCP700-4E	147	0.78	0.08	1.73
GTCP660-4	392	3.01	0.10	1.85
GTCP85-98CK	107	1.92	0.11	0.51
GTCP36-100E	115	2.06	0.04	0.35
RE220(GX)	68	0.44	0.04	0.31
GTCP36-150RJ	68	0.44	0.04	0.31
GTCP36-150	68	0.44	0.04	0.31
HGT1700	261	0.41	0.04	2.50
APS5000	110	0.45	0.05	1.04
GTCP131-9N	113	0.51	0.04	0.69
PW980A-N	470	6.57	0.59	1.23
GTCP36-100N	115	2.06	0.04	0.35
GTCP36-150N	68	0.44	0.04	0.31
GTCP85-98DHF	107	1.92	0.11	0.51

Main sources:

- *FAA*
- *Zurich Airport*
- *OEM*
- *Advanced Aircraft Flight Performance, Antonio Filippone*
- *ICAO Air Quality Manual Doc 9889 edition 2011*
- *IATA Guidance material and Best Practices for Fuel and Environmental management edition 2011*
- *OEM press releases*
- *IATA Estimates*