ICAO

ENVIRONMENT

Scoping Report on

Environmental Metrics of Relevance To the Global Aviation System

Deliverable of ICAO Committee on Aviation Environmental Protection (CAEP)

2022

Notes

This state of play report is produced by ICAO Committee on Aviation Environmental Protection (CAEP) Working Group 2 on Airport and Operations during the CAEP/12 cycle. Following the review by subsidiary bodies, the ICAO Council approved the technical recommendation made by CAEP and approved the publication of this report during the 226th Session, which took place from 24 May to 23 June 2022.

Disclaimer

TABLE OF CONTENTS

1. Executive Summary

During the CAEP/11 cycle, Working Group 2 (WG2) - Airport and Operations was requested to consider the possibility to develop environmental Key Performance Indicators (KPIs) for use in an Air Traffic Management (ATM) context. The work was conducted in coordination with Working Group 1 - Noise Technical and Working Group 3 - Emissions Technical. The conclusions of the work were that further work would be necessary to better understand the current environmental metrics used by States and operational stakeholders beyond an ATM environment and to assess the performance of all players within the global aviation system.

This document was prepared during the CAEP/12 cycle. It provides an overview of some metrics used by different States and operational stakeholders to assess the environmental performance of aviation, with the original objective of drawing a conclusion on whether or not some metrics could be considered to describe environmental performance at the global level. The metrics that are presented in this state-of-play report may be considered as widely applicable to describe environmental performance at the global level, but whether or not they are appropriate to describe a specific performance depends on the specific circumstances, including Local/State/Region regulations, resource constraints, data availability, etc. From that perspective, the document details a list of potential metrics/indicators that may be considered to describe environmental performance on a case by case basis by different stakeholders.

The ICAO Global Air Navigation Plan (GANP) has identified five Key Performance Indicators (KPIs) related to ATM. Many of these metrics/indicators are based on surveillance data and act as proxies for environmental performance. This state-of-play report describes additional metrics/indicators used by various stakeholders grouped into four categories:

- Airline Fleet Operations,
- ATM Operations,
- Airport Operations and
- State/Regional/Global Levels

The document also discusses the implementation of Environmental Management Systems (EMS) and other voluntary activities sometimes adopted by different stakeholders in support of process performance.

2. Acronyms and abbreviations

ACA	Airport Carbon Accreditation
ACARS	Aircraft Communications Addressing and Reporting System
ACI	Airport Council International
ADS-B	Automatic Dependent Surveillance - Broadcast
AJF	Alternative Jet Fuel
ANP	Aircraft Noise and Performance
ANS	Air Navigation Service
ANSP	Air Navigation Service Providers
ARN	Stockholm Arlanda Airport (IATA code)
ARP	Airport
ASK	Available Seat Kilometre
ASMA	Arrival Sequencing and Metering Area
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
CAA	Civil Aviation Authority
CAAFI	Commercial Aviation Alternative Fuels Initiative
CAEP	Committee on Aviation and Environmental Protection
CCO	Continuous Climb Operations
CDO	Continuous Descent Operations
CORSIA	Carbon Offsetting Reduction Scheme for International Aviation
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CSR	Corporate Social Responsibility
dB	decibels
DNL	Day-Night average Sound Level
EASA	European Union Aviation Safety Agency
ECAC	European Civil Aviation Conference
EMS	Environmental Management System
EPNdB	Effective perceived noise in decibels
FANS	Future Air Navigation Systems
FDR	Flight Data Recorder
FEI	Flight Efficiency Initiative
g	gram
GANP	Global Air Navigation Plan
GCD	Great Circle Distance
GHG	Greenhouse gases
GIS	Geographic Information System

IAP	Instrument Approach Procedure
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
kg	kilogram
KPI	Key Performance Indicator
LAmax	Maximum A-weighted Noise Level
Lden	Day-Evening-Night Sound Level
Lmax	Maximum Sound Level
N/A	Not Applicable
NM	Nautical Mile (1852 m)
NO_X	Nitrogen Oxide
OEM	Original Equipment Manufacturer
OOOI	Out-Off-On-In
PKT	Passenger Kilometre Transported
PBN	Performance Based Navigation
PRC	Performance Review Commission
RNAV	Area Navigation (earlier Random Navigation)
RTK	Revenue Tonne Kilometre
SAF	Sustainable Aviation Fuel
SCR	Shortest Constrained Route
SEL	Sound Exposure Level
SESAR	Single European Sky ATM Research
ToC	Top of Climb
ToD	Top of Descent
UHC	Unburned hydrocarbons
WG	Working Group

3. Terminology

Term	Definition	Source
ACARS	Aircraft Communications Addressing and Reporting System (ACARS) is a digital data link system for the transmission of messages between aircraft and ground stations, which has been in use since 1978. At first it relied exclusively on VHF channels but more recently, alternative means of data transmission have been added which have greatly enhanced its geographical coverage.	SKYbrary, www.skybrary.aero
Aircraft	Any machine that can derive support in the atmosphere from the reactions of the air other than the reactions of the air against the earth's surface.	ICAO Annex 1 – Personnel Licensing
FTK	Freight Tonne Kilometre A metric tonne of freight or mail carried one kilometre.	ICAO
GCD	The shortest distance between two points on the surface of the Earth by using the Vincenty distance formula associated with the World Geodesic System – 1984 (WGS 84) adopted by ICAO (Annex 15).	ICAO
Greenhouse Gases (GHG)	Greenhouse Gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary GHGs in the earth's atmosphere. Moreover, there are a number of entirely human-made GHGs in the atmosphere, such as the halocarbons and other chlorine-and bromine-containing substances, dealt with under the Montreal Protocol. Beside CO_2, N_2O and CH_4, the Kyoto Protocol deals with the GHGs sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).	IPPC

OOOI	OOOI is an acronym meaning Out Off ON IN. It is recorded via ACARS for a flight segment; aircraft OUT of the gate, wheels OFF the runway into the air, wheels ON the runway, and aircraft IN the gate. It is	EUROCONTROL ATM Lexicon, ext.eurocontrol.int/lexicon
PTK	Passenger Tonne-Kilometres Passenger tonne-kilometres performed, which are obtained by applying a standard weight per passenger to the passenger-kilometre performed. (See also Revenue Tonne-Kilometre below.)	ICAO Doc. 9626 - Manual on the Regulation of International Air Transport
Revenue Passenger	A passenger carried for which the airline receives remuneration. Note: Revenue passenger, a term which, for ICAO statistical purposes refers to passengers paying 25 per cent or more of the normal applicable fare.	ICAO Doc. 9626 - Manual on the Regulation of International Air Transport
RTK	An RTK is generated when a metric tonne of revenue load is carried one kilometre. Where such load includes passenger load, the number of passengers is converted into weight load, usually by multiplying this number by 90 kilogrammes (to include baggage).	ICAO Doc. 9626 - Manual on the Regulation of International Air Transport

4. Introduction

During the CAEP/11 cycle, Working Group 2 (WG2) - Airports and Operations was requested to consider the possibility to develop environmental Key Performance Indicators (KPIs) for use in an Air Traffic Management (ATM) context. The work was conducted in coordination with WG1 and WG3. The conclusions of the work were that further work would be necessary to better understand the current environmental metrics used by States and operational stakeholders beyond an ATM environment and to assess the performance of all players within the global aviation system.

This document was prepared during the CAEP/12 cycle by WG2 under a task called Environmental Metrics of Relevance to the Global Aviation System.

The high level objective of this state-of-play document is to provide an overview of some metrics used by different States and operational stakeholders to assess the environmental performance of aviation, with the view of drawing a conclusion on whether or not some metrics could be used to describe environmental performance at the global level. States and operational stakeholders that have not yet defined local metrics or are considering revising existing ones would be able to refer to the state-of-play document as a basis for further work. While this document presents a menu of some relevant metrics, it is up to States and operational stakeholders to determine what is useful and practical for their own purposes.

In today´s operations, environmental metrics are typically associated with physical indicators such as gaseous emissions (covering greenhouse gases and gases associated with Local Air Quality) and noise. Metrics could also be linked to process performance, such as usage of an Environmental Management System (EMS), voluntary environmental performance initiatives, or training stakeholders involved in operations (e.g., Flight Crews, Air Traffic Controllers).
ICAO has established five comprehensive strategic objectives:

- Aviation Safety
- Air Navigation Capacity and Efficiency
- Security and Facilitation
- Economic Development
- Environmental Protection

Information in this environmental metrics state-of-play document is related to the ICAO strategic objectives:

- “Air Navigation Capacity and Efficiency,” introduced in Section 4.2.
- “Environmental Protection”, introduced in Section 4.3.

This document is intended to catalogue useful metrics in measuring aviation’s contribution to these two ICAO strategic objectives. The research that has led to the publication of this document was carried out by an international team of aviation related environmental and operational experts with capabilities across operators, airports, aerospace manufacturers, air navigation service providers, and regulators.

4.1 Measuring Environmental Performance: Background and fundamentals

It was the eminent Scottish mathematician and physicist Lord Kelvin who said, "If you can't measure it, you can't improve it". Put simply, in order to measure an environmental impact, we need to understand which data are required to characterise the impact. There are a myriad of definitions of metrics, but the key terminology and focus in this document will be on '**Key Performance Areas'**, '**Metrics'** and '(Key) **Performance Indicators'**, described below.

4.1.1 Key Performance Area

According to ICAO[1], Key Performance Areas (KPAs) are a way of categorizing performance subjects related to high-level ambitions and expectations.

4.1.2 Metric

According to ICAO[1], a Supporting metric is synonymous with a metric and defined as follows:

Supporting metric. *Supporting metrics are used to calculate the values of performance indicators. For example, cost-per-flight-indicator = Sum(cost)/Sum(flights). Performance measurement is done through the collection of data for the supporting metrics (e.g. this leads to a requirement for cost data collection and flight data collection).*

Further, ICAO[2] states that a metric should be **SMART**.

- **S**pecific
- **M**easurable
- **A**ccurate
- **R**eliable
- **T**imely

Metrics are created from data, or combinations of data sets, to enable the characterisation of quantities and/or impacts. For example, the CO_2 production by aircraft could be described as a metric, but since there are various types of aircraft in service at a given time, with different CO_2 production values, this metric is of little use, on its own, in analysing trends. To improve its value, this metric can be added to another data set. Take, for example, the CO_2 production of an aircraft's cruise phase; this might be measured, using the metric "tonnes of CO_2 per km flown in cruise."

[1] ICAO Document 9883 – Manual on Global Performance of the Air Navigation System
[2] ICAO Document 9854 – Global Air Traffic Management Operational Concept

This could be calculated by taking the total CO_2 emission for the cruise phase and dividing by the total distance flown in this phase – a combination of two sets of data, giving a better characterisation of performance.

4.1.3 Performance Indicator

Performance Indicators (PIs) are created from (combinations of) metrics to enable the analysis of trends in values over time or space. As an example, a performance indicator, such as “daily percentage of aircraft producing more than *x* tonnes of CO_2 during its cruise phase” is a value that allows for tracking of CO_2 performance of a fleet over time. It has the advantage of being independent of the number of aircraft flown in a day. It is, however, only valid if there are aircraft that exceed *x* tonnes of CO_2 per km in cruise. This does not necessarily invalidate the PI – we might only be interested in reducing emissions to below *x* tonnes per km of cruise.

If a PI is important and particularly effective at defining an impact, it is common to define it as a Key Performance Indicator (KPI). This does not necessarily mean that a KPI for one organisation is considered essential for other organisations, i.e. other organisations may regard it as a PI rather than a KPI.

Note: A Performance indicator is sometimes referred to as an Indicator.

4.1.4 Metric vs. Performance Indicators

A metric can be used as an indicator if it allows for the analysis of trends. For instance, “Total production of NO_X” at an airport is an indicator-metric allowing analysis of the trend in NO_X production at that airport[3].

4.2 Air Navigation Capacity and Efficiency

The ICAO Global ATM Concept sets out KPA expectations in general terms for the ATM domain[4]. The ICAO Global ATM Concept has its background in the Special Committee on Future Air Navigation Systems (FANS), established in 1983, with its main task to consider the technical, operational, institutional and economic issues of the future air navigation systems and adopt recommendations for the further development of civil aviation for a period of 25 years.

After a series of conferences and meetings of this body, ICAO adopted the FANS concept in 1991, in which the primary attention was given to the broader use of satellite navigation. However, experts had quickly come to the conclusion that the application of modern technology was not the only factor to be taken into account, but the challenges were much more complex and involved a

[3] SESAR JU - 16.03.02 (D006) - GHG KPIs and Metric Final Set
[4] EUROCONTROL ATM Lexicon. https://ext.eurocontrol.int/lexicon/index.php/Key_Performance_Area

number of organizational, economic, legal and institutional aspects. These broader considerations were introduced in ICAO Document 9854 – Global Air Traffic Management Operational Concept which was subsequently referred to as the Global Air Navigation Plan (GANP)[5].

In order to expedite the work on performance, the Thirteenth Air Navigation Conference recommended ICAO to consider establishing a group of performance experts under the GANP Study Group (GSG) (Recommendation 4.3/1 refers). ICAO, therefore, formed the GANP Performance Expert Group (GANP-PEG) to maintain, evolve and develop the global performance management framework of the GANP, and in particular to contribute to the coherency and consistency related to the performance of the Global Aviation Safety Plan (GASP) (ICAO Document 10004) and Global Aviation Security Plan (GASeP) (ICAO Document 10118).

A summary of the GANP performance ambitions are classified into eleven different KPAs summarized in Table 1 below, which, broadly speaking, is a way of categorising ICAO performance subjects related to high level ambitions and expectations of the future ATM system by 2040 and beyond. These expectations are interrelated and cannot be considered in isolation.

KPA	Ambition
Access and Equity	No aviation community member excluded or treated unfairly.
Capacity and Resilience	Nominal capacity easily scalable with demand. Disruptive events do not interrupt service provision and do not significantly affect the performance of the system.
Cost effectiveness	No increase of total direct Air Navigation Service (ANS) cost while maintaining the safety and quality of service. Significant increase of ANS productivity, irrespective of demand.
Efficiency	Reduction of the gap between the flight efficiency achieved and the desired optimum trajectory of airspace users.
Environment	ANS-induced inefficiencies to be progressively removed to contribute to the global ICAO aspirational goals for CO_2 emissions. To benefit from achieved flight efficiency gains.
Flexibility	To absorb required changes to individual businesses and operational trajectories.
Interoperability	Essential at an operational and technical level.
Participation by the ATM community	Pre-agreed level of participation to make the maximum shared use of the air navigation resources.
Predictability	No impact in ANS delivery variability including asset availability.
Safety	Zero ANS-related accidents and a significant (50%) reduction of ANS-related serious incidents.
Security	Zero significant disruptions due to cyber incidents

Table 1: Summary of the GANP performance ambitions.

[5] ICAO GANP, https://www4.icao.int/ganpportal/GanpDocument#/?_k=m7nx6a

KPIs linked to environment performance and ATM from the GANP are presented in Section 5.2.2 - 5.2.7 below.

Alternative ways of outlining KPAs have also been identified, for instance, by the Single European Sky ATM Research (SESAR) program, which defines 10 KPAs: Access and Equity, Capacity, Civil-Military coordination, Cost Efficiency, Environment, Flexibility, Human Performance, Predictability and Punctuality, Safety and Security.

4.3 Environmental Protection

ICAO serves as a multilateral platform for cooperation on international aviation environmental protection. Over the years, the national governments who participate together under the Chicago Convention, also commonly referred to as 'ICAO Member States', have agreed to concentrate their aviation environmental collaboration on three core areas as previously mentioned:

- Climate change and aviation emissions
- Aircraft noise
- Local air quality

Countries are pursuing these objectives through ICAO primarily via their development of new global aviation standards. They have also agreed to aspirational goals for international aviation, and have prioritized ICAO's Environmental Protection resources on:

- Airframe, propulsion, and other aeronautical and technological innovations
- Optimizing flight procedures to reduce fuel burn
- Increasing the production and deployment of sustainable aviation fuels and clean energy
- Implementing the Carbon Offsetting Reduction Scheme for International Aviation (CORSIA)

It should be noted that there are interdependencies between "Air Navigation Capacity and Efficiency" and "Environmental Protection" in terms of common usage of some metrics and certain elements.

This state-of-play document will report on identified metrics used in these domains by State and other different aviation stakeholders.

5. Metrics

Each metric/indicator described in this state-of play report has been categorised into one of four main categories:

- Airline Fleet Operations,
- ATM Operations,
- Airport Operations and
- State/Regional/Global Levels

The information was collected via public data sources.This mapping is used to link the identified metric/indicator to a main category noting that a certain metric/indicator identified in the first three categories can be scalable, e.g. from local level up to global level.

Further, each metric/indicator has been linked to one, or more of four groups ("pillars"):

- Sustainable Aviation Fuel (SAF),
- Greenhouse gases (GHG),
- (Local) Air Quality and
- Noise.

The table in which the metrics/indicators are presented below are based on the presentation of KPIs in the ICAO GANP with two additional elements, *Pillar* and *Comments*, according to the following format:

Title	The title of the metric
Definition	The definition of the metric
Measurement unit	How the metric is measured
Pillar	*Which pillar(s) the metric belong to (SAF, GHG, Noise, LAQ)*
Operations measured	What aspects of the operation are measured
Variants	If different possibilities to measure the indicator are available
Objects characterized	For what operational scenarios/stakeholders that are included in the analysis
Utility of the metric	What the purpose of the metric is
Parameters	What are the required parameters
Data requirement	What information is required to generate the metric
Data feed providers	Which stakeholders are suppling data
Formula/algorithm	How the indicator is measured
References & Examples of use	Examples from where and by whom the metric is used
Comment	*Free text when required, e.g. interdependencies with other KPAs, strengths and weaknesses identified*

5.1 Airline Fleet Operations

The following Section represents a list of metrics/indicators that airline operators can consider when defining how they can measure environmental performance specific to their fleet and their operation. Not all metrics/KPIs need to be applied. Airline operators can prioritise the metrics and indicators that are best suited for their operation and fleet and that can be supported with data collection capabilities to enable performance monitoring.

5.1.1 Average aircraft age

Title	Average aircraft age
Definition	Measurement of the average aircraft age
Measurement unit	years
Pillar	GHG, Noise, LAQ
Operations measured	Actual IFR flights
Variants	To consider all operating aircraft or divided into airline operation, cargo operators, business aircraft operation etc.
Objects characterized	This metric is intended to give an indication of the number of new aircraft being used
Utility of the metric	This metric is intended to give a clear indication of the aircraft fleet age. The younger the average aircraft age, the greater the usage of modern aircraft, which acts as a proxy for efficiency and noise performance
Parameters	Average aircraft age in an ICAO region integrated to give a global number
Data requirement	Date of entry into service for each individual aircraft
Data feed providers	State aircraft registry, Airline records, Original Equipment Manufacturer (OEM
Formula/algorithm	Age (converted to years) = Current date - Entry into service date
References & Examples of use	European Aviation Environmental Report[6] Airline Corporate Social Responsibility (CSR)/Environmental reports
Comment	Aircraft age can be used as a proxy for environmental efficiency on the basis that newer aircraft technology typically delivers improved fuel burn, emissions and noise performance. This metric is intended to give an indication on the amount of new aircraft being operated in a certain aircraft population. The aircraft population is scalable.

[6] https://www.easa.europa.eu/eaer/

5.1.2 Aircraft model Certification/Entry into service

Title	Aircraft model Certification/Entry into service
Definition	Measurement of the average aircraft age compared to aircraft certification/Entry into service
Measurement unit	years
Pillar	GHG, Noise, LAQ
Operations measured	Actual IFR flights
Variants	N/A
Objects characterized	This metric is intended to give an indication of the level of new aircraft technology being used in airline fleets, being a proxy for efficiency
Utility of the metric	The Entry into service year of an aircraft type can give an indication of the technology level of the aircraft in an ICAO region integrated to give a global number
Parameters	N/A
Data requirement	Date of Entry into service for each aircraft model
Data feed providers	State aircraft registry, airline records
Formula/algorithm	Age (converted to years) = Current date - Entry into service date
References & Examples of use	IATA Aircraft Technology Roadmap to 2050[7]
Comment	Technological progress is not necessarily linked to the production date (Average aircraft age) of the individual aircraft, rather to the Entry into service of the model

[7] https://www.iata.org

5.1.3 Fuel or CO_2/Revenue Passenger Kilometre (RPK)

Title	Fuel or CO_2/Revenue Passenger Kilometre (RPK)
Definition	Average CO_2 emissions or fuel consumption per RPK
Measurement unit	litres fuel/100 RPK gram CO_2/RPK
Pillar	GHG
Operations measured	Actual IFR flights
Variants	N/A
Objects characterized	Applicable to passenger traffic, either individual flights or a cluster of flights, scalable.
Utility of the metric	Applicable to passenger traffic to characterize the relative energy efficiency/ CO_2 emission
Parameters	The GCD is fixed, the Passengers are fixed for a given flight. Total fuel consumption from gate-to-gate is determined after a given flight. ICAO Annex 16, vol. IV, Part II, Appendix 2. proposes different methods to calculate the consumed fuel with reference to CORSIA. **Method A** *Fuel consumed = Fuel in tanks after fuel uplift (current flight) - Fuel in tanks after fuel uplift (next flight) + fuel uplift (next flight)* **Method B** *Fuel consumed = Fuel at block on (previous flight) -* *Fuel at block on (current flight) + fuel uplift (current flight)* **Block off / Block on** *Fuel consumed = Fuel at block off (current flight) - Fuel at block on (current flight)* **Fuel uplift** *Fuel consumed = Fuel uplift (current flight)* **Block hour and average consumption on route per aircraft type** *Fuel consumed = Block hours · average fuel burn* IATA Recommended Practice (1678)[8] assumes that fuel consumed/usage is proportional to aircraft mass. The passenger fuel usage is the ratio of total passenger mass to total mass multiplied by the total fuel used. This method is used to cater for belly cargo on passenger aircraft.
Data requirement	Fuel used, Departure Airport and Destination Airport to determine GCD, Passenger numbers and cargo mass.
Data feed providers	Airline data
Formula/algorithm	$\text{Total passenger fuel usage} = \left[\frac{\text{total passenger mass}}{\text{total mass}}\right] \cdot \text{total fuel usage}$ Where,

[8] https://www.iata.org/contentassets/34f5341668f14157ac55896f364e3451/rp-carbon-calculation.pdf

	Total mass = Total passenger mass + total cargo mass Total passenger mass = number of seats · 50 kg + + number of passenger · 100 kg $\frac{Fuel}{RPK} = \frac{\text{Total passenger fuel used [litres]}}{\text{Passengers} \cdot \text{GCD}}$ $\frac{CO_2}{RPK} = \frac{\text{Total passenger fuel used [kg]} \cdot 3.16}{\text{Passengers} \cdot \text{GCD}}$ *Note: the 3.16 conversion factor from fuel to CO_2 applies to JET-A1.*
References & Examples of use	European Aviation Environmental Report. Airline CSR/Environmental reports. IATA Recommended Practice (1678)
Comment	Identified to be used by some airlines (passenger traffic). It can be used on a single flight but more commonly aggregated average numbers on a series of flight as well within a given time period. The term Revenue Passenger Kilometre (RPK) is synonymous with Passenger Kilometre Transported (PKT). Other units can be used as well.

5.1.4 Fuel or CO_2/Revenue Tonne Kilometre (RTK)

Title	Fuel or CO_2/Revenue Tonne Kilometre (RTK)
Definition	Average CO_2 emissions or fuel consumption per RTK
Measurement unit	litres fuel/100 RTK kg CO_2/RTK
Pillar	GHG
Operations measured	Actual IFR flights
Variants	N/A
Objects characterized	Applicable to passenger and cargo traffic, either individual flights or a cluster of flights, scalable.
Utility of the metric	Applicable to passenger and cargo traffic.Fuel/CO_2 per RTK is an efficiency measure that account for the amount of fuel used/CO_2 emitted in relation to the passengers, luggage and cargo. This can be presented on airlines basis and scaled up to ICAO region basis or global basis.
Parameters	The GCD is fixed, the Passengers are fixed for a given flight. ICAO default conversion factor is 100 kg/Passenger Total fuel consumption from gate-to-gate is determined after a given flight. ICAO Annex 16, vol. IV, Part II, Appendix 2. proposes different methods to calculate the consumed fuel with reference to CORSIA. **Method A** *Fuel consumed = Fuel in tanks after fuel uplift (current flight) - Fuel in tanks after fuel uplift (next flight) + fuel uplift (next flight)* **Method B** *Fuel consumed = Fuel at block on (previous flight) - Fuel at block on (current flight) + fuel uplift (current flight)* **Block off / Block on** *Fuel consumed = Fuel at block off (current flight) - Fuel at block on (current flight)* **Fuel uplift** *Fuel consumed = Fuel uplift (current flight)* **Block hour and average consumption on route per aircraft type** *Fuel consumed = Block hours · average fuel burn*
Data requirement	Fuel used, Departure Airport and Destination Airport to determine GCD, passenger and cargo statistics
Data feed providers	Airline data
Formula/algorithm	$\frac{\text{Fuel}}{\text{RTK}} = \frac{\text{Fuel used [litres]}}{\text{(Total cargo payload + passengers)[kg]} \cdot 0.1 \cdot \text{GCD [km]}}$

	$$\frac{CO_2}{RTK} = \frac{\text{Fuel used [kg]} \cdot 3.16}{\text{(Total cargo payload + passengers) [kg]} \cdot 0.1 \cdot \text{GCD [km]}}$$ *Note: the 3.16 conversion factor from fuel to CO_2 applies to JET-A1.* *The 0.1 conversion factor in the denominator is used to convert the total revenue load in kg to metric tonnes.*
References & Examples of use	Airline CSR/Environmental reports
Comment	Used by industry to account for passengers, cargo and luggage. ICAO conversion factor is 100 kg/passenger. Other units and conversion factors can be used as well

5.1.5 Fuel or CO_2/Freight Tonne Kilometre (FTK)

Title	Fuel or CO_2/Freight Tonne Kilometre (FTK)
Definition	Average CO_2 emissions or fuel consumption per FTK
Measurement unit	litres fuel/100 FTK kg CO_2/FTK
Pillar	GHG
Operations measured	Actual IFR cargo flights
Variants	N/A
Objects characterized	Applicable to cargo traffic, either individual flights or a cluster of flights, scalable.
Utility of the metric/PI	Applicable to cargo traffic. Fuel/CO_2 per FTK is an efficiency measure that account for the amount of fuel used/CO_2 emitted in relation to the cargo transported. This can be presented on airlines basis and scaled up to ICAO region basis or global basis.
Parameters	The GCD is fixed Cargo is monitored Total fuel consumption from gate-to-gate is determined after a given flight. ICAO Annex 16, vol. IV, Part II, Appendix 2. proposes different methods to calculate the consumed fuel with reference to CORSIA. **Method A** *Fuel consumed = Fuel in tanks after fuel uplift (current flight) - Fuel in tanks after fuel uplift (next flight) + fuel uplift (next flight)* **Method B** *Fuel consumed = Fuel at block on (previous flight) -* *Fuel at block on (current flight) + fuel uplift (current flight)* **Block off / Block on** *Fuel consumed = Fuel at block off (current flight) - Fuel at block on (current flight)* **Fuel uplift** *Fuel consumed = Fuel uplift (current flight)* **Block hour and average consumption on route per aircraft type** *Fuel consumed = Block hours · average fuel burn*
Data requirement	Fuel used, Departure Airport and Destination Airport to determine GCD, cargo data.
Data feed providers	Cargo airlines.
Formula/algorithm	$\frac{\text{Fuel}}{\text{FTK}} = \frac{\text{Fuel used [litres]}}{\text{Cargo [kg]} \cdot 0.1 \cdot \text{GCD}}$ $\frac{CO_2}{\text{FTK}} = \frac{\text{Fuel used [kg]} \cdot 3.16}{\text{Cargo[kg]} \cdot 0.1 \cdot \text{GCD}}$

	Note: Cargo measured in kilograms for the equations above. The 3.16 conversion factor from fuel to CO_2 applies to JET-A1. The 0.1 conversion factor in the denominator is used to convert the total revenue load in kg to metric tonnes.
References & Examples of use	Cargo airline CSR/Environmental reports
Comment	Typically used by cargo operators Other units can be used as well.

5.1.6 Fuel or CO_2/Available Seat Kilometre (ASK)

Title	Fuel or CO_2/Available Seat Kilometre (ASK)
Definition	Average CO_2 emissions or fuel consumption per ASK
Measurement unit	litres fuel/100 ASK gram CO_2/ASK
Pillar	GHG
Operations measured	Actual IFR flights
Variants	N/A
Objects characterized	To present the relative fuel consumption/CO_2 emissions per ASK
Utility of the metric/KPI	Applicable to passenger traffic to characterize the relative energy efficiency/ CO_2 emission with focus on the technology level of the aircraft
Parameters	Total fuel consumption from gate-to-gate is determined after a given flight The GCD is fixed The number of seats is fixed for a given flight
Data requirement	Fuel used, Departure Airport and Destination Airport to determine GCD and the number of available seats
Data feed providers	Aircraft manufacturer
Formula/algorithm	$\frac{\text{Fuel}}{\text{ASK}} = \frac{\text{Fuel used [litres]}}{\text{Available Seats} \cdot \text{GCD}}$ $\frac{\text{CO}_2}{\text{ASK}} = \frac{\text{Fuel used [kg]} \cdot 3.16}{\text{Available Seats} \cdot \text{GCD}}$ *Note: the 3.16 conversion factor from fuel to CO_2 applies to JET-A1.*
References & Examples of use	Aircraft manufacturer data
Comment	Typically presented by OEMs since they have no impact on the number of passengers flying. It is sensitive to the number of seats. Other units can be used as well.

5.1.7 NO_X/CO/UHC/100 RPK or FTK

Title	NO_X/CO/UHC/100 RPK or FTK
Definition	Specific emissions of NO_X/CO/UHC
Measurement unit	g NO_X/CO/UHC per 100 RPK or FTK
Pillar	LAQ
Operations measured	Actual IFR flights
Variants	NO_X/CO/UHC can be presented
Objects characterized	Applicable to passenger traffic, either individual flights or a cluster of flights, scalable.
Utility of the metric	The objective is to determine specific emissions of NO_X/CO/UHC
Parameters	Total NO_X/CO/UHC emissions from gate-to-gate is determined after a given flight, the GCD is fixed, the Passengers/Freight are fixed for a given flight
Data requirement	Airline data
Data feed providers	Airline data
Formula/algorithm	It has not been identified.
References & Examples of use	Lufthansa Group CSR report[9]
Comment	NA

[9] https://www.lufthansagroup.com/media/downloads/en/responsibility/LH-sustainability-report-2019.pdf

5.1.8 Total airline fuel consumption/CO_2 emissions

Title	Total airline fuel consumption/CO_2 emissions
Definition	Aggregated amount of fuel consumed/CO_2 emissions emitted
Measurement unit	Mass or volume with different prefixes
Pillar	GHG
Operations measured	Usage of Jet fuel (absolute number) converted to CO_2 when needed
Variants	N/A
Objects characterized	This indicator gives total fuel consumption/emissions of CO_2. Data can be presented from a local (micro) level through a global (macro) level.
Utility of the metric	Applicable to all operation
Parameters	Total fuel consumption possibly converted to CO_2
Data requirement	Airline fuel record or CSR report
Data feed providers	Airline data
Formula/algorithm	The sum of all fuel usage $CO_2 \text{ emissions} = \text{fuel usage [kg]} \cdot 3.16 \left[\frac{\text{kg } CO_2}{\text{kg}}\right]$ *Note: the 3.16 conversion factor from fuel to CO_2 applies to JET-A1.*
References & Examples of use	Airline data
Comment	Can be used on local and global scale Other units can be considered as well.

5.2 ATM Operations

The following represents a list of metrics/indicators that ANSPs and airlines can consider when defining how to measure environmental performance for air traffic management and specific to an airspace volume / ANSP. Not all metrics/KPIs need to be applied. ANSPs, working with airline operators, should prioritize the metrics and indicators that are best suited for their airspace and traffic and that can be supported with data collection capabilities to enable performance monitoring.

5.2.1 Three dimensional Inefficiency score (3Di)

Title	Three Dimensional Inefficiency Score (3Di)
Definition	3Di is a metric that compares the actual three dimensional trajectory of an aircraft with a nominal 'optimal' profile. The 'optimal' profile is defined as achieving requested flight level in cruise phase, clear climb to and descent from that flight level and a point to point great circle distance in the lateral plane (incorporating an element of 'achieved distance' from the European KEA metric
Measurement unit	Observed surveilance positional data compared with a nominal optimal flight profile
Pillar	GHG
Operations measured	All elements of flight from entry into airspace of concern to exit from airspace in both vertical and horizontal dimensions
Variants	If different possibilities to measure the metric is available
Objects characterized	Air Navigation Service Providers (ANSPs), Airlines
Utility of the metric/PI	To identify inefficiency in the ATM network and enable improvement
Parameters	Aircraft 3D data
Data requirement	Surveillance data
Data feed providers	Surveillance data
Formula/algorithm	3Di score by flight is calculated as a combination of: Horizontal flight efficiency - defined as the difference between the UK portion of the overall optimal flight distance and the actual flight path flown within UK airspace. Horizontal flight efficiency is measured from the actual entry and exit point into and out of UK Flight Information Region, where the optimal flight distance is calculated using the same logic as the EUROCONTROL KEA algorithm. Vertical flight efficiency - defined as the difference in altitude between the reference (requested) flight level and the actual altitude of the period of level flight, alongside the time spent in level flight. Vertical inefficiency is split into flight phase (climb, cruise and descent).
References & Examples of use	In the UK 3Di performance targets are set by the aviation regulator and financially incentivized.
Comment	3Di, at lower altitudes, can have interdependencies/relationships with noise metrics, this is common with many if not all ATM emissions metrics.
Formula/algorithm	Specific formulations may vary. EUROCONTROL uses the following calculation: Level segments in the climb/descent trajectory are detected using the vertical speed limit and level band limit. The

	methodology considers a data point as the start of a level segment when the following conditions are met: ▪ The altitude difference with the next data point is less than or equal to the level band limit; and ▪ The vertical speed towards the next data point is less than or equal to the vertical speed limit. The level segment ends when the altitude difference between the altitude of the beginning of the level segment and the altitude of a data point is more than the level band limit or when the vertical speed between two consecutive data points is more than the vertical speed limit.
References & Examples of use	EUROCONTROL Performance Review Unit Dashboard Airline Flight Efficiency Initiatives
Comment	For full details on how to measure CCO/CDO performance in Europe, visit the Eurocontrol website[10] or watch an animation[11]

[10] https://www.eurocontrol.int/articles/continuous-climb-and-descent-operations

[11] https://www.youtube.com/watch?v=mUkMPb5eVJI

5.2.2 Taxi-out additional time (from the GANP)

Title	Taxi-out additional time
Definition	Actual taxi-out time compared to an unimpeded/reference taxi-out time.
Measurement unit	Minutes/flight
Pillar	GHG, LAQ
Operations measured	The duration of the taxi-out phase of departing flights
Variants	Variant 1 – basic (computed without departure gate and runway data) Variant 2 – advanced (computed with departure gate and runway data)
Objects characterized	The KPI is typically computed for individual airports, or clusters of airports (selection/grouping based on size and/or geography).
Utility of the metric/KPI	This KPI is intended to give an indication of the efficiency of the departure phase operations on the surface of an aerodrome. This may include the average queuing that is taking place in front of the departure runways, non-optimal taxi routing and intermediate aircraft stops during taxi-out. The KPI is also typically used to estimate excess taxi-out fuel consumption and associated emissions (for the Environment KPA). The KPI is designed to filter out the effect of physical airport layout while focusing on the responsibility of ATM to optimize the outbound traffic flow from gate to take-off.
Parameters	Unimpeded/reference taxi-out time: Recommended approach for the basic variant of the KPI: a single value at airport level, e.g. the 20th percentile of actual taxi times recorded at an airport, sorted from the shortest to the longest. Recommended approach for the advanced variant of the KPI: a separate value for each gate/runway combination, e.g. the average actual taxi-out time recorded during periods of non-congestion (needs to be periodically reassessed).
Data requirement	For each departing flight: Actual off-block time (AOBT), Actual take-off time (ATOT). In addition, for the advanced KPI variant: Departure gate ID Take-off runway ID
Data feed providers	Airports (airport operations, A-CDM), airlines (OOOI data), ADS-B data providers and/or ANSPs
Formula/algorithm	At the level of individual flights: 1. Select departing flights, exclude helicopters, 2. Compute actual taxi-out duration: ATOT minus AOBT, 3. Compute additional taxi-out time: actual taxi-out duration minus unimpeded taxi out time. At aggregated level: 4. Compute the KPI: sum of additional taxi-out times divided by number of IFR departures
References & Examples of use	Comparison of ATM-Related Operational Performance: U.S./Europe (September 2016)

	Singapore / US / Europe benchmarking study (CAAS - FAA - EUROCONTROL, 2017) China / Europe benchmarking study (CAUC - EUROCONTROL, 2017) PRC Performance Review Report (EUROCONTROL 2017) EUROCONTROL Performance Review Unit Dashboard[12] Single European Sky Performance Scheme CANSO Recommended KPIs for Measuring ANSP Operational Performance (2015)
Comment	GANP KPI02

[12] https://ansperformance.eu

5.2.3 Filed flight plan en-route extensions (from the GANP)

Title	Filed flight plan en-route extension
Definition	Flight planned en-route distance compared to a reference ideal trajectory distance.
Measurement unit	% excess distance
Pillar	GHG
Operations measured	The planned en-route distance, as selected during the preparation of flight plans.
Variants	Variant 1, using a 40 NM cylinder around the departure and destination airport as the start/end of en-route airspace. Variant 2, using a 40 NM cylinder around the departure airport and a 100 NM cylinder around the destination airport as the start/end of en-route airspace.
Objects characterized	The KPI can be computed for any volume of en-route airspace; this implies that it can be computed at State level (covering the FIRs of a State).
Utility of the metric/KPI	This KPI measures the en-route horizontal flight (in)efficiency contained in a set of filed flight plans crossing an airspace volume. Its value is influenced by route network design, route & airspace availability, airspace user choice (e.g. to ensure safety, to minimize cost and to take into account wind and weather) and airspace user constraints (e.g. overflight permits, aircraft limitations). A significant gap between this KPI and the Actual en-Route Extension KPI indicates that many flights are not flown along the planned route, which should trigger an analysis of why this is happening.
Parameters	A 'Measured area' is defined for which the KPI is computed. For example, a State. A 'Reference area' is defined as a (sub)regional boundary considered, containing all 'Measured areas', for example States within the same ICAO Region. Departure terminal area proxy: a cylinder with 40 NM radius around the departure airport. Destination terminal area proxy: a cylinder with 40 NM radius around the destination airport (variant 1). For variant 2 the radius is 100 NM.
Data requirement	For each Flight plan: -Departure airport (Point A) -Destination airport (Point B) -Entry point in the 'Reference area' (Point O) -Exit point from the 'Reference area' (Point D) -Entry points in the 'Measured areas' (Points N) -Exit points from the 'Measured areas' (Points X) -Planned distance for each NX portion of the flight
Data feed providers	ANSPs

Formula/algorithm	For the horizontal trajectory of each flight, different parts (trajectory portions) are considered: 1. The part of the flight which is within the reference area (segment OD). If airports A and/or B are located within the reference area, the points O and/or D are placed on the airport reference point (ARP). 2. The part of the flight for which the State level indicator is computed (between points N and X). If points A and/or B (the airports) are located within the measured State, the points N and/or X are placed on the 40 NM circle (variant 1) around the airport reference point as shown in Figure 2, to exclude terminal route efficiency from the indicator. Between points N and X, three quantities can be computed: the planned distance (length of flight plan trajectory), the local direct distance (great circle distance between N and X, not required for this indicator), and the contribution of the trajectory between N and X to the completion of the great circle distance between O and D. This contribution is called the "achieved distance". The formula for computing this is based on four great circle distances interconnecting the points O, N, X and D: achieved distance = [(OX-ON)+(DN-DX)]/2. When a given flight traverses multiple States, the sum of the planned distance in each State equals the total planned distance from O to D. Likewise the sum of all achieved distances equals the direct distance from O to D. The extra distance for a portion NX of a given flight is the difference between the actual/flight planned distance and the achieved distance. The total extra distance observed within a measured area (e.g. a State) over a given time period is the sum of the planned distances across all traversing flights, minus the sum of the achieved distances across all traversing flights. The KPI is computed as the total extra distance divided by total achieved distance, expressed as a percentage.
References & Examples of use	- ICAO EUR Doc 030 EUR Region Performance Framework Document (July 2013) - Comparison of ATM-Related Operational Performance: U.S./Europe (September 2016) - PRC Performance Review Report (EUROCONTROL 2017) - EUROCONTROL Performance Review Unit Dashboard[13] - Single European Sky Performance Scheme - CANSO Recommended KPIs for Measuring ANSP Operational Performance (2015)
Comment	GANP KPI04

[13] https://ansperformance.eu

5.2.4 Flight time variability (from the GANP)

Title	Flight time variability
Definition	Distribution of the flight (phase) duration around the average value.
Measurement unit	Minutes/flight
Pillar	GHG
Operations measured	Scheduled flights with the same flight ID on a given airport-pair (flight XYZ123 from A to B): the gate-to-gate duration, and at more detailed level the duration of the individual flight phases (taxi-out, airborne, taxi-in)
Variants	Different parameter values possible (see 'Parameters').
Objects characterized	The KPI is typically computed for the scheduled traffic flows interconnecting a given cluster of airports (two or more; selection/grouping based on size and/or geography).
Utility of the metric/KPI	The "variability" of operations determines the level of predictability for airspace users and hence has an impact on airline scheduling. It focuses on the variance (distribution widths) associated with the individual phases of flight as experienced by airspace users. The higher the variability, the wider the distribution of actual travel times and the more costly time buffer is required in airline schedules to maintain a satisfactory level of punctuality. In addition, reducing the variability of actual block times can potentially reduce the amount of excess fuel that needs to be carried for each flight in order to allow for uncertainties.
Parameters	Minimum monthly flight frequency filter: flights with a frequency less than 20 times per month are not included in the indicator. Outlier filter: Variant 1: Only 70% of the (remaining) flights are considered in the indicator, i.e. the 15th percentile (percentile 1) is used to determine the shortest duration, the 85th percentile (percentile 2) is used to determine the longest duration Variant 2: Only 60% of the (remaining) flights are considered in the indicator, i.e. the 20th percentile (percentile 1) is used to determine the shortest duration, the 80th percentile (percentile 2) is used to determine the longest duration
Data requirement	For each flight: OOOI data: gate "out" (AOBT), wheels "off," wheels "on," and gate "in" (AIBT) actual times.
Data feed providers	Airlines
Formula/algorithm	At the level of flights with the same flight ID, at monthly or longer (e.g. annual) time aggregation level:

	1. Exclude flight IDs not meeting the minimum monthly frequency requirement 2. Sort flights in ascending order of flight (phase) duration 3. Identify shortest (percentile 1) and longest (percentile 2) duration 4. Compute variability: (longest – shortest) / 2 At the more aggregated level: 5. Compute the KPI: weighted average of the individual flight ID variabilities
References & Examples of use	Comparison of ATM-Related Operational Performance: U.S./Europe (September 2016) PRC Performance Review Report (EUROCONTROL 2017) CANSO Recommended KPIs for Measuring ANSP Operational Performance (2015)
Comment	GANP KPI15

5.2.5 Actual en-route extension (from the GANP)

Title	Actual en-route extension
Definition	Actual en-route distance flown compared to a reference ideal distance.
Measurement unit	% excess distance
Pillar	GHG
Operations measured	The actual distance flown by flights in en-route airspace.
Variants	Variant 1, using a 40 NM cylinder around the departure and destination airport as the start/end of en-route airspace. Variant 2, using a 40 NM cylinder around the departure airport and a 100 NM cylinder around the destination airport as the start/end of en-route airspace.
Objects characterized	The KPI can be computed for a traffic flow or a volume of en-route airspace; this implies that it can be computed at State level (covering the FIRs of a State).
Utility of the metric/KPI	This KPI measures the en-route horizontal flight (in)efficiency as actually flown, of a set of IFR flights crossing an airspace volume. Its value is influenced by route network design, route & airspace availability, airspace user choice (e.g. to ensure safety, to minimize cost and to take into account wind and weather) and airspace user constraints (e.g. overflight permits, aircraft limitations), and tactical ATC interventions modifying the trajectory (e.g. reroutings and 'direct to' clearances). The KPI is also typically used to estimate the excess fuel consumption and associated emissions (for the Environment KPA) attributed to horizontal flight inefficiency.
Parameters	Identical to the parameters of the 'Filed Flight Plan en-Route Extension' KPI.
Data requirement	For each actual flight trajectory: Departure airport (Point A) Destination airport (Point B) Entry point in the 'Reference Area' (Point O) Exit point from the 'Reference Area' (Point D) Entry points in the 'Measured Areas' (Points N) Exit points from the 'Measured Areas' (Point X) Distance flown for each NX portion of the actual flight trajectory, derived from surveillance data (radar, ADS-B…).
Data feed providers	ANSPs, ADS-B data providers
Formula/algorithm	Identical to the formula/algorithm of the 'Filed Flight Plan en-Route Extension' KPI.
References & Examples of use	ICAO EUR Doc 030 EUR Region Performance Framework Document (July 2013) Comparison of ATM-Related Operational Performance: U.S./Europe (September 2016)

	PRC Performance Review Report (EUROCONTROL 2017) EUROCONTROL Performance Review Unit Dashboard[14] Single European Sky Performance Scheme CANSO Recommended KPIs for Measuring ANSP Operational Performance (2015)
Comment	GANP KPI05

[14] https://ansperformance.eu

5.2.6 Level off during climb (from the GANP)

Title	Level-off during descent
Definition	Distance and time flown in level flight before Top of Climb.
Measurement unit	NM/flight and minutes/flight
Pillar	GHG, Noise
Operations measured	Actual IFR flights.
Variants	Variant 1: Average distance flown in level flight before Top of Climb Variant 2: Average time flown in level flight before Top of Climb
Objects characterized	The KPI is typically computed for traffic flows, individual airports, or clusters of airports (selection/grouping based on size and/or geography).
Utility of the metric/KPI	This KPI is intended to give an indication of the amount of level flight during the climb phase. Ideally, there should be no level flight during climbs because level flight results in a higher fuel burn and possibly more noise. Aircraft should reach their cruising altitudes as soon as possible since the fuel consumption is lower at higher altitudes.
Parameters	Analysis radius: the radius around the analysed airport within which the climb trajectory is analysed (e.g. 200 NM). Vertical speed limit: maximum vertical speed used to detect the start and end of a level segment (e.g. 300 feet/minute). Level band limit: altitude band within which data points have to stay to be included in a level segment (e.g. 200 feet). Minimum level time: minimum time duration for a level segment to be considered in the results (e.g. 20 seconds). Exclusion box percentage: percentage of the Top of Climb altitude which is used to define the lower altitude of the exclusion box (e.g. 90%). E.g. level segments occurring above the lower altitude limit of the exclusion box and longer than the exclusion box time are excluded from the results. Exclusion box time: a level segment in the exclusion box and longer than the exclusion box time is excluded (e.g. 5 minutes). Minimum altitude: the altitude where the level segment detection during the climb starts. The trajectory below this altitude is not analysed (e.g. 3000 feet).
Data requirement	For each flight trajectory: 4D data points (latitude, longitude, altitude and time). Departure airport ARP coordinates
Data feed providers	Trajectory data providers (reporting archived actual trajectories based on ADS-B and/or other surveillance data sources) and/or ANSPs.
Formula/algorithm	Level segments in the climb trajectory within the analysis radius are detected using the vertical speed limit and level band limit. The methodology considers a data point as the start of a level segment when the following conditions are met: the altitude

	difference with the next data point is less than or equal to the level band limit; and the vertical speed towards the next data point is less than or equal to the vertical speed limit. The level segment ends when the altitude difference between the altitude of the beginning of the level segment and the altitude of a data point is more than the level band limit or when the vertical speed between two consecutive data points is more than the vertical speed limit. or equal to the vertical speed limit. The level segment ends when the altitude difference between the altitude of the beginning of the level segment and the altitude of a data point is more than the level band limit or when the vertical speed between two consecutive data points is more than the vertical speed limit.
References & Examples of use	Comparison of ATM-Related Operational Performance: U.S./Europe (September 2016) PRC Performance Review Report (EUROCONTROL 2017) EUROCONTROL Performance Review Unit Dashboard[15]
Comment	GANP KPI17

[15] https://ansperformance.eu

5.2.7 Level-off during descent (from the GANP)

Title	Level-off during descent
Definition	Distance and time flown in level flight after Top of Descent.
Measurement unit	NM/flight and minutes/flight
Pillar	GHG, Noise
Operations measured	Actual IFR flights.
Variants	Variant 1: Average distance flown in level flight after Top of Descent Variant 2: Average time flown in level flight after Top of Descent
Objects characterized	The KPI is typically computed for traffic flows, individual airports, or clusters of airports (selection/grouping based on size and/or geography).
Utility of the metric/KPI	This KPI is intended to give an indication of the amount of level flight during the descent phase. Ideally, there should be no level flight during descents because level flight results in a higher fuel burn and possibly more noise. Ideally, aircraft should be able to descend from Top of Descent until touchdown.
Parameters	Analysis radius: the radius around the analysed airport within which the descent trajectory is analysed (e.g. 200 NM). Vertical speed limit: maximum vertical speed used to detect the start and end of a level segment (e.g. 300 feet/minute). Level band limit: altitude band within which data points have to stay to be included in a level segment (e.g. 200 feet). Minimum level time: minimum time duration for a level segment to be considered in the results (e.g. 20 seconds). Exclusion box percentage: percentage of the Top of Descent altitude which is used to define the lower altitude of the exclusion box (e.g. 90%). E.g. level segments occurring above the lower altitude limit of the exclusion box and longer than the exclusion box time are excluded from the results. Exclusion box time: a level segment in the exclusion box and longer than the exclusion box time is excluded (e.g. 5 minutes). Minimum altitude: the altitude where the level segment detection during the descent ends. The trajectory below this altitude is not analysed (e.g. 1800 feet).
Data requirement	For each flight trajectory: 4D data points (latitude, longitude, altitude and time) Arrival airport ARP coordinates
Data feed providers	Trajectory data providers (reporting archived actual trajectories based on ADS-B and/or other surveillance data sources) and/or ANSPs.
Formula/algorithm	Level segments in the descent trajectory within the analysis radius are detected using the vertical speed limit and level band limit. The methodology considers a data point as the start of a level segment when the following conditions are met:

	the altitude difference with the next data point is less than or equal to the level band limit; and the vertical speed towards the next data point is less than or equal to the vertical speed limit. The level segment ends when the altitude difference between the altitude of the beginning of the level segment and the altitude of a data point is more than the level band limit or when the vertical speed between two consecutive data points is more than the vertical speed limit.
References & Examples of use	Comparison of ATM-Related Operational Performance: U.S./Europe (September 2016) PRC Performance Review Report (EUROCONTROL 2017) EUROCONTROL Performance Review Unit Dashboard[16]
Comment	GANP KPI19

[16] https://ansperformance.eu

5.3 Airport Operations

The following Section represents a list of metrics/indicators that airports and airlines can consider when defining how to measure an airport's environmental performance. Not all metrics/KPIs need to be applied. Airports, working with airline operators and States, should priotiritize the metrics and indicators that are best suited for their airport operation and that can be supported with data collection capabilities to enable performance monitoring.

5.3.1 Percent of aircraft certified to Chapter *x* noise limits

Title	Percent of aircraft certified to Chapter *x* noise limits
Definition	Number of operating aircraft meeting Chapter *x* noise limit compared to all operating aircraft.
Measurement unit	Percentage (%) of aircraft meeting a given Chapter according to ICAO Annex 16
Pillar	Noise
Operations measured	Arriving and departing aircraft
Variants	Percentage of aircraft that are α Effective perceived noise in decibels (EPNdB) below Chapter x noise limits
Objects characterized	Applicable to passenger and cargo traffic, either individual flights or a cluster of flights, scalable.
Utility of the metric	The metric indicates the amount of traffic that meets a certain Chapter in accordance with ICAO Annex 16.
Parameters	Aircraft noise certification data from all aircraft
Data requirement	Aircraft noise certification data
Data feed providers	Airline data and/or State registry
Formula/algorithm	Aircraft meeting Chapter *x* noise limit/Total number of aircraft
References & Examples of use	Airline CSR report
Comment	Jet and heavy propeller-driven aircraft types of aircraft must comply with noise certification requirements as stipulated in ICAO Annex 16 and the associated noise limits, currently referred to as Chapters 2, 3, 4, 5 and 14. These Chapters represent the increasingly stringent standards that have been agreed over time.

5.3.2 Utilization of noise preferential routes

Title	Utilization of noise preferential routes
Definition	Number or percentage of aircraft utilizing noise preferential/ noise abatement routes.
Measurement unit	% of flights
Pillar	Noise
Operations measured	Arriving and departing aircraft
Variants	Percentage of aircraft on track, different lateral dimensions of the noise preferential routes can be considered.
Objects characterized	This metric is intended to give an indication of how often and how well the aircraft are able to fly a noise preferential route as deviations from the route may cause noise disturbances.
Utility of the metric	To monitor the utilization of noise preferential routes
Parameters	Aircraft trajectories and the geographical location of the noise preferential routes.
Data requirement	Surveillance data
Data feed providers	ANSP
Formula/algorithm	The number of flights utilizing a noise preferential route divided by the total number of flights. The calculation can be made on a route by route basis or by separating arriving and departing aircraft or for all aircraft movements.
References & Examples of use	CANSO-Measuring Operational Environmental Performance, London Gatwick Airport, Stockholm Arlanda Airport
Comment	Typically used by airports.

5.3.3 Exposure to a Noise Contour

Title	Exposure to a Noise Contour
Definition	Contour area or number of people inside a given noise contour
Measurement unit	Number of people, area
Pillar	Noise
Operations measured	Arriving and departing aircraft
Variants	Different noise exposure metrics—e.g., Day-Night average sound level (DNL), Sound Exposure Level (SEL), Maximum A-weighted Noise Level (LAmax), number of events above a threshold, etc. Different decibel (dB) thresholds. Different time scales, including definitions of day, evening and night time periods.
Objects characterized	This metric is intended to give an indication on the size of or number of people residing inside a noise contour.
Utility of the metric	The size of or number of people inside a noise contour is helpful as it allows the assessment of number of people disturbed or highly disturbed by aircraft noise.
Parameters	Number of people, noise exposure level
Data requirement	Airport traffic data such as aircraft types, runway usage and routes. Aircraft Noise and Performance (ANP) data. Detailed geospatial population data.
Data feed providers	Airports (traffic data), ANSPs (routes), European Union Aviation Safety Agency (EASA) or EUROCONTROL (ANP data), local authorities (population data).
Formula/algorithm	European Civil Aviation Conference (ECAC) Doc. 29 (noise calculations), Geographic Information System (GIS) analysis (population calculations)
References & Examples of use	European Aviation Environmental Report.
Comment	NA

5.3.5 Noise energy index

Title	Noise energy index
Definition	The sum of noise energy to which the ground is exposed
Measurement unit	10^{16} Joules
Pillar	Noise
Operations measured	Arriving and departing aircraft
Variants	TSEL (Total Second Equivalent Level) – a Danish metric integrating the calculated equivalent noise level over an area.
Objects characterized	Noise
Utility of the metric	When an aircraft flies to an airport, and later departs again, the area around an airport is exposed to a certain amount of noise energy. The 'noise energy' index uses certified aircraft noise data to calculate a proxy for the total noise energy received on the ground during an aircraft landing and take-off, irrespective of how the aircraft is operated. The individual noise energy from each flight operation is then summed at the European level.
Parameters	Aircraft certified noise characteristics and traffic data
Data requirement	Traffic data, certification data
Data feed providers	Airport, EASA
Formula/algorithm	$\text{Noise Energy} = \Sigma_{aircraft}\left(N_{dep}10^{\frac{LAT+FO}{20}} + N_{arr}10^{\frac{APP-9}{10}}\right)$ N_{dep} and N_{arr} are the numbers of departures and arrivals by aircraft type weighted for aircraft substitution. LAT, FO and APP are the certified noise levels in EPNdB at the three certification points (lateral, flyover, approach) for each aircraft type
References & Examples of use	EASA[17,18]
Comment	Note that this is an "index". The EPNdB is a weighted measurement and using that as a foundation does not yield energy in the calculation given above.

[17] https://www.easa.europa.eu/eaer/topics/overview-aviation-sector/noise

[18] https://www.easa.europa.eu/eaer/appendix

5.3.6 Airport Carbon Accreditation

Title	Airport Carbon Accreditation programme
Definition	Number of airports participating in the Airport Council International (ACI) Airport Carbon Accreditation (ACA) programme
Measurement unit	Number of airports participating to the ACA programme.
Pillar	GHG
Operations measured	This metric gives the number of airports participating in the ACA programme
Variants	Six levels of accreditation, can be monitored on ICAO regional or global level
Objects characterized	To identify which airports that are participating to the ACA programme.
Utility of the metric	Applicable to all airports
Parameters	Identified airports participating in the ACA programme
Data requirement	ACA participating airports
Data feed providers	ACA
Formula/algorithm	The sum of all airport participating in the
References & Examples of use	EASA[19] ACA[20]
Comment	Aggregated carbon performance data at global and regional levels is published in the programme's annual reports.

[19] https://www.easa.europa.eu/eaer/topics/overview-aviation-sector/noise
[20] https://www.airportcarbonaccreditation.org/

5.4 State/Regional/Global Levels

The following Section represents a list of metrics/indicators that States can collect to monitor, at a macro level, aviation environmental performance at local, regional, and global levels. Not all metrics/indicators should be applied. States should work with their operational stakeholders to prioritize the metrics and indicators to be used to monitor environmental performance at local and regional levels.

5.4.1 Total aviation fuel consumption

Title	Total aviation fuel consumption
Definition	Total jet fuel usage
Measurement unit	Litres, kg
Pillar	GHG
Operations measured	Usage of jet fuel (absolute number)
Variants	N/A
Objects characterized	This metric gives total (absolute) usage from the aviation sector
Utility of the metric/PI	Applicable to passenger or cargo traffic, scalable
Parameters	Fossil fuel is most of the fuel consumption, could be presented as fossil based fuel and SAF in the future.
Data requirement	Airline fuel record or CSR report
Data feed providers	Airline data or State registry or fuel supplier data
Formula/algorithm	The sum of all fuel usage
References & Examples of use	US Bureau of Transportation Statistics[21], European Aviation Environmental Report, Airline CSR/Environmental reports.
Comment	Can be used on local and global scale Typically linked to usage of fossil fuel Could be separated from the usage of SAF Other units can be used as well

[21] https://www.bts.gov/

5.4.2 Alternative Jet Fuel (AJF) conversion processes

Title	Number of approved AJF conversion processes certified for use in aviation
Definition	An AJF specification that has been approved for commercial airline use by standards development organisation \ASTM International[22].
Measurement unit	Number of approved AJFs by ASTM
Pillar	SAF
Operations measured	N/A
Variants	N/A
Objects characterized	An increased number of conversion processes approved for AJF production will create the possibility to accelerate the production and usage of AJFs.
Utility of the metric	A large amount of approved AJF conversion processes is considered an enabler for increased AJF production
Parameters	Number of approved AJF conversion processes certified for use in aviation by ASTM International
Data requirement	ASTM International standard, ASTM D7566, Specification for Aviation Turbine Fuels Containing Synthesized Hydrocarbons.
Data feed providers	AJF manufactures and/or suppliers
Formula/algorithm	N/A
References & Examples of use	ICAO[23], at the moment 8 conversion processes have been approved for AJF production (April 2021)
Comment	The trend of approved conversion processes could be considered to be monitored over time

[22] ASTM International is a globally recognized leader in the development and delivery of voluntary consensus standards.
[23] https://www.icao.int/environmental-protection/GFAAF/Pages/default.aspx

5.4.3 Airports distributing Sustainable Aviation Fuels (SAF)

Title	Number of airports regularly distributing blended SAF
Definition	A SAF specification that has been approved for commercial airline use by standards development organisation ASTM International.
Measurement unit	Number of airports
Pillar	SAF
Operations measured	N/A
Variants	N/A
Objects characterized	The metric is typically computed for airports in a region or on a global scale
Utility of the metric	An increased number of Airports distributing SAFs is considered an enabler to accelerate the usage of SAFs.
Parameters	Number of airports that regulary distributes SAF
Data requirement	Airports regulary distributing SAF
Data feed providers	SAF producers/distributors, airports
Formula/algorithm	Number of airports regularly distributing blended SAF
References & Examples of use	ICAO[24]
Comment	The trend of monitoring airports distributing SAF over time could be considered

[24] https://www.icao.int/environmental-protection/GFAAF/Pages/default.aspx

5.4.4 Flights operated with SAF

Title	Number of flights that have used a blend of SAF
Definition	The sum of all flights that have operated on SAF
Measurement unit	Number of flights
Pillar	SAF
Operations measured	All civil aviation
Variants	Variant 1: Aggregated data of flights operated with SAF on an annual basis Variant 2: Total amount of flights operated with SAF
Objects characterized	
Utility of the metric	An increased number of Airport distributing SAFs is considered an enabler to accelerate the usage of SAFs
Parameters	Flights that has uploaded SAF
Data requirement	Amount of flights that has uploaded SAF
Data feed providers	SAF distributors, aircraft operators
Formula/algorithm	The sum of all flights operated with SAF
References & Examples of use	ICAO[25]
Comment	The trend of monitoring flights operated with SAF over time could be considered

[25] https://www.icao.int/environmental-protection/GFAAF/Pages/default.aspx

5.4.5 Amount of SAF produced/procured/consumed

Title	SAF production/procurements/consumption
Definition	The yearly amount of SAF produced for aviation. The yearly amount of SAF procured by aviation. The yearly amount of SAF consumed for aviation.
Measurement unit	litres/year
Pillar	SAF
Operations measured	All civil aviation
Variants	Variant 1: The amount of SAF produced Variant 2: The amount of SAF procured Variant 3: The amount of SAF consumed
Objects characterized	This indicator can be used on regional or global basis
Utility of the metric	The metric can be used to measure amount of SAF produced/procured/consumed over time. Idealy the SAF production/procurement/consumption should be as large as possible to minimize usage of fossile fuel. It can be used on a regional and global basis.
Parameters	SAF production data, SAF procurement data, SAF consumption data
Data requirement	SAF production data, SAF procurement data, SAF consumption data
Data feed providers	SAF producers, SAF distributors, operators
Formula/algorithm	The sum of SAF produced/procured/consumed
References & Examples of use	Aviation Benefits Beyond Borders[26] Neste SAF[27] World Energy Paramount[28]
Comment	Could be considered to be presented in relationship with fossile fuel produced/procured/consumed for trend analysis purposes

[26] https://aviationbenefits.org/media/166740/fact-sheet_5_aviations-energy-transition.pdf

[27] https://www.neste.com/products/all-products/aviation

[28] https://www.worldenergy.net/paramount/

5.4.6 Total NO_X/CO/UHC emissions

Title	Total NO_X/CO/UHC emissions
Definition	Amount of NO_X/CO/UHC emitted
Measurement unit	tonnes
Pillar	LAQ
Operations measured	Actual IFR flights
Variants	NO_X/CO/UHC can be presented
Objects characterized	Applicable to all operation on a global basis
Utility of the metric	The objective is to determine absolute emissions of NO_X/CO/UHC in a macro scale
Parameters	Data can be presented from a local (micro) level through a global (macro) level.
Data requirement	NO_X/CO/UHC emissions
Data feed providers	Airline data
Formula/algorithm	Not identified
References & Examples of use	European Aviation Environmental Report. Airline CSR/environmental reports
Comment	The European Aviation Environmental Report refers to the usage of the EUROCONTROL IMPACT tool.

6. Environmental Management Systems

6.1 Environmental Management Systems

According to ICAO Doc. 9968, Report on Environmental Management System (EMS) Practise in the Aviation Sector, a formal definition of an EMS is as follows:

> *"A systematic approach for organizations to bring environmental considerations into decision-making and day-to-day operations. It also establishes a system for tracking, evaluating and communicating environmental performance. An EMS helps ensure that major environmental risks and liabilities are identified, minimized and managed."*

An EMS is similar to a Quality Management System, an Energy Management System, and a Safety Management System (SMS). Well known to aviation stakeholders, an SMS is a business-like approach to safety with its systematic, precise, and proactive approach to safety.

In a similar way, an Environmental Management System (EMS) manages the aspects of an organization's environmental impacts, environmental performance and compliance obligations through a structured, systematic, and documented approach. It facilitates:

- Reduced impact on the environment;
- Sound (effective and efficient) environmental performance;
- Continuous improvement;
- Meeting legal and other environmental obligations; and
- A due diligence approach to environmental management for the organisation and its staff.

By adopting a systematic and due diligence approach to environmental management, aviation stakeholders are able to improve their environmental performance, reduce business risk and demonstrate improved environmental performance to stakeholders. Many of the metrics presented in this document may be relevant for inclusion in an EMS to aid in tracking environmental performance.

To reach improved performance in any system, these are often the results of different underlying activites. This is valid for the aviation sector as well. Different voluntary activities have been identified amongst stakeholders and one example related to airlines is covered below.

Airlines could work with Flight Efficiency Initiatives (FEIs), also commonly known as fuel conservation programs. FEIs could be launched independently or as part of an EMS. FEI is linked to first identify operational opportunities to conduct its operation more efficient, followed by developing, promoting and adopting new operational procedures. Ideally, these changes in operational procedures should be monitored, if data is available. A myriad of different metrics/indicators could be linked to its operation if the data required is easily available. Different data sources could be considered, such as:

- Fuel consumption data (aggregated and non-aggregated data);
- Flight planning data vs. actual data;
- Maintenance data; or,
- Data collected from the Flight Data Recorder (FDR).

Training of operational personnel could be part of this FEI.

7. Conclusions

The metrics/indicators that are presented in this state-of-play report may be considered as widely applicable to describe environmental performance at the global level, but whether or not they are appropriate to describe a specific performance depends on the specific circumstances, including Local/State/Region regulations, resource constraints, data availability, etc. From that perspective, the document details a list of potential metrics/indicators that may be considered to describe environmental performance on a case by case basis by different stakeholders. Note that this document does not represent an exhaustive list of aviation environmental metrics.

The ICAO GANP has identified KPIs related to ATM. Many of these metrics/indicators are based on surveillance data and act as proxies for environmental performance. An example of such an open data source, monitoring and reporting activity in line with the ICAO GANP is the EUROCONTROL Performance Review Unit Dashboard, updated on a monthly basis with latest data[29].

It is recognized that stakeholders are working on improving environmental performance by monitoring these initiatives by different metrics/indicators, other then the ones identified in the GANP. EMS and other voluntary activities are commonly adopted by different stakeholders, such as training of operational personal to educate and promote various initiatives.

Airlines typically monitor physical metrics/indicators (energy intensity) such as: Fuel/CO_2 per RPK and Fuel/CO_2 per RTK , which seems to be mature and a well-established indicators on a global basis. Other metrics/indicators could be linked to a myriad of operational initiatives, if the data is easily available. Different data sources could then be considered, such as:

- Fuel consumption data (aggregated and non-aggregated data)
- Flight planning data vs. actual data
- Maintenance data
- Aircraft mass information
- Data collected from the Flight Data Recorder (FDR)

Fleet data is typically linked to aircraft age, certification or entry into service of the aircraft.

In the Airport domain, many variants of different noise metrics have been identified, as listed in Section 5.3. It has been noted that the ACI Airport Carbon Accreditation programme is well deployed on a global basis.

---

[29] https://ansperformance.eu

On the State/Regional/Global Level, total fuel consumption is typically reported. The monitoring of indicators/metrics linked to SAF, as presented in Section 5.4 are undertaken by some stakeholders, and can be expected to generate further attention in the future, since SAF implementation will be a major contributor to achieving decarbonisation targets in the coming years.