POLICY

Non-CO2 Aviation Emissions

In 2021 the aviation industry committed to reaching Net-Zero carbon emissions by 2050. Acknowledging the climate warming effect of non-CO_2 emissions from aviation, IATA is actively engaging in initiatives for monitoring and developing strategies to address the climate impacts of these emissions and support effective policy making.

BACKGROUND INFORMATION

Aviation accounts for approximately 2% of human-made global CO_2 emissions. However, the total climate impact of aviation also includes non-CO_2 emissions which are considered to cause an effect on climate comparable as that from CO_2 emissions. While the scientific understanding of the non-CO_2 climate effects of aviation has grown more robust, there are presently no established methods available to monitor non-CO_2 emissions on a per flight basis or tools to mitigate them.

However, European policymakers have started to consider potential regulations to address the climate impact of these emissions by incorporating them into the EU Emissions Trading Scheme (ETS). This requires that non-CO_2 emissions per flight (expressed in terms of CO_2 equivalents) can be measured accurately by aircraft operators using science-based data. The following details the limitations of this approach and outlines how IATA will work with industry partners and governments effectively to address the climate impact of non-CO_2 emissions.

Non-CO_2 emissions explained

Emissions from burning jet fuel consist of carbon dioxide (CO_2), water vapour (H_2O), nitrogen oxides (NO_x), sulphur oxides (SO_x), carbon monoxide (CO), soot (PM 2.5), unburned hydrocarbons (UHC), aerosols, and traces of hydroxyl compounds (-OH), most of which are released in the atmosphere at cruise altitudes of 8–13 km above mean sea level [1].

When water vapour is released from jet engines at altitude under certain high humidity conditions (ice supersaturated regions) it can condense into exhaust carbon particles as well as into atmospheric aerosols. If the air is sufficiently humid, the water vapour can condense further into crystals and a cloud can be formed. Such clouds, formed from the condensation of exhaust aircraft water vapor, are called condensation trails or contrails.

The main climate change contributions from non-CO_2 emissions of aviation come from the formation of persistent contrails and particularly the resulting aviation-induced clouds, as well as from the chemical atmospheric reactions driven by NO_x emissions.

While the effect of these emissions has been estimated at an aggregate level, the capacity to accurately measure their climate impact at an airline or individual-flight level is very limited. Furthermore, considerable uncertainties regarding the overall climate effect of these emissions remain [1].

For nitrogen oxides, the amount of NO_x emitted by an aircraft depends primarily on engine design, technology, and operating conditions (idle, take-off, descent, etc.), as well as on the atmospheric conditions (temperature, pressure, and humidity) at which this engine operates. This variability also applies to the formation of contrails, which relies on atmospheric conditions, engine and aircraft design, and fuel composition.

Although contrails are not always formed, their effect depends on whether they are persistent, the location and time of the day at which they are formed, the weather conditions, the combined effect of multiple contrails, and, importantly, whether they have a cooling or warming effect. This makes calculating their net climate effect on a per flight basis extremely complex.

Operational and technological solutions

Technological and operational measures that increase fuel efficiency can also reduce CO_2 and non-CO_2 emissions. However, measures targeted to reduce non-CO_2 emissions can sometimes lead to increases in CO_2 emissions. For example, derating thrust can reduce NO_x emissions significantly during take-off and climb but the reduced climbing gradient can prolong climbing times, causing increased fuel consumption and noise [2]. Any non-CO_2 avoidance needs to ensure that it does not come at the price of higher CO_2 emissions. Technological options include the use of lean burn and Advanced RQL (Rich burn Quick quench Lean) combustors, and the future potential to inject atomized water droplets for cooling the engine airflow during take-off. Both options show the potential to reduce NO_x emissions markedly, by up to 40% and to 50% respectively [2][3].

Regarding contrail avoidance, flights can be diverted away from the regions where weather conditions would likely cause the formation of contrails and contrail-induced clouds, though this too comes with the risk of increased CO_2 emissions if the diverted flight path is longer or suboptimal. Success in this approach depends upon improving the accuracy of predictions of ice supersaturated regions. Encouragingly, it is estimated that only a very small number of flights would need to be diverted: a study conducted in Japanese airspace reported that diverting only 1.7% of flights could more than halve contrails' total effective radiative forcing (ERF) with minimal fuel penalty and a marginal increase in CO_2 emissions [4].

While improvements in navigation could yield significant climate benefits, they rely on data collection for parameters that are currently not gathered in real-time, such as the relative humidity of the air at cruise altitude. A proper characterization of forecasted contrails would ensure that flight diversions do not result in negative trade-offs, including additional CO_2 emissions.

The effect of alternative fuels on Non-CO_2 emissions

While the use of neat (unblended) low-aromatic sustainable aviation fuel (SAF) is currently not permitted, research has shown that SAF can reduce the mass and number of soot particles emitted, which in turn could potentially decrease the lifetime of contrail cirrus clouds [5].

Emissions of sulphur oxides (SO_x) also enhance contrail formation due to their coating effect on soot particles that are formed from the sulphur content in conventional jet fuel. Since neat SAF contains no sulphur, its use eliminates the effect of SO_x on contrail formation.

Manufacturers have committed to delivering 100% SAF-compatible aircraft by 2030.

Whereas electrical propulsion would eliminate all CO_2 and non-CO_2 emissions, batteries remain the least scalable solution since they can only be deployed for sub-regional aircraft. Such aircraft fly at altitudes where contrails are not formed.

Hydrogen aircraft would eliminate all carbon emissions including the soot particles where contrails nucleate and form. However, they would emit an increased quantity of water vapour compared to conventional jet fuel or SAF. There is evidence to suggest that hydrogen aircraft would still produce contrails, though these would differ from those created by aircraft today.

With no solid carbon emissions, but increased water vapour, hydrogen contrails would likely be made of fewer but larger ice crystals. The optic density, duration, and radiative forcing of these contrails are still subject to further research. The use of hydrogen would fully eliminate NO_x emissions when used in a fuel cell to power an electric aircraft or could considerably reduce them if hydrogen is used in a jet engine [6].

KEY CONSIDERATIONS FOR POLICYMAKERS

Accurately predicting the net climate effect of single flights would require the collection of technical and climatological data through methods that are presently not available to the industry. A transitional period would be necessary for scaling the data collection solutions to an entire fleet of operating aircraft.

Ongoing and further research regarding technological and operational solutions to minimize both CO_2 and non-CO_2 emissions is required in order to advance the understanding of how to avoid unintended environmental trade-offs, and externalities. Such issues exist between CO_2 and non-CO_2 emissions, and also among different types of non-CO_2 emissions. For example, some combustor technologies might reduce NO_x but increase carbon particles; more efficient engines will reduce CO_2 emissions but could be more prone to creating contrails, etc. These very complex interdependencies need to be better understood and analysed using consistent metrics and timeframes.

Including non-CO_2 provisions in the EU ETS (or equivalent market-based schemes) at this stage would be premature. There is high risk of such policy measures creating significant market distortions, adding operational complexity, reducing connectivity, and producing negative climate-related trade-offs and externalities in the absence of accurate measurements and commercially available solutions. Furthermore, charges imposed would divert industry resources that could otherwise be invested in mitigating the overall climate impact of aviation.

To address the obstacles that stand in the way of a near-term solution to reducing non-CO_2 emissions, IATA is partnering with climate scientists, aircraft and engine manufacturers, technology developers, airlines, governments, and other stakeholders across and beyond the air transport sector with the specific purpose of producing a plan for how to monitor and report on non-CO_2 emissions. Initially, our work will focus on:

- Identifying technological and operational solutions for reducing both CO_2 and non-CO_2 emissions,
- Identifying tools and methods to help improve the scientific understanding of non-CO_2 climate impacts,
- Assessing the feasibility of deploying instruments and systems to measure and relay in-flight parameters in a timely manner,
- Contributing towards methods and metrics for comparing non-CO_2 emissions in relation to CO_2 emissions by collaborating with climate scientists.

References

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