Ref. Ares(2022)7272349 - 20/10/2022

EUROPEAN COMMISSION
DIRECTORATE-GENERAL FOR MOBILITY AND TRANSPORT
Aviation
Aviation Policy

Brussels,
MOVE/E1/JP

NOTE FOR THE ATTENTION OF [redacted], HOU DG CLIMA.B.4 , [redacted], HOU DG RTD.C.3, [redacted], HOU OF DG ENER C.2

Subject: Non-CO_2 impacts of aviation – progress of DG MOVE

EP and Council have put forward several amendments regarding non-CO_2 emissions in aviation under ETS and ReFuel Aviation. The Commission adopted in 2020 a Communication on non-CO_2 with a list of possible actions and DG MOVE has been coordinating and overseeing work on each of these actions. The purpose of this note is to update you regarding the work carried out notably DG MOVE, RTD and EASA on all the actions listed in the Commission communication, in order to support our work regarding FF55 Trilogues and future actions under COM programmes like Horizon Europe, etc.

1. INTRODUCTION

In November 2020, the European Commission published a Communication to the European Parliament and to the Council based on an EASA report with an updated analysis of the non-CO_2 climate impacts of aviation[1] - hereafter, "the report". The report highlights the links between possible policy measures to address non-CO_2 impacts and safety of aviation. Because of this work, we consider that ensuring a pivotal role for EASA in future non-CO_2 related research and actions is important from both an environmental and safety perspectives.[2]

In its Sustainable and Smart Mobility Strategy adopted in December 2020, the Commission said it would follow-up on the measures suggested in the EASA report. A number of research activities have taken and are taking place and that the Commission is expected to support further research via Horizon Europe on both the scientific understanding of climate impacts and potential policy follow-up measures.[3]

[1] COM(2020) 747 final - Updated analysis of the non-CO_2 climate impacts of aviation and potential policy measures pursuant to EU Emissions Trading System Directive Article 30(4).

[2] For further information about non-CO_2 impacts, see Annex B.

[3] See Annex C for a list of ongoing research addressing non-CO_2.

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2. POLICY MEASURES TO ADDRESS NON-CO_2 EMISSIONS

Under the general reference to "non-CO_2 emissions" the following is covered: contrail cirrus clouds (due to atmospheric conditions and the presence of aromatics, sulphur and impurities in kerosene), oxides of nitrogen (NO_x), soot particles, oxidized sulfur species, and water vapour. Beyond a better understanding of the fundamental science, the key challenge lies in the need to be able to clearly demonstrate that any potential policy measures – notably legislative - result in proportionate environmental benefits; are politically, technically and administratively feasible; and do not have perverse outcomes regarding CO_2 emission reduction *(N.B. there is a "trade off" between decreasing CO_2 and decreasing non-CO_2 emissions in aviation where a level of scientific uncertainty still remains and requires further research).*

The Commission is already addressing some of these points where scientific research have reached maturity, namely via environmental certification standards (based on ICAO standards) for aircraft engine emissions. These include Oxides of Nitrogen (NO_x) as well as the mass and number of non-volatile Particulate Matter (nvPM) emissions. Such technology/design - related measures are focused on manufacturing.[4]

Addressing the remaining uncertainties is critical for robust regulatory impact assessments to ensure 'no regret' policy options. In addition, the international context should be duly considered, including whether further policy measures should be taken at ICAO level to maximize benefits and preserve undistorted competition in international aviation. The ICAO CAEP work programme for 2022 to 2025 includes already four actions on operational opportunities to reduce contrail formation, update to the air quality and climate impacts of aviation non-CO_2 emissions, assessment of contrail forcing and the uncertainties and trends on fuel composition (see Annex D).

Possible new policy measures to address non-CO_2 climate impacts from aviation assessed in the report accompanying the Commission communication are divided into three categories: market-related; fuel related; and air traffic management (ATM), with two options under each of these. In principle, the options could co-exist with one another *(see Annex A for a list of the 6 measures).*

<u>The two market-related measures</u> are already being addressed in Fit for 55 package, albeit not directly aimed at non-CO_2. The revision of the Energy Taxation Directive (ETD) removes fuel tax exemption used in aviation. The minimum tax rates will promote the shift to cleaner fuels and more fuel-efficient aircraft. The revised EU ETS, implementing CORSIA in the EU, will have a similar impact; the increasing carbon price for fossil fuels emissions, will strengthen the market signal for uptake of cleaner fuels, namely fuels emitting less CO_2 **and** non-CO_2. Consequently, by promoting those fuels, both proposals would address not only CO_2, but also other pollutants, such as NO_x.[5]

The amendments from the European Parliament regarding the ongoing ETS revision discussions include three relevant elements, where we consider that b) and c) are neither science-based nor proportionate: a) monitoring of non-CO_2 emissions; b) based on this, the Commission would submit a legislative proposal to mitigate non-CO_2 emissions; c)

[4] The latest global environmental standards were adopted by ICAO in 2017. These covers aircraft engine non-volatile Particulate Matter (nvPM) mass and number.

[5] The size of NOx reduction benefits would depend on clean fuel type and propulsion system design.

pending the legislative proposal, a fixed CO_2-equivalent factor (i.e. multiplier) would be applied in the ETS (gradually increasing from 1.8 to 2.0 by 2030).

The European Parliament amendments under ReFuelEU include relevant aspects regarding non-CO_2, namely empowering EASA to monitor the aromatics and sulphur content of conventional aviation fuels or the establishment of a Sustainable Aviation Fund for the period from 2023 to 2050 to accelerate the decarbonisation of the aviation sector, including efforts to reduce the non-CO_2 effects of aviation.

Regarding the ATM-related policy proposals, further research is still required in order to ensure "no regret" actions. In that sense, a number of studies, including live trials, has been taking place. The Commission is already addressing the two proposals by financing some of those projects, via Horizon 2020 / Europe, including via SESAR3 JU (Annex C).

In conclusion, the finance, market-based and ATM-related proposals are being addressed. Regarding the two fuel-related measures, the Commission has already delivered as well on the first one, and technical work is about to start on the second while pending validation on the way to go regarding policy-making.

- **Mandatory supply of Sustainable Aviation Fuels**:

The Commission has already put forward a legislative proposal as part of the FF55 package which is a win-win solution, reducing both the CO2 and non-CO2 emissions at the same time: ReFuelEU Aviation proposes a gradual ramp up for mandatory SAF supply and uptake on flights departing from an EU airport (subject to a *de minimis* clause). The proposal is currently in co-decision and expected to be adopted early in 2023.

Under ReFuelEU, EASA will have access to key data regarding the volume and characteristics of SAF used, along with the associated lifecycle emissions. Further research would be needed to assess the specific reductions in non-CO_2 emissions from the use of SAF in aircraft engines. Furthermore, DG MOVE has chosen EASA to implement a European Parliament Preparatory Action on an EU SAF Clearing House to support the approval process for new SAF production pathways and set-up an EU Fuel Standards Group to help coordinate work in this area.[6]

Further market-based measures (e.g. taxonomy soon to be adopted delegated act) should incentivize 100% SAF usage, best of class emissions performance and development of zero-emissions aircraft.

- **Reduction in maximum limit of aromatics and sulphur within fuel specifications:**

The presence of aromatics in kerosene fosters the generation of contrails, which is the main non-CO_2 effect of aviation. The actual aromatics content in Jet A-1 fuel currently used within the aviation sector is not well known, with studies showing that it can vary significantly. As such, the specifications of fuels being used in Europe will first need to

[6] The primary aim of an EU Clearing House is to investigate the feasibility of supporting producers to certify SAF against fuel specification standards, thereby providing a single and independent European capability. It would remove technical barriers to increased SAF use. Leveraging past and existing EU research programmes, this preparatory action covers the definition, validation and testing of the concept to be implemented in Europe.

be monitored in order to be able to assess the impact of a reduced maximum limit of aromatics, taking safety considerations duly into account.[7]

Depending on the outcome of initial monitoring, fuel specifications may need to be addressed. Currently, fuel specifications are managed through four main standardisation bodies[8], none of them EU-based. Engagement with these bodies to address the climate benefits of low aromatic/sulphur fuels would be crucial for international harmonization.

A policy proposal to reduce the maximum limit of aromatics within fuel specifications is promising but faces a number of challenges. First, there are safety concerns associated with the minimum amount of aromatics present in kerosene, in particular with older aircraft models. Second, the definition of a maximum limit of aromatics is an issue with international complications as there are different standardisation bodies, none of them based in Europe. Therefore, work in ICAO CAEP should also be promoted.

Another possible policy option, somewhat related to the reduction of aromatics, relates to the reduction of sulphur in kerosene.[9] A European Parliament Pilot Project aimed at setting a European body for jet fuel standards and safety certification was recently approved by DG MOVE and its implementation work shall start as of 2023. A particular aspect of this project would be to advance in lowering the minimum thresholds for aromatics and sulphur, fostering the evolution in engine technologies and to pave the way for jets to operate with a 100% SAF composition of fuels.

3. CONCLUSION AND NEXT STEPS

The non-CO_2 impacts of aviation will stay high on the political agenda as demonstrated by a number of amendments on non-CO_2 to the Fit for 55 package (both for the EU ETS and ReFuel aviation proposals). After EASA's report in 2020 annexed to the Commission communication on on-CO2, where a number of possible policy measures was indicated, it is important for the Commission to show that it is already taking action. This is indeed the case regarding all the six recommendations: the two on financial and ATM-related proposals, and the legislative proposal about a mandatory supply of Sustainable Aviation Fuels (through ReFuelEU Aviation) are all ongoing. Regarding the final one, the reduction in maximum limit of aromatics/sulphur within fuel specifications, technical work is about to start with both the new SAF Clearing House pilot project and the 2023 EP pilot project on jet fuel standards (the pre-assessment phase of the pilot projects for 2023 was concluded by DG BUDG with a positive assessment for this project), both managed by DG MOVE and allocated/to be allocated to EASA. regarding the way to tackle the content of aromatics, and in particular Sulphur, DG MOVE is making sure that technical work start very soon, both through EASA and CAEP.

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7 CAEP/13 work item E.02 includes the monitoring of trends in aviation fuel. This is an on-going item from past CAEP cycles and EASA has previously tried to collate information on this through State Letters. Unfortunately without getting much feedback. The Def Stan committee used to publish statistics on this, but stopped some time ago. This is a data gap that should be addressed.

8 ASTM and Def Stan are the two main fuel specifications used on a global basis. There are other Russian and Chinese specifications. Typically, commercial aircraft (e.g. Airbus) are certified to fly on fuels meeting ASTM, Def Stan, Russian and Chinese specifications.

9 Under current non-ICAO standards, there is no minimum sulphur content, while the maximum is 3000 ppm. However, the mean presence of sulphur concentration is significantly lower than the stipulated maximum value. From a technical perspective, desulphurization from 2500 ppm down to 10-100 ppm is not a complicated process. To be noted that SAF generally contain almost no sulphur.

(signed)

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Annex A Policy measures identified in the report from the Commission to the European Parliament and the Council and expanded at the EASA report

Name of measure	Advantages	Disadvantages	Timescale for implementation
A NO_x charge	— Internalises the external costs of a well-understood non-CO_2 climate impact in the cost of flying; — Reduces demand and consequently also CO_2 and other emissions; — nvPM and full climate impact could be addressed in a similar manner but would be more complicated.	— Could incentivise technological development that leads to increased CO_2 emissions — Uncertainty about the direction of climate impact of NO_x in the future (warming/cooling is dependent on background concentrations of other pollutants)	Mid-term
Include aircraft NO_x emissions in EU ETS	— Internalises the external costs of a well-understood non-CO_2 climate impact in the cost of flying; — Reduces demand and consequently also CO_2 and other emissions; — Legislative framework already in place; — nvPM and full climate impact could be addressed in a similar manner but would be more complicated.	— Could incentivise technological development that leads to increased CO_2 emissions — Uncertainty about the direction of climate impact of NO_x in the future (warming/cooling is dependent on background concentrations of other pollutants) —Uncertainty about climate impact of NO_x emissions is larger than for CO_2 emissions. Care should be taken to maintain the credibility of the EU ETS	Mid-term
Reduction in maximum limit of aromatics within fuel specifications	— Reduction in contrail formation; — If ASTM and/or DEF STAN standards are adjusted, then the measure has a global impact. — Lowers PM emissions: positive impact on local air quality and climate change.	— Uncertain what the current aromatics content is and hence what the new standard should be to have an effect — initiatives to change fuel standards could be a long process and the outcome is uncertain — Legality of EU incentive for the sale of low-aromatics fuels next to existing fuel standards unclear	Mid- to long term
Mandatory use of Sustainable Aviation Fuels	— Reduction in contrail formation and SO_x emissions — Reduction in fuel lifecycle CO_2 emissions — Reduction in nvPM emissions. — Potential increase in	— Smaller geographical scope (fuel uplifted in Europe) compared to standard for maximum aromatics content of fuel — Increased incentive for tankering from outside EU	Short- to mid-term

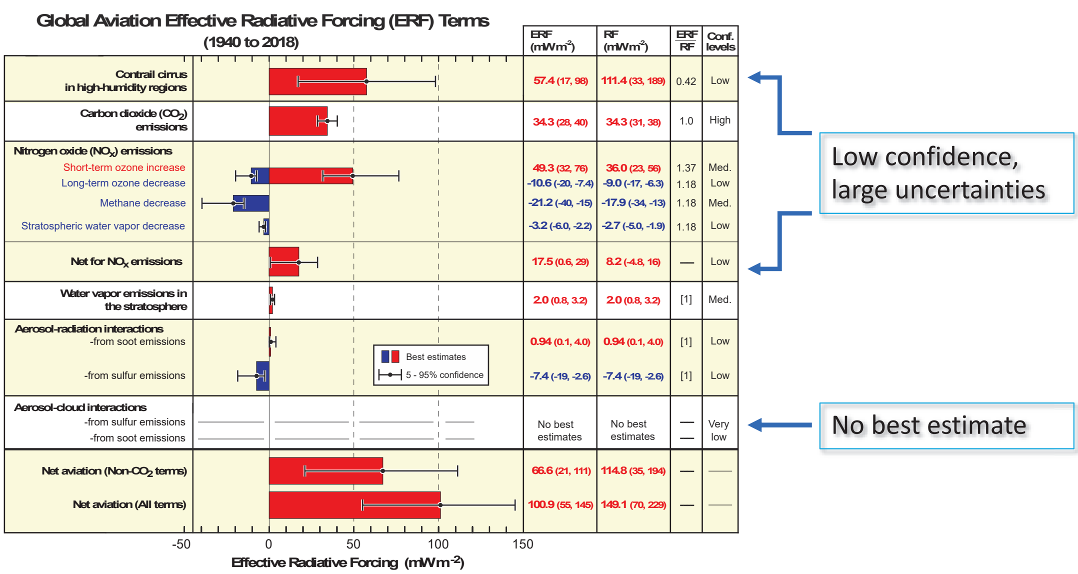
	aircraft fuel efficiency.		
Avoidance of ice-supersaturated areas	— Reduction in contrail cirrus	— Trade-offs in detour (extra CO_2) versus reduced contrail effect — Limited scope because the measure cannot be implemented in crowded airspace	Mid-term
A climate charge	— Internalises the costs of all the CO_2 and non-CO_2 emissions from aviation	— No scientific consensus on the cost function — Involves weighting impacts of different pollutants that are active across different time periods	Long-term

Annex B Non-CO2 impacts of aviation

This annex was written with the support of EASA experts.

Radiative Forcing Metrics

Radiative Forcing (RF) is a term used to describe when the amount of energy that enters the Earth's atmosphere is different from the amount of energy that leaves it. Energy travels in the form of radiation: solar radiation entering the atmosphere from the sun, and infrared radiation exiting as heat. If more radiation is entering Earth than leaving, then the atmosphere will warm up thereby forcing changes in the Earth's climate. The metric Effective Radiative Forcing (ERF) was introduced in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report in 2013 as a better predictor of the change in global mean surface temperature due to historic emissions by also accounting for rapid adjustments in the atmosphere (e.g. thermal structure, clouds, aerosols etc.).



The figure above suggests that non-CO_2 emissions represent the largest fraction of the total Effective Radiative Forcing (ERF) of aviation. However, it is important to note that the **uncertainties from the overall non-CO_2 effects are 8 times larger than those from** CO_2, and the **overall confidence levels of the largest non-CO_2 effects (e.g. contrails) are 'low'**. While no best estimates of ERF have been provided for the aerosol-cloud interactions from sulphur and soot emissions, these should not be ignored since they could potentially be important.

The main non-CO_2 impacts from aviation are due to contrail cirrus, oxides of nitrogen (NO_x), soot particles, oxidised sulfur species, and water vapour. The report recognized that a number of measures already in place also contribute to reducing the climate impacts of aviation non-CO_2 emissions such as EASA environmental certification standards (based on ICAO SARPs) for aircraft engine emissions of NO_x and non-volatile Particulate Matter (nvPM).

The key challenges relate to the complexity of non-CO_2 climate impacts and the trade-offs between non-CO_2 various impacts and those of CO_2 emissions. The report recognizes how this complexity poses a challenge to the policy measures analysed. To be added that regarding possible trade-offs, there is a need to assess the very long-term CO_2 (hundreds to thousands of years) and much shorter-term non-CO_2 (hours to decades) climate impacts.

Nevertheless, some measures that reduce the CO_2 emissions might as well serve to reduce the non-CO_2 emissions. This is, for example, the case with the reduction of fuel burn (e.g. via aircraft technology improvements or via improvements in air traffic management), which will lead to a reduction of both CO_2 and non-CO_2. Those "win-win" policy options would ensure 'no regret' actions and should therefore be prioritized.

Another possible "win-win" solution is the increase of uptake of sustainable aviation fuels (SAF) – be it advanced biofuels or power-to-liquid fuels –, which will result in a reduction of net CO_2 emissions and in a reduction of soot particulate emissions (thus creating less persistent contrail-cirrus clouds). Increasing the use of SAF could even be a "win-win-win" solution, as it could as well reduce the local air pollutants around airports.

On the other hand, novel propulsion technologies such as hydrogen based combustion engines and hydrogen fuel cells are promising technologies expected to gradually enter service as of 2030 and are aimed to mainly address the CO_2 impact however will emit water vapour and NO_x. As such, research to understand the climate impact of emissions from these novel aircraft technologies would be beneficial.

How could the non-CO_2 emissions be monitored?

Non-CO_2 emissions and their climate impact are not directly proportional to fuel burn (as per CO_2), so calculating non-CO_2 emissions will involve modelling. Current accuracy associated with best practise modelling of aircraft emissions is considered to be approximately +/-3% for fuel burn and CO_2 emissions and +/-10 to 15% for NO_x and nvPM emissions. A reflection is needed whether this level of accuracy is enough and fit for purpose for policy action, notably for legislative proposals.

UBA Study (2019)[10]: Monitoring of non-CO_2 emissions based on real flight data is technically possible (by using "Climatological latitude-height dependent factor"), but potentially burdensome and costly for airlines. Also, verifying this information is potentially challenging. Airlines, state authorities and verifiers would need to build additional expertise to implement such system. In this study, the monitoring methodology is not fully explained and unclear what sort of peer review has been performed.

There is also a need to quantify non-CO_2 emissions from potential future "zero emissions vehicles", such as hydrogen aircraft.

Approach to calculate equivalent CO_2 emissions (CO_2e)

[10] Report on behalf of the German Environment Agency on the "Integration of Non-CO_2 Effects of Aviation in the EU ETS and under CORSIA" available here: https://www.umweltbundesamt.de/en/publikationen/integration-of-non-CO2-effects-of-aviation-in-the

In terms of comparing aviation CO_2 emissions with non-CO_2 emissions and their impacts on a common scale, 'equivalent emissions metrics' are required (CO_2-e). The CO_2-e metric that is currently widely used, including within the EU ETS, is the Global Warming Potential for a time-horizon of 100 years (GWP100). Other time-horizons are also possible (e.g. 20, 50, 200 years).

Other metrics to calculate CO_2-e do exist, including an alternative form of GWP (GWP*) and Global Temperature Potential (GTP). All metrics entail subjective user choices.

Open questions

- Is this level of uncertainty on the climate impact metric (e.g. ERF) of aviation emissions fit for purpose as a basis for policy action?

- If not, what is an acceptable level of uncertainty?

- What additional research could be performed in the short term to reduce the level of uncertainty?

- What is an appropriate equivalence metric (e.g. GWP) and selected timeline (e.g. 100 years) to calculate CO_2e and underpin impact assessments of policy options?

Annex C List of current EU Research related projects regarding the non-CO_2 climate impacts of aviation

From Horizon 2020:

1. ACACIA - https://www.acacia-project.eu/ 'Advancing the Science for Aviation and Climate' the scientific focus of this project is improving the scientific understanding of those impacts that have the largest uncertainty, in particular, the indirect effect of aviation soot and aerosol on clouds (ACACIA project objective 1). Duration: Jan 2020 – Jun 2023, overall budget: € 2 999 500.

2. ALTERNATE - https://www.alternateproject.com/. Expected outcome includes a better understanding of the potential climate change mitigation strategies based on the use of alternative jet fuel pathways. Duration: Jan 2020 – Dec 2022, overall budget € 2 600 387,13.

3. CLIMOP - https://www.climop-h2020.eu/. Aims at understanding which aspects of aviation operations can be implemented to reduce the climate impact of the aeronautic industry. Duration: Jan 2020 – Jun 2023, overall budget: € 3 064 272,50.

4. SENECA - https://seneca-project.eu/ '(LTO) noiSe and EmissioNs of supErsoniC Aircraft' this project focuses on potential noise and climate impacts of future supersonic aircraft. Even if non.CO_2 impacts are not the main focus, they could be part of the research produced during the report. Duration: Jan 2021 – Dec 2024, overall budget € 4 999 611,25.

5. More & Less - https://cordis.europa.eu/project/id/101006856 'MDO and Regulations for Low-boom and Environmentally Sustainable Supersonic aviation', again with a focus on future supersonic aircraft. Duration Jan 2021 – Dec 2024, overall budget € 6 336 211,25.

From Horizon Europe:

6. HORIZON-CL5-2021-D1-01-01: Improved understanding of greenhouse gas fluxes and radiative forcers, including carbon dioxide removal technologies. For non-CO_2, the purpose is to study the global warming contribution of different radiative forcers. Transports are one of the areas referred: "the action should examine the application of this knowledge in relevant sectors (such as transport, industry, agriculture and health) with a view to better understand co-benefits and trade-offs of mitigation policies with other societal benefits, including human health."

7. HORIZON-CL5-2021-D5-01-05: Greenhouse gas aviation emissions reduction technologies towards climate neutrality by 2050. "Regarding the reduction of aviation non- CO_2 emissions, the selection of technologies and operational measures should consider climate optimised flight trajectory planning avoiding

sensitive areas, should be compatible with operational procedures and aligned with a potential inclusion of non-CO_2 emissions in EU and International aviation market-based measures (e.g. EU Emissions Trading System and ICAO CORSIA)."

8. HORIZON-CL5-2022-D5-01-12: Towards a silent and ultra-low local air pollution aircraft. "This topic aims to support the EU and ICAO LAQ and noise policies. This topic aims for new aircraft and engine technologies that satisfy the design and operational interdependencies between CO_2, non-CO_2 and noise emissions, are compatible with approved operational procedures and are aligned with the European industrial roadmaps for further development, validation and integration beyond 2030."

From SESAR 3:

9. Aviation-induced cloudiness (AIC) data collection and analysis. The aim is to set up a data collection and data analysis concept that can continue beyond the life of the demonstration, in order to support the continuous assessment of the evolution of the atmospheric metrics that are relevant to better understand the non-CO_2 impact of aviation and the impact of the policy actions.

10. Development of a MET service to publish and dynamically update 'ECHO areas' (see below). This element builds on previous SESAR work on Environmental Change Functions, and aim at aggregating the environmental impact assessment into a single continuously updated ECHO area publishing service; ECHO areas are those areas of the airspace where there is high certainty that aircraft emissions would cause a disproportionately high environmental impact due to aviation induced cloudiness (AIC) with a warming effect.

11. Comparative study on potential metrics to be adopted in the ATM domain to aggregate non-CO_2 and CO_2 impacts on climate change: e.g. GWP 100, ATR 20, ATR 100 or alternative metrics, taking as a starting point the options outlined in the 2020 EC report on non-CO_2 impacts of aviation. The project should start with a state of the art of environmental metrics and engage with all relevant stakeholders, in order to provide insight into the pros and cons of each potential metric and aim at formulating informed recommendations for the way forward, including identification of additional research needs, if applicable. This research should build on the work on Environmental Change Functions in SESAR ER project ATM4E, and consider metrics that can be used in different contexts, e.g. for operational decision making in the pre-tactical and tactical phases of ATFM, for operational decision making in real time by ATC, for post-operations analysis and for environmental performance monitoring at network level.

From European Parliament

12. EP Pilot project to start in 2023 to consider EU fuel standard to reduce sulphur/aromatics. This would be more fuel refinery focused and not directly linked to how the aircraft is operated.

Annex D ICAO CAEP (2022-2025) non-CO_2 relevant measures

The ICAO CAEP work programme for 2022 to 2025 includes four actions:

- To gather information on operational opportunities to reduce contrail formation, aircraft induced cirrus and possibly other non-CO_2 effects. And identify potential interdependencies of possible measures on other (environmental) parameters, such as fuel burn and flight efficiency.

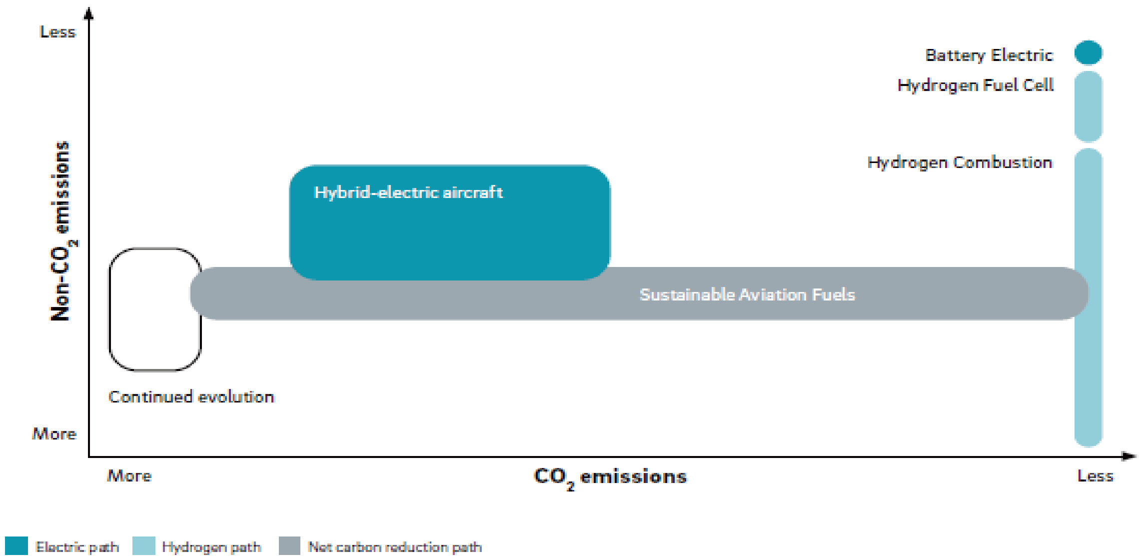
- To update to the air quality and climate impacts of aviation non-CO_2 emissions (with a particular focus on trade-offs between the CO_2 climate and non-CO_2 air-quality impacts, interdependencies of CO_2 and non-CO_2 climate impacts).

- Assessment of the contrail forcing term and the overall uncertainties, tradeoffs between contrails and CO_2 (avoidance), co-benefits with lower C footprint fuels with lower aromatic/Sulphur content.

- To monitor trends in 1) petroleum-based aviation kerosene fuel supply composition, 2) aviation alternative fuel-based kerosene fuel supply, and 3) blended fuel types. Consider the impacts of fuel composition on nvPM or precursors of vPM at the engine exit and the corresponding emission indices. This would permit to assess, for example, the potential benefit of fossil fuel desulfurization on emission indices.

Annex E Impact of type of clean fuels on CO_2 and non-CO_2

D: Comparing environmental impact
Potential solutions by intensity of CO_2 and non-CO_2 emissions



Source: Roland Berger