Non-CO_2 climate effects of aviation
Safran's views and actions

June 27th 2025 – ISA Toulouse
Contrails and sustainability

Valérie Guénon – Safran Aircraft Engines

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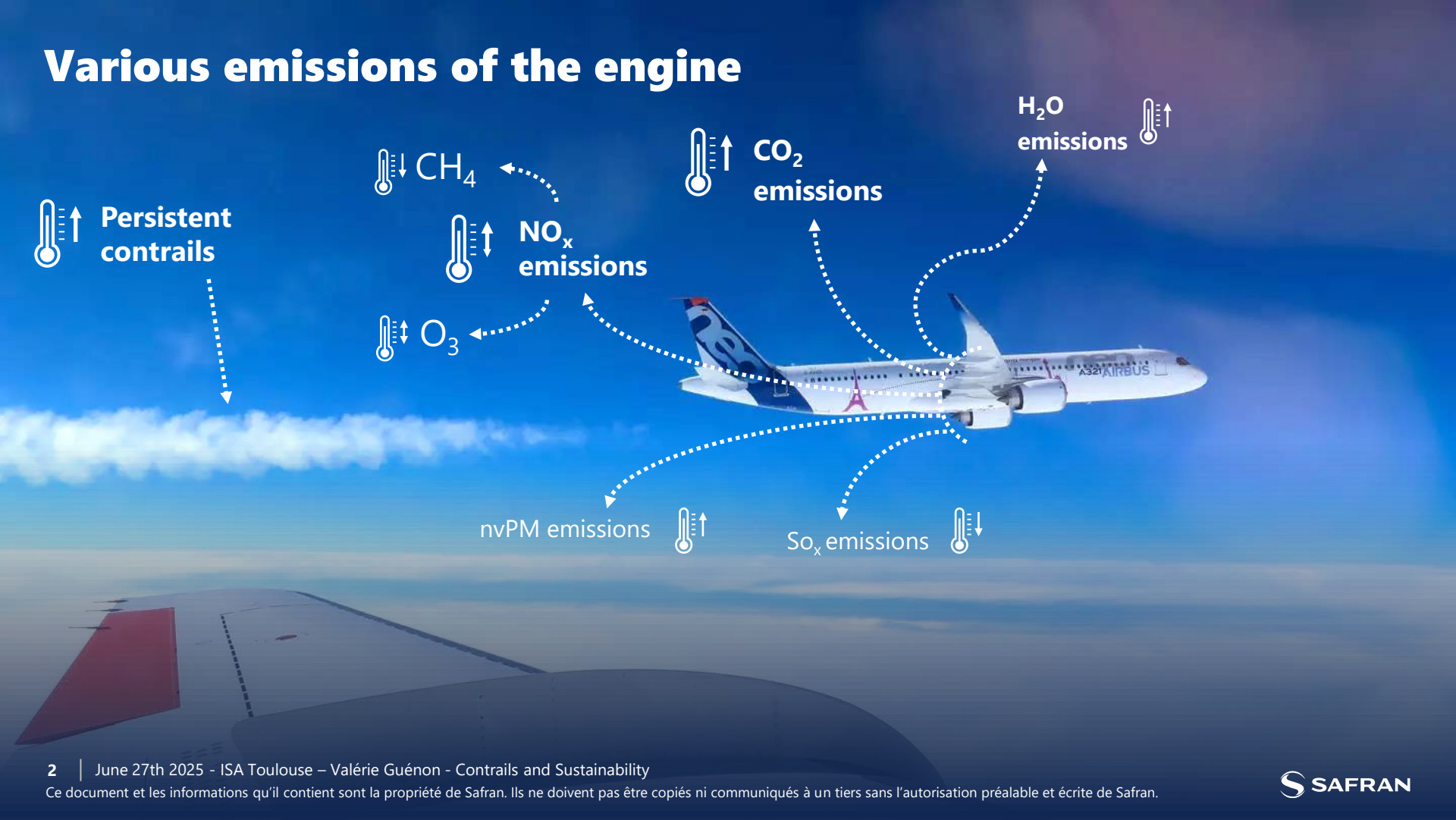
Various emissions of the engine



Zoom on condensation trails

At engine exhaust
- Aerosols (incl. particules)
- Very humid (water vapor)
- Warm

1

The exhaust plume cools down and water vapor condenses on particles to form liquid water droplets

2

Water droplets freeze and form ice crystals that grow progressively

3

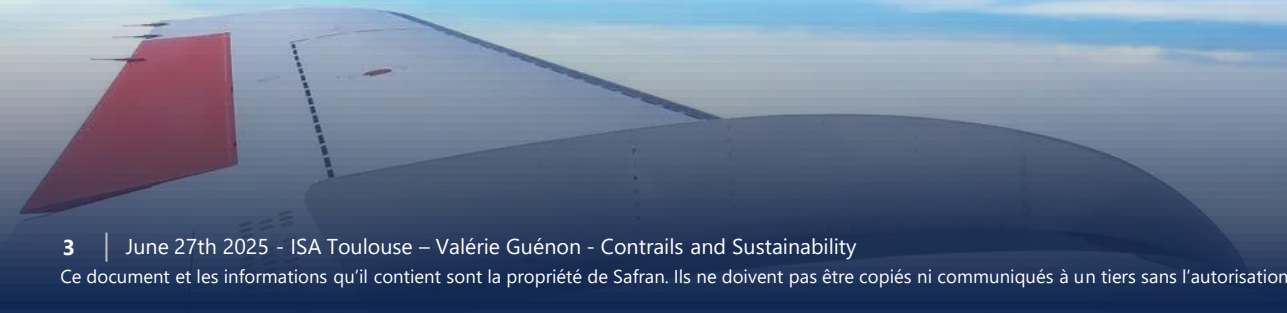
The condensation trail persists if the phenomenon takes place in an Ice Super Saturated Region (ISSR)

5% of contrails last > 10 hours

Otherwise, the condensation trail dissipates after a few minutes

4

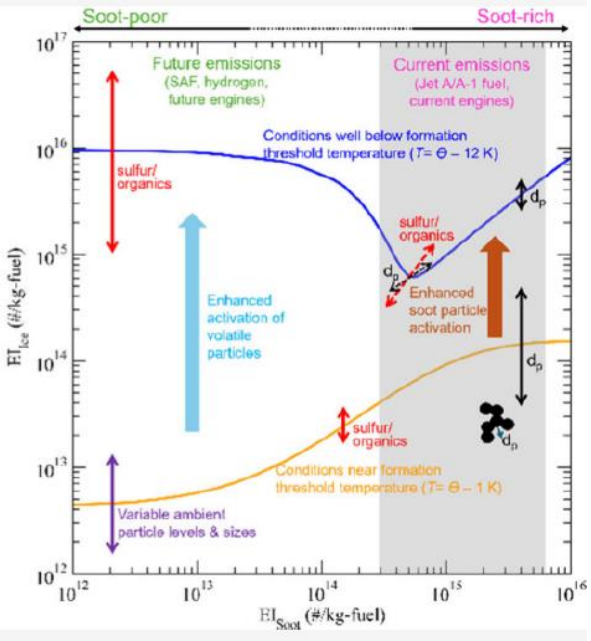
Ambient air: very cold (<-30°C)
variable humidity



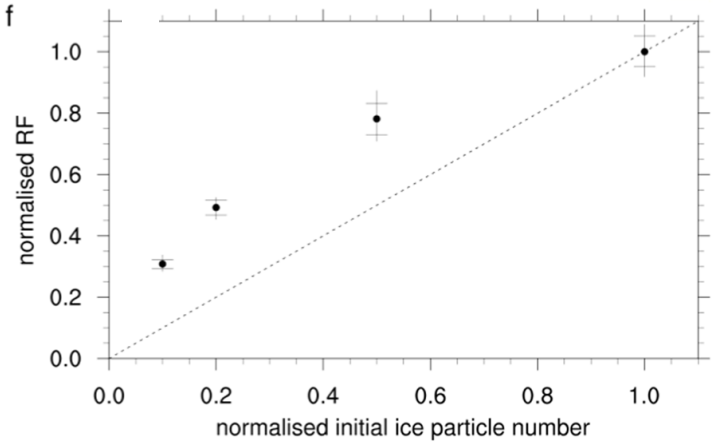
Reducing condensation trails impact

Way 1: reduce the number of particles and the radiative influence of ice crystals (optical depth)

- Influence of **combustion chamber technology** (RQL vs. Lean Burn)



- **Change the fuel properties** (SAF, Jet-A1 / SAF mix, aromatics reduction, etc.)
- **More research needed** to understand complex effect
  - Opposite effects with very low nvPM emissions
  - Unknown effects for H_2
  - Effect of sulfur, background conditions etc.



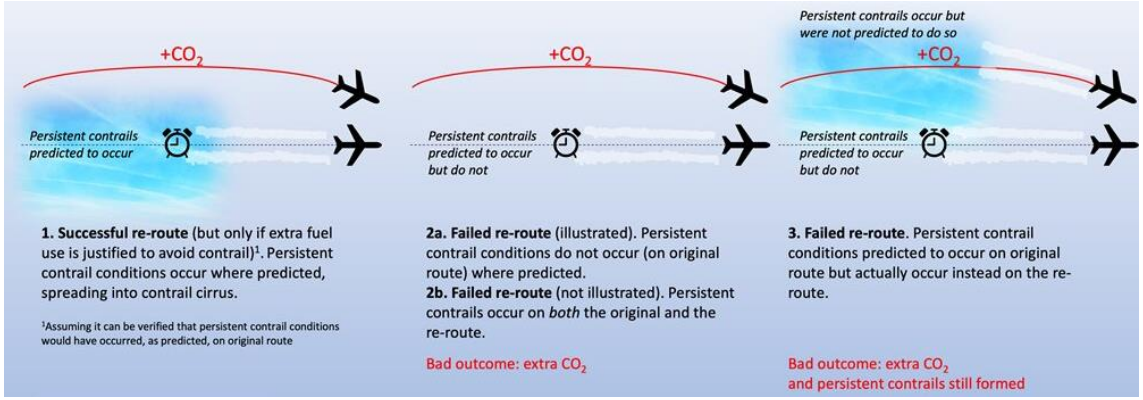
Reducing condensation trails impact

Way 2: avoid Ice Super Saturated Regions to avoid warming persisting condensation trails occurrence

ISSR very large, but thin (less than 1 km)
About 5% of flights create 80% of contrails

- Modify the flight level where and when it is necessary
- Ensure that it creates a climate benefit, considering the increased fuel burn

- Prediction of ISSR : ongoing, but not yet mature
- Optimize Air Traffic Management to dynamically reroute flights, ensuring flight safety, on several flight control zones
- Predict the impact of contrails (cooling / warming) before the flights to establish robust flight plans: existing models, yet to be improved



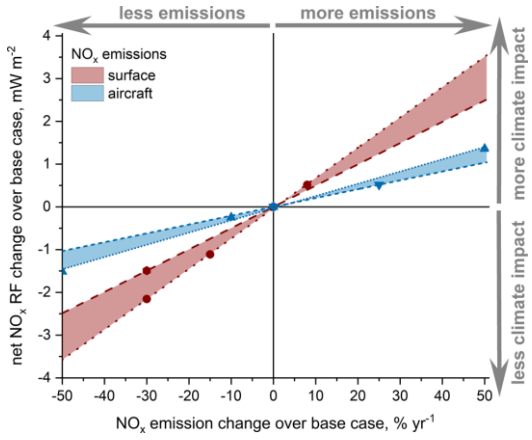
Source : Lee and Shine, 2021, https://www.greenairnews.com/?p=1421

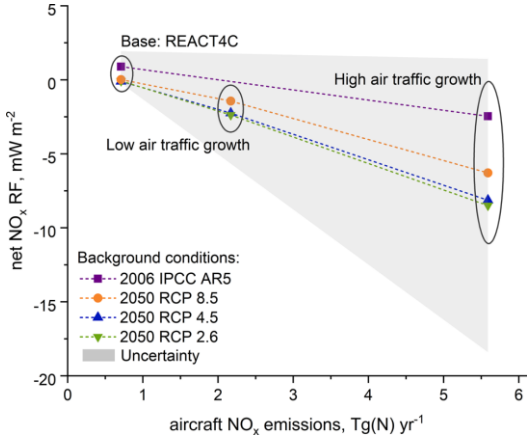
Attractive solutions, that still need to be made robust

Research works and in-flight tests are still needed before large-scale implementation

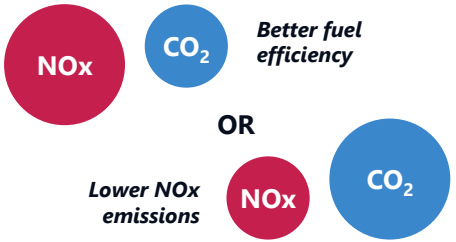
Reducing NOx impact

- **NOx emissions are regulated by ICAO**
  NOx emissions divided by 4 in 50 years through combustor technology
- **Dependency on background emissions**
  Less background emissions ➔ less aviation NOx radiative forcing





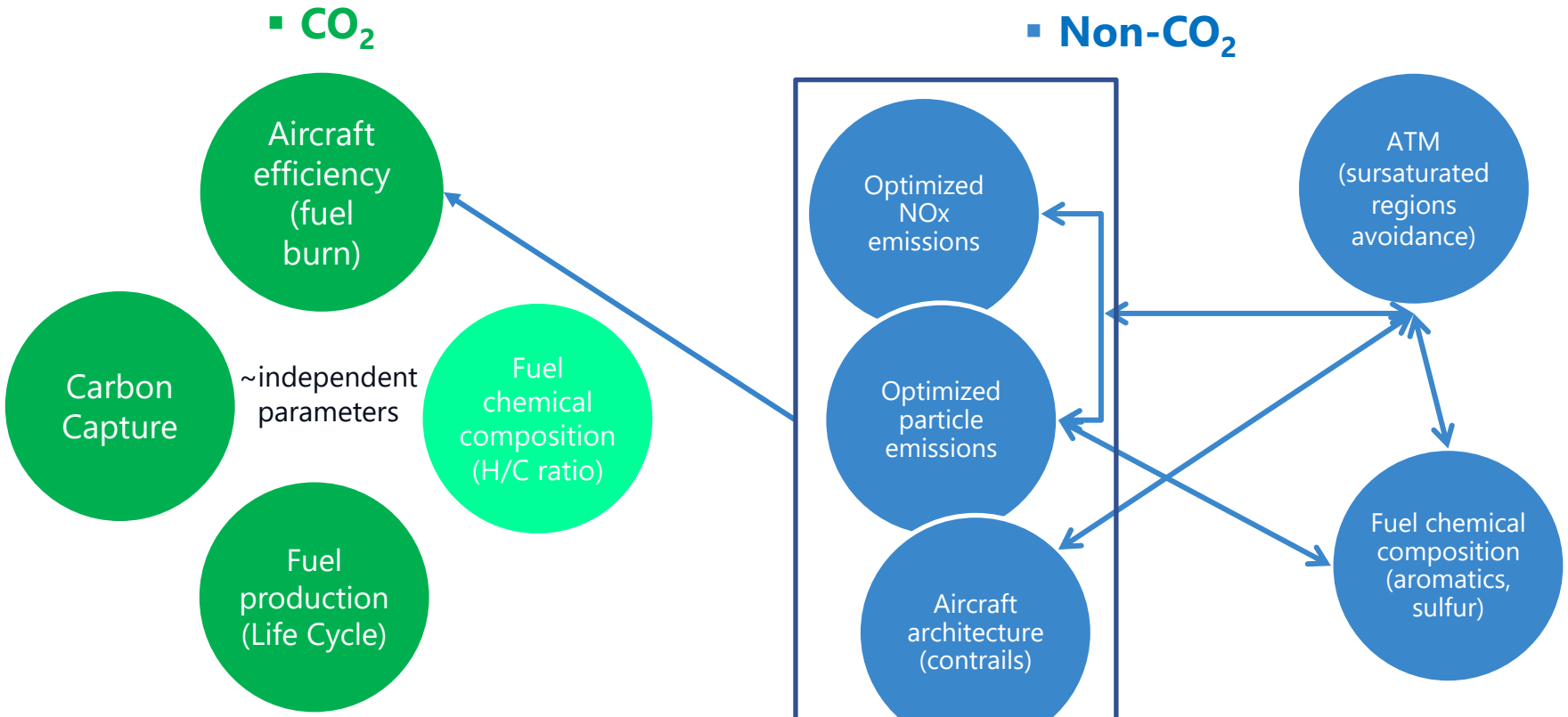
- **Challenging NOx / CO_2 trade-off**
  Climate benefit through NOx reduction leads to increased fuel burn



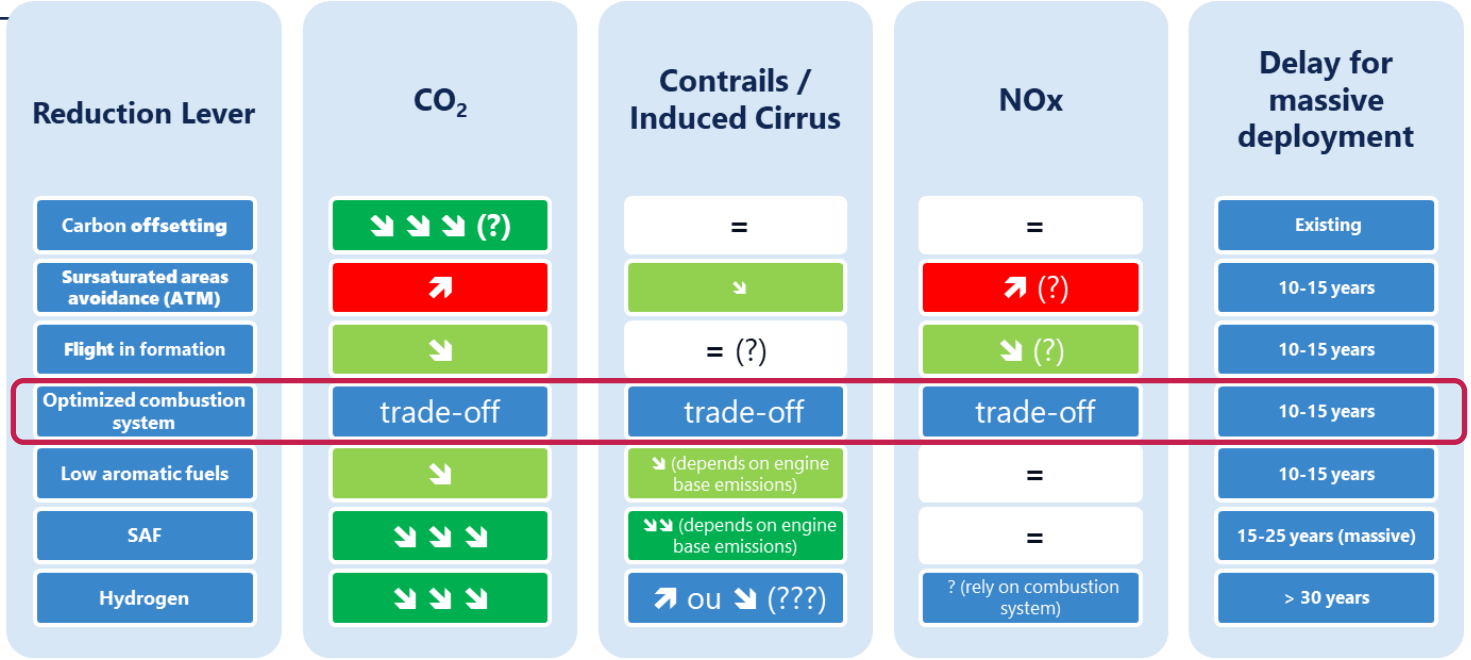
NOx have a short-term warming effect which could decrease or even become cooling in the longer term

Several scientific studies recommend to give priority to CO_2 reduction versus NOx reduction while complying with NOx standard

Non-CO2 effects : complex, with multiple mitigation levers



A set of trade-offs



Reduction Lever	CO_2	Contrails / Induced Cirrus	NOx	Delay for massive deployment
Carbon offsetting	↘ ↘ ↘ (?)	=	=	Existing
Sursaturated areas avoidance (ATM)	↗	↘	↗ (?)	10-15 years
Flight in formation	↘	= (?)	↘ (?)	10-15 years
Optimized combustion system	trade-off	trade-off	trade-off	10-15 years
Low aromatic fuels	↘	↘ (depends on engine base emissions)	=	10-15 years
SAF	↘ ↘ ↘	↘↘ (depends on engine base emissions)	=	15-25 years (massive)
Hydrogen	↘ ↘ ↘	↗ ou ↘ (???)	? (rely on combustion system)	> 30 years

Safran accelerates its technical efforts internally and through scientific cooperation to minimize uncertainty and make the right technology choices

A set of research topics

Model the 4D climate impact of NO_x with complex physical and chemical phenomena

Understand the effect of very low nvPM emissions, of organic compounds and of sulphur on contrails formation

CH_4

CO_2 emissions

H_2O emissions

Water vapor impact according to fuel type

NO_x emissions

Persistent contrails

Model the effect of flight routes changes on climate

O_3

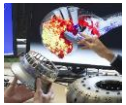
Model contrails 4D climate impact

? Cloud/aerosol interactions

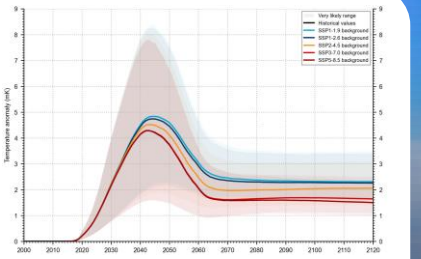
nvPM emissions

SO_x emissions

Establish the effect of engine architecture and new aircraft configuration on formation and climate effect of contrails



Understand the effect of SAF and combustor technology on emissions



Evaluate the complete 4D climate impact of a fleet with the aircraft/engine/fuel combination

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Joint Statement from CTOs Advocating for Advancing Science on Aviation's Non-CO_2 Impacts on Climate Change - Tuesday, July 23, 2024, Farnborough, UK

- Improve **understanding of contrail formation, persistence,** and climate impact
- Improve **understanding of emissions properties**
- Build research on **aerosol cloud interactions**
- Improve understanding of the radiative impact and modeling **uncertainty of NOx emissions**
- Improve understanding of the **interdependencies and trade-offs** of aviation emissions (NOx, soot, contrails, CO2, and noise)
- Establish and improve **common models for quantifying** the effect of aviation on climate
- Research on **airspace network impacts of mitigation** should be further investigated.

AIRBUS
BOEING
DASSAULT AVIATION
GE Aerospace
ROLLS ROYCE
RTX
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EU ETS revision – Adopted in 2023

A more stringent emissions trading scheme for aviation

- Progressively **removes free emission allowances for aviation** (from 2023 to 2026).
- Introduces a mechanism to **support the use of SAF**.
- Maintains the intra-European scope (EEA) until December 2026 while the international **CORSIA** mechanism from ICAO applies to extra-European flights. After a review of CORSIA by 1 July 2026, the EU ETS scope could be revised in 2027.
- Introduces the **consideration of climates effects, known as « non-CO_2» effects,** in airline reports on their emissions. First text in the world to legislate on these effects.

DIRECTIVES

- *Aircraft operators shall report once a year on the non-CO2 aviation effects occurring from 1 January 2025*
- *That monitoring, reporting and verification framework shall contain, at a minimum, the three-dimensional aircraft trajectory data available, and ambient humidity and temperature to enable a CO2 equivalent per flight to be produced.*
- *by 1 January 2028, the Commission should submit a report, and, where appropriate and based on an impact assessment, submit a legislative proposal containing mitigation measures for non-CO2 aviation effects, by expanding the scope of the EU ETS to cover such effects.*

A small focus on fuel

- **Current « simple » vision :**

Aromatics / sulfur → Particles → Ice cristal → Contrails → Cirrus → Warming

- **With such a vision, massively reducing aromatic content in fuel can have a major impact on aviation environmental footprint**
- **Nevertheless, such evolution could have major impact**
  - Increase of discrepency in fuel quality
  - Potential impacts on current technologies
  - Impact on the definition of future 100% SAF grades

EASA hosts first EU Aviation Fuel Stakeholder Forum

22 Apr 2024 SUGGESTED

Cologne, April 22, 2024 – The European Union Aviation Safety Agency (EASA) hosted the first EU Aviation Fuel Stakeholders Forum on April 18-19, 2024. The event marked the launch of a network of European fuel stakeholders to strengthen cooperation in Europe, with the aspiration of optimising the jet fuel composition to respond to environmental challenges.

Extra

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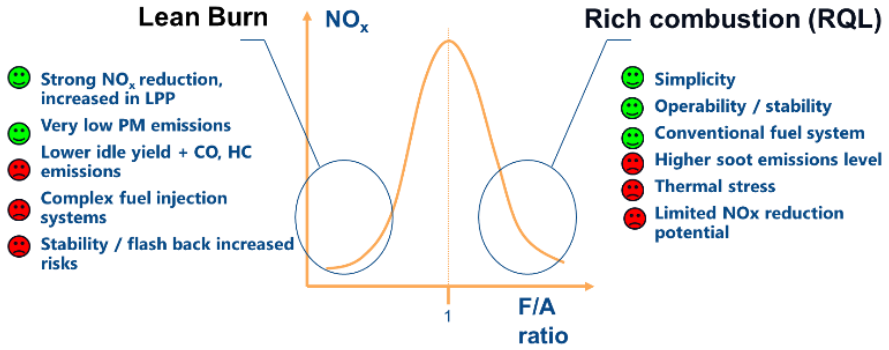
One priority is to examine the feasibility of lowering the aromatics and sulphur content of conventional jet fuels; this will support the mitigation of aviation's impact on the environment, with a particular focus on the effects of non-CO_2 emissions on climate. Another key objective of the EU Aviation Fuel Stakeholders Forum is to enable the development of long-term innovative solutions in the field of aviation fuels — in alignment with international stakeholders.

Potential impact on Safran products

- **International regulations**
  - Inclusion of non-CO_2 effects on ETS regulation
  - Decision to include non-CO_2 effects in the work-programme of the ICAO CAEP14 cycle (2025-2028)



Additional trade-offs in the development of future engines

- **Fuel properties**
  - Definition of future 100%SAF grades
  - Evolution of fuel quality at EU level (EASA)

New constraints on aircraft certification

- Evolution of fuel quality / increase of quality discrepancy
- Interdependence between chemical composition and fuel properties must be evaluated
- Non-drop-in 100%SAF grade, need for new propulsion system design / qualification

What we do in Safran

Stakes

- **Decarbonize aviation: at the core of Safran's mission**
- **Low carbon aircraft: R&T priority**
  Develop technologies for ultra efficient aircrafts
  Enable the extensive use of sustainable aviation fuels (SAF)
  Contribute to the reduction of non-CO2 effects

Needs

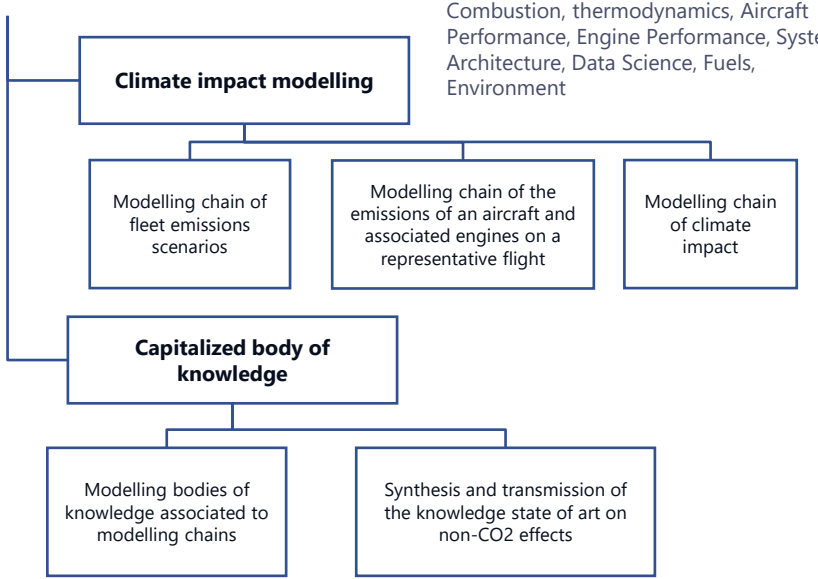
- Organize the internalization and efficient sharing of knowledge on non-CO_2 effects
- Acquire the capacity to quantify the emissions and the complete climate impact (CO_2 and non-CO_2) of aircrafts and associated engines
- Facilitate exchanges and discussions with airframers to ensure robust and efficient technologies and product developments, and with stakeholders, regulatory agencies and international organizations for advice

Working group ENICMA (Évaluation iNterne de l'Impact Climatique des Moteurs d'Avions)

3 years objectives (2026)

Perimeter : aircrafts in exploitation

Pluri-disciplinar team
Combustion, thermodynamics, Aircraft Performance, Engine Performance, Systems Architecture, Data Science, Fuels, Environment



Conclusions and perspectives

- **Safran addresses non-CO_2 effects as part of its climate strategy**
  - Safran strongly increasing expertise through a dedicated expert team, a strong collaborative network and a constant discussion with our industrial partners (Airbus, TTE…)
- **Academic work must accelerate to reduce current uncertainties**
- **Non-CO2 effects integrated in regulations**
  - Technical and scientific implementation still to be defined
  - Unlikely but still possible: application a multiplier to CO_2 emissions
  - ICAO CAEP address non-CO_2 effects. No regulation foreseen in the short term
- **A multiple trade-off subject for engine manufacturers**
  - All environmental impacts must be addressed
  - Impact on future fuel quality can also have an impact on engine technologies
  - Urgent need for scientific understanding for proper engine technical choices

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