

AIMS & OBJECTIVES

Published in April 2022, the **Aerospace Technology Institute's** (ATI) technology strategy **Destination Zero** puts sustainability at the core of UK aerospace research and development. The sector remains steadfast in its aim to reduce carbon emissions in line with the UK government and aviation's commitment to Net Zero 2050.

Current activities to address aviation's climate and environmental impacts also target improvements in local air quality through measures such as reducing oxides of nitrogen (NO_x), and addressing noise emissions in line with certification requirements. Reducing the negative effects of wider non-carbon dioxide (non-CO₂) emissions is also critical.

This **ATI Non-CO₂ Technologies Roadmap** is the first of its kind. It reflects the UK aerospace sector's collective view of the research actions needed to improve understanding and reduce broader atmospheric emissions from aircraft.

This roadmap will inform the activities to be prioritised for funding under a new **ATI Non-CO₂ Programme** to open in May 2024. Its publication follows the initial phase of a new joint non-CO₂ funding programme between NERC, ATI, DfT, DBT & IUK launched in October 2023 for projects to be funded through NERC, on fundamental science. **The ATI Non-CO₂ Programme** will focus predominantly on industrial research, and technology development or enabling-technology projects.

This programme will build upon the fundamentals, focusing on developing technologies and scaling up solutions for practical implementation. It will bring academia, government institutions, and industry players together to translate theoretical concepts into viable technologies. This flow from fundamental to industrial research is vital for driving advancements in non-CO₂ technologies, reflected in the broad scope of the roadmap.

The Non-CO₂ Technologies Roadmap has been generated following comprehensive consultation with industry, academia, aviation and international stakeholders. It complements the existing Destination Zero roadmaps; Ultra-Efficient Technologies, Zero-Carbon Technologies and Cross-Cutting Enabling Technologies. In some instances, non-CO₂ technology research and development will also span across one or more of the existing technology roadmaps.

Guidance on this and full details for applications to the ATI's funding programmes is available on the [ATI website](#).

NON-CO₂ EMISSIONS

Collectively, non-CO₂ emissions refers to the direct and indirect effects of combustion found in aircraft exhaust plumes, aside from carbon dioxide. Depending on the engine fuel type, exhaust plumes contain CO₂ and other gases, plus aerosols.

Non-CO₂ emissions in aviation may include (non-exhaustive list):

- Contrails
- Oxides of Nitrogen (NO_x) and products of their interaction with other gases such as ozone (O₃) and methane (CH₄)
- Carbon monoxide (CO)
- Water vapour (H₂O)
- Sulphur compounds including sulphur oxides (SO_x) and sulphate aerosols
- Particulates, soot and unburnt hydrocarbons (HC)
- Hydrogen (H₂)

Non-CO₂ emissions from aviation are considered to contribute a climate impact in terms of global warming. However, there remains a high level of uncertainty as to the quantified impacts - usually expressed in terms of radiative forcing (W/m²). The level of uncertainty varies depending on the emission type and in some cases, emissions may also impart a cooling effect. The climate impact is highly complex and variable depending on many factors including the atmospheric altitude of emissions, weather and regional specifics such as the occurrence of ice super saturated regions (ISSRs). In addition, there are complex interactions and interdependencies between emission types, as well as variation in the persistence and length of time different emissions impact the climate.

Addressing the priority areas identified in the Non-CO₂ Technologies Roadmap will reduce uncertainty in fundamental science and deliver technology solutions to mitigate or prevent non-CO₂ emissions during flight.



SCOPE & PRIORITIES FOR INVESTMENT

The ATI will prioritise industrial research, technology development and enabling-technology projects with the potential to deliver the greatest sustainability and economic benefit for the UK. The Non-CO₂ Technologies Roadmap shows the milestones to 2050, with the following priority areas for research:

Fuel characteristics

- Research relating to the introduction and ramp up of sustainable aviation fuels (SAF) and other alternatives, including hydrogen both in fuel cells and gas turbine combustion. This theme also includes adaptations to the kerosene specification to improve its non-CO₂ credentials, plus optimised operational use of hybrid fuel combinations or SAF.

Aircraft technologies

- Research focused on delivering instrumentation and sensing solutions for emissions measurement and management; systems and controls related to the use of hydrogen including water vapour release; engine controls or combustion developments; technologies to manage hybrid or dual fuel systems.

Knowledge, data, and operations

- Research related to modelling, measurement and data correlation activities; atmospheric understanding of particulates and contrails formation; NO_x interactions at altitude; water vapour from H₂ use; data management systems for flight operation mitigations and through-life modelling.

While three areas have been identified as key to delivering reductions in climate impact, addressing these will also require consideration of the interdependencies and potential unintended consequences of mitigations. Guided by the latest scientific understanding, changes to one emission type should not adversely impact another to create a detrimental climate impact. This complexity of the non-CO₂ emissions understanding and mitigations will drive the need for expertise and activities across other sectors such as space (satellites), weather forecasting, air traffic control or fuel chemistry supported by relevant funding streams.

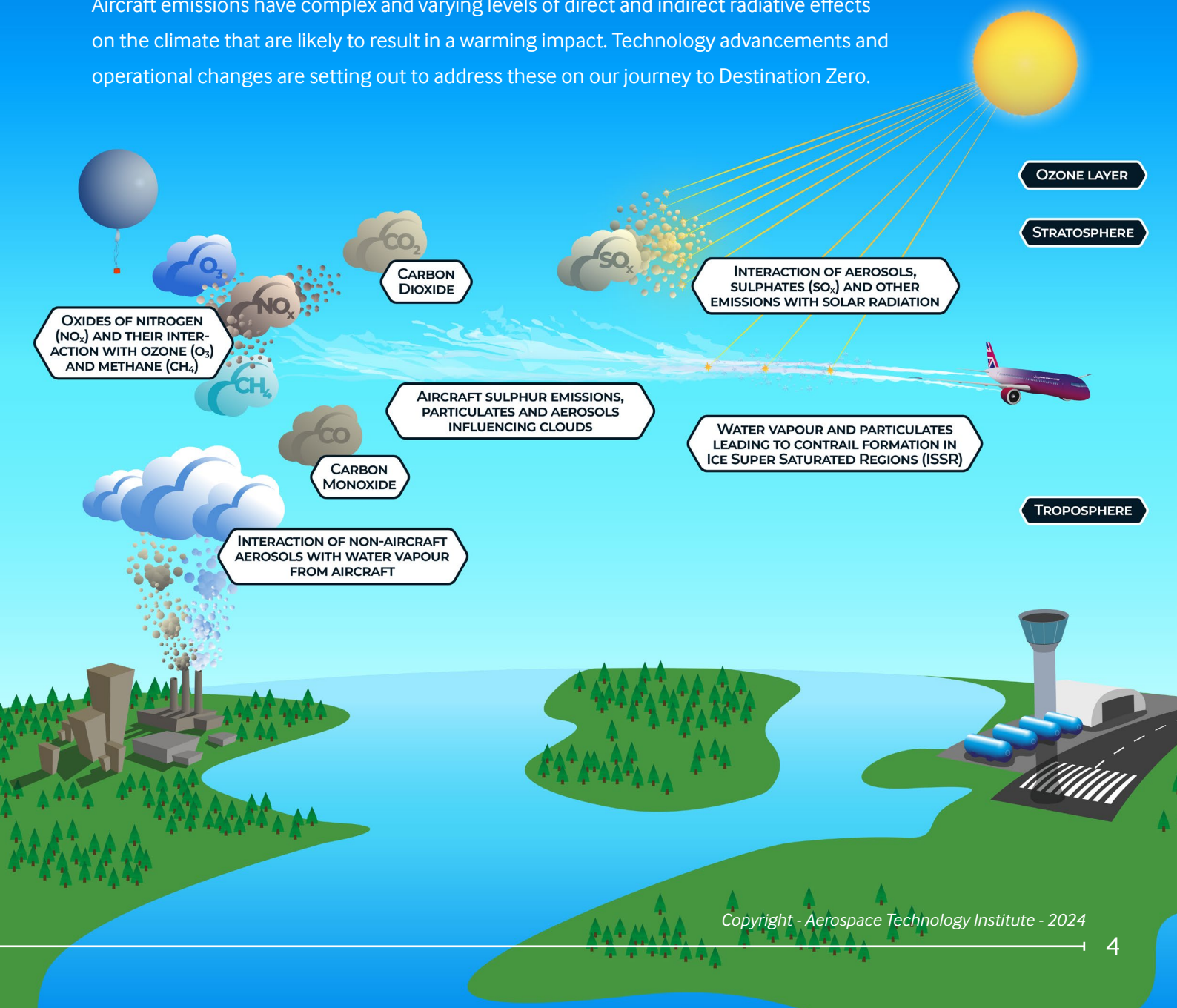


CONCLUSION

The publication of this Non-CO₂ Technologies Roadmap and introduction of an associated funding programme will serve as further strategic investment for the benefit of the UK aerospace sector accelerating our journey to Destination Zero. The ATI continues to work with stakeholders across government, aerospace and aviation to unlock technologies key to keeping the global economy connected while meeting environment commitments.

AIRCRAFT EMISSIONS AND THEIR CLIMATE INTERACTIONS

Aircraft emissions have complex and varying levels of direct and indirect radiative effects on the climate that are likely to result in a warming impact. Technology advancements and operational changes are setting out to address these on our journey to Destination Zero.



NON-CO₂ TECHNOLOGIES ROADMAP

AIRCRAFT
CONCEPTS/
MILESTONES

FUEL
CHARACTERISTICS
FOSSIL, SAF, H₂ OR
ALTERNATIVE

AIRCRAFT
TECHNOLOGIES

KNOWLEDGE,
DATA &
OPERATIONS

