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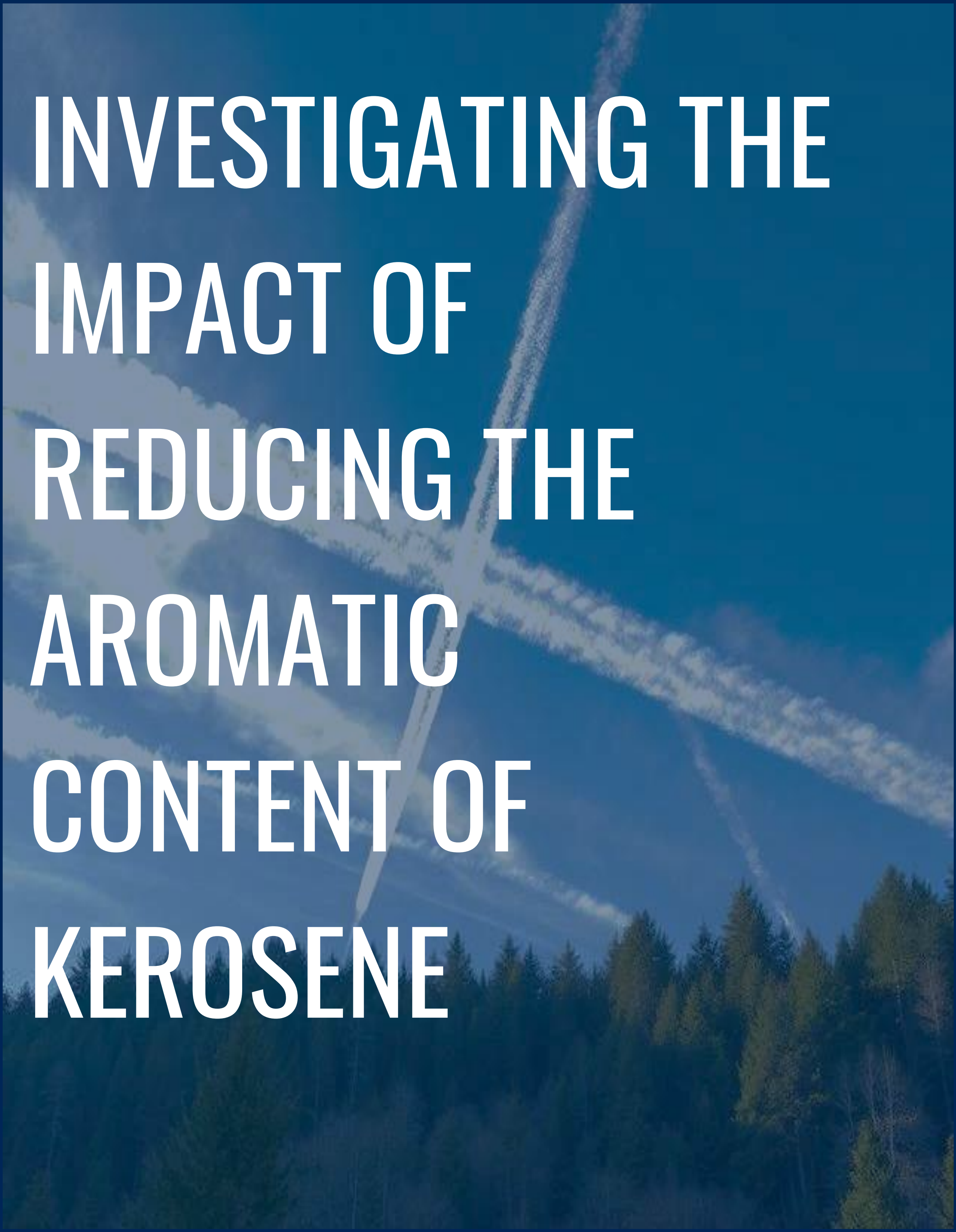


INVESTIGATING THE IMPACT OF REDUCING THE AROMATIC CONTENT OF KEROSENE

Aviation's crucial role

Aviation is essential for global connectivity, but current decarbonisation technologies like electrification and hydrogen are still developing. This means liquid hydrocarbon fuels, such as kerosene, remain the primary option for long-haul flights. Effects of CO_2 emissions from jet fuel are well-known, other environmental impacts, particularly from aromatic compounds in aviation fuel, require further attention.

This DfT funded report critically reviews how jet fuel components, especially aromatics, affect contrail formation and climate. With fossil-based jet fuels dominating for years to come, understanding and mitigating their non-CO_2 emissions is crucial. The in-depth report explores reduction or removal of aromatics from kerosene to lessen contrail formation. It addresses technical, safety, and cost challenges, along with potential CO_2 trade-offs.

Contrails

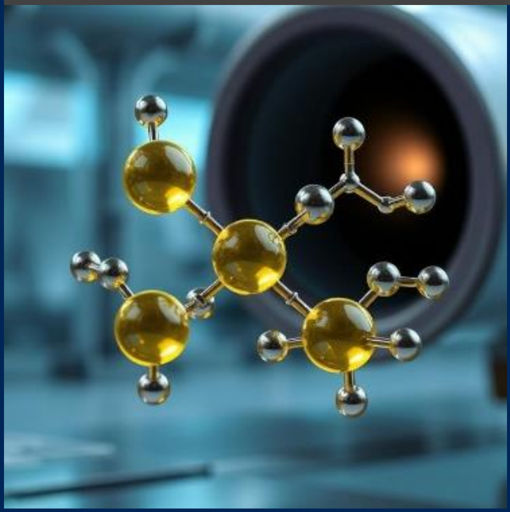
Contrails are ice crystal clouds formed behind aircraft when water vapor in the exhaust freezes onto soot particles. These soot particles are produced from aromatic compounds in jet fuel, particularly di-aromatics. Contrails are a significant non-CO_2 contributor to aviation's climate impact, potentially the largest. Contrails both warm and cool, depending primarily on time of day, but their net effect is considered to be warming, trapping heat in the atmosphere. The processes of contrail formation and their radiative effects are complex and not fully understood, leading to uncertainties in quantifying their overall impact. Reducing the aromatic content of jet fuel is being explored as a potential method to reduce soot particles and, consequently, contrail formation, but this must be balanced against other factors, such as increased CO_2 emissions from fuel hydrotreatment and the operational implications for the aviation industry.

Report content

- A comprehensive literature review examining contrail formation, the role of soot particles, and the impact of fuel composition on emissions.
- An analysis of refinery processes, including hydrotreating, required to reduce aromatic and naphthalene content in jet fuel, considering resource requirements, costs, and associated CO_2 emissions.
- A detailed analysis of the trade-offs between the potential benefits of reduced contrails and the increased CO_2 emissions resulting from the refining process, along with cost, safety, operational, and global market implications.
- Consideration of existing and potential regulatory and industry initiatives, including the development of Sustainable Aviation Fuels (SAF) and other low-carbon technologies, such as hydrogen and electric-powered flight.
- An evaluation of the potential impacts of altering fuel composition on engine performance, maintenance needs, safety, and the potential need for fuel additives.
- An assessment of the risks associated with using hydrogen content as a proxy for specific fuel molecule types when targeting soot reduction.

Key findings

- **Aromatic content and contrails:** Reducing the aromatic content of jet fuel is expected to decrease soot emissions, which in turn could lessen contrail formation and their warming effect.
- **Scientific uncertainty:** While progress has been made in understanding contrails, there's still low scientific confidence in quantifying their global effect due to complex interactions and limited modelling capabilities.
- **Soot and ice crystals:** A relationship exists between the number of soot particles emitted and the number of ice crystals formed in contrails. Fewer ice crystals can lead to a reduced radiative effect.
- **Aromatic content and soot emissions:** Studies suggest a link between the aromatic content of fuel and soot emissions, with di-aromatic compounds like naphthalene playing a significant role in soot formation. However, the chemistry of this process is not fully understood.



- **Jet fuel composition:** Jet fuel is a complex mixture with specifications focused on combustion and safety. Aromatic content is regulated within a range, but specific aromatic compounds are not routinely measured.
- **Challenges of reducing aromatics:** Reducing aromatic content would require significant investment in refineries and testing facilities, especially if specific compounds are targeted.
- **Hydrogen content as a proxy:** Using hydrogen content as a proxy for regulating aromatic content is considered risky and potentially ineffective due to the complex nature of soot formation.
- **Costs and CO_2 trade-offs:** Reducing aromatics increases fuel production costs and energy consumption, leading to additional CO_2 emissions. This creates a trade-off between reducing contrails and increasing CO_2.
- **Hydrogen demand conflict:** Increased hydrotreating for aromatic reduction could conflict with the growing demand for hydrogen in SAF production and hydrogen-powered aircraft.
- **Safety implications:** Any changes to jet fuel specifications require careful risk analysis due to safety implications related to fuel handling, airframe, and engine performance.
- **CO_2 emission increase:** Studies suggest that reducing aromatic content could increase CO_2 emissions from fuel production by approximately 3% per tonne of jet fuel.
- **Complex trade-off calculation:** Comparing the warming effect of reduced contrails against the increased CO_2 from fuel production is complex due to differing timescales of warming effects.
- **Overall risk assessment:** Until uncertainties related to safety, feasibility, cost, and environmental impact are addressed, reducing aromatic content carries significant risks and could potentially have adverse climate consequences.

Recommendations

1. **Improve evidence base:** Enhance understanding of whether regulatory actions targeting soot's role in contrail formation would effectively mitigate aviation's non-CO_2 effects on climate. This requires large-scale international research efforts and further investigation into the relationship between aromatic levels and soot emissions.
2. **Detailed trade-off study:** Conduct a detailed study of the potential trade-offs between decreased contrails and increased CO_2 emissions at the refinery. This study should model additional energy costs and explore different CO_2-e metrics to ensure the environmental outcome is better than the counterfactual of no regulation.
3. **Fuel property trade-offs:** Undertake a detailed study of the trade-offs in fuel properties as the aromatic content changes and its viability for aviation use. This study should test representative fuels to assess changes in critical properties such as lubricity, thermal stability, and soot creation performance.
4. **Explore costs:** Significant infrastructural changes would be required to remove or reduce aromatic content. These require careful analysis and cost estimation.

The full report *Investigating the Impact of Reducing the Aromatic content of Kerosene*, published in 2025, was co-authored by Professor Mohamed Pourkashanian (University of Sheffield), Professor David Lee (Manchester Metropolitan University), Professor Chris Lewis (University of Sheffield), Professor Marc Stettler (Imperial College London), Dr Simon Blakey (University of Birmingham), Dr John Andresen (Heriot-Watt University), Dr Roger Teoh (Imperial College London), Dr Ehsan Alborzi (University of Sheffield), Dr Jonathan Knapton (University of Birmingham), Professor Piers Forster (University of Leeds) and Professor Mercedes Maroto-Valer (Heriot-Watt University).
For a copy of the full report, contact the Energy Innovation Centre, details overleaf.

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