



University of  
**Sheffield**

**EIC**

# Investigating the impact of reducing the aromatic content of kerosene



Department  
for Transport



University of  
**Sheffield**

**EIC**

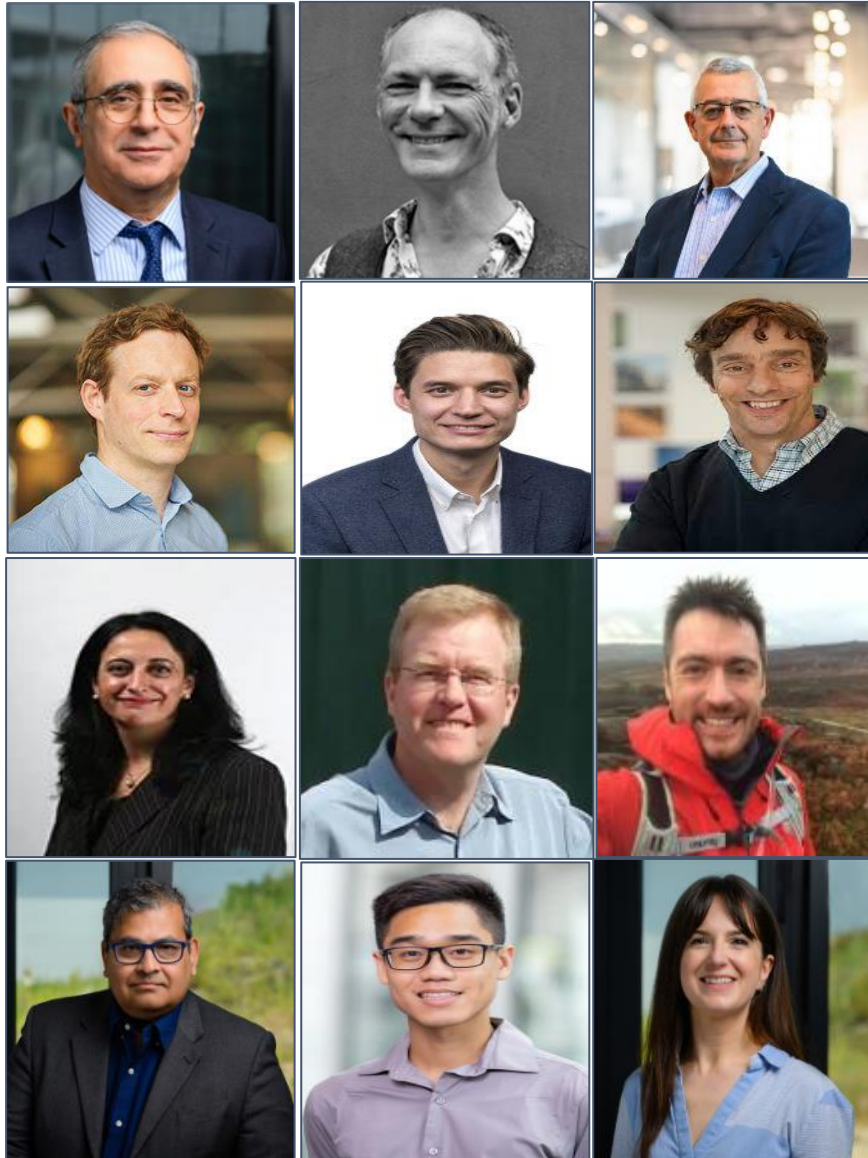


**European Union**  
European Regional  
Development Fund



Department for  
Energy Security  
& Net Zero

**NORTHERN  
POWERHOUSE** HM Government



## Project

Department for Transport (DfT-UK) initiated the “*investigating the impact of reducing the aromatic content of kerosene*” project to explore the relationship between the aromatic content of jet fuel and contrail formation, and to establish if reducing the aromatic content of kerosene might have a positive climate impact.

## Project Team

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## Expert Advisory Board

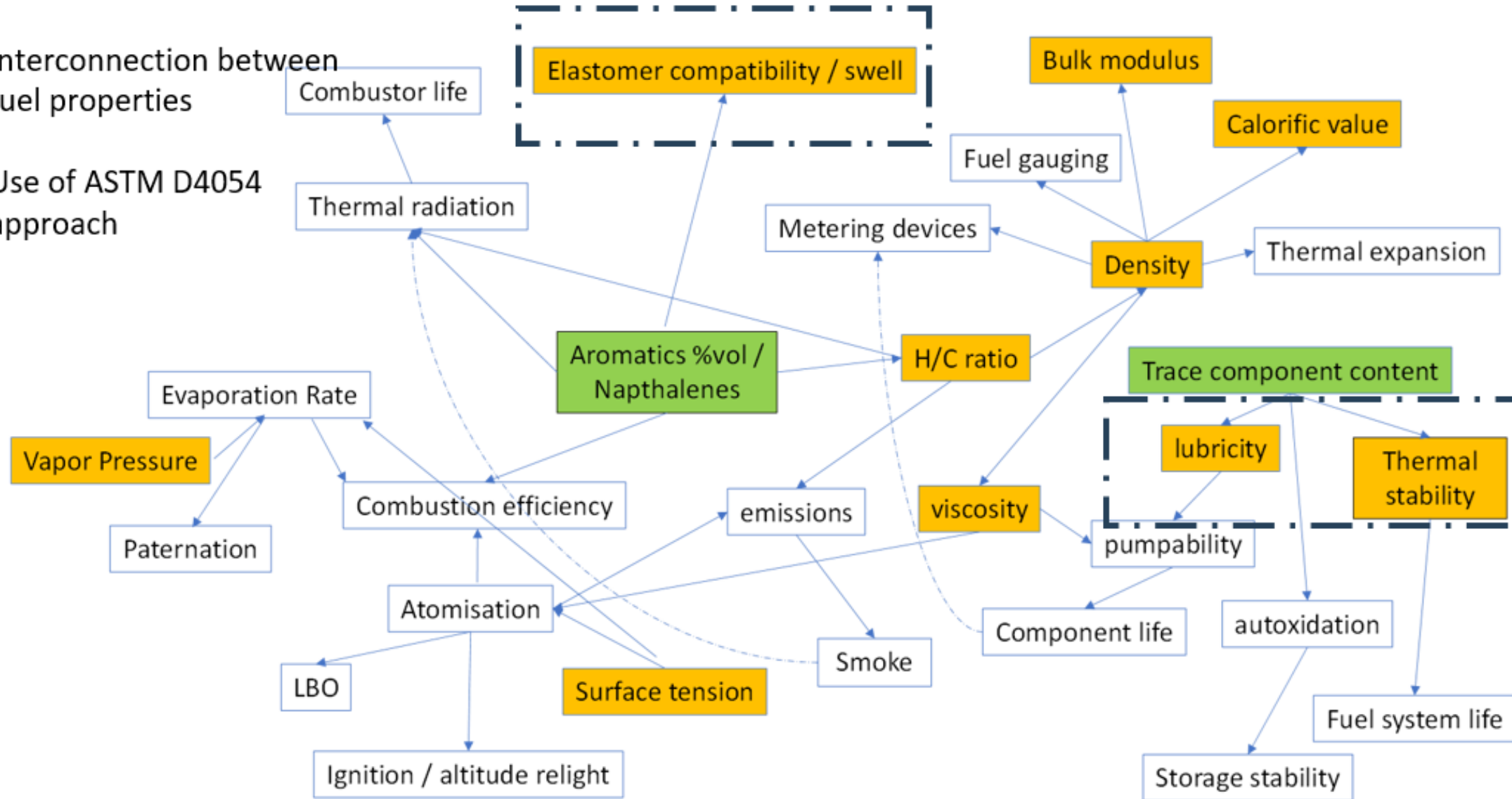
The authors gratefully acknowledge the support of the industry-based EAB in providing valuable input and comments on the work undertaken within this study. EAB advisors included: Alastair Hobday (Rolls-Royce), Timothy F. Rahmes and Stephanie C. Williams (Boeing), Johan Dekeyser (Independent), Maxime Gauthier and Hamzah Ahmed (Airbus).

# Introduction

E.g. Increased hydrotreating

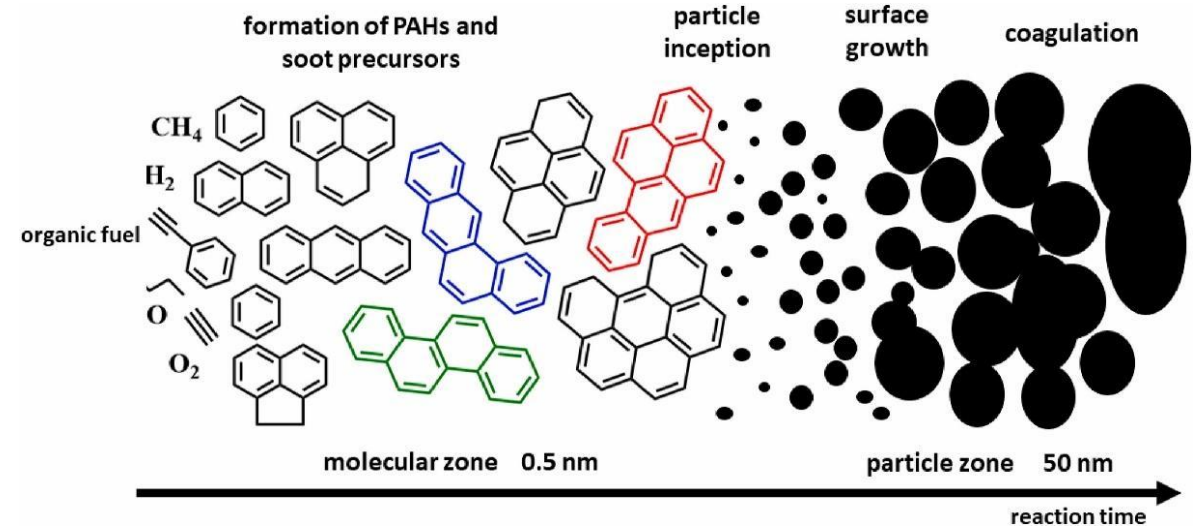
Interconnection between fuel properties

Use of ASTM D4054 approach

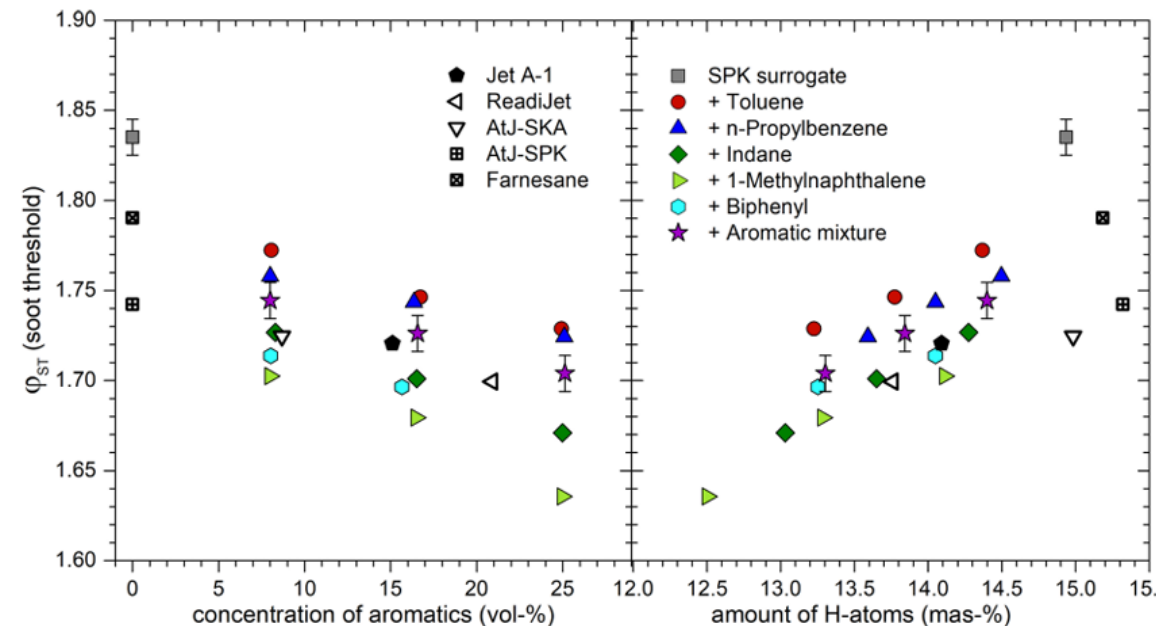


# Soot formation & Aromatic Speciation

- Aromatic from Organic fuel form PAHs, soot precursors which following hydrogen abstraction and carbon addition and nanoparticle inception lead to surface growth and coagulation of particles [89].
- Different aromatic structures vary in their soot forming potential [39].
- At low TRL, fuels with higher volume % concentration of aromatics were found to produce soot more readily [39].
- Soot forming potential was found to trend loosely with the inverse of fuel hydrogen content, or proportional to hydrogen deficiency [39].



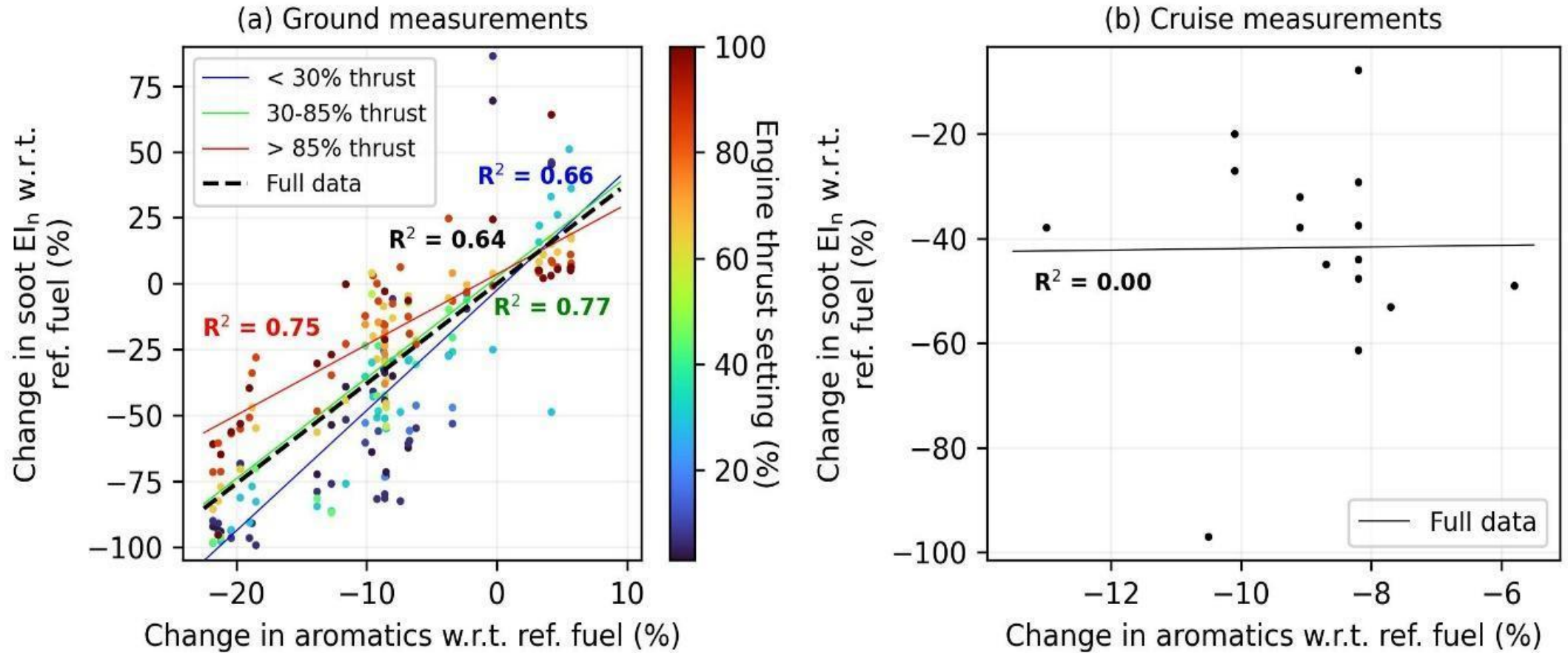
[89]



[39]

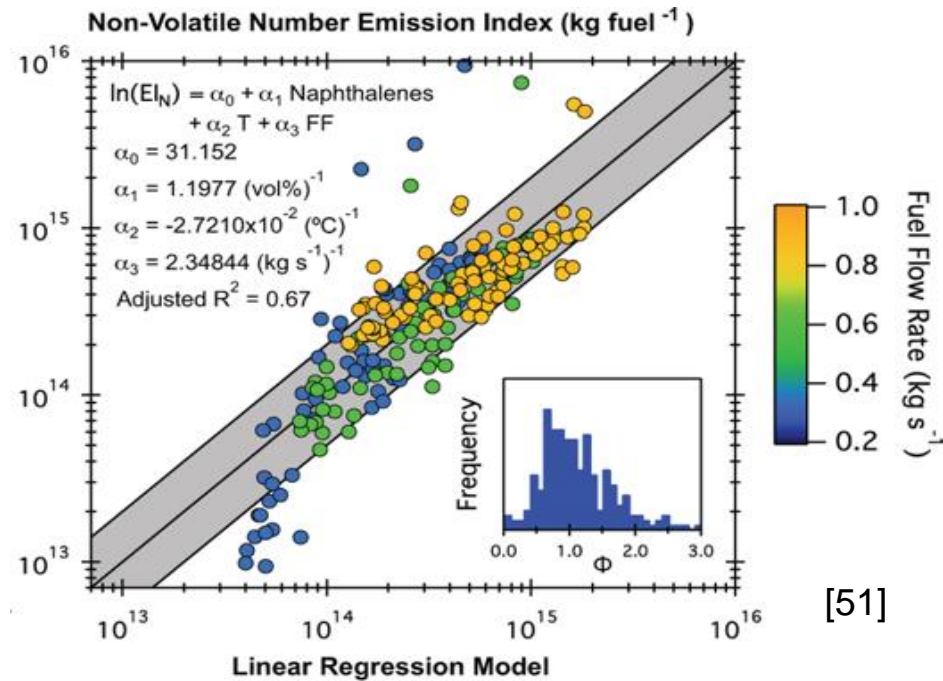
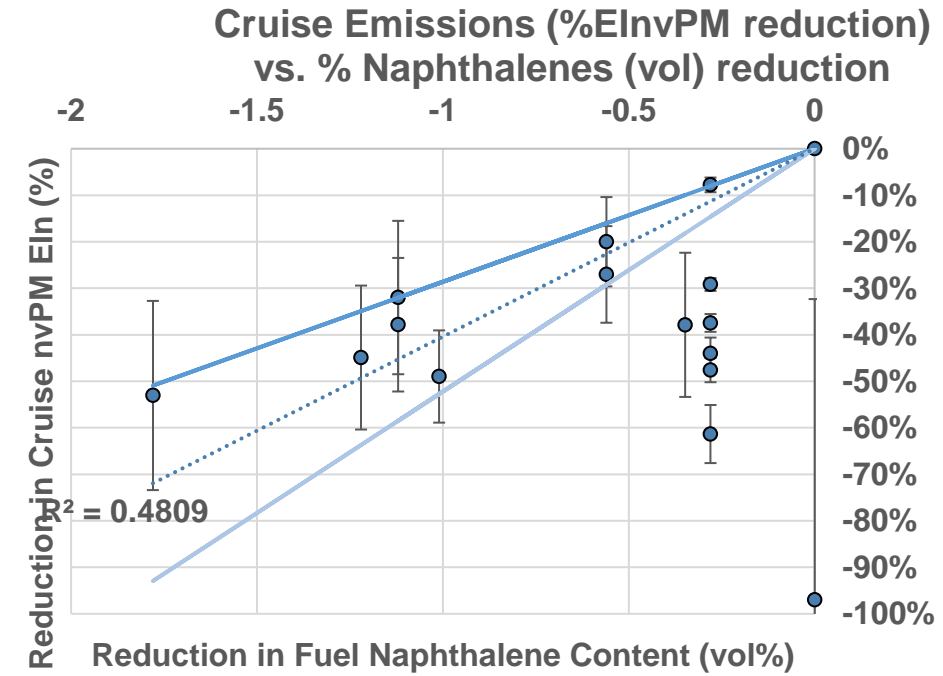
[89] = 89<sup>th</sup> reference in TAVI 4106 report

# Total Aromatic Content, ground and cruise

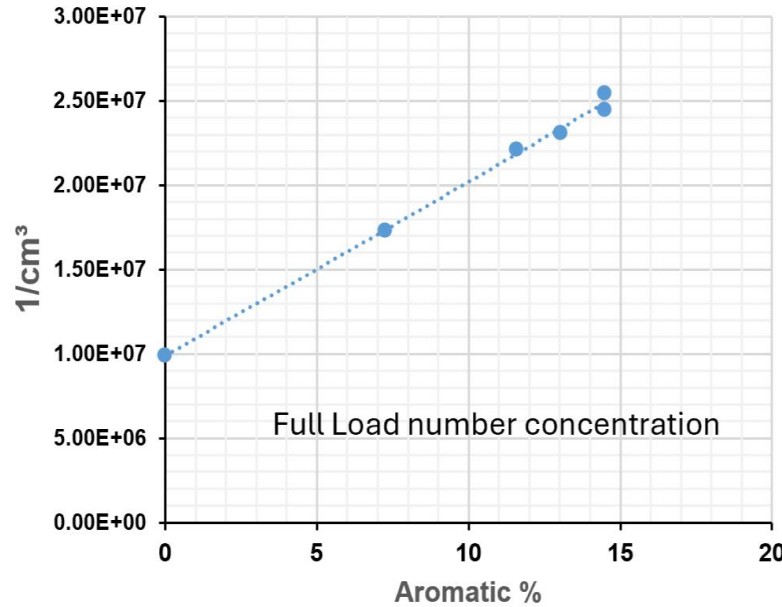
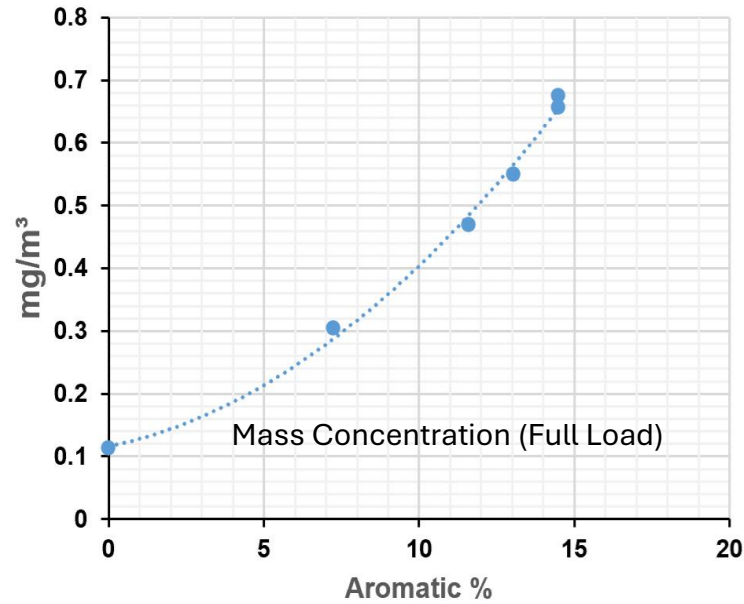


## Fuel Naphthalene Content

- Naphthalene content reduction has a stronger effect nvPM reduction than mono-aromatics or total aromatics like for like (per vol%)
- High degree of experimental uncertainty and co-dependency on other parameters in addition to naphthalene content such as:
  - Engine hardware
  - Thrust setting
  - Sulphur content
- The work of Moor et al. [51] using linear regression shows that Naphthalene is the largest fuel parameter effecting nvPM Number Emissions Index.

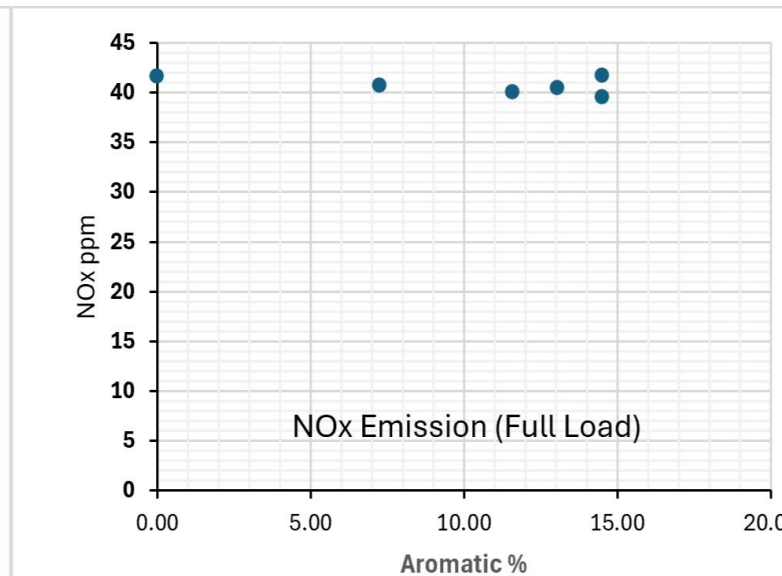
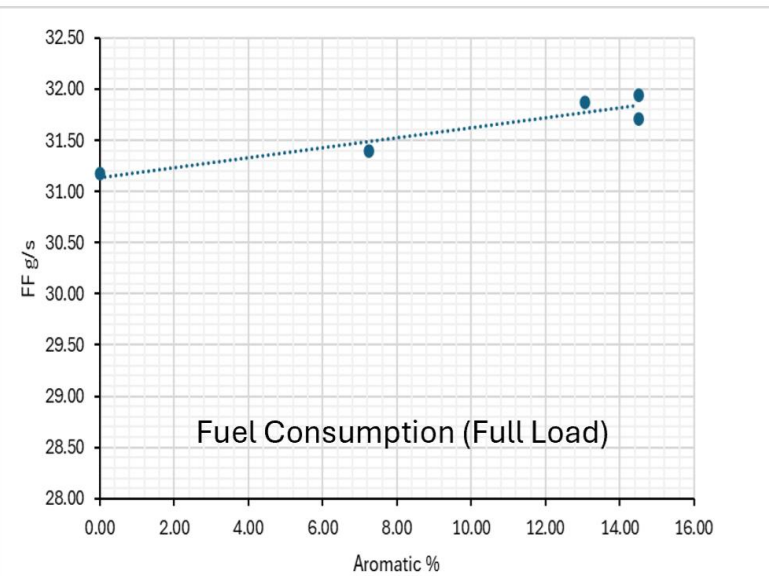
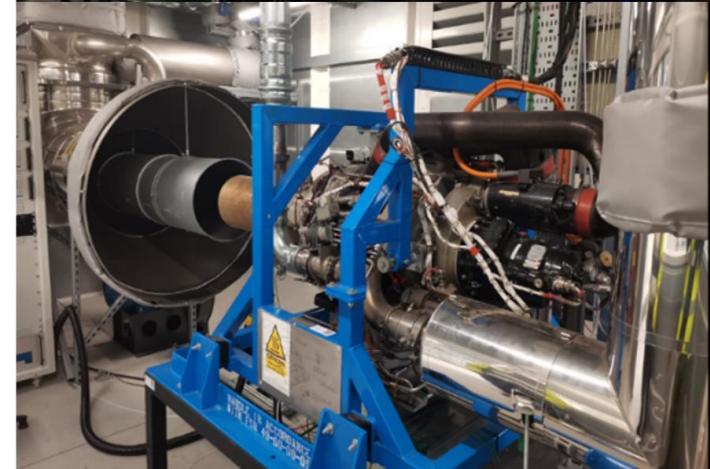


# “Closing the Gap” Jet Fuel Test Campaign



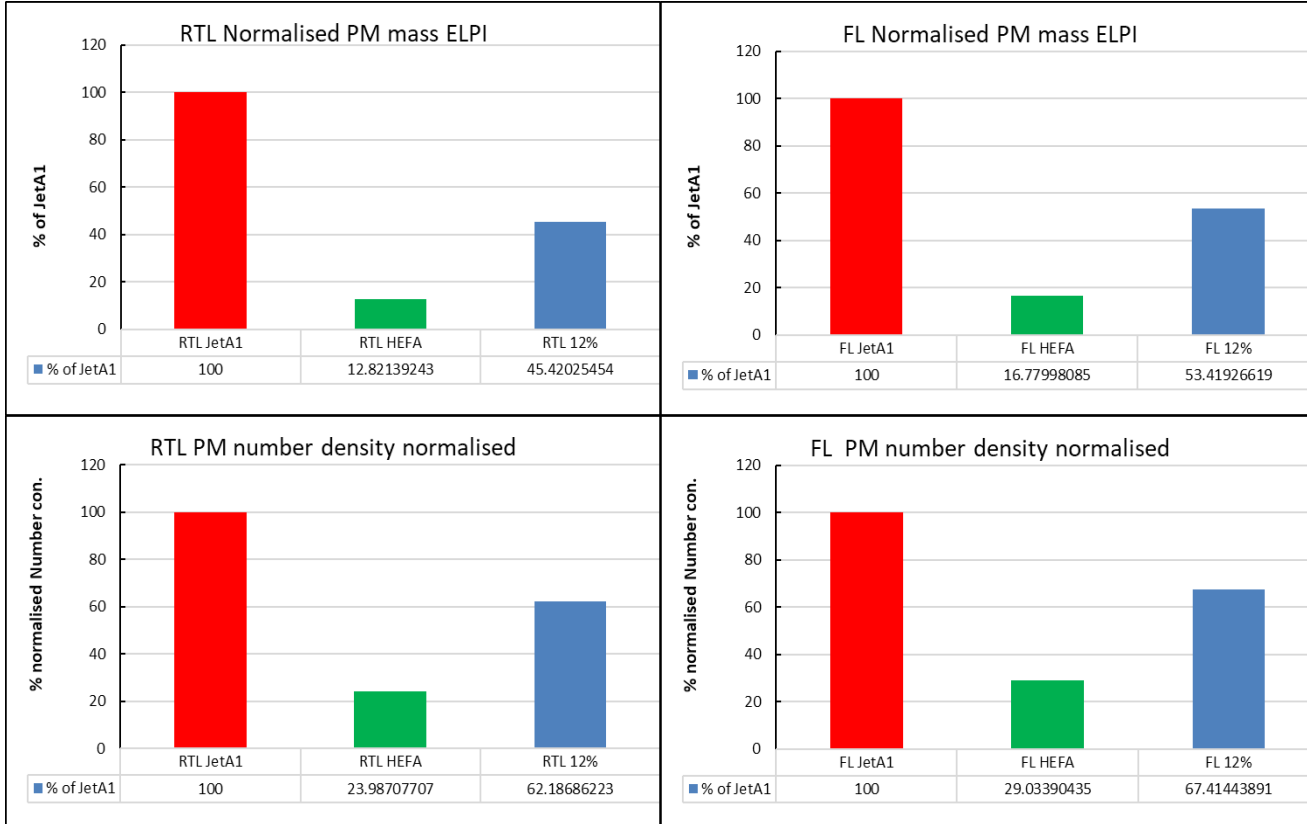
Experimental setup:

- A Honeywell 131-9A APU at two different loading conditions
- 6 fuel samples tested



Flight100 SAF testing resulted in a reduction in particulates, with potential benefits for local air quality around airports and in the reduction of persistent contrails

Normalised data from the LII-300 and ELPI representing % reduction of nvPM (mass and number) from APU test at low load and full load conditions.

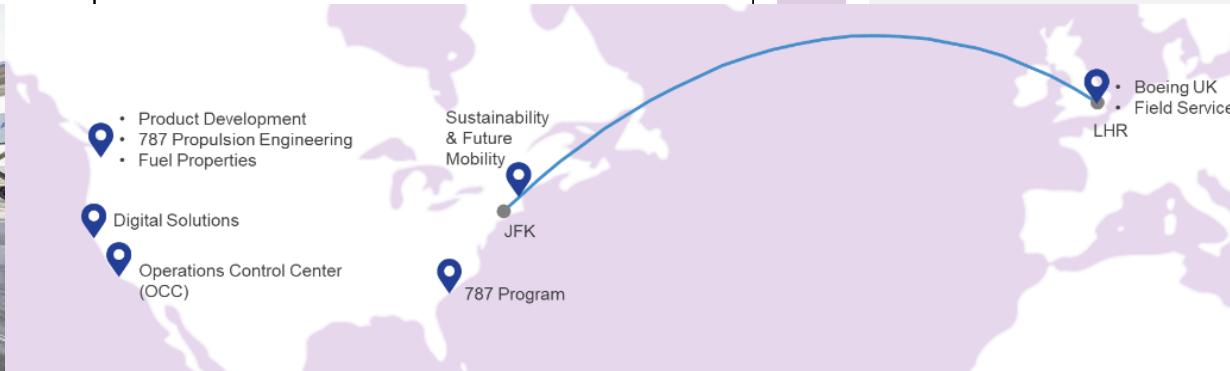


The APU testing revealed a marked reduction in both the number and mass of particulate emissions when using Flight-100 fuel (HEFA-12.7% SAK) and the HEFA component compared to conventional Jet A-1

350kg of fuel was saved during Flight100 as a result of the higher energy density. This could save up to 400,000 tonnes of jet fuel globally based on a 10% SAF target by 2030

Flight100 SAF generated **40% less particulates** vs Jet A-1

The pure HEFA component generated 70% less particulates compared to that of Jet A-1



## Summary of Recommendations

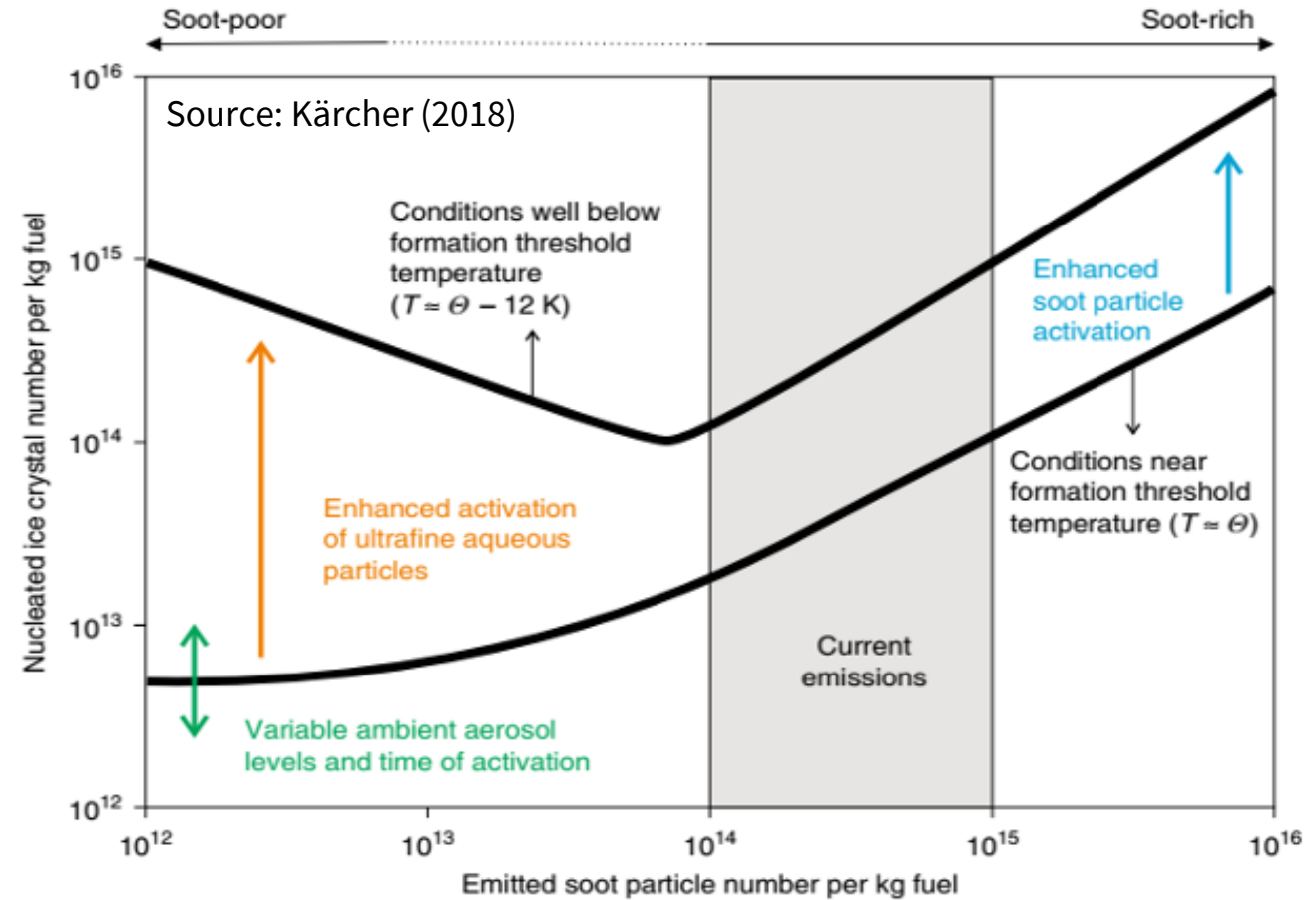
- 1. Improve the evidence base that regulatory actions to target soot's role in contrail and contrail cirrus formation would be an effective measure to mitigate aviation's non-CO<sub>2</sub> effects on climate.*
- 2. Undertake a detailed study (within the existing known uncertainties) of the potential trade-offs between decreased contrails and contrail cirrus by reducing soot emissions via fuel regulatory interventions and increased CO<sub>2</sub> at the refinery. This is important since without such a detailed study, there is a significant risk that the environmental outcome is worse than the counterfactual of no regulation.*
- 3. Undertake a detailed study of the trade-offs in fuel properties as the aromatic content changes.*
  - Studies where one fuel has been hydrotreated to different levels to observe the changes in fuel properties are limited (there are only 3) and at a pilot plant scale.*

# Additional Slides

### Impact of Aromatics on Soot Formation

- There is an observed relationship, supported by theoretical modelling, between the number of soot particles emitted, and the number of ice crystals.
- Largely by empirical observation, i.e. without supporting mechanistic evidence and understanding, it appears that di-aromatic compounds, such as naphthalene play a significant (but not sole) role in soot formation.
- If the aromatic content of jet fuel were subject to more stringent limits, this would require further investment at refineries and in testing facilities, particularly if individual classes of compounds, such as naphthalene (multiring aromatics), were to be targeted.

### Modelled dependence of ice crystals on soot

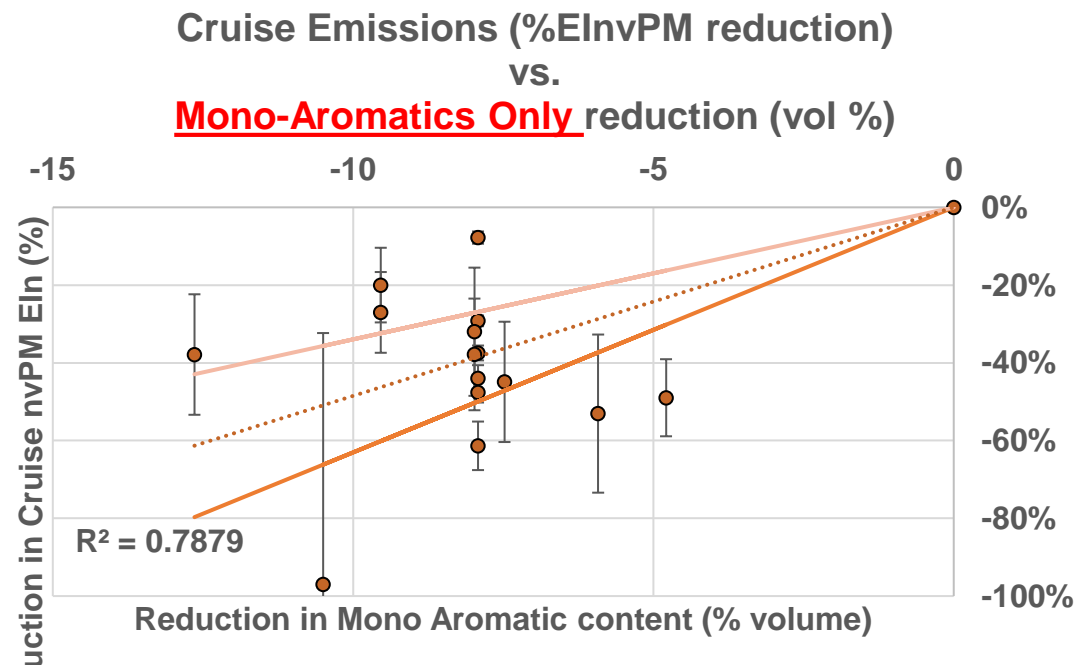
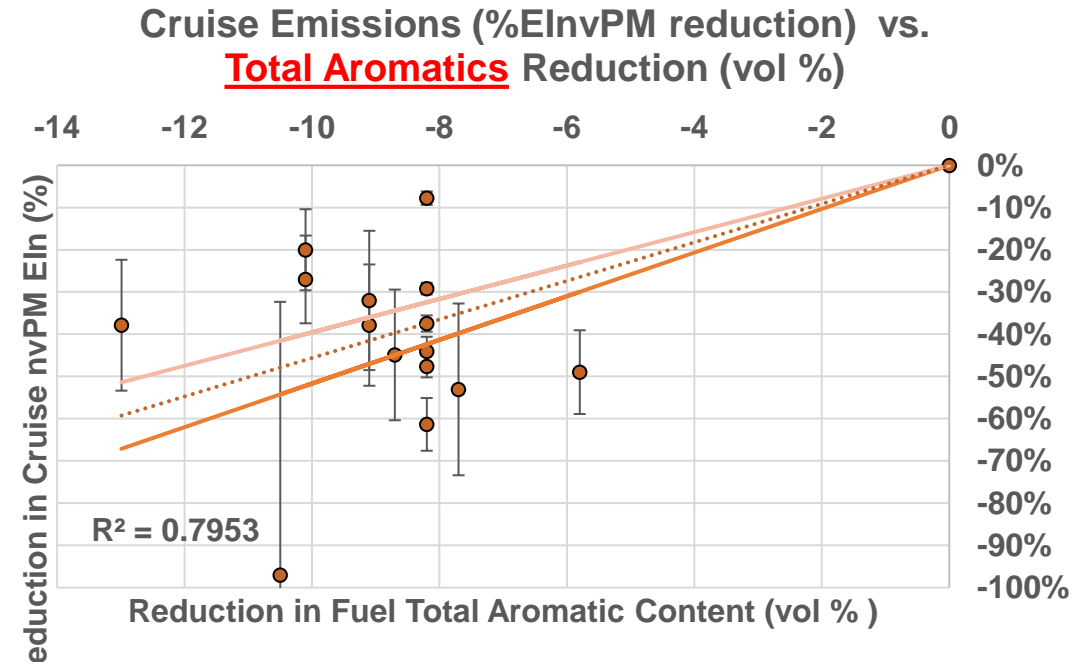


No measurements have yet been made to confirm this. Global models cannot yet capture this region

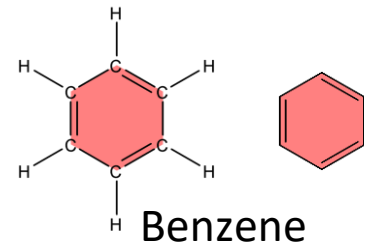
Limited measurements confirm this, limited modelling capture this qualitatively

## Total Fuel Aromatic & Mono-Aromatic Content

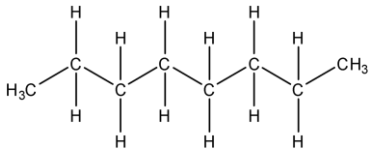
- nvPM emissions are likely to reduce with reduction in total aromatic content, mono-aromatic content and naphthalene content.
- High degree of experimental uncertainty and co-dependency on other parameters in addition to naphthalene content such as:
  - Engine hardware
  - Thrust setting
  - Sulphur content



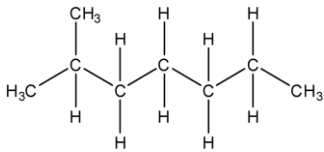
# Fuel Composition



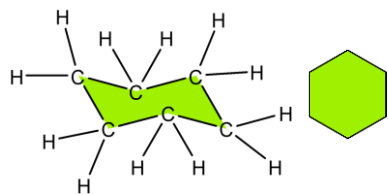
(not present in jet fuel)



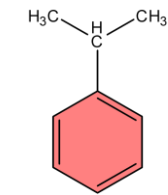
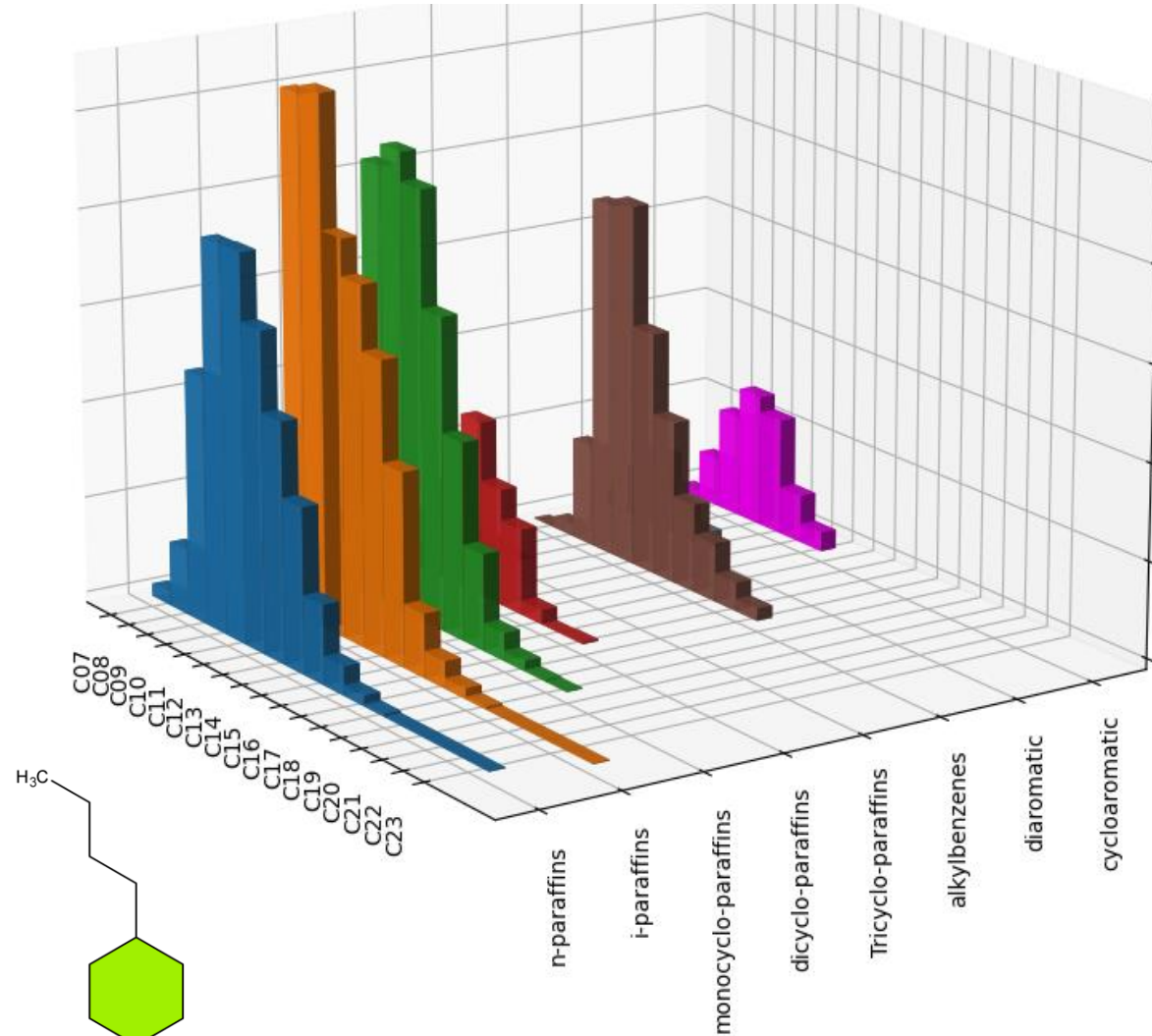
n-paraffin



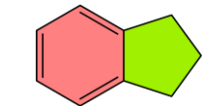
iso-paraffin



cyclo-paraffins

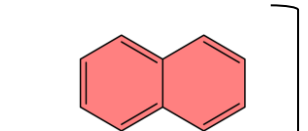


alkylbenzene

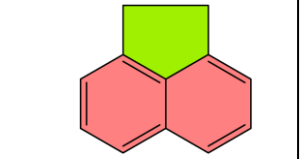
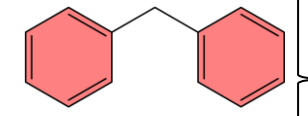


cyclo-aromatic

Mass %



di-aromatics (naphthalenes)



Aromatics