Aviation fuel composition changes to reduce non-CO_2 emissions: European refinery impacts & effects on fuel quality

Concawe Symposium

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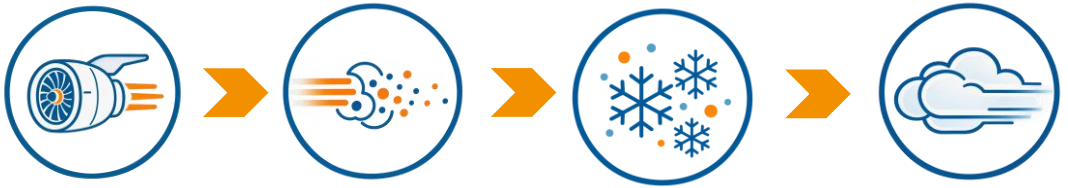
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Overview of non-CO_2 Emissions in aviation

Aircraft non-CO_2 exhaust emissions can result in contrail formation



Aircraft exhaust contains water vapour and particulates.



1 **ENGINE**

Hot exhaust leaves the engine.

2 **EXHAUST**

Exhaust particulates mix with very cold surrounding air.

3 **ICE CRYSTALS**

Water condenses and freezes around the particles.

4 **CONTRAIL CLOUD**

Ice crystals can persist and form cirrus clouds.

Condition: Cold, humid air at cruise altitude. In drier air, the trail disappears quickly.

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Contrails may have climate effects

Persistent contrails can form contrail cirrus clouds with varying degrees of radiative forcing
This can reflect sunlight out but also trap outgoing heat

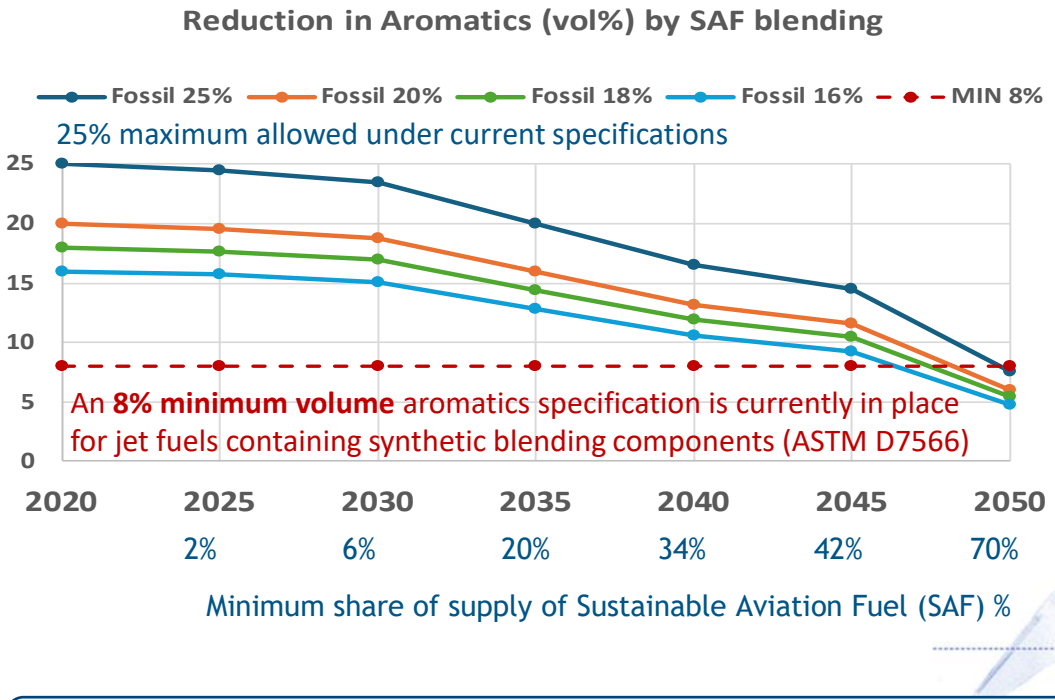




KEY TAKEAWAY: Contrails can affect the climate, however it is uncertain what is the global mean surface temperature effect of this.
Engine technology and fuel properties, such as reducing aromatics, napthalenes and sulphur, can help to reduce contrail formation and persistence.

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SAF* Blending reduces aromatic content





Beware of the 8% blend wall



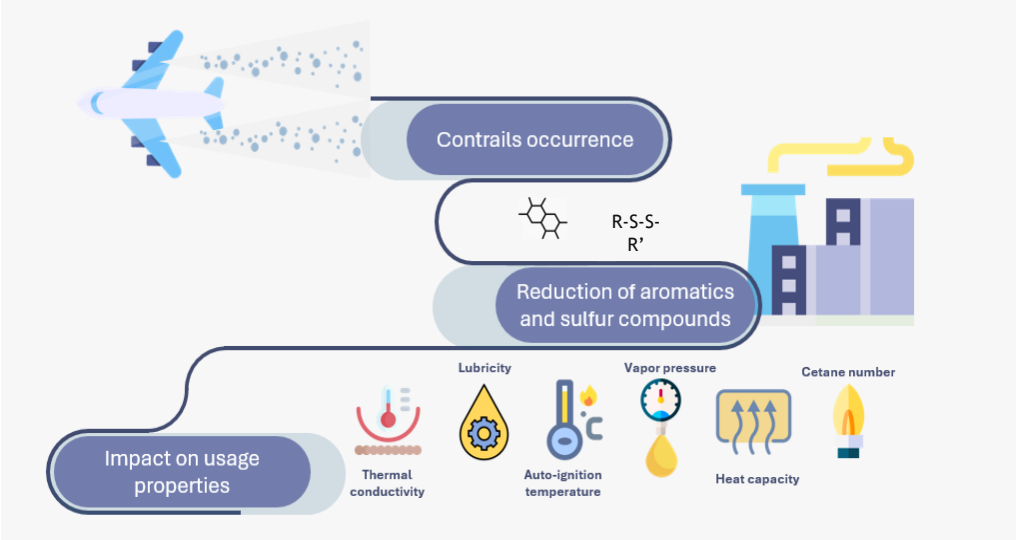
KEY TAKEAWAY: Aromatics in fossil jet are critical to maintain an aromatic blending window to allow safe SAF blending to the 8% aromatic minimum. **At least 16% is needed in the base fuel for a 50:50 SAF blend**

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** Based on use of paraffinic Synthetic Blending Components.*

Study on European refinery impacts & fuel quality

Considering various fuel compositional change scenarios to mitigate non-CO_2 emissions



Jet fuel contains aromatics consisting of mostly mono-aromatics, as well as some naphthalenes

Study consisted of 3 Parts:

1. A **jet fuel survey** was conducted to collect information on the configuration, unit capacity, blending recipes & current fuel quality to assess the extent to which EU refineries could be capable of meeting specification changes.

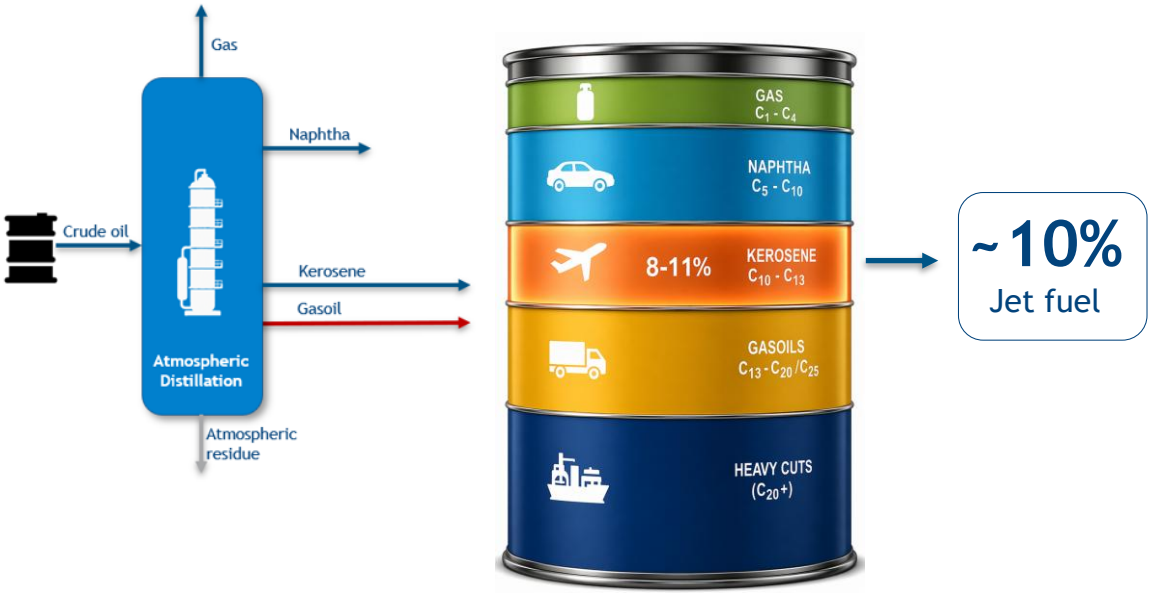
2. **Refinery techno-economic study** where all EU refineries were modelled as 1 aggregate system using Concawe refinery LP model. This was used to assess various Jet fuel specification scenarios and to quantify:
   - *Capital (CAPEX) and operating costs (OPEX);*
   - *Additional refining CO_2 emissions resulting from the change.*

3. Using **lab blends** of various levels of hydrotreated Jet fuel, critical **fuel properties** were measured to identify any safety or operational risks to consider for specification changes.

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Jet fuel production – simplified overview

Simplified Distillate Scheme



Atmospheric distillation produces most of the kerosene used for jet fuel, but refineries cannot blend it directly and use different configurations for jet fuel production.

Merox or "sweetening" units may be the only processing step in some refineries, converting mercaptans into disulphides while not affecting other properties such as total sulphur content, aromatics or naphthalenes.

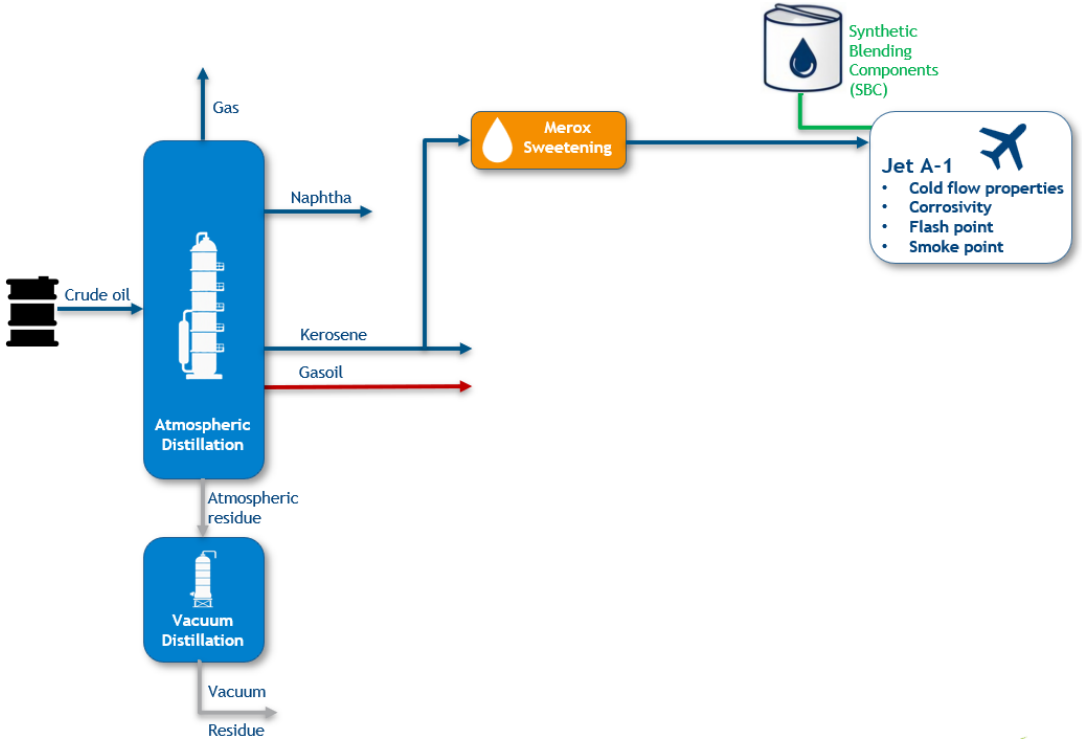
Hydrotreatment units (HT) may be present in some refineries with different designs and capacities, and depending on the design, they can reduce sulphur, naphthalenes, and to some extent aromatics.

Hydrocrackers (HCK) may be present in some refineries, where they convert heavier feedstocks into low-aromatic kerosene.

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Jet fuel production – simplified overview

1 – Jet production by Merox



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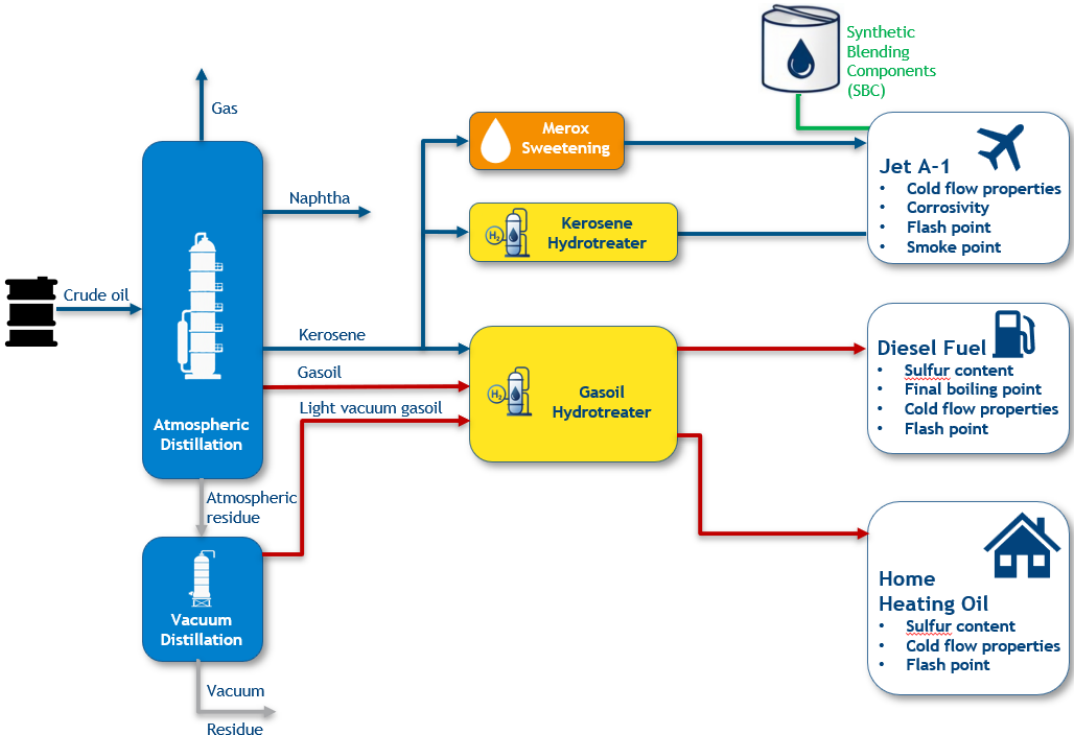
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Jet fuel production – simplified overview

2 – Jet production by Hydrotreating



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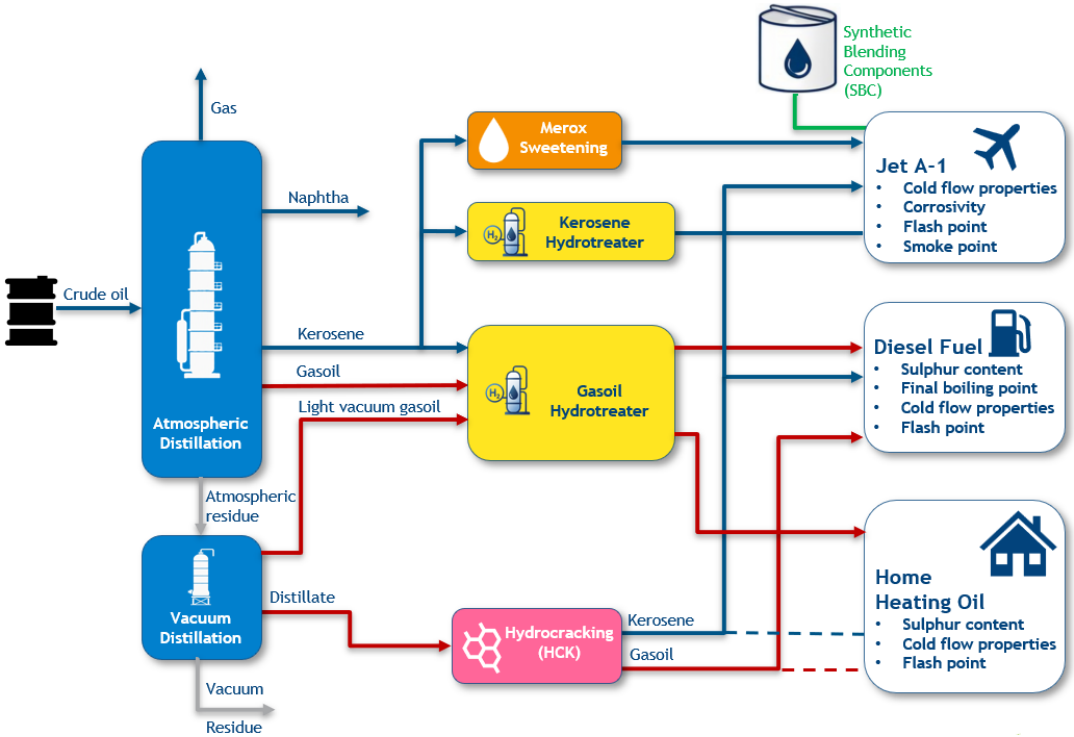
Hydrotreatment units (HT) may be present in some refineries with different designs and capacities, and depending on the design, they can reduce sulphur, naphthalenes, and to limited extent aromatics.

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Jet fuel production – simplified overview

3 – Jet production by Hydrocracking



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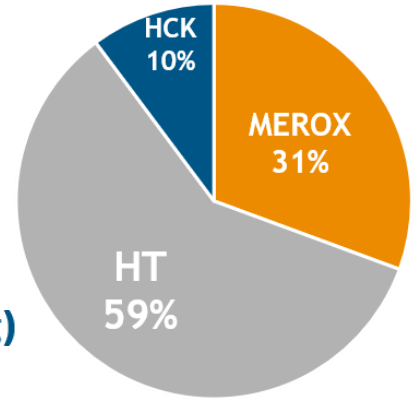
Part 1: Refinery Survey

INFORMATION COLLECTED FROM CONCAWE MEMBERS ABOUT THEIR REFINERIES IN EU27+3 COUNTRIES

- Main units used in jet fuel production and pressure level when relevant
- Blending recipe (vol% from: Merox, KHT, other HT, HCK, other conversion unit, other components)
- Average fuel qualities (Aromatics, Naphthalenes, Sulphur) in 2024

MAIN CONTRIBUTING UNIT FOR JET BLENDING ACROSS REFINERIES

1. Merox
2. HT (Hydrotreating)
3. HCK (Hydrocracking)



=> DATA RECEIVED FROM 49 REFINERIES

Majority rely on Hydrotreating (HT)
59% of refineries surveyed use HT as their main contributing unit to jet blending

One third mainly rely on Merox
31% of refineries would not be able to achieve any reduction in Sulphur, Aromatics and Naphthalene's without major investments or major de-optimisation as they rely mainly or only on Merox units

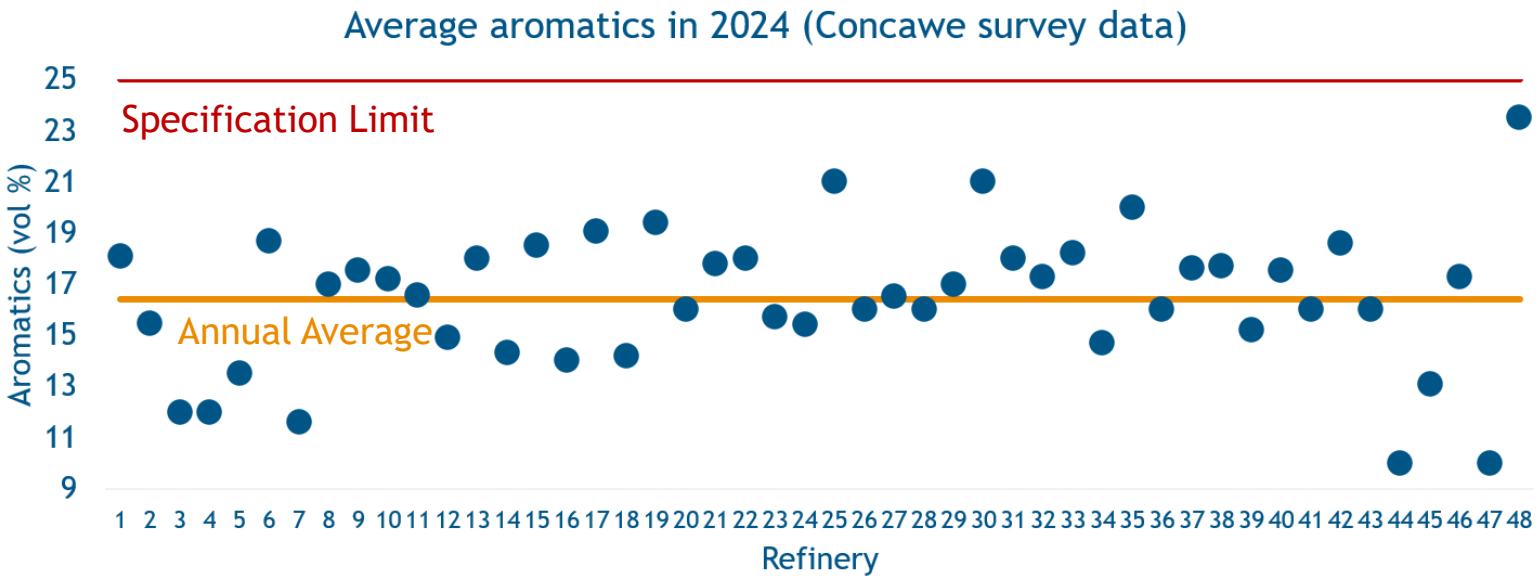
Hydrocracking plays a smaller role
Only 10% of refineries rely mainly on HCK units.

Since the potential to improve jet fuel quality depends on refinery process technology, importers may encounter the same obstacles if equipped only with Merox units. This puts security of supply at risk as there is no guarantee that imports could offset a decrease in EU production

A decision to invest in new hydrotreaters is questionable in the context of Refuel EU Aviation & fossil demand decline – Reduction of Jet fuel production may be the alternative

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Part 1: Refinery Survey – Average aromatics



KEY TAKEAWAY The Annual Average will always be below the Specification Limit. This gap is necessary to allow refineries the flexibility to maximise jet fuel yield. Lowering the specification limit will likely lower the yield.

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Part 2 – EU refining study

Scope: Techno-Economic Assessment (TEA) of the reduction of sulphur, aromatics and naphthalenes in the production of fossil jet fuels in the EU27+3* refining system

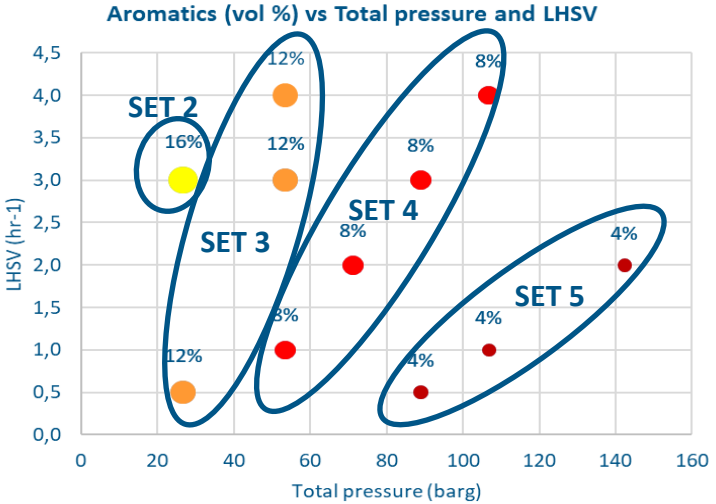
- ***Concawe Linear Programming (LP) model*** *used to assess the impact in a current single refinery configuration, in which the capacities of all EU27+3 refineries have been included.*

  »*Amalgamating all units of the EU refining system in one single refinery results in an "ideal" case which cannot be representative of the sum of the real costs which will have to borne by individual refineries and significantly understate the difficulty the industry would face in meeting specification changes.*

Main cases' definition (Specification Scenarios)

Case	Aromatics	Naphthalenes	Sulphur
ASTM D1655	ARO ≤ 25 vol%	NAP ≤ 3.0 vol%	S ≤ 3000 ppm wt
Set 1	ARO ≤ 20 vol%	NAP ≤ 0.5 vol%	S ≤ 1000 ppm wt
Set 2	ARO ≤ 16 vol%	NAP ≤ 0.4 vol%	S ≤ 1000 ppm wt
Set 3	ARO ≤ 12 vol%	NAP ≤ 0.3 vol%	S ≤ 1000 ppm wt
Set 4	ARO ≤ 8 vol%	NAP ≤ 0.2 vol%	S ≤ 500 ppm wt
Set 5	ARO ≤ 4 vol%*	NAP ≤ 0.1 vol%	S ≤ 100 ppm wt

*This level of aromatics does not meet the 8% minimum vol specification to be met in line with ASTM D-7566 and it should be considered purely theoretical



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Main Results of “What if” scenarios

IMPORTANT DISCLAIMER: The model used for this calculation represents all EU refineries as if they were joined together as a single refinery. This simplification is useful to assess impacts on the whole system and estimate an “optimistic order of magnitude” for their economic effects but it does not represent the sum of economical impact of each individual refinery in reality.

Set 1 & 2
Kerosene streams reallocation

- Specifications are achievable by existing HT and HCK units but Merox units’ jet production is out of specification and minimised*
- **MAIN ASSUMPTION: What if production could be fully reallocated to refineries with HT and HCK units?**
  - **OPEX: +0,5 – 0,9 billions EUR/y (excluding logistics and CO_2 cost)**
  - **Extra CO_2 refinery emissions: +1,3 – 2,1 Mt/y (26-45 kg CO_2/ T jet)**

* In reality those refineries with only merox should consider whether to invest into a new HT unit as stream reallocation between separate sites has limited feasibility

Set 3 & 4 & 5
Investments in high pressure KHT

- No refinery can achieve the new set of specifications
- **MAIN ASSUMPTION: What if all jet production would come from investing in new high-pressure kero hydrotreaters?**
  - **CAPEX for new units: +5,0 – 11,8 billions EUR (excluding additional H2 production plant)**
  - **OPEX: +0,6 – 0,9 billions EUR/y (excluding logistics and CO_2 cost)**
  - **Extra CO_2 refinery emissions: +1,4 – 4,5 Mt/y (30-93 kg CO_2 / T jet)**

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Part 3 – Effect of hydrotreating on fuel quality

INCREASED HYDROTREATING :
➜ REDUCED AROMATICS, NAPHTHALENES & SULPHUR
➜ ALSO CHANGES MANY OTHER FUEL PROPERTIES

Some key properties measured in the Concawe study:



Lubricity
Wear protection



Auto-ignition temperature
Unintended ignition sensitivity may change



Permittivity
Electrical behaviour



Surface tension
Droplet and surface behaviour



Cetane number
Ignition quality



Heat capacity
Ability to absorb heat



Vapour pressure
Tendency to evaporate



Thermal conductivity
Rate of heat transfer through fuel

TAKEAWAY: Hydrotreating reduces lubricity to low levels and changes many other fuel properties – Requires careful further study

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Key Messages

- **Reducing the aromatics content, naphthalenes and sulphur of Jet fuel is not easily done and would come at higher fuel cost and increased CO_2 emissions of production**
- **Over 30% of European refineries will not be able to achieve any reductions in properties specifications without significant capital investment. These investments may not be forthcoming and may result in refinery closures.**
- No refineries in Europe can reduce aromatics content much below 16% vol without **significant capital investment** and this may accelerate refinery closure and increasing the risk of supply (importers face the same challenges so there might not be import to compensate loss of EU production).
- To comply with the ASTM D-7566 specification requiring a minimum of 8% vol. aromatics, conventional **jet fuel must maintain an aromatic content greater than 16% vol** to allow the permitted max 50% SAF blending
- Some key aviation fuel properties vary significantly with hydroprocessing, affecting aircraft safety and operability. **Extensive further study would be required.**

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Environmental Science for European Fuel Manufacturing

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Thank you for your attention

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