

Used cooking oil: one feedstock, different technologies A comparative study

Preliminary results

Presentation to

**FUELS OF THE
FUTURE**



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Study commissioned by EWABA and MVaK



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Authors: Carlo Hamelinck, Matti Defiliet,
Bas Smeets, Eric van den Heuvel

Which UCO pathway delivers the highest environmental benefits?

- Used cooking oil, UCO can be used to produce several types of renewable and sustainable fuel, via different pathways
- The four fuel types that are currently often considered are:

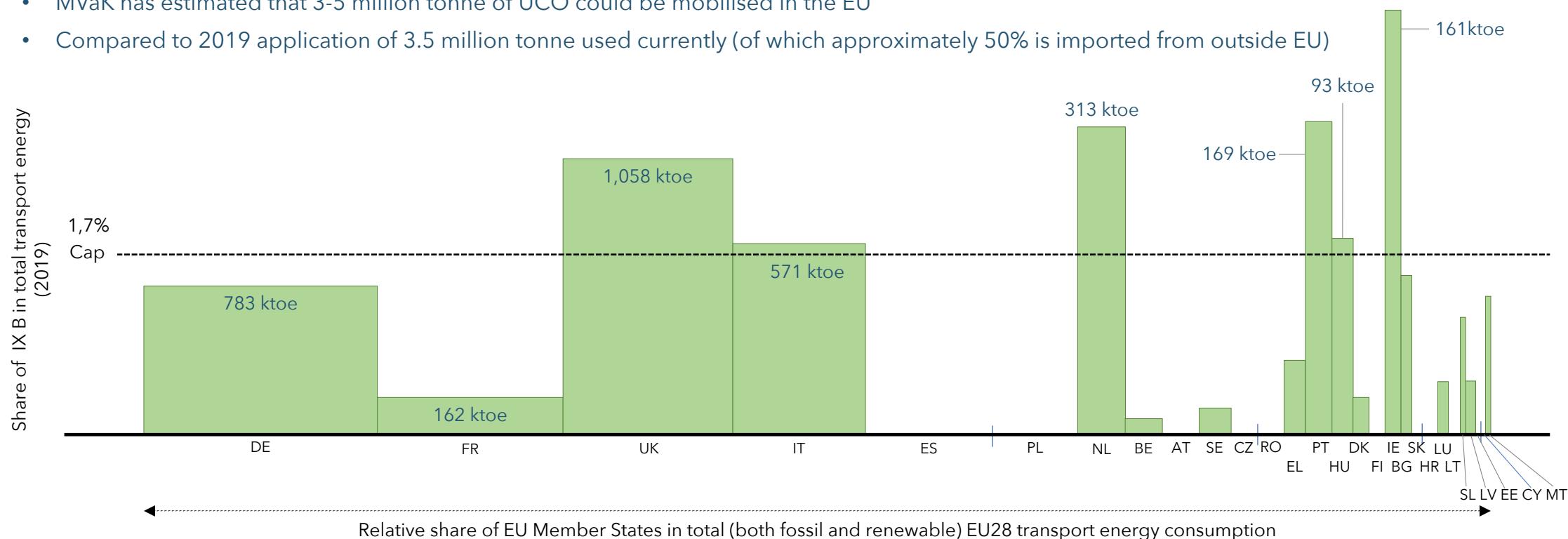
<p>UCOME "Biodiesel"</p> <p>Through a relative simple process, vegetable oils are converted into biodiesel which can be used in blends with diesel or pure as B100 in road transport</p>	<p>UCO-HVO "Renewable diesel"</p> <p>Through a complex process, vegetable oils are converted into drop-in type diesel which can be used up to high fractions in road transport</p>	<p>Co-processed UCO "Co-processed renewable diesel"</p> <p>Vegetable oils can be co-processed in existing oil refineries up to a fraction of about 5-10% simultaneous with the otherwise fossil feedstock</p>	<p>UCO-HEFA "Sustainable Aviation Fuel"</p> <p>Via a complex process, vegetable oils are converted to sustainable aviation fuel that can be used in 50% blends with fossil jet fuel</p>
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- Each of these fuels falls in the Annex IX B category of the Renewable Energy Directive (RED II)
- The contribution of Annex IX B fuels to the RED II target of renewable energy in transport is limited to 1.7%
- This is actually a soft cap and Member States can implement higher national caps or targets
- Waste streams like UCO are eventually limited in available volumes
- So: how can UCO best be deployed?

Market context

Use of Annex IX-B in EU28 Member States in 2019

- Member States can only *report* up to 1.7% of these fuels in the frame of the RED transport target
 - Member States can set higher targets for these fuels to obligated parties within their own markets
 - Contribution of Annex IX B fuels is above 1.7% in some Member States, and below in other
 - Overall, there is still room to increase the deployment of Annex IX B biofuels, until 1.7% is reached on an EU level
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- UCO collection rates in the EU are increasing
 - MVaK has estimated that 3-5 million tonne of UCO could be mobilised in the EU
 - Compared to 2019 application of 3.5 million tonne used currently (of which approximately 50% is imported from outside EU)



Results

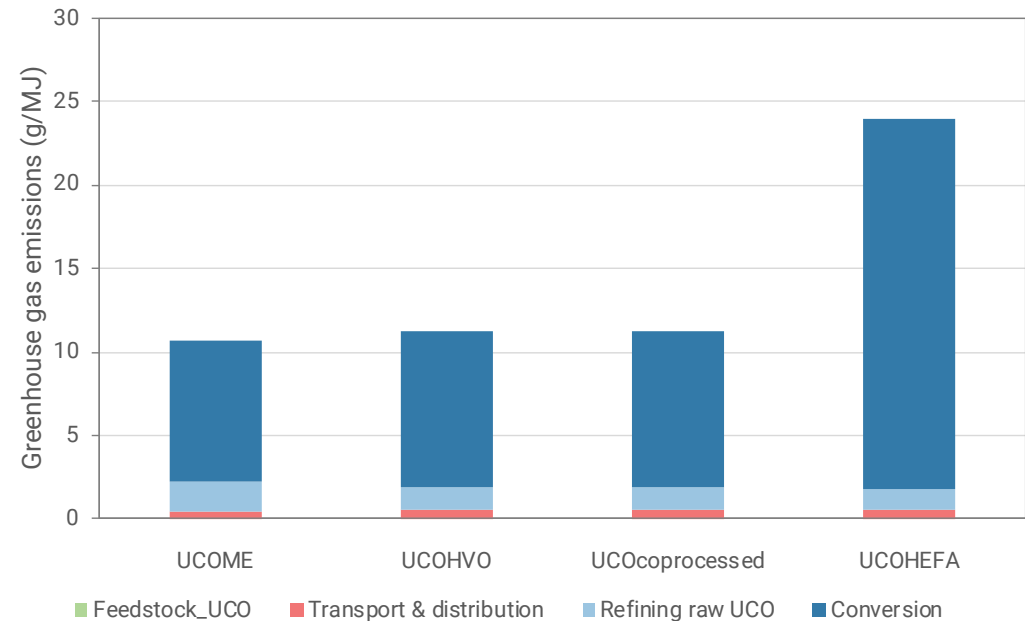
Carbon footprint

Main results

- All pathways achieve good savings compared to fossil fuels
- UCOME and HVO and co-processing achieve about 11-12 g/MJ
- This implies about 90% greenhouse gas savings
- In line with the typical value reported in the Renewable Energy Directive and other literature
- HEFA has a higher greenhouse gas impact, of about 24 g/MJ, which still means about 70% emission reduction
- In literature, ranges are found from about 14 - 28 g/MJ

Details

- Conversion step always contributes most to the carbon footprint
- In HEFA the hydrogen and steam use increase the footprint
- Co-products carry part of the carbon emissions
- The conversion efficiency does not play a role, because feedstock emissions are assumed to be zero
- Sourcing feedstock over longer distances would incur transport emissions which would be most visible in less efficient pathways



Results

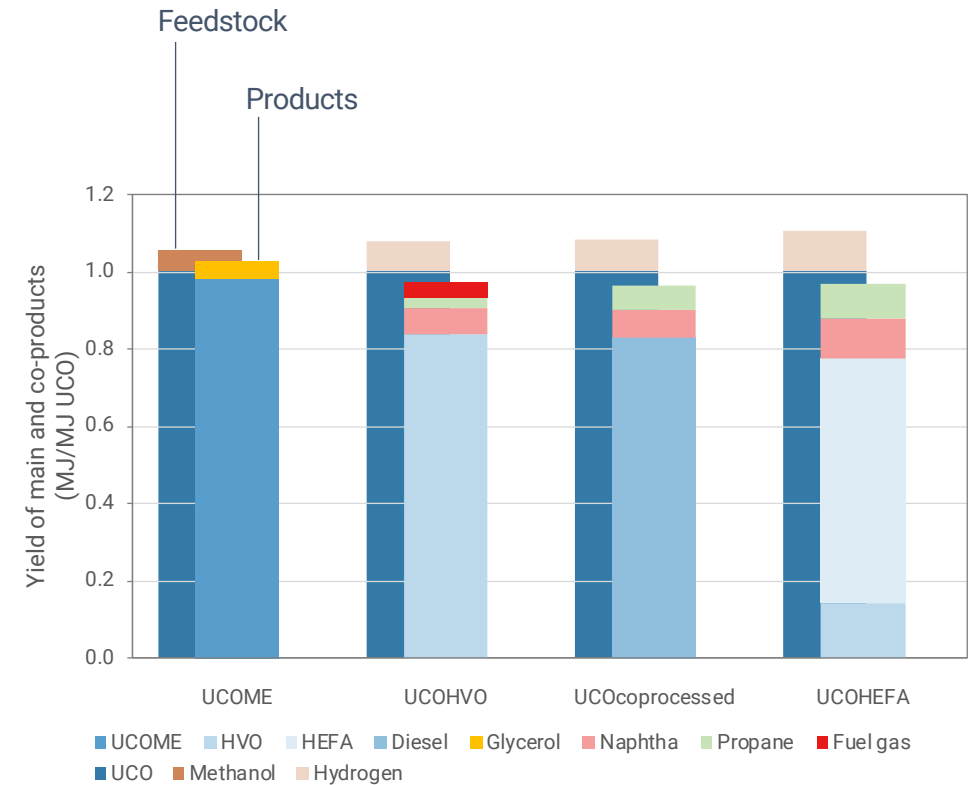
Feedstock conversion efficiency

Comparison on energy basis

- Conversion efficiency to main fuel is highest via UCOME pathway
- Cracking of the fatty acid chains produces more co-products: naphtha, propane and fuel gas
- Overall conversion efficiency from UCO to sum of products, is comparable for all pathways
- When including the input of methanol or hydrogen the HEFA pathway has lowest overall conversion efficiency
- Compared to HVO, some additional hydrogen is required for isomerisation in case of HEFA

Co-products cost energy

- Fuel gas and propane are not always co-produced
- Often used for internal energy supply
- When co-produced, this energy needs to be sourced externally

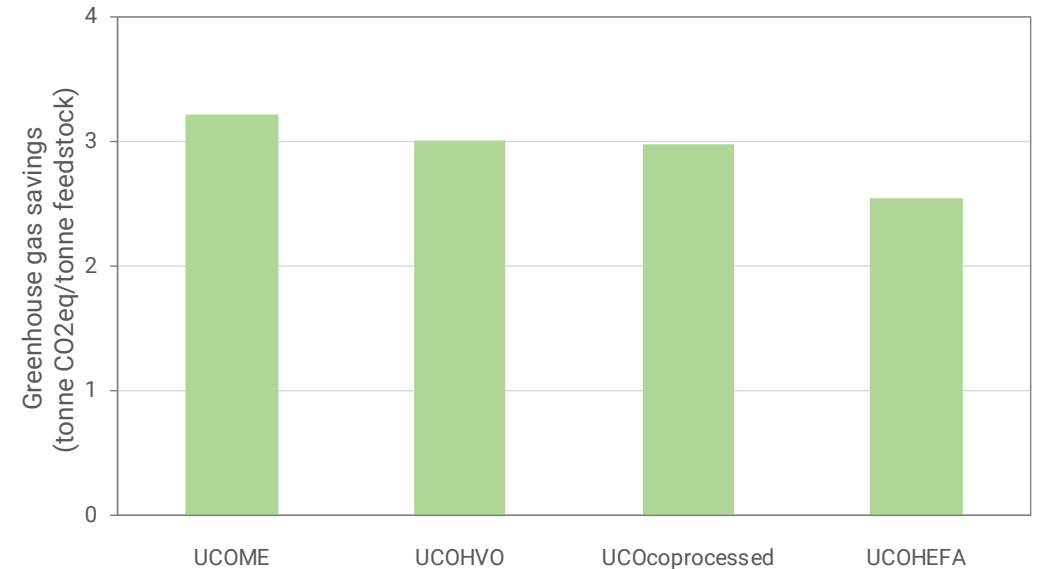


Results

Carbon efficiency

Main results

- Savings achieved by fuels, combined with fuel yield per feedstock (all products considered)
- UCOME has best overall carbon savings per tonne of feedstock
- Lower yields of the main product in the other pathways lead to lower carbon efficiencies
- This means that if UCO is a limited feedstock, it is best used to replace fossil fuels via the UCOME pathway
- Results for HVO and coprocessing are also good
- HEFA achieves least carbon savings per tonne of UCO feedstock
- HEFA and HVO results represent maximal co-products
- If naphtha and propane are used for process energy, then savings per amount of product improve, but similar net result



Results

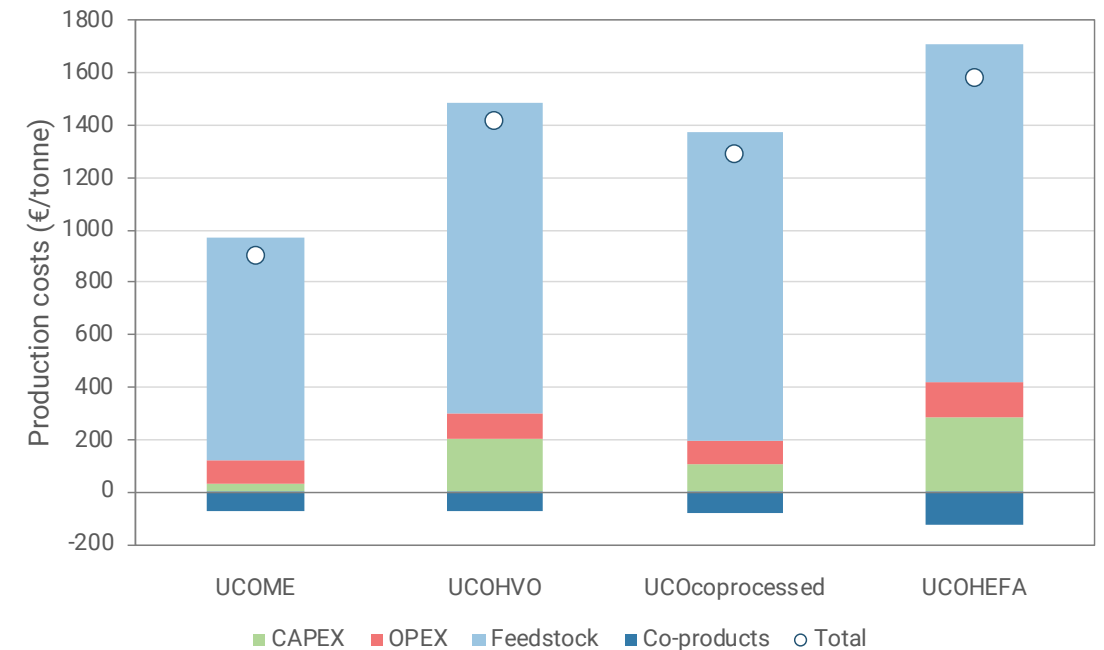
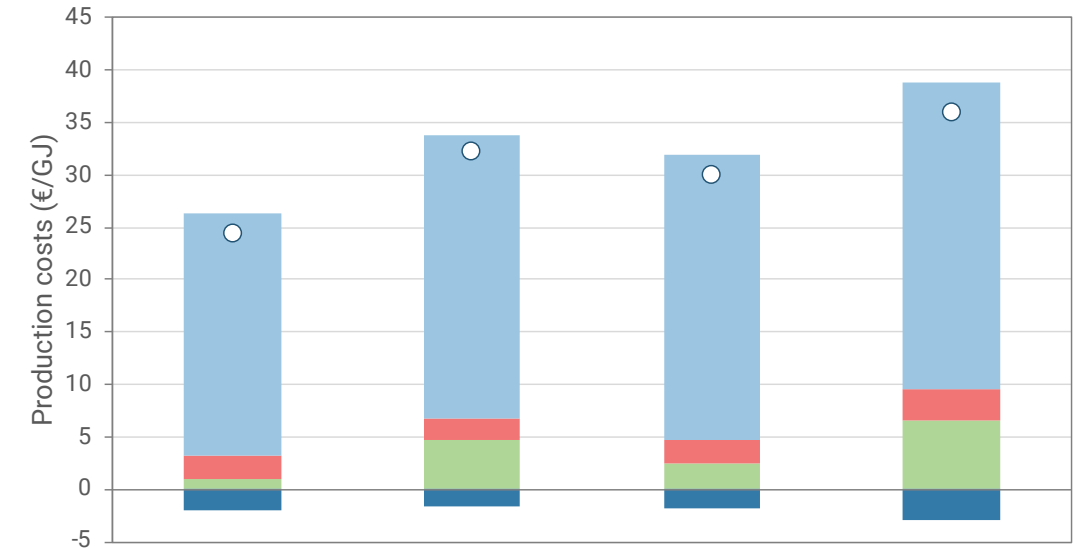
Production costs

Main results

- UCOME has the lowest production costs and UCO HEFA the highest
 - UCOME is the most attractive because
 - (1) High feedstock efficiency towards final product
 - (2) Simple tech with low investment costs
 - Costs of HVO appear slightly higher than via coprocessing
 - Still, co-processing is less attractive: it requires 90% fossil operation
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- Feedstock costs are the most dominant factor in all four pathways
 - Therefore, conversion efficiency has major impact on differentiation between the pathways

Important when considering literature

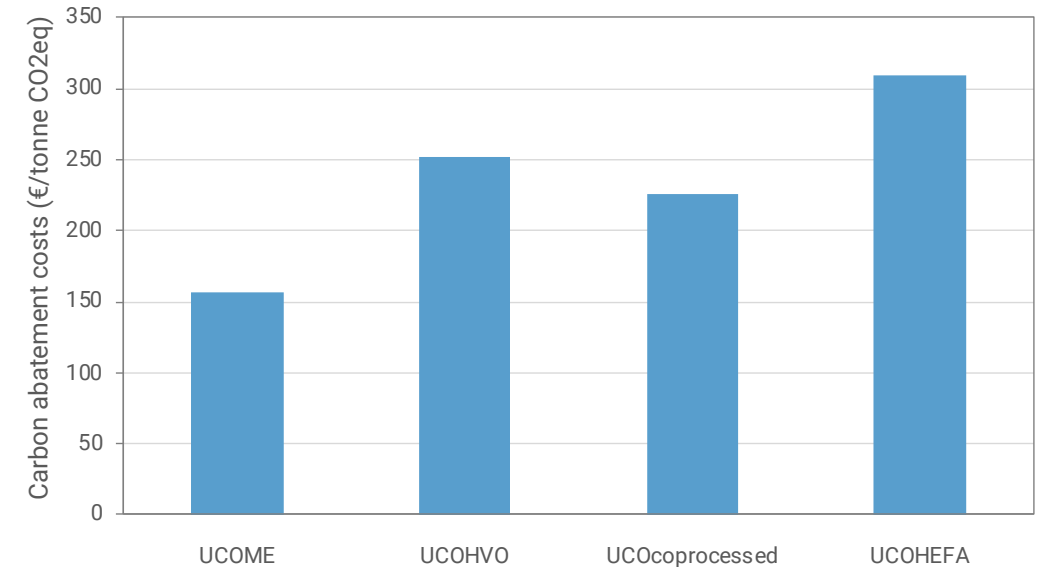
- Literature reports broad range of production costs for UCOME
 - UCOME : 17 - 29 €/GJ, as research took place over long time
- Narrower ranges for new fuels, based on less feedstock variations
- Every year will see different production costs
- Relative position to each other and to replaced fossil is important



Results

Carbon abatement costs

- Combination of marginal fuel costs with carbon savings gives abatement costs
- UCOME has lowest carbon abatement costs of the four pathways
- Absolute results are sensitive to reference fuel prices!
- 0.20 €/l cheaper fossil diesel increases abatement costs with 70 €/tonne
- Results should be regarded in relative sense
- UCO HEFA has highest abatement costs, despite replacing a pricier fossil fuel



Results

Air quality

Literature does not allow for full & just comparison

- Limited literature about HEFA, none about coprocessed
- Most literature focuses on air quality from renewable fuels compared to fossil fuels
- Barely literature that allows for comparison between renewable fuels
- Older literature relates to older engines, not representative
- Impossible to compare gains in road transport to gains in aviation

Main findings

- Air quality mostly determined by type of engine and combustion characteristics
- Difference found in air quality impact between fuel types in older engines
- In modern engines this difference becomes negligible, both in passenger cars and heavy duty vehicles
- Euro engine standards have decreased air pollution emissions considerably over the past 30 years, both for passenger vehicles and heavy duty vehicles
- For instance, Euro VI engines (heavy duty) have 60x less PM emissions and 20x less NOx emissions than Euro I engines

Air pollutant emissions by fuel from modern and older cars

Fuel	Modern cars			NO	PM	VOCs
	NO	PM	VOCs			
Diesel						
FAME Biodiesel						
HVO						

Air pollutant emissions by fuel from modern and older heavy-duty vehicles

Fuel	Modern heavy-duty			NO	PM	VOCs
	NO	PM	VOCs			
Diesel						
FAME Biodiesel						
HVO						

Older = Euro 3 or equivalent (e.g. model year 2000 in Europe)
Modern = Vehicles that meet Euro 6 emissions standards or equivalent.

Sources:
* IEA-AMF, 2017. Air Quality Implications of Transport Biofuel Consumption.
* Emission standards: <https://dieselnet.com/standards/eu/hd.php>

Summary findings per indicator

Carbon footprint

- Both UCOME and HVO have low GHG impact per MJ
- HEFA production has highest GHG impact per MJ
- Material efficiency does not impact footprint as UCO starts at zero
- UCOME allows for highest savings per tonne of feedstock

Production costs

- UCOME has lowest production costs while HEFA has highest
- Feedstock costs represent largest share of costs in each pathway
- Therefore, feedstock conversion efficiency is determining factor
- UCOME combines high feedstock efficiency with low capital costs

Carbon abatement costs

- Carbon abatement costs of UCOME are significantly lower than of other pathways

Air quality

- This study found no significant differences between pathways in air quality performance
- Engine and operation determine emissions more than fuel does
- Literature claims that some fuels perform better than others could not be substantiated

Regional added value

- Most employment occurs in UCO collection – same for all pathways
- UCOME offers slightly more employment per product output
- HVO, HEFA and co-processing often concentrated in port cities
- Difference in regional added value between fuel pathways small

Summary

- Application of UCOME plays a major role in decreasing the greenhouse gas emissions of existing car fleet
- In view of the urgency of climate action, renewable fuels should focus on minimising greenhouse gas impact
- We find that UCOME has highest carbon efficiency of all UCO pathways, and HEFA the lowest
- When the deployment of UCO is limited, and carbon emission reduction is main goal, then UCO is best deployed as UCOME in road transport
- Once the passenger car segment will become dominated by electric vehicles, then UCO might best be deployed as UCOME in heavy road transport and shipping, from a climate mitigation perspective
- UCOME contribution can be increased by introducing higher blends (B10, B20 or B30) or pure (B100)
- UCO can also be used to produce other fuels
- Such fuels are not additional, but compete with UCOME
- A focus on HVO and HEFA will reduce the contribution of UCO to carbon abatement, and increase the costs
- Also, it would cause a loss of capital invested in current UCOME conversion capacity

More information

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gear
up



Carlo Hamelinck

carlo.hamelinck@studiogearup.com

Cruquiusweg 111-A

Amsterdam the Netherlands

+31 6 3968 9395

www.studiogearup.com