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Hydrogenated vegetable oil (HVO)

LAB SCALE BENCH SCALE PILOT PLANT DEMONSTRATION **PRODUCTION**

INTRODUCTION

Hydrogenated vegetable oil (HVO) is a renewable diesel which can be produced from various vegetable oils and fats which contain triglycerides and fatty acids. The term HVO is used for renewable diesel fuels derived from hydrogenation and hydrocracking of different feedstocks such as tall oil, rapeseed oil, waste cooking oil, and animal fats. HVO is also referred to as Hydro-processed Esters and Fatty Acids (HEFA). Overall, it has similar chemical properties as fossil diesel. Some differences are that it has a lower density and energy content than fossil diesel. HVO is free from sulphur, oxygen and aromatic hydrocarbons, and has a high cetane number. It is today the second largest renewable diesel alternative world-wide and is blended in fossil diesel being sold as mixtures at fuel filling stations.

APPLICATIONS

HVO has a quite similar chemical composition to fossil diesel fuel and can be used as a renewable fuel in existing diesel engine vehicles (pure or blended). HVO is considered a high-quality diesel substitute and is therefore often referred to as renewable diesel. HVO is a paraffinic diesel fuel and specified in the standard EN 15940:2016, which covers hydrotreated HVO and Fischer-Tropsch GTL products containing up to 7,0 % (V/V) of fatty acid methyl ester (FAME). Diesel fuel standards, such as EN 590 and ASTM D 975, are met with high blending ratios of HVO. Biodiesel (FAME) standards are not applicable for HVO. HVO is today blended with fossil diesel and sold at fuel filling stations.
HVO has also been approved to be used as an aviation (bio jet) fuel, based on ASTM D7566-14. In 2011, an updated version of the standard was published, allowing up to 50% biobased components (HVO) to be added to conventional jet fuel. HVO is therefore an important alternative in the implementation of renewable aviation fuels.

PRODUCTION PROCESS

HVO is produced by hydrogenation and hydrocracking of vegetable oils and animal fats using hydrogen and catalysts at high temperatures and pressures. In this hydrotreating process, oxygen is removed from the feedstocks consisting of triglycerides and/or fatty acids. The resulting products consist of straight-chained hydrocarbons (paraffins) with varying properties and molecular size depending on the feedstock characteristics and the process conditions. The conversion usually takes place in two stages: hydrotreatment followed by hydrocracking/isomerization. The hydrotreatment typically takes place between 300 – 390°C. For treatment of triglycerides, propane is a typical by-product.

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Hydrotreatment reaction for fatty acids
$RCOOH + 2H_2 \rightarrow R\text{-}H + 2H_2O$
Hydrotreatment reaction for triglycerides (typically vegetable oils)
$C_3H_5(RCOO)_3 + 12H_2 \rightarrow C_3H_8 + 3RCH_3 + 6H_2O$

Firstly, hydrogen is added to double bonds in the renewable feedstock. Thereafter, more hydrogen is added to remove propane by cleaving the triglycerides to fatty acids. Lastly, the fatty acids are converted to hydrocarbons by hydrodeoxygenation (removing oxygen as water) and/or decarboxylation (removing oxygen as carbon dioxide). Thereafter, the hydrocarbons are converted to a quality that meets the end-user criteria, for example conventional petroleum fuel criteria by isomerization and cracking treatment.
The production of HVO is well-developed at industrial scale. The investment cost for HVO facilities are generally higher than for biodiesel production plants (FAME production from vegetable oils). The hydrogen used in the HVO production today mainly comes from fossil sources.
HVO can be produced from any kind of vegetable oil and fats consisting of triglycerides and fatty acids. Some examples of feedstocks are rapeseed oil, sunflower oil, soybean oil, corn oil, palm oil, waste cooking oil, tall oil, and animal fats. Thereby, the process is flexible to convert a wide range of low-quality waste and residue materials to hydrocarbon based drop-in fuels. All HVO must fulfil the sustainability criteria stated by the EU Renewable Energy Directive (RED). The vegetable oils used (i.e. triglycerides) are also used as feedstocks for producing FAME (fatty acid methyl esters) biodiesel.
Compared to FAME, combustion of HVO in engines generally gives lower NO_x emissions and reduced issues of poor cold properties (e.g. flow properties), storage instability and aging of the fuel. HVO is a renewable paraffin with similar combustion properties as other renewable paraffins such as Fischer-Tropsch liquids, which are produced via biomass gasification and chemical synthesis.
HVO can be produced in dedicated facilities which produce 100% HVO, or it can be co-processed with fossil oil in refineries. In co-processing, biobased feeds of typically 5-10 % are blended with fossil feeds. Higher blends of biobased material are also used, for example by Preem in Sweden. In co-processing, the biobased components are fractionated in different refinery lines and end up as multiple products. The HVO process can also be modified to produce renewable kerosene, for example for the jet fuel applications.

STATE OF THE ART

The first HVO refinery in Europe was invested by Neste in 2007. In 2011, tall oil-based HVO was introduced in Sweden. Today HVO is the third most common biofuel in the world after ethanol and FAME. In Europe, several refineries have been re-constructed to treat HVO instead of fossil feedstocks. ENI has converted their refinery in Venice, Italy to annually produce 0.4 billion litres. Today's largest feedstock globally for producing HVO is palm oil. The global production of HVO in 2019 reached around 14.2 billion litres. The HVO output in the EU reached 2.8 billion litres in 2018 and is expected to reach 4.5 billion litres in 2020. In EU, HVO plants are under construction in Sweden (St1) and France (Total), to annually produce 0.3 and 0.7 billion litres respectively. Further HVO plants are planned in Finland (UPM) and Italy (ENI) to annually produce 0.7 and 0.8 billion litres of HVO respectively.

HVO can also be upgraded to sustainable aviation fuel (SAF). AltAir Fuels supplies HVO-based SAF and produces around 13 million litres per year. Many initiatives are taken world-wide for producing SAF in the near future.

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MAJOR STAKEHOLDERS:

- Neste
- Total S.A.
- AltAir Fuels
- Eni
- Renewable Energy Group
- Preem
- SkyNRG
- St1
- Statoil
- ConocoPhillips
- Petrobas

INFO BOX:

Molecular formula: $C_nH_{2(n+2)}$
Comparison of Fuel properties:

	HVO	Diesel
Density at 20 C [kg/l]	0.78[a]	0.83[i]
Lower heating value [MJ/kg]	44.4[a]	43.1[i]
Cetane number	>80[a]	50[i]
Fuel equivalence	0.97[i]	1[i]
GHG [gCO2eq/MJ]	11.5[b], 50[c]	88.7*

Median values are used for simplification. Please refer to the standard for ranges.

[a]Aatola Hannu, Larmi Martti, Sarjovaara Teemu, Mikkonen Seppo: Hydrotreated Vegetable Oil (HVO) as a Renewable Diesel Fuel: Trade-off between NOx, Particulate Emission, and Fuel Consumption of a Heavy Duty Engine.
[b]waste cooking oil HVO: https://www.iscc-system.org/wp-content/uploads/2017/05/2.-Henke_ISCC_Technical_Committee_061216.pdf
[c]palm oil-based HVO
https://dspace.library.uu.nl/bitstream/handle/1874/371109/Behrends2018.pdf?sequence=1&isAllowed=y
[i]FNR 2012.
*https://publications.jrc.ec.europa.eu/repository/bitstream/JRC76057/reqno_jrc76057_default_values_report__online_version1.pdf

Utilization: Substitute diesel; transportation fuel; power generation fuel;
Relevant fuel regulations: EN15940, CEN TS 15940, EN590, ASTM D975, World-wide Fuel Charter (Category 4)
Main feedstocks: Oil seeds, used cooking oil, waste animal fat
Scale of production: Industrial scale

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FURTHER INFORMATION

- https://www.eafo.eu/alternative-fuels/advanced-biofuels/hvo
- http://www.etipbioenergy.eu/value-chains/conversion-technologies/conventional-technologies/hydrotreatment-to-hvo
- https://f3centre.se/en/fact-sheets/hefa-hvo-hydroprocessed-esters-and-fatty-acids/
- http://news.bio-based.eu/mineral-oil-groups-ramp-up-hvo-production-in-the-eu/
- https://biofit.bioenergy2020.eu/projects/displaymap/9QTOQqmK