How hydrogen plays a role in refining

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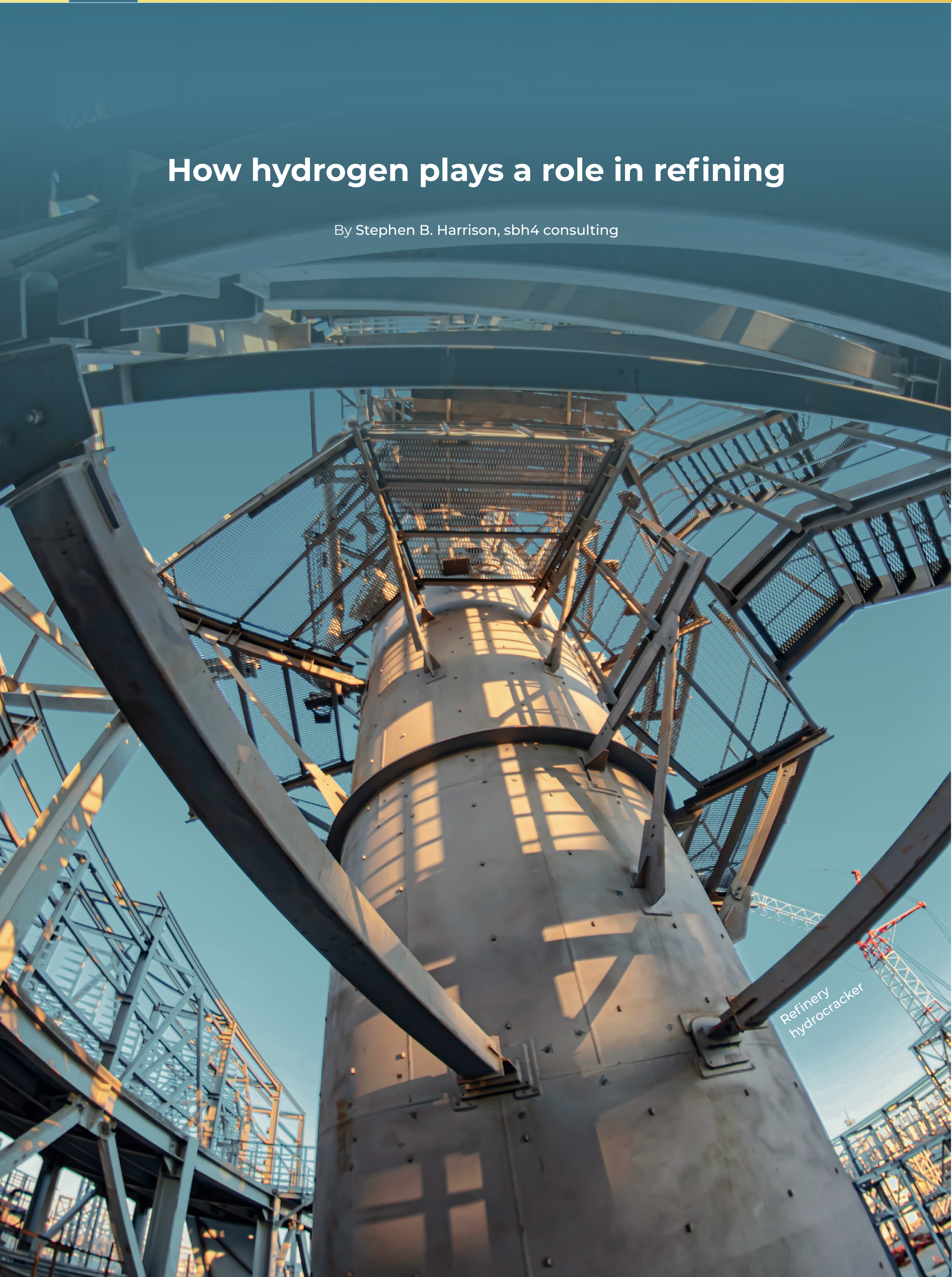


Refinery hydrocracker

As EU member states look to transpose green hydrogen consumption targets for mobility under the Renewable Energy Directive (RED) III, most nations are looking toward the so-called "refinery route" to meet quotas.

RED III requires renewable fuels of non-biological origin (RFNBO) – including green hydrogen – to make up 1% of all transport fuels by 2030. Most recently, the German cabinet approved plans to establish legally binding quotas under RED III, while allowing fossil fuels produced with green hydrogen to count.

From 2026, RFNBOs will need to make up 0.1% of transport energy, growing to 1.2% in 2030, and 8% by 2040 – setting Germany slightly ahead of the EU-wide RED III 1% target.

"For the first time, there is an obligation for mineral oil companies to use green hydrogen produced from wind and solar power," said Environment Minister Carsten Schneider. "This creates a secure demand that will drive the expansion of the new hydrogen infrastructure."

While the refinery route faces criticism over concerns about fossil infrastructure lock-in, industry players say it is easier to implement, due to its avoidance of barriers associated with pure hydrogen mobility, like a fragmented refuelling infrastructure map and high-cost burdens.

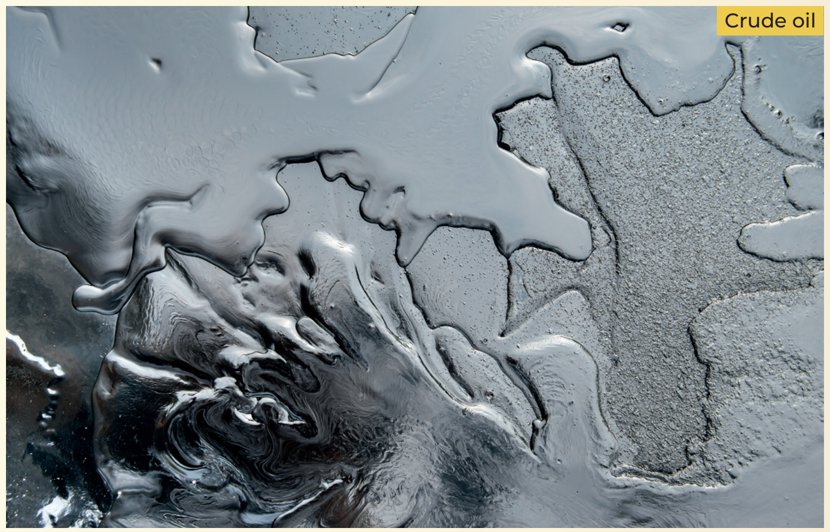
Sulphur production

Hydrogen for traditional refineries

Hydrogen enables chemical conversions which increase the usability, product yields and profitability of traditional refined products and biofuels. This 'champagne' application elevates expensive hydrogen molecules to their highest value: as a chemical reagent to enable the production of liquid fuels.

Fossil crude must be refined to yield marketable liquid fuels. As part of this refining operation, isomerisation, hydrocracking, hydrodeoxygenation and hydrotreating are required. These are standard processes which are used extensively today.

Crude oil is a mixture of hydrocarbons of various types and chain lengths. Some of these molecules are too short to be used as gasoline, diesel or kerosene, and others are too long. The long, waxy molecules can be hydrocracked to make smaller chain hydrocarbons which are suitable for diesel and kerosene. Hydrogen is reacted with the waxes in the presence of a catalyst to crack them into shorter molecules.



Crude oil

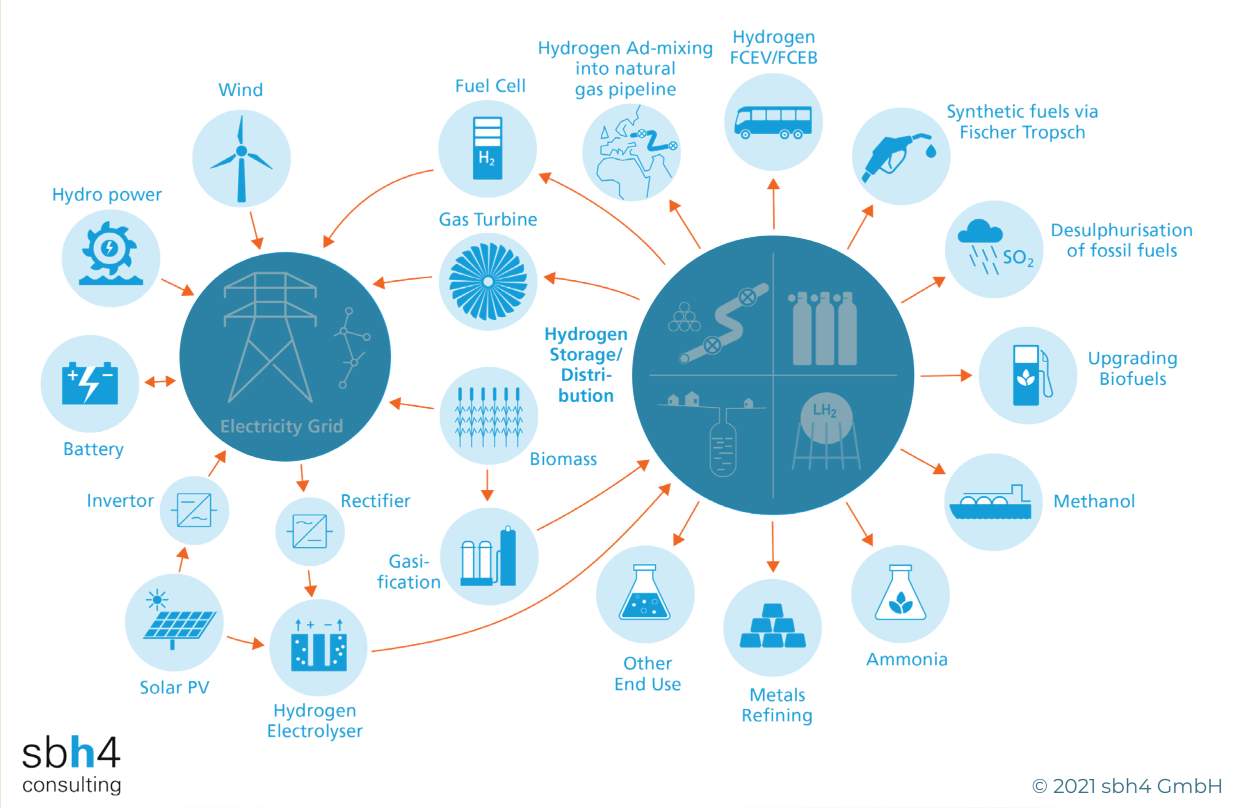
Some crudes contain oxygenates such as ethers, alcohols and esters. These molecules can be corrosive and damaging to fuel storage infrastructure. So, hydrogen is reacted with them to remove the oxygen atoms and yield water.

Sour crudes contain a high amount of sulphur locked into the hydrocarbons. Biofuels can also contain sulphur compounds. Removal of the sulphur is essential to comply with environmental regulations to avoid acid rain and protect human health. If they are not removed, sulphur compounds can also produce sulphuric acid which destroys storage and processing equipment.

Isomerisation

Another processing requirement is isomerisation. Isomerisation converts the long straight paraffins to branched hydrocarbon isomers. These look more like a tree with branches rather than >>

Renewable hydrogen production, distriution, storage and itilisation value chains



>> a long stick. Isomerisation takes place in the presence of hydrochloric acid and a catalyst, which is often based on platinum.

The isomerisation reaction itself does not consume hydrogen. However, hydrogen is added in the overall isomerisation process to support side reactions such as cracking of carbon-carbon double bonds that may simultaneously take place.

Paraffinic linear hydrocarbons can freeze at the very cold temperatures encountered during high altitude flight. Isomerised, non-linear molecules remain liquid at colder temperatures which is essential for aviation fuel, since the temperature at high altitude can be as low as -40°C. Thankfully, the 'Jet' fuel specification is very strict about controlling these safety-critical aspects of liquid fuel quality.

Hydrogen transmission

The city of Los Angeles in California is home to a circa 12-mile hydrogen pipeline. It has been built by Air Products, largely through re-purposing crude oil, natural gas and refined products pipelines. The south west end of the pipeline is in the industrialised City of Carson, where hydrogen is produced on a steam methane reformer at a large petroleum refinery.

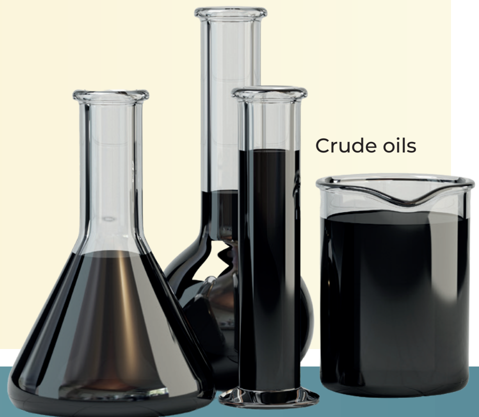
Hydrogen travels through the pipeline and heads to north and east. It traverses the cities of Los Angeles, Long Beach, Lakewood and Bellflower. The final offtake point is at the World Energy's biorefinery, in the City of Paramount.

World Energy uses 20 tonnes per day of hydrogen to convert up to 3,500 barrels per day of non-edible vegetable oils and beef tallow into renewable fuels. The bio-fuel products include aviation kerosene, diesel, gasoline, and fuel gas.

If the pipeline did not exist, more than 20 compressed hydrogen truck deliveries would be required each day to deliver hydrogen to World Energy's Paramount Refinery. Avoidance of these truck movements improves urban safety, in addition to reducing traffic congestion and air pollution from the vehicle emissions.

Hydrogen for biofuel processing

The term HVO refers to hydro-treated vegetable oil. HVO is a broad classification of liquid fuels which may include bio-diesel or sustainable aviation fuel. HEFA means hydroprocessed esters and fatty acids. In addition to plant-based oils, treated animal fats such as beef tallow or poultry fat can be included within the HEFA definition.


Crude oils


Los Angeles

Fatty acids and esters are hydrocarbon molecules which contain oxygen atoms. These oxygen atoms must be removed to increase the cetane value of the fuel. Removal of the oxygen also reduces the corrosive potential and ensures that the resultant biofuel is a drop-in replacement for conventional fossil diesel or kerosene.

The chemical conversion to remove the oxygen is known as hydrodeoxygenation. On the bio-refinery, it may take place by reacting the feedstock with hydrogen at around 30 bar pressure at a temperature close to 300°C. Various metal catalysts combined with acidic promoters are known to enhance the reaction. Cobalt-molybdenum or nickel-molybdenum catalysts have been shown to be effective.

Unsaturated hydrocarbons can be unstable and polymerise over time, especially if traces of oxygen are present. This could transform the properties of the fuel to be outside the appropriate specification for cloud point and pour point.

In turn, this would make the fuel highly viscous at low temperatures experienced during flight or when driving a truck in winter. Viscous fuel is hard to pump to the engine, and in the worst case, may freeze, preventing fuel from reaching the engine and stalling the aircraft or truck.

The hydrogenation reaction targets double bonds between unsaturated carbon atoms. Hydrogen splits the double bond and joins the hydrocarbon molecule. Hydrogen, therefore, plays an essential role in ensuring driver and passenger safety in biofuels.

Food scarcity and second-generation biofuels

Some years ago, there was concern that too many farmers were growing crops for biogas production rather than marketing their crops as food for livestock or people. This led to growth in biomethane production as a renewable fuel, but was simultaneously perceived to trigger food price inflation.

'Food versus fuel' considerations have led to a preference for waste oils as the input to HEFA processing facilities. However, there are only so many chips that get fried around the world. Waste oils are not produced for fuel; they are a secondary result of food preparation. Biofuels from waste vegetable oils therefore, have a limited scalability.

With recognition of the scalability limitations of first-generation biofuels and their potential to result in food scarcity and environmental habitat loss, so-called second-generation biofuels have emerged. They are produced from non-food crops and post-harvest waste.

Algae is also a source of esterified lipids, which can be extracted from the algae to be processed in a similar manner to the HEFA products. Pyrolysis oils derived from waste lignocellulosic biomass, such as straw, can also be processed in this way.

Gasification of forestry waste can also yield syngas for Fischer-Tropsch fuel production. In these cases, no land must be diverted from food production to generate clean biofuels. Biofuels generated through these pathways are currently being considered for new large-scale SAF production plants in Europe and the US.

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