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Powerfuels in Passenger Cars

Powerfuels can complement direct electrification of passenger cars to defossilise global road transport.

Road transport constitutes a significant source of CO_2 emissions as well as local air pollutants: Globally, road transport is responsible for 11.9 % of greenhouse gas (GHG) emissions, and 60 % of these emissions come from passenger travel (cars, motorcycles, and buses)1). Within the European Union, passenger cars alone account for approximately 61 % of GHG emissions from road transport, and 12 % of total EU GHG emissions2).

The introduction of alternative propulsion systems and fuels for passenger cars constitutes an important measure to reduce GHG emissions, and can also improve local air quality. Propulsion systems and renewable fuels that could contribute to mitigating GHG emissions for cars include, e.g., battery and plug-in hybrid electric vehicles, as well as gaseous and liquid biofuels and powerfuels.

Powerfuels could either be used in fuel cell vehicles (FCEVs), which power an on-board electric motor using oxygen from the air and compressed hydrogen, or as drop-in gaseous or liquid replacement fuels for internal combustion engine (ICE) cars.

Advantages of using powerfuels compared to battery electric vehicles (BEVs) include the higher range and the lower time for refuelling. In addition and similarly to battery electric vehicles, FCEVs can contribute to improved air quality in urban areas, as they are locally emission-free.

Liquid and gaseous drop-in powerfuels offer the advantage of being fully compatible with the existing distribution and storage infrastructure as well as the vehicle technology of ICEs, as they can be produced to closely resemble crude oil-based diesel/ gasoline/ Liquefied Petroleum Gas (LPG) or natural gas in their basic properties, or even improve on them in terms of lower local emissions. Liquid and gaseous powerfuels could thus gradually be blended into conventional fuels and hereby contribute to defossilising the existing fleet of ICE passenger cars – as well as creating a large offtake market for powerfuels.

Passenger cars account for 61 % of total GHG emissions from road transport in Europe2)

While their market share increases, electric cars currently only account for 2.6 % of global passenger car sales3)

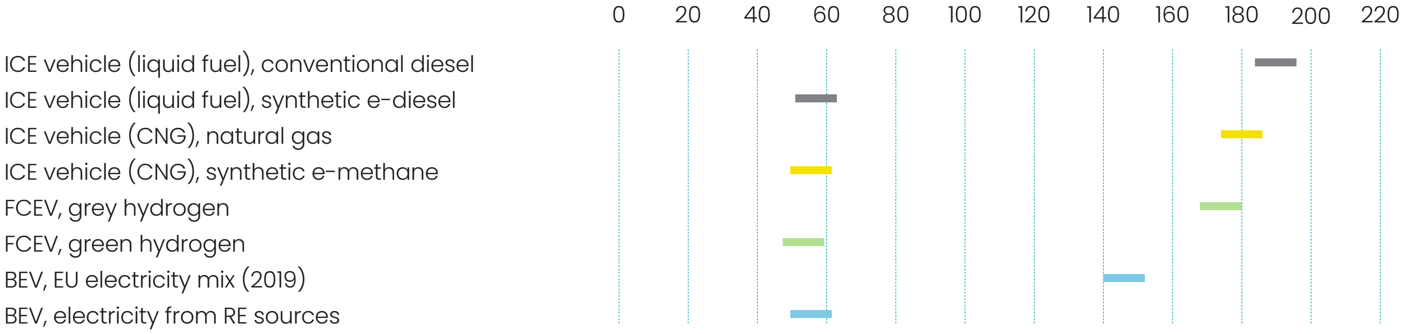
H_2 Hydrogen (to fuel FCEVs):

- ✓ No harmful local emissions (e.g. CO_2 and NO_x emissions); less noise pollution and higher efficiency compared to ICE vehicles
- ✓ On average higher range than BEVs and considerably shorter refuelling time
- ✓ Suitable for long term energy storage
- ⚠ High investment costs for vehicle and fuel technology as well as high distribution costs
- ⚠ Lower energy density than methane or liquid fuels

Synthetic hydrocarbons (e.g. methane or gasoline):

- ✓ Possibility to use existing refuelling infrastructure and vehicles; fast refuelling
- ✓ "Drop-in" characteristics allow gradual substitution of conventional fuels
- ✓ Better properties for international transport than electricity and hydrogen, thus suited to production in regions with high solar and wind intensity or excess of hydro power
- ⚠ Not locally emission-free as carbon-based powerfuels; local emissions depend on exhaust gas treatment technologies and maintenance of the vehicles
- ⚠ Application in passenger cars remains a point at issue; other areas of application (e.g. aviation) might be prioritised due to lack of defossilisation alternatives[1]

Lifecycle GHG emissions of passenger cars by propulsion system and fuel/ electricity mix (gCO_2eq/km)



Underlying assumptions: All numbers are based on the state of technology at the date of publication of the underlying study (2019). Weight of vehicle: 1200-1400 kg depending on propulsion system, modelling mid-range passenger cars; lifetime: 12 years; annual km: 15.000. "Conventional diesel": diesel fuel produced from fossil crude oil; "synthetic e-diesel": Fischer-Tropsch fuel produced from green hydrogen (electrolyser run by wind power) and carbon from biogenic sources; "synthetic e-methane": compressed gaseous fuel produced from green hydrogen (electrolyser run by wind power) and carbon from biogenic sources; "grey hydrogen": produced via steam methane refining from natural gas; "green hydrogen": produced from wind power via electrolysis; "current electricity mix": EU 28 electricity mix in 2019; "electricity from RE sources": provided by wind power. Source: Joanneum Research, 2019[4]

ICE vehicles

When ICE vehicles are fuelled with liquid or gaseous powerfuels, and renewable electricity is used for their production, lifecycle GHG emissions can reach values below 70 g CO_2eq/km with the current state of technology, depending on the carbon sources used. Lifecycle emissions are thus on par with vehicles equipped with other propulsion systems using renewable electricity or fuels.

FCEVs

FCEVs fuelled with grey hydrogen from natural gas have lifecycle GHG emissions that are below those of ICE vehicles using conventional diesel or gasoline but still above 150 g CO_2eq/km. Using hydrogen from renewable electricity (RE), GHG emissions are below 70 g CO_2eq/km with the current state of technology, and on par with lifecycle emissions of RE-powered BEVs.

BEVs

With the current technology and electricity mix, estimated lifecycle GHG emissions of BEVs are already lower than 150 g CO_2eq/km. Using electricity from renewable energy sources reduces lifecycle GHG emissions further. However, as for FCEVs, the lifetime of the vehicle has a significant impact on the GHG emissions per kilometre resulting from the production phase.

All powerfuels-driven vehicles have a significantly higher range than BEVs. In addition, refuelling times are considerably shorter. Costs of powerfuels are currently considerably higher than those of conventional fuels used in passenger cars but are expected to decrease significantly in the next decades.

- Compared to other powerfuels that could be used in passenger cars, e.g. hydrogen or synthetic methane, liquid powerfuels like synthetic diesel or gasoline have higher production costs. However, their cost is expected to decrease significantly over the next decades, with costs expected to amount to values slightly above 1€ per litre of diesel equivalent by 2050[6]. Another liquid powerfuel that could be used in passenger cars is e-methanol, either in low-level blends for conventional ICE vehicles, or in high-level blends in vehicles specifically designed for methanol fuels.

- FCEVs offer a driving and fuelling experience resembling that of ICE vehicles. Advantages include no harmful local emissions and a higher well-to-wheel energy efficiency compared to ICE vehicles. In addition, green hydrogen has the lowest production costs of all powerfuels that could be used in passenger cars from today's perspective, does not require additional input factors like CO_2 unlike other powerfuels, and can directly be used in FCEVs without further conversion processes. However, high investments in vehicle technology and infrastructure are required.

Light-duty individual transport's potential leverage effect for market ramp-up of powerfuels

More than 15 million cars are newly registered in the European Union every year[7], and road transport accounts for approximately 71 % of total EU consumption of oil-derived fuels[8]. The sector is therefore a large potential market for powerfuels. What is more, manufacturers of passenger cars face high GHG emission reduction costs and steep fines when failing to comply with the European Union's CO_2 emissions targets, which require average new-vehicle CO_2 emissions to fall by 37.5 % by 2030, compared to 2021 levels[2]. The potential willingness to pay for the market integration of low-emission fuels is thus higher than in other sectors.

[1] It should be noted in this context that liquid powerfuels that can be used in road transport are also by-products in the production of renewable synthetic kerosene. Establishing a demand market for liquid powerfuels in road transport could hence potentially also boost competitiveness and proliferation of the latter. [2] CO_2 emission standards for cars and vans at EU level are currently being reviewed, with a proposal of the European Commission expected for June 2021.

References: 1) Emissions by sector, Our World in Data, University of Oxford, 2020; 2) Greenhouse gas emissions from transport in Europe, European Energy Agency, 2019; 3) Electric vehicles, International Energy Agency, 2020; 4) Geschätzte Treibhausgasemissionen und Primärenergieverbrauch in der Lebenszyklusanalyse von Pkw-basierten Verkehrssystemen, Joanneum Research, 2019; 5) Vergleich Alternative Antriebe, Pkw-Label, German Energy Agency (dena), 2020; 6) "E-Fuels" Study, German Energy Agency (dena) and Ludwig-Bölkow-Systemtechnik (LBST), 2017; 7) European Vehicle Market Statistics 2019/20, International Council on Clean Transportation (ICCT), 2019; 8) Transport Briefing, European Environment Agency, 2020.

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