Hydrogen Won't Fly Today

Prepared by Stefan Unnasch and Kathleen Dailey, Life Cycle Associates, LLC
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Solar powered flight is an option for the future. Today solar-enabled aviation fuels provide the best opportunity for carbon natural flight.

Aviation is responsible for 2.1% of all human-induced CO_2 emissions (ATAG, 2022). Modern planes use kerosene as fuel, which releases CO_2 into the atmosphere. A solution to the CO_2 emitted is hydrogen fuel, which does not produce emissions. Hydrogen is a sustainable fuel and is now gaining attention as a possible aviation fuel alternative. Planes using hydrogen would only emit water and still function as well as traditional planes. Commercial hydrogen aircraft is far from being a reality – reports estimate hydrogen powered aviation will begin entering the market by 2035 (O'Callaghan, 2020). Developments in liquid hydrogen storage could lead to medium-range flight up to 4,400 mi by 2040, leaving long-range flights to traditional aviation fuel. The refueling infrastructure does not exist and hydrogen is more expensive and difficult to store onboard than kerosene-based fuel. Bringing hydrogen fuel to the market has significant challenges. If overcome, the aviation industry could be much greener, contributing to a decarbonized world. Of course, the legacy fleet of 25,000 jets, which is expected to grow to over 35,000 (Cooper, 2017) by 2035 will continue to operate on kerosene. Even if a goal (AirBus, 2022) of hydrogen flight by 2035 is achieved, most flights will still require kerosene through the middle of the century.

Although hydrogen is promising, it won't be able to deliver net-zero carbon emissions on its own. Biomass-derived sustainable aviation fuel (SAF) is developing beyond waste oils and fats. Synthetic paraffinic kerosene (SPK) is a bio-derived fuel that provides the means to deliver renewable hydrogen as aviation fuel due to its higher energy density and chemical composition.

While liquid hydrogen provides the opportunity for zero emission flight, challenges with cryogenic storage on the plane and fuel infrastructure mean that this option is decades away.

Hydrogen-powered flight is a potential way forward. Aesthetically, hydrogen planes would be similar to traditional planes. Smaller planes would use hydrogen-powered fuel cells that provide electric propulsion to turn propellers, while larger planes could burn hydrogen to power jet engines (O'Callaghan, 2020). Hydrogen planes would require developments in propulsion, on-board storage, airport logistics, as well as redesign of the entire plane which would replace wing storage of fuel with cryogenic tanks. Planes would need to be refueled where new ways of transporting hydrogen to airports is required.

Furthermore, the energy density of liquid hydrogen is approximately a quarter of jet fuel – for the same amount of energy it needs a storage tank four times the size (Henderson, 2021). While integration is a challenge, standards, codes, and regulations need to be prepared. Currently, liquid hydrogen is three times as expensive as conventional jet fuel and is likely to remain that way for the next few decades – limiting liquid hydrogen's role in greening aviation.

The choice of aircraft architecture is dominated by the location of the hydrogen storage. The diameter of liquid hydrogen tanks affects the gravimetric efficiency and internal volume, where a solution is an increased fuselage volume (FlyZero, 2022). The FlyZero project led by Aerospace Technology Institute came up with a concept for a liquid hydrogen-powered midsize aircraft that would be able to fly 279 passengers non-stop from London to San Francisco, or from London to Auckland, New Zealand with one stop for refueling (Holt, 2021). The aircraft has a 54-meter wingspan and two turbofan engines and would offer the same speed and comfort as today's aircraft with zero emissions. Cryogenic fuel tanks would be included in the rear fuselage, storing hydrogen at -250 degrees Celsius. Two smaller tanks along the forward fuselage would keep the plane balanced as fuel is used.

Priority technology challenges for hydrogen powered aircraft that need to be addressed before achieving certification and entering service include the following:

- Liquid hydrogen behavior and materials compatibility data
- Liquid hydrogen storage
- Cryogenic fluid pumps
- Hydrogen combustion systems
- Aircraft integration of cryogenic hydrogen fuel systems

While pursuing research of hydrogen aircraft is promising. The challenge in achieving net-zero carbon emissions by 2050 is that hydrogen will not be able to deliver this on its own. Low carbon impact SAF available in limited quantities from waste oils and plants like carinata, algae, and camelina are just under development. Parallel investment in biomass-based SAF is required to achieve carbon neutral flying goals. As each option has advantages, it is too early to choose one over the other as the solution to decarbonize aviation.

Hydrogen has the highest energy density of any fuel, shown in Table 1, with more than double the energy density of conventional jet fuel – an airplane could achieve long range flight on pure hydrogen if it could be stored. SPK has a 1% higher energy density than conventional jet because of its chemical composition with more hydrogen per carbon atom. The improved energy density of SPK results in a reduction of fuel weight. For example, a 2,000-mile trip would require 364 kg less fuel to go the same distance based on the conventional jet fuel use and energy for a typical cargo airplane shown in the table. Assuming a comparable energy use for flight, the weight of liquid hydrogen would be less than that of jet fuel but additional weight for the storage system would results in added weight and developing and certifying designs to accommodate liquid hydrogen will take over a decade.

SPK provides a practical means to deliver renewable hydrogen as an airplane fuel. It has an improved energy density over conventional jet fuel and is available from low GHG emitting sources. The carbon in biomass reacts is saturated with hydrogen to make a pure straight chain hydrocarbon to achieve a higher energy density than conventional jet fuel.

Fuel	**SPK**	**Conventional Jet**	**Liquid Hydrogen**
Density (g/L)	749.4	802.0	70.8
LHV (MJ/kg)	44.1	43.2	120
Carbon (wt%)	84.5%	86.2%	0%
Fuel Temp. (F)	Ambient	Ambient	-423
Range & Storage	😀	😑	😮
Trip Length	2000	mi	
Fuel Use			
kilograms	16,776	17,140	6,170
Giga Joules	739.8	740.4	740.4

Table 1. SPK provides improved energy density compared to conventional jet fuel. The weight reduction results in 643 MJ of energy savings over a 2,000-mile flight. That's 14.6 kg of fuel savings that is not burned or 364 kg of additional cargo that the plane can carry.

Source: GREET

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