© Shutterstock.com

Reassessing liquid hydrogen's role in drone performance

By **Stephen B. Harrison** on Mar 24, 2026

Hydrogen offers a set of physical properties that make it a high-performance fuel in weight-sensitive applications.

There are certain properties that hydrogen, whether it be grey, blue or green, exhibits as a high-performance fuel. These characteristics put it in a class of its own.

Vertical take-off and landing (VTOL) drones are seeing rapid adoption across civilian, industrial and defence applications. Among emerging applications, unmanned aerial vehicles (UAVs) are particularly well positioned to benefit from liquid hydrogen's high specific energy and system-level performance advantages.

Green hydrogen has become synonymous with decarbonisation and the energy transition. However, in some cases, this focus has overshadowed hydrogen's intrinsic performance advantages as an energy carrier.

In a class of its own

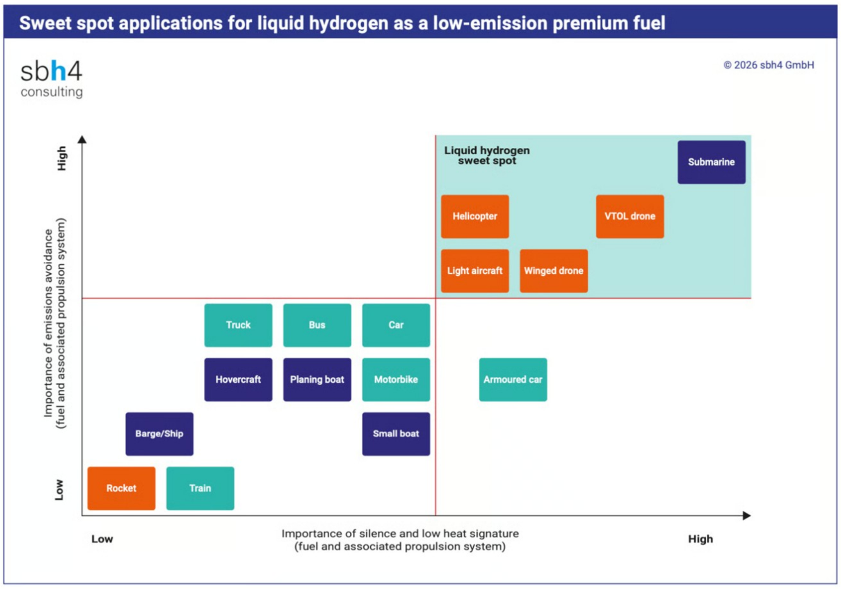
Hydrogen's gravimetric energy density is more than three times that of conventional aviation kerosene. While hydrocarbons win on volumetric energy density, aviation and aerospace applications are primarily constrained by mass rather than volume. Where high-performance drones are used, the challenge is to conquer gravity. In this respect, hydrogen represents a compelling alternative.

Hydrogen has advantages over other fuels, and liquid hydrogen offers advantages over compressed gaseous hydrogen.

Daniel Costa Blanes, CTO at French cryogenic technology firm Hydvance, said, "Liquid hydrogen and gaseous hydrogen have the same gravimetric energy density, but liquid hydrogen has a volumetric energy density of almost three times that of compressed gaseous hydrogen at 350 bar, and almost twice that of compressed gaseous hydrogen at 700 bar."

The higher volumetric density of liquid hydrogen, relative to compressed gas, enables more compact storage, which can reduce vehicle size and aerodynamic drag.

- **Velocity**. Faster flight consumes more energy. In cruise, energy demand increases approximately with the square of velocity ($E \propto v^2$) for fixed-wing configurations. Achieving the same range in a shorter time means carrying more energy in the fuel tanks.
- **Distance**. Longer-duration missions consume more energy. And they need more fuel on board to provide the energy, meaning at take-off, a lot of energy is expended lifting fuel. In practice, total energy requirements increase non-linearly with range due to aerodynamic and mass-related effects. A catapult launch can help to mitigate this for lighter drones. But broadly speaking, range either means carrying a heavier mass of fuel or upgrading to a fuel with a higher energy density.
- **MTOW**. Heavier payloads mean more energy is required to combat gravity during the take-off and climb sections of the mission. Again, this can be mitigated for some drones using catapult launch. However, after the climb, there must still be energy left to achieve the required range. Liquid hydrogen packs enough energy into the tank to enable a high maximum take-off weight (MTOW) and a long-range flight. For VTOL multi-rotor systems, power requirements scale non-linearly with MTOW.



Reducing the UAV fleet size and cost

The use of liquid hydrogen can materially reduce total fleet size and associated capital expenditure.

"Faster drones get to and from their objective location sooner," Hydrvance's Costa Blanes said. "This is critical in applications where one or more drones are in continuous operation, such as a fleet of logistics drones. Higher speed means fewer drones are required to perform the required missions or deliveries."

Longer range means that fewer drones are required for continuous surveillance of a remote location. Consider the case that it takes a drone two hours to fly to its destination and another two hours to return to base. If the fuel energy is sufficient for five hours of flying time, only one hour is available for surveillance at the destination location.

For permanent monitoring of the remote location, in this case, a minimum of five drones is required. And this assumes zero refuelling time. Add the refuelling time, and the fleet size grows to six or seven drones.

© Shutterstock.com

Upgrading the fuel to liquid hydrogen to increase the range significantly reduces the number of drones required. Using 1kg of liquid hydrogen, rather than 1kg of aviation kerosene, would approximately triple the range of the drone, meaning it has 12 hours of flying time. With the same four hours required for outbound and inbound flight, the liquid hydrogen drone can spend eight hours at the reconnaissance site.

Using liquid hydrogen means that only two drones are required to perform the continuous surveillance mission. One drone is at the remote location for eight hours. The other is returning from the location, being refuelled and flying back out to the location during this eight-hour period. The refuelling and reloading with any payload can now take four hours.

Powertrain

The mass and volume of fuel are relevant, but the integrated powertrain, fuel storage and fuel system must be considered to fully compare fuel types.

When considering hydrogen as a fuel, low-temperature PEM (LTPEM) fuel cells offer low stack-level mass. However, for high performance, they require humidifiers and cooling equipment. These balance-of-plant components reduce system-level specific power to a range of 0.5–0.8kW/kg.

This is typically lower than kerosene-fuelled internal combustion engines (ICEs), which can generally achieve 1–1.5kW/kg. The consequence is that an LTPEM fuel cell would be heavier than a kerosene-powered ICE. LTPEM fuel cell powertrains reduce the performance advantages of switching to hydrogen as a fuel.

On the other hand, a powertrain system using a high-temperature PEM (HTPEM) fuel cell offers a power-to-weight ratio up to 1.2-kW/kg, competing with an ICE. The higher temperature operation of the HTPEM fuel cell means cooling equipment is lighter because the temperature differential to ambient is higher. Additionally, they do not require the humidifier equipment, which a powerful LTPEM system would need.

"It should also be noted that internal combustion engines are mature with few breakthroughs on the horizon," Costa Blanes added. "Conversely, as emerging technologies, PEM and HTPEM fuel cells are getting lighter and more powerful year on year. We believe it is likely that PEM will achieve a power density of 1kW/kg will be achieved within this decade, increasing to, and potentially surpassing, 2kW/kg during the next decade."

Fuel storage

Kerosene can be stored in a lightweight plastic tank or within the wings. In the system gravimetric index-stakes, this is perhaps the main advantage that it has over hydrogen.

Compressed hydrogen can be stored in 'light-weight' carbon-fibre composite tanks. However, the term lightweight is relative. They are indeed lighter than the steel tanks they have replaced, but 700 bar carbon fibre hydrogen tanks add a lot of mass to the combined fuel and storage system.

The efficiency of a storage tank is defined by the mass of fuel compared to the total mass of the fuel + tank system. The tank system is comprised of the tank itself plus the associated safety devices for pressure relief; equipment for hydrogen temperature and pressure conditioning to the application; re-fuelling connections; and sensors.

© Hydvance

Hydvance CEO, Thomas Andrieu, added, "In the case of liquid hydrogen, the mass efficiency, gravimetric index, or fuel yield, can reach 30%. For compressed gaseous hydrogen, it struggles to rise above 10%."

Achieving 30% fuel yield for liquid hydrogen means avoiding heavy materials such as steel in the construction of the tank. Aluminium alloys provide a favourable balance of strength, weight, and cost for aerospace liquid hydrogen tanks.

Additionally, aluminium alloys are not sensitive to hydrogen embrittlement. Furthermore, it is less expensive than other high-strength materials such as fibre reinforced composites and titanium.

"For land-based liquid hydrogen storage applications, a double-walled cryogenically insulated steel tank would be acceptable. In aviation and aerospace, mass matters most: aluminium is by far the better choice for VTOL drones," Andrieu concluded.

Despite its advantages, liquid hydrogen introduces several engineering and operational challenges. These include cryogenic storage requirements, boil-off management, refuelling infrastructure, and system integration complexity.

Safety considerations and the cost of liquefaction and distribution also remain key barriers to widespread adoption. As a result, system-level optimisation is critical when evaluating hydrogen against alternative energy carriers.