ENERGY

SPACE SOLUTIONS

GREEN HYDROGEN FOCUS REPORT

INTRODUCTION

In a world transitioning away from fossil resources to alternative energy sources, green hydrogen can become a solution with huge potential, as both energy vector and feedstock for sustainable materials. Unlike other types of hydrogen, such as grey and blue, green hydrogen is produced with electricity from renewable sources.

Moreover, green hydrogen is particularly interesting as a valuable alternative fuel, as well as a feedstock in the production of synthetic fuels such as e-methanol and e-kerosene, which are critical to help decarbonise hard-to-abate sectors – cement and steel industries, heavy road transport, shipping and aviation – where electrification is not easily achieved or not possible.

Additionally, green hydrogen can help balance the power grid as it can be produced from surplus energy and stored for use when needed – addressing the widespread fluctuating supply and demand challenges with renewable electricity more broadly.

Green hydrogen can also be produced locally at small scale, promoting energy security and energy communities and contributing to a just transition.

While the uptake of low-emissions hydrogen has been held back by factors such as uncertain demand and regulatory environments, the latest data shows that the sector continues to grow and mature. Innovation continues to move at an impressive pace, with a record number of technologies across the hydrogen value chain showing significant progress since 2024.

WHY FOCUS ON GREEN HYDROGEN?

ESA's Business Applications and Space Solutions (BASS) programme, together with members of the Task Force for Innovation and Energy through Space (Energy Task Force) recognise the potential for space applications to accelerate the scaling up and adoption of green hydrogen – and with that, the value in supporting pilot activities to demonstrate the value-added of innovative space applications a to help scale up the production and up-take of green hydrogen.

The market size for green hydrogen, while currently relatively small, presents great opportunities. The EU's Renewable Energy Directive (RED III) sets a target for 42% of all industrial hydrogen to be green and for the production and import or green hydrogen to ramp up to 20 million tonnes by 2030. This in a context where current market signals suggest global demand is set to accelerate from 2030 onwards, peaking anywhere

between 150 and 500 million tonnes by 2050, depending on factors such as policy developments, continuing global climate ambitions and the use of carbon capture technologies. The EU's decarbonisation agenda offers a promising springboard, aiming for carbon neutrality by 2050 with green hydrogen and renewables at the heart of the mix.

Current challenges with scaling up the production and use of green hydrogen include:

- lack of grid connections and infrastructure, which also leads to high upfront costs
- technical challenges relating to the low density of hydrogen
- a lack of awareness leading to public and investor scepticism
- a lack of technical, safety and regulatory standards
- high cost of production ($6-7/Kg of green hydrogen)
- operational challenges such as fluctuating renewable input and harsh environmental conditions at coastal and offshore sites.

POTENTIAL USE CASES

Supporting the energy transition: Building resilience into a renewable-dependant energy system by improving efficiencies and balancing renewable supply and demand.

Decarbonising the hard-to-abate transport sector: Long-haul shipping and aviation cannot be viably electrified, so require alternative fuel solutions to reach ambitious decarbonisation targets.

Solar and wind resource assessment: Hydrogen production through electrolysis relies on renewable energy like solar or wind power. Identifying areas with the highest potential for renewable energy generation ensures that hydrogen production sites are in regions with reliable and abundant renewable energy sources.

Identifying locations for offshore hydrogen production: Assessing offshore wind resources, ocean currents, seabed topography, and other factors that can influence the feasibility of setting up offshore hydrogen facilities. Providing a route-to-market for otherwise potentially stranded offshore wind resources.

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General land use and topography analysis: Identifying, for example, flat, open areas that are less prone to natural hazards like flooding or landslides, making them more suitable for setting up production facilities and associated infrastructure like wind and solar production sites. Protecting biodiversity by carrying out a detailed environmental assessment at the site selection stage.

Water availability assessment: Electrolysis requires substantial quantities of water, so the availability of fresh water or groundwater resources are important. At the same time, it is vital to ensure that the hydrogen production doesn't negatively impact local water availability for other uses, such as agriculture and drinking.

SatEO data can identify and monitor high-emission areas and sectors, contrasting them with those using cleaner energy such as green hydrogen.

Infrastructure and accessibility analysis: Proximity to existing infrastructure is important for hydrogen production sites. Suitable sites have access to power lines, pipelines, and transportation networks to facilitate efficient transportation and distribution of the hydrogen produced. New safe and reliable distribution and storage solutions also need to be developed.

Climate and weather data assessment: Understanding the optimal load factor for the hydrogen plant together with other relevant data on electricity prices and market conditions, as well as securing infrastructure from unwanted impacts due to unforeseen weather events.

On-demand maintenance assessment: Monitoring extreme temperatures, high humidity or emissions can help understand equipment performance and schedule maintenance when it is needed to prevent damage or degradation, and to minimise safety risks and environmental impacts.

Safety, monitoring and operation: When dealing with underground storage or extraction, monitoring the operational parameters and materials' properties, which vary depending on pressure and temperature in loading cycles.

HOW CAN SPACE HELP?

There are many ways space technology can be applied and add value to innovative ideas in the green hydrogen sector. Here are some examples of different space technologies and how they could be used:

- Satellite Communication (SatCom) provides low-latency, real-time monitoring and control of networks and assets at any location, whether remote or not. When integrated with Internet of Things (IoT) technologies, SatCom can track key indicators essential for efficient green hydrogen production including plant performance, production rates, hydrogen purity, and storage conditions. This seamless connectivity ensures optimal operation, early fault detection, and data-driven decision-making.
- Satellite Earth Observation (SatEO) data can be used to identify optimal regions for energy converter installations and to pinpoint new areas with potential based on land use type, water availability, proximity to protected areas, and residential zones. SatEO data can identify and monitor high-emission areas and sectors, contrasting them with those using cleaner energy such as green hydrogen.
- Satellite Navigation (SatNav), enabled by Global Navigation Satellite Systems (GNSS), plays a crucial role in the safe, reliable, and cost-effective transportation and storage of hydrogen. By providing precise location tracking, SatNav helps to identify the most efficient and secure routes for distributing hydrogen from production sites to end users.

Special thanks for the expertise and contributions from members of the ESA BASS Energy Task Force:

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