The Evolving Hydrogen Safety Ecosystem

The hydrogen safety ecosystem brings together sensing technologies, relevant standards, and system level design practices that ensure hydrogen can be produced, stored, transported, and used safely across a wide range of applications. It covers everything from electrolysers and hydrogen powered transport to refuelling stations, industrial equipment, and residential energy, supported by strong safety engineering practices, regulatory requirements, and proven gas detection solutions.

Hydrogen is increasingly being adopted across Europe's energy transition, where it serves as a clean energy carrier, industrial feedstock, and storage medium in a range of decarbonisation applications. However, hydrogen's physical properties, including being colourless, odourless, highly diffusive, and flammable over a wide concentration range, introduce unique safety challenges when compared with conventional fuels.

Why does hydrogen pose such a safety risk compared to other combustible gases?

Hydrogen's lower flammability limit (LFL) of around 4% in air means that even relatively small leaks can form combustible mixtures. Because hydrogen rises and disperses quickly, risks are often concentrated in enclosed or semi-enclosed spaces such as ceilings, equipment housings, or confined industrial environments.

Hydrogen sensors are not just monitoring tools, they are active risk mitigation devices, capable of triggering alarms, ventilation, or system shutdown before concentrations reach dangerous levels.

Scope of the Hydrogen Ecosystem

The hydrogen ecosystem encompasses a wide range of applications, each with distinct safety considerations:

- **Commercial and energy infrastructure**: Electrolysis plants, storage facilities, distribution pipelines, and hydrogen refuelling stations.
- **Transportation**: Fuel cell electric vehicles (FCEVs), buses, trains, maritime vessels, and emerging aviation applications.
- **Industrial:** Refining, ammonia production, steelmaking, and chemical processing where it often involves large volumes, high pressures, and complex plant environments.

- **Residential and distributed energy**: Hydrogen blending into gas grids, boilers, and fuel-cell-based combined heat and power (CHP) systems.

As highlighted by a range of European initiatives, including EU funded research programmes, industry partnerships, and standardisation bodies, the success of hydrogen technologies depends directly on the robust integration of safety measures into system design and operation.

Regulatory and Standards Landscape

In Europe, hydrogen safety is governed by a combination of directives, standards, and sector specific codes. For gas sensing devices, the most relevant are the ATEX Directives, covering equipment (2014/34/EU) and workplace safety (1999/92/EC), which define requirements for operation in explosive atmospheres and are supported by standards such as the EN 60079 series.

Together, these frameworks set requirements for leak detection, alarm systems, ventilation, material compatibility, and risk assessment across different applications, supporting a safe by design approach that reduces the need for mitigation action.

When Detection Makes the Difference

There are numerous documented cases, particularly in industrial gas handling and fuel infrastructure, where hydrogen detection systems have prevented escalation of leaks into fires or explosions. In such instances, sensors have triggered automatic shutdowns, isolation valves, or ventilation systems.

While hydrogen incident databases show that leaks do occur, they also demonstrate that well designed detection and alarm systems significantly reduce the likelihood of serious accidents, reinforcing their importance in hydrogen safety culture.

The Role of Gas Sensing Technologies Today

Within this ecosystem, catalytic and metal oxide semiconductor (MOS) technologies are best suited to low level leak detection and safety monitoring within the Lower Explosive Limit (LEL). However, selecting the “right sensor for the right job” remains key as performance requirements vary significantly across applications , from fast-response leak detection in refuelling stations to long-term stability in residential systems .

Catalytic hydrogen sensors are typically used in safety critical applications where rapid detection of flammable concentrations above the lower explosive limit is required, such as in fuel cells and hydrogen storage systems, as they provide a fast and reliable response suitable for triggering shutdown actions. In contrast, metal oxide sensors are better suited to detecting low hydrogen concentrations from ppm levels up to a few percent, making them ideal for early leak detection, continuous monitoring in pipelines or confined spaces, and environments with low oxygen where catalytic sensors cannot operate effectively.

Figaro Engineering's Hydrogen sensor options

Below is an introduction to both the catalytic and MOS sensors within the Figaro portfolio together with the applications they are most suited to and key specifications.

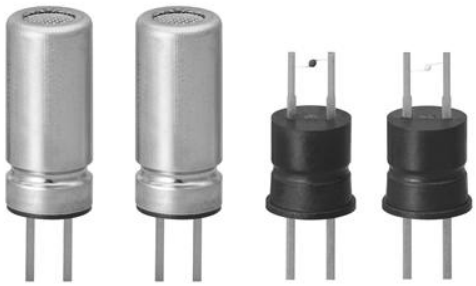
Their robustness, cost-effectiveness, and proven field performance make them indispensable in today's hydrogen safety landscape.

Catalytic Sensors

The **Figaro TGS6812** catalytic bead sensor remains a proven solution for broad-spectrum combustible gas detection in industrial safety applications. Its strength lies in environments where multiple gases may be present, making it particularly well suited to **industrial manufacturing and chemical plants, utilities and gas distribution infrastructure, and power generation systems using mixed fuels**. The TGS6812-D00 catalytic gas sensor can detect hydrogen concentrations of up to 100% LEL, and is characterised by high accuracy, good durability, long term stability, a fast response time and a linear response curve. It detects hydrogen as well as other flammable gases such as methane and LPG, making it well suited for monitoring gas leaks in stationary fuel cell systems that convert these fuels into hydrogen.

The TGS 6812 integrates seamlessly into existing safety systems and meets common standards such as EN 60079-29-1 making it an ideal choice for fixed gas detection applications where reliable performance, compatibility with established systems, and detection of multiple gases are important for safety and explosion protection.

The **Figaro CGM 6812** builds on the performance of the TGS 6812 by providing a pre-calibrated, temperature compensated module with a linearised output, significantly simplifying OEM system design. This is especially beneficial in large-scale or distributed safety systems, such as gas transmission networks, chemical plants, and hydrogen facilities, where consistent performance across multiple detection points is required. The module reduces the need for complex analogue circuitry, in-house calibration, and compensation algorithms, enabling faster development cycles, improved reliability, and lower total cost of ownership. Its integrated design also supports plug-and-play deployment and easier certification alignment, making it an attractive option for OEMs developing safety-critical gas detection systems across a wide range of industrial applications.



The **TGS6A10** represents a new generation of hydrogen-specific catalytic sensing, engineered to meet the demands of rapidly expanding hydrogen ecosystems. Optimised for 0 - 4 % vol. hydrogen detection, it is particularly suited to **electrolysers, hydrogen production plants, high-pressure storage systems, and vehicle refuelling stations, as well as fuel cell-based power generation**. Designed in line with Fuel Cell Electric Vehicle (FCEV) requirements, it offers fast response, long-term stability (over 15 years without maintenance), and resistance to siloxane poisoning, ensuring dependable operation in harsh and contamination-prone environments. With its compact, light weight, low-power design and high durability, the TGS6A10 provides a future-ready solution for hydrogen safety monitoring, where precision, longevity, and minimal maintenance are critical.

In use in the TOYOTA MIRAI

The TGS6A10 is already in use on board TOYOTA's latest hydrogen-powered vehicle, the MIRAI, and meets the stringent performance and quality standards of TOYOTA as well as GTR-13 (Global Technical Regulation No. 13 on Safety of Hydrogen and Fuel Cell Vehicles), the safety standard for FCEV sensors. The sensor module is available as the CSD-05 (with PWM output) or CSD-04 (with CAN interface).

MOS sensors

The Figaro **TGS 2616-C00** is designed for use in portable gas detectors and leak detection for gas appliances, and it complements primary detection systems based on catalytic or infrared sensors. Supporting cost effective multi point deployment, the device is well suited to **emerging hydrogen infrastructure such as electrolyser buildings, storage rooms, and fuel cell manufacturing facilities.** With excellent low level hydrogen selectivity and ppm level detection capability, it offers fast response times that are critical given hydrogen's rapid dispersion and low ignition energy. The sensor is also well suited to methane hydrogen blend applications, helping to future proof system designs.

For further information on sensors:

Next Generation Hydrogen feature
TGS 6812 product information
TGS 2616 product information

For further information on pre-calibrated sensor modules:

CGM 6812
CSD-04/05 FCEV module