

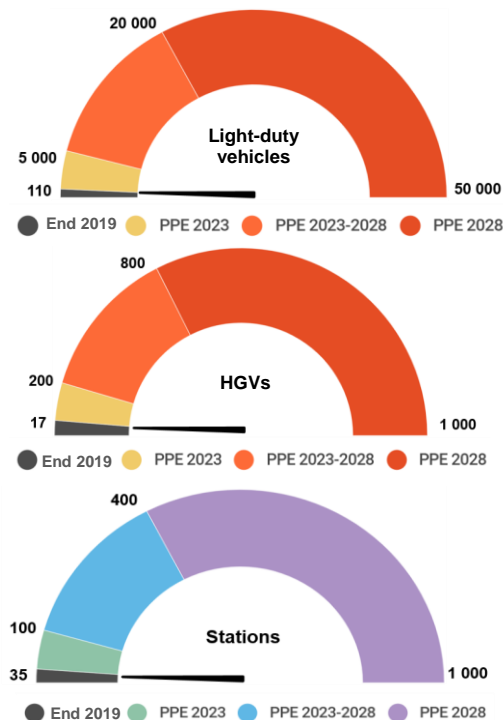
Hydrogen and transport: the risks should not be underestimated

In November 2019, France's lawmakers passed a law that aims to make the country carbon neutral by 2050. The country's course for the coming 10 years is defined in a multiannual energy programme (PPE) initiated in April 2020 by a ministerial decree. One of the goals in the programme is the development of low-carbon and renewable (i.e., not derived from fossil fuels) hydrogen for industrial, energy and transport applications.

Whilst profound societal, economic and behavioural changes throughout France will be necessary to achieve these goals, the fact remains that hydrogen poses risks that must not be overlooked. Against the backdrop of these goals, this flash takes a look back at three events — each at a key stage in the transport of hydrogen — that took place around the globe in 2019.

In 2019, transport accounted for around 30% of energy consumption in France and remains 90% dependent on fossil fuels. Although hydrogen-powered vehicles are already a reality, the 900 kt of hydrogen produced annually in France is largely used by the industrial sector (desulphurisation of petroleum-based fuels, ammonia synthesis, methanol production, etc.) and is derived 95% from fossil fuels. One of the targets in the PPE is to use industrial-grade hydrogen containing a blend of 20–40% carbon-free hydrogen by 2028.

This blend will be used to develop and supply hydrogen-powered transport throughout the country, particularly via commercial vehicles.



Source: Avere-France / AAA Data, Athypac, PPE 2019-2023 2024-2028



ARIA 53903 – 01/06/2019 – SANTA CLARA (USA)

An explosion followed by a fire occurred at a hydrogen production and storage company. Upon arriving, the firefighters saw several parked tankers that were burning and were likely to contain liquid hydrogen (tank containing 2–4 t of hydrogen) or gaseous hydrogen (cylinders totalling 200–500 kg of hydrogen). Nearby businesses and homes were evacuated. The fire was put out in just over 1 hour with no further explosions. No infrastructure outside the site was damaged. Firefighters used thermal imaging and took air samples to ensure that hydrogen no longer posed a threat. The hydrogen filling station was destroyed. The operator took its tanker fleet off the road to be inspected.

The accident downed 9 out of the 11 hydrogen fuelling stations in the area, affecting 1,000 owners of fuel-cell cars for several weeks. Site employees said that a few minutes before the explosion, hydrogen began leaking while it was being transferred to a distribution trailer.

ARIA 53902 – 23/05/2019 – GANGWON (SOUTH KOREA)

A hydrogen storage tank at a new-energy research centre exploded, destroying the centre's 5,100 m² building and damaging the windows and structures of neighbouring buildings. Two people died and six others were injured. This reservoir was part of a research project combining the production of electricity by photovoltaic panels and a water electrolysis process. The Korean government is still investigating the accident.



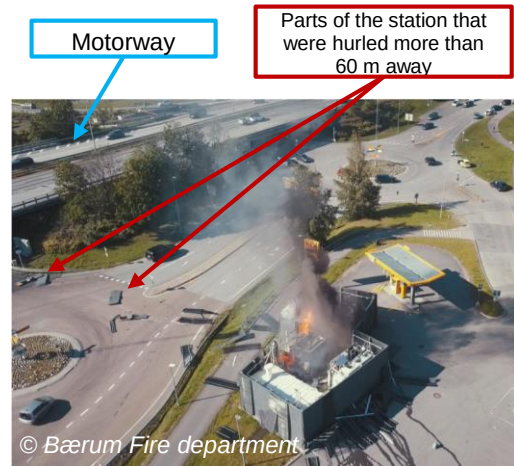
ARIA 53772 – 10/06/2019 – KJØRBO (NORWAY)

An explosion followed by a fire occurred at a hydrogen fuelling station. Hydrogen was produced on-site by an electrolyser. Emergency services arrived seven minutes after the explosion. A 500 m cordon was set up. The motorway and nearby roads were closed to traffic. Firefighters brought the fire under control two and a half hours after the explosion.

The blast of the explosion caused the airbags of nearby vehicles to deploy, slightly injuring three people. The nation's hydrogen supply was interrupted. Makers of fuel-cell vehicles put deliveries of new vehicles on hold. All the operator's hydrogen fuelling stations, whether featuring the same technology or not, were temporarily closed while an investigation was being carried out in Europe, the USA and South Korea.

After 17 days of investigating, the operator determined that the incident was caused by a leak on the high-pressure hydrogen storage unit (cylinders containing hydrogen compressed at 200 bar).

The bolts on the ring between the coupling flange and one of the cylinders had not been adequately torqued. This allowed hydrogen to leak out and form a highly explosive mixture with air. The source of ignition has yet to be determined. The operator scheduled inspections at stations featuring the same assembly systems (four in Norway, three in Iceland and three in Germany). It updated its assembly procedures and made improvements to the quality of its verifications (double checks). It looked into ways to improve detection of hydrogen leaks and avoid the presence of ignition sources at its sites (flat surfaces free of gravel, better ventilation).



Whether considering industries that use proven processes or new applications such as transport, the risks associated with the physicochemical properties of hydrogen are the same. An analysis of 372 events involving hydrogen (produced or generated accidentally) in the ARIA database is a reminder that hydrogen remains a hazard even for proven industrial processes. For example, 73% of hydrogen incidents involved fires and/or explosions, 27% involved non-burning hydrogen leaks or hydrogen-induced stresses on materials without human consequences, 15% of fires and/or explosions involving hydrogen resulted in the death of at least one person and 43% resulted in injuries. In addition to regulations on the storage of hydrogen at facilities classified for environmental protection purposes (known in France as ICPE), the design and operation of hydrogen fuelling stations are governed in France by a ministerial order issued on 22 October 2018.

Hydrogen differs from other combustible gases in several ways, making it easier or more difficult to control the risks associated with it:

- ✓ **It leaks readily:** the element with the smallest atom in the universe, low viscosity and high permeability, hydrogen has everything it needs to be able to leak out of any container. Whilst hydrogen can disperse rapidly in open air, adequate detection systems and passive or active ventilation systems are necessary to prevent it accumulating in confined spaces. Special attention must be paid to shut-off valves, seals, connectors and how they are tightened and torqued. Helium, an inert gas similar in molecular size to hydrogen, can be used to test facilities for hydrogen leaks;
- ✓ **It damages metals and alloys:** hydrogen embrittlement and attack can eventually cause equipment to leak or break. These risks must be analysed during the design process and servicing and maintenance must not be overlooked;
- ✓ **It is extremely flammable:** its minimum ignition energy in air (20 μ J) is more than 10 times lower than that of propane or petrol. This energy can be provided by electrostatic discharges from the human body. In pure-oxygen environments (case of electrolyzers), the energy needed is just 3 μ J. Inerting during critical phases (start-up/shutdown, including emergency stops) as well as compressor shutdown devices reduce the risk of hydrogen-air mixtures (or hydrogen-pure air mixtures). Hydrogen burns with a flame that is nearly invisible in daylight, complicating emergency-response efforts. However, its low radiant heat means that the risk of flame spread induced by thermal effect due to radiant heat is limited;
- ✓ **It is highly explosive:** with a volume percentage of between 4% and 75% in air, hydrogen is 10 times more explosive than propane. Because it burns seven times faster than propane, it has a higher detonation rate. The shock wave generated by a hydrogen explosion depends on the geometry of the containment structure, the ignition energy and the mixture with the oxidant (i.e., oxygen). Unlike many flammable gases that are heavier than air (such as propane and butane), hydrogen's low density allows it to disperse quickly in the open air or in well ventilated spaces.

If you have comments or suggestions or want to report an accident or incident, contact us at barpi@developpement-durable.gouv.fr

Accident summaries logged in the ARIA database are available at www.aria.developpement-durable.gouv.fr