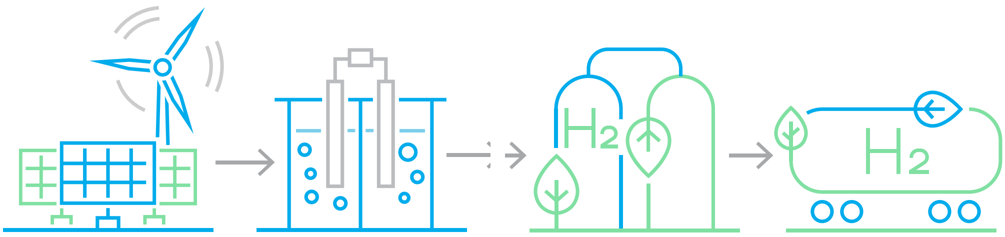
JULY 2022

PROPERTY MATTERS



Green Hydrogen: Thoughts on Underwriting from a Property Insurance Perspective

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Hydrogen (H_2) will play a leading role in the transition of energy sources from fossil fuels in the fight against climate change and to help reduce carbon dioxide (CO_2) emissions from fossil combustion processes. It serves as an energy carrier and storage medium for reverse power generation, as a fuel for transport and mobility means, and as a substitute for fossil hydrocarbons in various industries, such as steel mills, the petrochemical industry and refineries. In addition, it is also required as a raw material in the chemical industry, e.g. for the production of ammonia (NH_3), which is used in combination with nitric acid to produce artificial fertiliser (ammonium nitrate [NH_4NO_3]).

Hydrogen technology is seen by many policymakers as an important contributor to a low-carbon future, even though no significant quantities have been produced by "green" energy to date. However, states, organisations, and companies are striving to address this issue seriously and to initiate corresponding investment projects. For example, in August 2021, projects with a total capacity of 260 gigawatts were announced by an energy consortium in Europe and Australia in particular[1] and in March 2022, a 60 gigawatt plant was announced in Texas, U.S.[2]

Hydrogen produced from renewable energy sources such as wind, geothermal energy and the sun, is referred to as "green". Only water is released during combustion, and no CO_2. Hydrogen can be stored, liquefied and transported via pipelines, trucks or ships; it can be used universally as an energy source.

Content

About This Newsletter

Created for our clients, our Property Matters publication provides an in-depth look at timely and important topics affecting commercial and personal lines of property insurance.

The production of hydrogen is very complex depending on the applied production process, but from a technical point of view it is possible and proven on a large scale. The disadvantage is that the production of "green" hydrogen is currently disproportionately expensive compared to conventional processes, which are predominantly based on fossil fuels. For further optimisation, it will be necessary to develop new technologies and processes, the use of which, however, is associated with corresponding risks.

In this article, after a brief description of what is meant by "green" hydrogen and its characteristics, the fire and explosion hazards associated with it as well as possible protective measures are discussed, in order to conclude with some thoughts for its evaluation from the property insurance point of view.

Green hydrogen

Hydrogen can be produced in different ways.[3] Currently, the vast majority is produced through the use of fossil fuels, mainly natural gas and coal. Hydrogen is also produced as a by-product in refineries and, to a lesser extent, in chlorine gas production. The different production routes can be briefly described as follows, often indicated by colours:

- Green: by electrolysis, powered by renewable electricity
- Blue: with fossil fuels, in which CO_2 emissions are captured.
- Grey: with fossil gas, without CO_2 emissions being captured
- Black: using coal
- Brown: using lignite
- Turquoise: using heat to break down fossil gas as part of the pyrolysis process
- Purple, pink or yellow: by using electricity and heat from nuclear reactors

There are various electrolysis processes for the production of hydrogen. The basic principle is that water is split into hydrogen and oxygen (O_2) in an electrolyser with the help of electric current. If the electricity required for this comes from renewable energies, e.g. wind or photovoltaics, it is referred to as "green" hydrogen. In ideal circumstances, 39 kWh and 9 kg water are required to produce 1 kg hydrogen per electrolysis process.

During the electrolysis process, the protons at the cathode (negative pole) form hydrogen molecules that rise and are collected. The hydrogen produced in this way can then be stored in tank farms, for example, or supplied directly to applications via gas pipelines or other transport options, e.g. for electricity generation in fuel cells to generate energy in the private, commercial and/or industrial sectors. Hydrogen is increasingly being used in the field of carbon-neutral transport, e.g. in fuel cell vehicles, and in the chemical industry, in steel production or in power plants where it is converted back into electricity.

Hydrogen's characteristics

Hydrogen – the most common element in our universe – is present in bound form in almost all organic compounds. It has the lowest atomic mass of all elements: it is 14 times lighter than air and under normal conditions it is a colourless and odourless gas. Above a temperature of -253°C, the gas liquefies to a clear and colourless liquid. It has the highest diffusivity of all gases, is neither toxic nor corrosive or radioactive and burns while producing water without residue with a colourless flame that radiates very little heat.

Hydrogen only occurs bound, e.g. with oxygen as water (H_2O). Hydrocarbons such as methane (CH_4) or petroleum are also important hydrogen-containing compounds. In addition, more than half of all minerals known to date contain hydrogen. In the Earth's atmosphere, it is contained in water vapour.

Hydrogen data

- Burns with invisible flame
- Colourless and odourless
- Explosion limit: 4.0–75.0% by volume in air
- Detonation limit: 18.3–59.0% by volume in air
- Diffusion coefficient: 0.61 cm²/s
- Boiling temperature: -252.77°C = 20.39K
- Melting temperature: -258.60°C = 14.40K
- Auto-ignition temperature: 585°C
- Minimum ignition energy in air: 0.02MJ
- Max. combustion temperature in air at 29% H_2: 2,318°C
- Max. combustion temperature with pure O_2 at 29% H_2: >3,000°C
- Max. flame speed: 346cm/s

The maximum flame speed of hydrogen is about eight times greater than that of hydrocarbon-based gases.

In terms of mass, hydrogen has the highest energy density of the common fuels, but in terms of volume, the energy density of liquid hydrogen is only a third of that of natural gas or a quarter of that of petrol.

Hazards of hydrogen

Hydrogen can, as mentioned, form explosive mixtures with oxygen (oxyhydrogen). Hydrogen has an exceptionally wide explosion range, from 4% (lower explosion limit [LEL]) to 77% (upper explosion limit [UEL]) in air, i.e. even extremely rich mixtures are still ignitable compared to other flammable gases, e.g. methane.

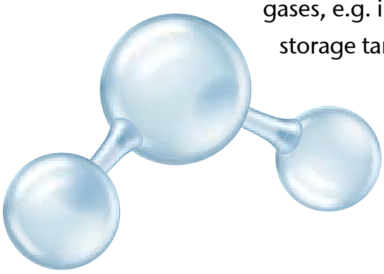
The minimum ignition energy of 0.02MJ at 30% hydrogen in air (stoichiometric mixture) is one of the lowest. Even the smallest electrical sparks, e.g. caused by electrostatic processes in hydrogen flowing out under high pressure, are sufficient to ignite such a mixture. In addition to the usual ignition sources, such as electrical sparks, which generate far more energy, tools falling to the floor or friction from textiles can also trigger ignition.

Compared to other combustible gases, an air-hydrogen mixture has an extremely high flame velocity which is used, among other things, in rocket engines, but which can have a particularly destructive force in the event of unintentional explosions.

Hydrogen burns with a very bright flame that is invisible in daylight. Although the flame burns at over 2,000°C and can reach up to 30m in length depending on the discharge pressure, it emits only a small amount of heat radiation which people perceive as warmth or heat. This is why there is a danger of a person unknowingly being too close to it. Even though the probability of igniting objects in the vicinity is lower than with conventional fuels, a hydrogen flame emits considerable ultraviolet radiation.

Due to its small molecules and low viscosity, hydrogen can escape from pipes and other structures more easily than denser gases. If this happens at sufficiently high pressure, hydrogen can even ignite itself.

Hydrogen diffuses particularly quickly into other gases, e.g. into air. In pipelines and also storage tanks, it can happen that H+ ions are formed on catalytically effective surfaces, i.e. ionised hydrogen, which penetrates the crystal lattice of certain steels, weakens its lattice structure and can cause embrittlement in the material.



Especially at points where there is increased stress in the material, this effect can accelerate the development of cracks as well as material failure and thus lead to leakage. Hydrogen-induced corrosion depends on various conditions, such as the type of crystal lattice (body-centred or face-centred), the surface quality of the metal (defects, fractures, welds) and the prevailing load situation (pressure, stress, temperature, alternating load).

Due to the small size of the hydrogen molecule and the associated high tendency to diffusion, a released hydrogen cloud spreads more rapidly than other flammable gases, e.g. liquid gas, and reaches existing ignition sources more quickly. However, this rapid spread also leads to a rapid dilution of the hydrogen concentration, e.g. in the air, which means that the LEL is undercut sooner than with other combustible gases. In the open air, gaseous hydrogen is therefore hardly detectable because it volatilises immediately after escape, which makes it difficult to find leaks, among other things.

Since hydrogen is much lighter than air, it spreads quickly throughout the available space, especially under a ceiling. Liquefied and cryogenic hydrogen, on the other hand, remains at the point of emission for a longer period of time and can be recognised by the formation of mist in its vicinity, but it also evaporates relatively quickly.

Release in a building is more problematic than in the open air, as ignition sources, e.g. ceiling lamps, are often also located above the point of release. Therefore, in buildings where the escape of hydrogen or other flammable gases is possible (workshops, laboratories), appropriate measures for explosion protection must be taken at least in those rooms or parts of the building that are potentially at risk. What these are depends on the type of building and the probability of a leakage based on a risk analysis. Ultimately, it always depends on the circumstances of the individual case.

If, for example, a fire occurs near a hydrogen tank, it is to be expected that fittings directly exposed to the fire will leak after a short time, causing hydrogen to escape and exacerbating the hazardous situation.

An internet search for damage experiences with hydrogen does not reveal that the hazard posed by hydrogen is higher than that posed by any other comparable flammable medium. In this respect, it can be assumed that hydrogen does not pose any novel risks. It becomes problematic along the hydrogen value chain, where human errors, e.g. during transport, filling or maintenance of the plants, cannot be ruled out.

Therefore, an individual risk assessment is recommended for industrial hydrogen plants in order to plan safety and establish appropriate guidelines.

Possible protective measures

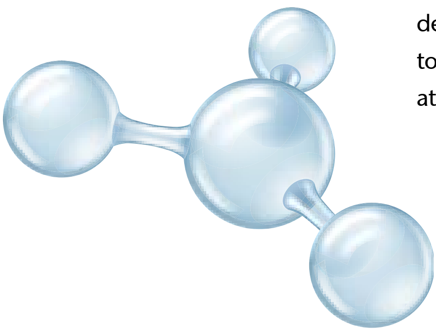
A particular challenge with hydrogen is its high risk of explosion. Consequently, in many areas of a hydrogen plant, the components must be designed for use in potentially explosive atmospheres in order to counteract the pressures generated during production as well as the highly flammable nature of hydrogen gas.

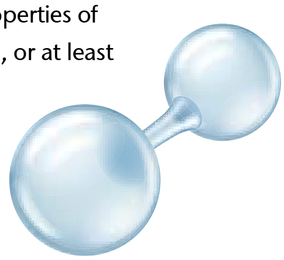
In many countries there are numerous international and national regulations on explosion protection, e.g. DIN EN IEC 60079[4] and DIN EN ISO/IEC 80079[5]. Among other things, these regulate which areas are considered potentially explosive. On this basis, appropriate measures are prescribed for primary (e.g. avoiding the occurrence of explosive atmospheres), secondary (e.g. avoiding ignition sources) and tertiary explosion protection.

The aim of primary explosion protection is to prevent the formation of hazardous explosive mixtures. In the present case, this means preventing hydrogen from being released in production, storage and transport facilities, e.g. pipelines, by means of sufficiently tight plant components. To this end, detachable connections should be kept to a minimum and hydrogen-carrying plant components should be protected from mechanical damage.

In order to avoid leakage, e.g. material embrittlement due to the use of unsuitable material, it is important to consider the operating conditions (gas pressure, temperature, mechanical load) in addition to the selection of materials. For this reason, stainless steel and composite materials are generally used for storage tanks, for example.

In addition, the immediate surroundings of hydrogen plants should be monitored by means of leakage detection detectors and gas detectors to prevent explosive atmospheres from forming in the first place. The selection of suitable sensor technology should be made according to the local risk conditions. The necessary sensors should be placed near the possible points of leakage and, taking into account the properties of hydrogen, at the highest point of the room, or at least as high as possible.





The alarm should report locally and to a permanently manned position. It should also be ensured that an effective ventilation strategy removes hydrogen from the room as quickly as possible, e.g. by automatically-opening window/roof openings or by activating vent fans when a gas alarm is triggered, before the mixture concentration exceeds the LEL. The gas supply should be automatically shut off to keep the quantity of escaping gas to a minimum. In addition, regular inspections and maintenance are essential to identify leaks at joints and along pipelines.

Secondary explosion protection includes measures that prevent the ignition of hazardous explosive atmospheres. This includes the safe design of electrical and other installations in spaces where the formation of a mixture cannot be completely excluded. Where possible, alternatives to electrical components should be used, e.g. pneumatic valves instead of solenoid valves. Proper earthing of all relevant parts and conductive floors should also be considered to avoid static discharges.

In addition, there is constructive ("tertiary") explosion protection, which limits the effects of an explosion. This means designing the installations and buildings in which an explosion could occur in such a way that they can withstand an explosion with limited damage (e.g. explosion-venting, explosion-resistant or explosion-pressure shock-resistant design) and that no people are endangered (e.g. pressure relief openings, discharge, etc.). It is therefore not a question of preventing an explosion, but of limiting the damage it causes.

Particular attention should be paid to how hydrogen spreads in the event of an unexpected release. Hydrogen accumulates in buildings/rooms especially below the ceiling, so suitable vents should be provided there. However, good ventilation of rooms should also be ensured in general.

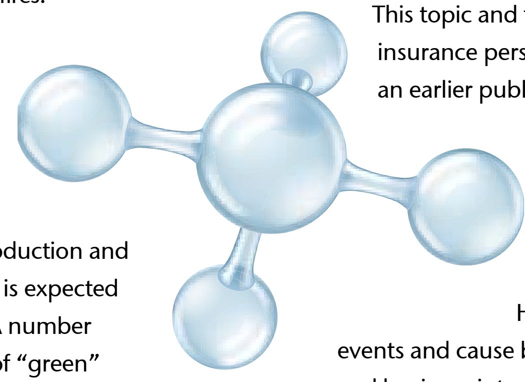
Equipment and machinery should be carefully maintained according to the manufacturer's recommendations. A combination of predictive maintenance, preventive maintenance measures and periodic maintenance procedures is recommended, e.g. predictive maintenance through the recording of process parameters such as temperatures, pressures, gas concentrations in the air, gas concentration in oxygen in the closed plant section, and cell voltages. Regular evaluation of the datasets obtained in this way can reduce risks and minimise plant downtimes.

It should be noted that CO_2 fire extinguishing systems must not be used in buildings/rooms where hydrogen can escape, as static electricity can be discharged when CO_2 escapes from the extinguishing nozzles, which can then ignite the hydrogen-air mixture. An alternative is, e.g. a nitrogen inert gas system.

Organisational fire and explosion protection should not be neglected. Special emphasis should be placed on training staff in the handling of hydrogen. This includes, among other things, emergency training with clear schedules and the assignment of responsibilities. Danger areas should be appropriately marked with warning signs and sufficient safety distances should be established in the vicinity of stationary hydrogen storage facilities so that burning escaping hydrogen does not cause any subsequent fires.

Thoughts on underwriting

The demand for insurance for the construction and operation of electrolysis plants and pipelines for the production and transport of "green" hydrogen is expected to increase in the near future. A number of projects for the production of "green" hydrogen have been announced by various countries or are already being realised.



Insurers should therefore develop a more detailed underwriting approach for this segment to capture the risks associated with "green" hydrogen production, storage and transport. While the basic technologies and processes are known, increasing optimisation measures are to be expected in order to reduce the costs of extracting and using the hydrogen thus obtained.

Along with this, new technology and process approaches (partly prototypes) are to be expected, which may be accompanied by additional risks. The risk of fire or explosion with the corresponding damage to property and loss of earnings can be considerable. In business interruption insurance, long delivery times are to be expected in the event of the failure of individual components or systems, among other things.

Essentially, similar considerations apply to hydrogen production/storage plants and transport systems as to existing energy risks such as for components in power stations, photovoltaic systems, and wind turbines.

Further questions arise in the context of a potential business interruption insurance. What impact has changing to reserve power sources from e.g. conventional power generation on the calculation for business interruption claims (additional cost) in the event of a failure of renewable energy based on an insured event (or damage)?

Another question is to what extent damage to a wind turbine or photovoltaic plant can be considered as business interruption damage of a hydrogen plant.

On the other hand, it is to be expected that the electricity generated from renewable energies will be temporarily stored, e.g. in large-scale lithium-ion storage facilities (BESS) to ensure a constant energy supply when the sun or wind are not available. Such facilities also represent an exposure that should not be neglected, entailing a not inconsiderable property and business interruption risk.

This topic and the associated risks from a property insurance perspective have been highlighted in an earlier publication.[6] The information contained therein should be taken into account accordingly if such energy storage facilities are included in the cover.

Summary

Hydrogen can lead to fires and explosion events and cause both significant property damage and business interruption damage. Hydrogen has been produced by various processes on a large industrial scale for more than 100 years; in the future, these production processes are to be largely replaced by the production of "green" hydrogen. In this process, the electricity needed for electrolysis is generated by renewable energies (wind and sun). So far, this process is significantly more cost-intensive than conventional methods, but optimisations are being pursued at full speed.

Hydrogen is a gas characterised by an extremely high explosion range in air. In this respect, it is also necessary for insurers to deal with the associated risks in the production, storage, transport and consumption of hydrogen. Preventive protective measures of primary, secondary, tertiary explosion protection as well as organisational measures can, in addition to personal injury, prevent possible losses in property and business interruption insurance or significantly reduce their effects. However, this requires that such risks are recognised and assessed accordingly.

Further reading

Energieträger Wasserstoff: Grundlagen, Anwendung, Speicherung, Infrastruktur; published by ASUE (Arbeitsgemeinschaft für sparsamen und umweltfreundlichen Enregieverbrauch e. V.), https://www.asue.de/sites/default/files/asue/themen/bio-erdgas/2020/broschueren/ASUE_Energietraeger-Wasserstoff_2020-02_Online.pdf (German only).

Reinhold Wurster, LBST/Dr Ulrich Schmidtchen: DWV Hydrogen Safety Compendium, November 2011, https://www.dwv-info.de/wp-content/uploads/2015/06/Wasserstoff_kompendium.pdf (German only).

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Endnotes

1 Largest proposed green hydrogen production projects worldwide based on electrolyser capacity as of August 2021, https://www.statista.com/statistics/1011849/largest-planned-green-hydrogen-projects-worldwide/
2 https://www.rechargenews.com/energy-transition/world-s-largest-green-hydrogen-project-unveiled-in-texas-with-plan-to-produce-clean-rocket-fuel-for-elon-musk/2-1-1178689
3 https://www.asue.de/sites/default/files/asue/themen/bio-erdgas/2020/broschueren/ASUE_Energietraeger-Wasserstoff_2020-02_Online.pdf
4 https://www.dke.de/de/normen-standards/dokument?id=7115571&type=dke%7Cdokument
5 https://www.beuth.de/de/norm/din-en-iso-iec-80079-34/290448402
6 Leo Ronken, "Large Battery Storage: Underwriting Challenges and Guidance", October 2021, General Reinsurance AG, https://www.genre.com/knowledge/publications/2021/october/pmint21-3-en.

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