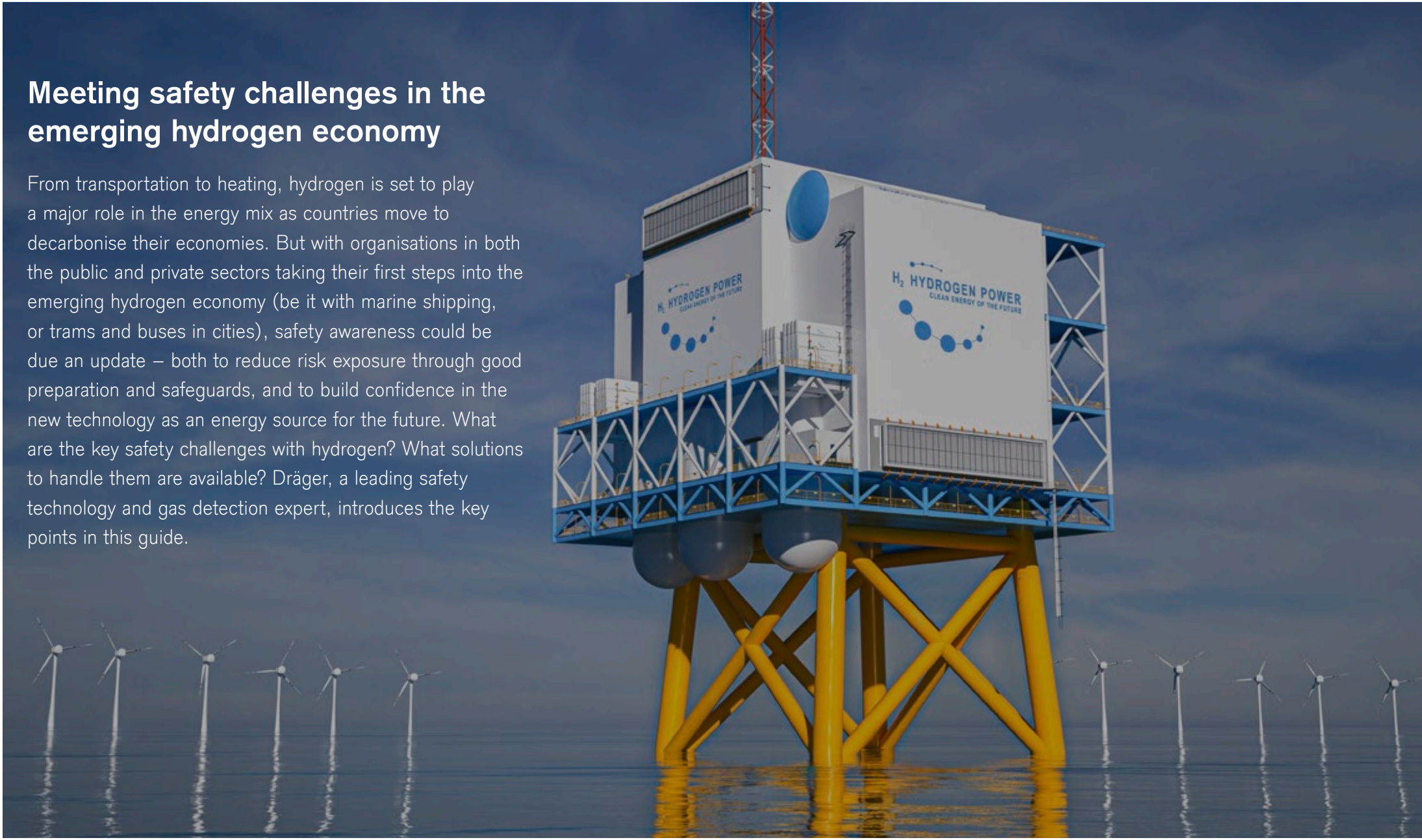
Dräger

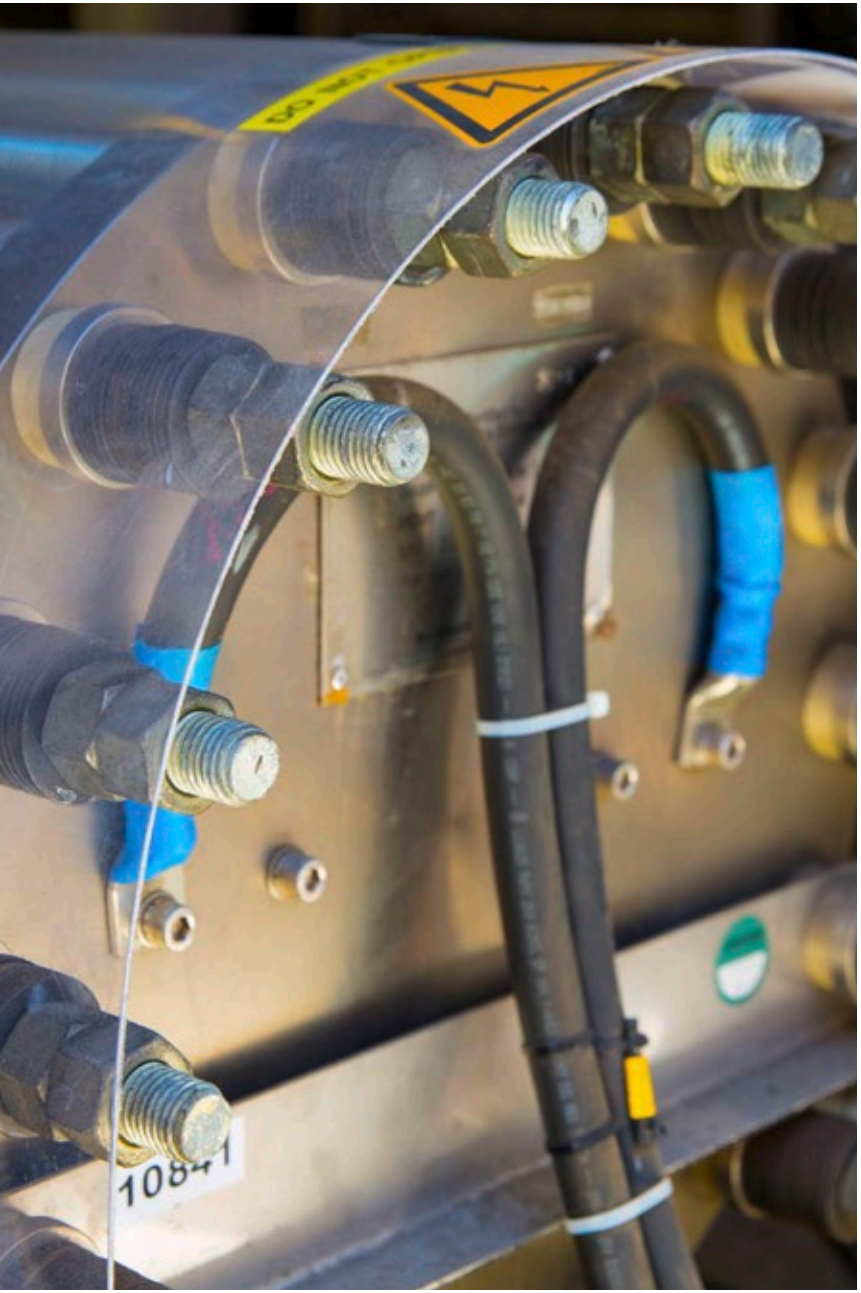
Hydrogen:
How to meet the safety challenges

Production, storage and transport of hydrogen bears special safety risks. To handle them needs expert knowledge in all phases of the process.

Meeting safety challenges in the emerging hydrogen economy

From transportation to heating, hydrogen is set to play a major role in the energy mix as countries move to decarbonise their economies. But with organisations in both the public and private sectors taking their first steps into the emerging hydrogen economy (be it with marine shipping, or trams and buses in cities), safety awareness could be due an update – both to reduce risk exposure through good preparation and safeguards, and to build confidence in the new technology as an energy source for the future. What are the key safety challenges with hydrogen? What solutions to handle them are available? Dräger, a leading safety technology and gas detection expert, introduces the key points in this guide.





Hydrogen is key to global clean energy initiatives

As countries move ahead on climate pledges undertaken in the Conference of the Parties (COP21) Paris agreement,[1] initiatives are underway worldwide to commercialise hydrogen energy. Government investments in Europe and Asia already top US$ 2 billion,[2] with much more planned. In its bid to be the first climate-neutral continent by 2050, Europe plans to meet 25 % of its future energy needs with hydrogen.[3] The resulting 2,250 terawatt hours (TWh) would replace fossil fuels now used for heating, transport, power generation and buffering, and industry, and would eliminate 560 Mt of CO2 emissions.[4] Japan, which recently adopted a net-zero-emissions target by 2050, aims by then to increase hydrogen production to 20 million metric tons (which would be equivalent to the power output of over 30 nuclear reactors).[5] And in the USA, analysts already forecast that by 2050 the country could meet around 14 % of its energy needs using "green" hydrogen from low-carbon sources.

These national-level goals are increasingly driving adoption of hydrogen technologies across the public and private sector.

HYDROGEN: FUEL OF THE FUTURE

Targets / Forecast by 2050:

EUROPE

- **25%** of energy demand covered
- **2,250** terawatt hours (TWh) produced
- **5.4 million** jobs
- **~EUR 820 bn** annual revenue

USA

- **14%** of energy demand covered from green hydrogen
- **100%** domestically produced

JAPAN

- **20 million** tonnes of hydrogen produced
- Equivalent to **over 30** nuclear reactors

[1] United Nations Climate Change, Conference of the Parties 21
https://unfccc.int/process-and-meetings/conferences/past-conferences/paris-climate-change-conference-november-2015/cop-21
[2] Roadmap to a US Hydrogen Economy 2020
https://static1.squarespace.com/static/53ab1feee4b0bef0179a1563/t/5e7ca9d6c8fb3629d399fe0c/1585228263363/Road+Map+to+a+US+Hydrogen+Economy+Full+Report.pdf
[3] Hydrogen Roadmap Europe 2019
https://www.fch.europa.eu/sites/default/files/Hydrogen%20Roadmap%20Europe_Report.pdf
[4] Hydrogen Roadmap Europe 2019
https://www.fch.europa.eu/sites/default/files/Hydrogen%20Roadmap%20Europe_Report.pdf
[5] Strategic Roadmap for Hydrogen and Fuel Cells, Japan Ministry of Economy, Trade and Industry, 2019
https://www.meti.go.jp/english/press/2019/pdf/0312_002a.pdf

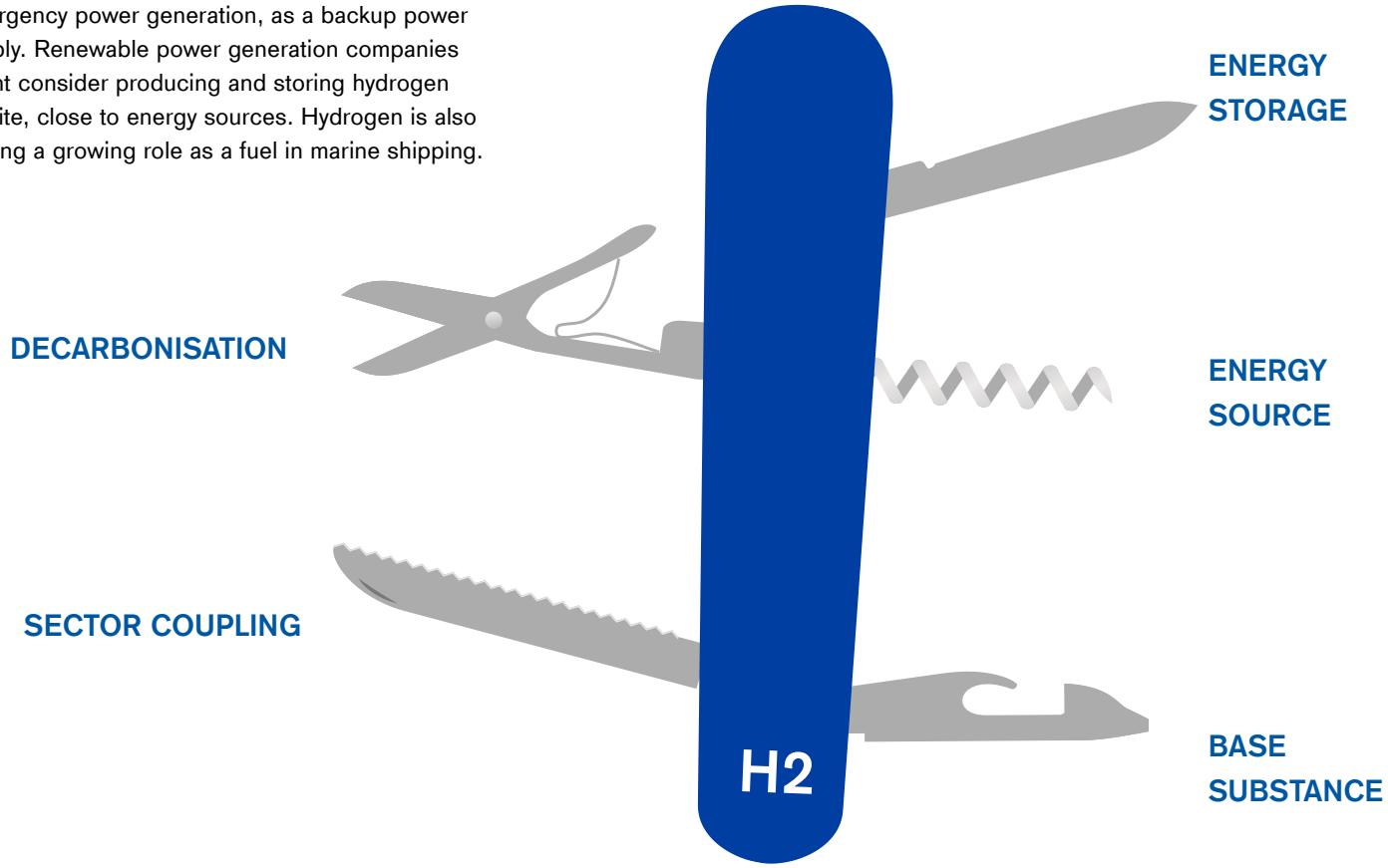
The multitool of energy solutions

It is no surprise that hydrogen features so prominently in emissions reduction plans. Dubbed the “multitool of energy solutions”, hydrogen is a versatile, clean vector in the bid to achieve net-zero carbon. Apart from reducing carbon emissions in traditionally difficult to decarbonize industries such as cement manufacture, it can be used in fuel cells to produce electricity and heat, be blended with natural gas or synthetized to kerosine.

Hydrogen is the only at-scale technology that can be used to store, transport and distribute energy over large geographies and between sectors (known as “sector coupling”). “Green” hydrogen – produced from wind or solar power and considered to be the only sustainable hydrogen solution in the long term – can be produced where energy is generated and be distributed to top up energy supplies. Hydrogen can also be used as a base substance in the production of ammonia and fertilizer (to date met by hydrogen from fossil fuels).

Hydrogen use is already being ramped up at all levels. Within the next ten years, hydrogen-powered transport, blended hydrogen heating, industry heat and feedstock, and power generation with hydrogen are expected to have a significant mass-market impact.

Public transport providers looking for ways to reduce their carbon footprint might turn to green hydrogen to power trams, trains and buses. Logistics companies see new opportunities with hydrogen as a fuel for fork-lift trucks on the shop floor. Others use it for emergency power generation, as a backup power supply. Renewable power generation companies might consider producing and storing hydrogen on site, close to energy sources. Hydrogen is also playing a growing role as a fuel in marine shipping.



[6] Roadmap to a US Hydrogen Economy 2020
https://static1.squarespace.com/static/53ab1feee4b0bef0179a1563/t/5e7ca9d6c8fb3629d399fe0c/1585228263363/Road+Map+to+a+US+Hydrogen+Economy+Full+Report.pdf

Heavyweight safety for a lightweight gas

Hydrogen is increasingly used by organisations to replace other fuels. Many of these new hydrogen users, although otherwise safety-aware in their systems and procedures, may be unfamiliar with the special challenges, safeguards and infrastructure required with hydrogen. Some may have knowledge of working with LPG as a fuel, for instance, but this has only limited applicability for working with hydrogen. As Dräger has experienced in numerous projects with customers, covering everything from advice on basic risk and safety considerations to safe practice in system maintenance, there is considerable demand for guidance on the practicalities of working with hydrogen.

The broader the rollout, the greater the need to raise awareness of the safety challenges – and how best to address them.

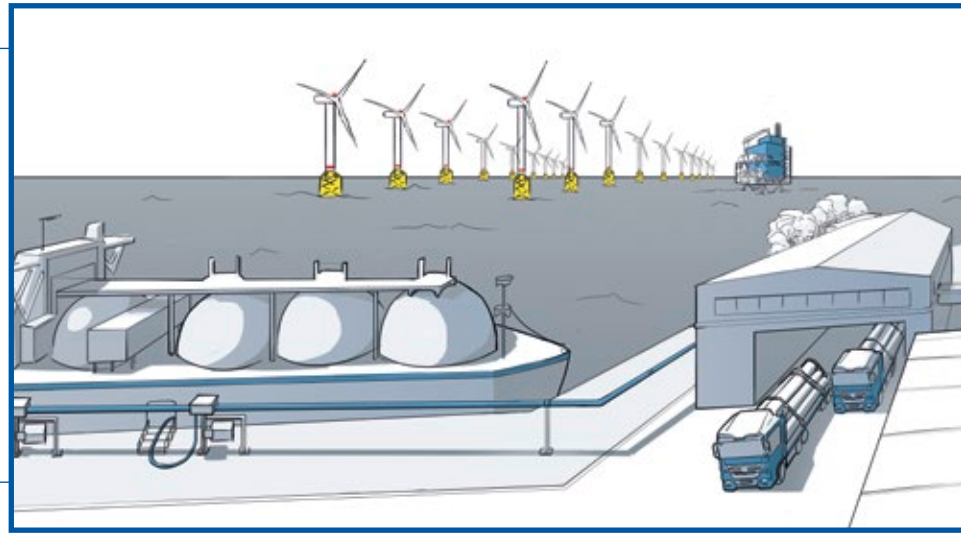
HYDROGEN PROFILE

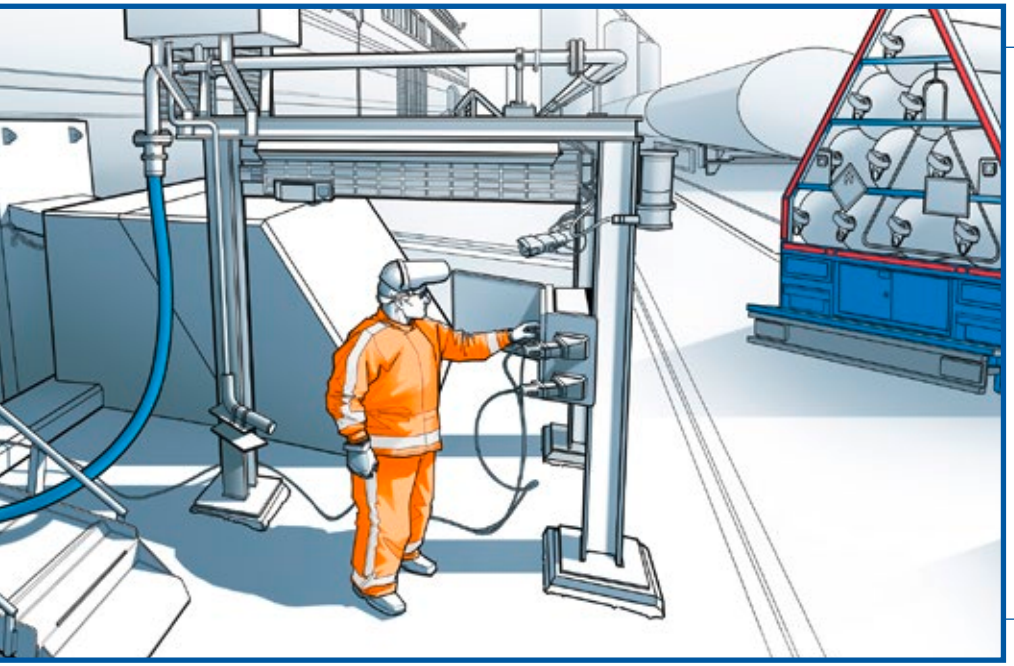
- ODOURLESS
- COLOURLESS
- PALE FLAME
- EXPLOSIVE

Applications and safety considerations

Hydrogen production (Power to X, which can be liquid or gas)

Although hydrogen is today produced chiefly from fossil fuels, carbon neutrality initiatives worldwide are expected to make far greater use of “green” hydrogen, generated from renewable sources, as well as “blue” hydrogen, which uses carbon capture and storage to avoid carbon emissions. Wind and solar farm operators could choose to produce green hydrogen via electrolysis on site for onward transport. This presents safety challenges which may be new to operators. Especially at the start of production, hydrogen is under extremely high pressure and is highly flammable. The flame itself is virtually invisible, which means plants require excellent safeguards against explosions.





Hydrogen storage and distribution

The midstream link in the value chain is about getting hydrogen from the point of production to the point of consumption. In many cases, hydrogen can be shipped to markets using existing infrastructure. Europe, for example, has well distributed and maintained gas networks and pipelines that can be used for hydrogen, although this requires monitoring and maintenance to be adapted. In shipping, dedicated bunkering stations serve to supply hydrogen as fuel to ships (e.g. truck to ship or shore to ship). In this sector, one common risk is of leaks at connector points along extensive pipeline networks.

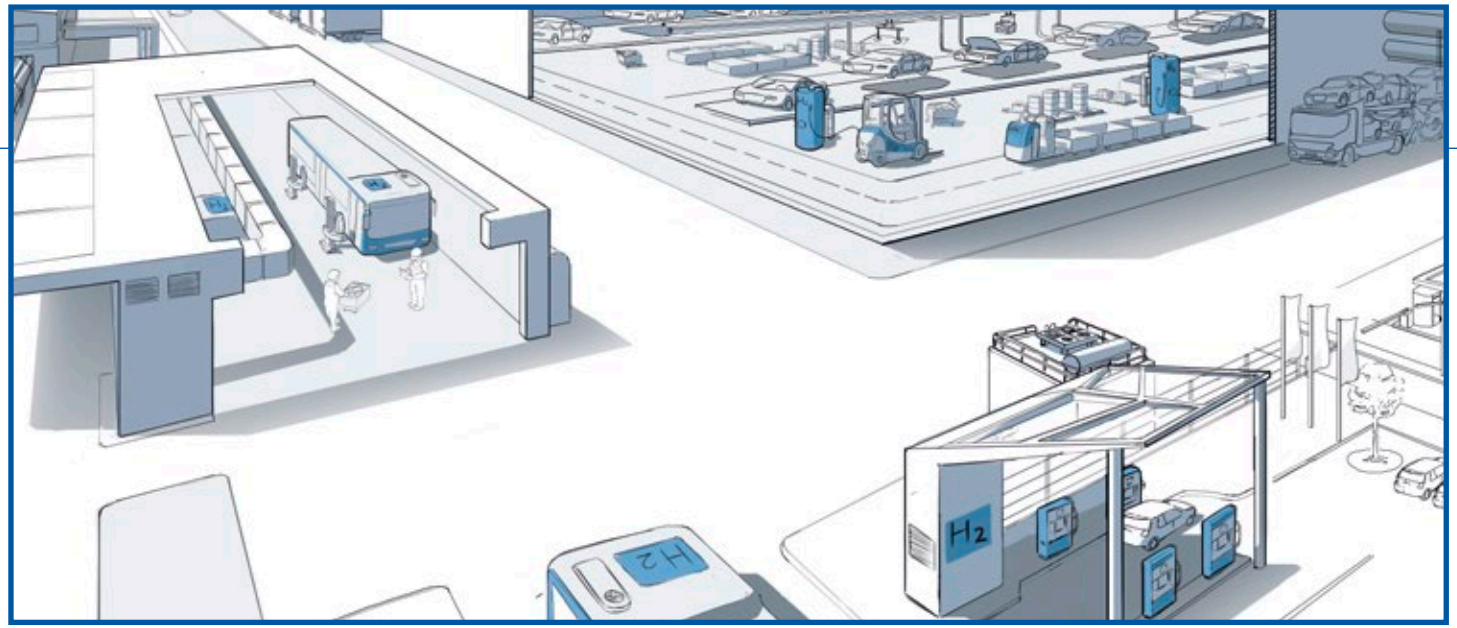
Most facilities, including tanks and valves, are safe, but the probability of safety incidents increases when people are involved. When heavy machines such as trucks are moved around, even minor bumps need to be taken seriously as they increase the risk of leakage.

Hydrogen fuel consumption

Hydrogen is increasingly emerging as a power source for applications that would previously have depended on fossil fuels. One key sector is mobility, at present one of the world's most fossil fuel-dependent sectors. (In the EU, for example, analysts have calculated that a 90 % reduction in emissions in this sector will be needed by 2050 to achieve net zero emissions.[7]) Fuel cell electric vehicles (FCEVs) are an obvious solution because they produce no tailpipe emissions. Hydrogen is used where electricity is not directly feasible, for long-distance transport for example (buses, trains, trucks and maritime transport).

An entire value chain has emerged around the hydrogen consumption sector, comprising activities such as fuel cell production, the associated service infrastructure such as fuel stations or repair shops, as well as facilities for garaging vehicles. In these areas, it is often the case that organisations extend their core business to embrace hydrogen, meaning that the requisite

hydrogen safety experience must be built up.



[7] European Environment Agency 2020
https://www.eea.europa.eu/themes/transport/term/increasing-oil-consumption-and-ghg

The special safety challenges of hydrogen

Hydrogen does not impose major new risks compared to other fuels, and the actual hydrogen fuel cell is a very safe unit. The trouble spots occur where people are involved in tasks along the hydrogen value chain, from production to use – refilling tanks, for example, transport and maintenance. Even though specific challenges differ between applications, plant safety is common to all – and this involves all the measures to ensure safe installation, maintenance and operation of plant and equipment. Here are some of the risk factors which Dräger explores in projects with customers:

EXPLOSION
Unlike actual explosives, pure hydrogen cannot explode. The risk comes when it hits the air. For hydrogen to cause an explosion, oxygen needs to be present, and its volumetric concentration needs to be between 4 % and 77 % by volume in air, the Lower and Upper Explosion Levels (LEL and UEL). But if hydrogen is allowed to escape, even a static spark from clothing would be enough to set off an explosion.

INVISIBLE FLAME
Hydrogen burns with a very pale flame that is invisible in daylight. Because it emits little of the infrared radiation that humans perceive as heat, it cannot be sensed as heat (and is also less likely to ignite objects in the vicinity). A hydrogen flame does however emit substantial ultraviolet radiation. Special UV detectors are therefore required to alert to the presence of hydrogen flames.

LEAKS
Owing to its small molecules and low viscosity, hydrogen can leak from pipelines and other structures more easily than denser gases. In fact, when it leaks from a pipe at sufficiently high pressure, hydrogen can even self-ignite. As well as pipelines engineered to hydrogen-ready specifications, regular inspection is imperative to detect leak points at joints and along pipelines. Fixed leak detectors add another layer of safety.

PERMEATION
Hydrogen can easily permeate materials and in some cases embrittle them. For this reason, stainless steel and composite materials are typically used for storage tanks.

CO ALARMS
Carbon monoxide (CO) sensors are cross-sensitive to hydrogen. If used near possible hydrogen exposure, CO sensors should be compensated for hydrogen so that cross-sensitivity and false alarms are reduced to a minimum.

GAS POCKETS
Like ammonia and methane, hydrogen is less dense than air and forms gas pockets below indoor ceilings when leaking. The presence of hydrogen will not be perceived at ground level, even when dangerous amounts are accumulating beneath the ceiling. When hydrogen and methane are mixed, hydrogen can form gas pockets above methane. Hydrogen detectors are therefore typically placed at the top, with methane detectors below that level.

ODOURLESS AND COLOURLESS
Hydrogen has no smell and no colour, so is undetectable for humans. With methane, this issue is mitigated by adding odorants, and research is in progress to determine whether this will also be possible with hydrogen. Gas and leak detectors are essential.

Assessing the risks – planning for safety

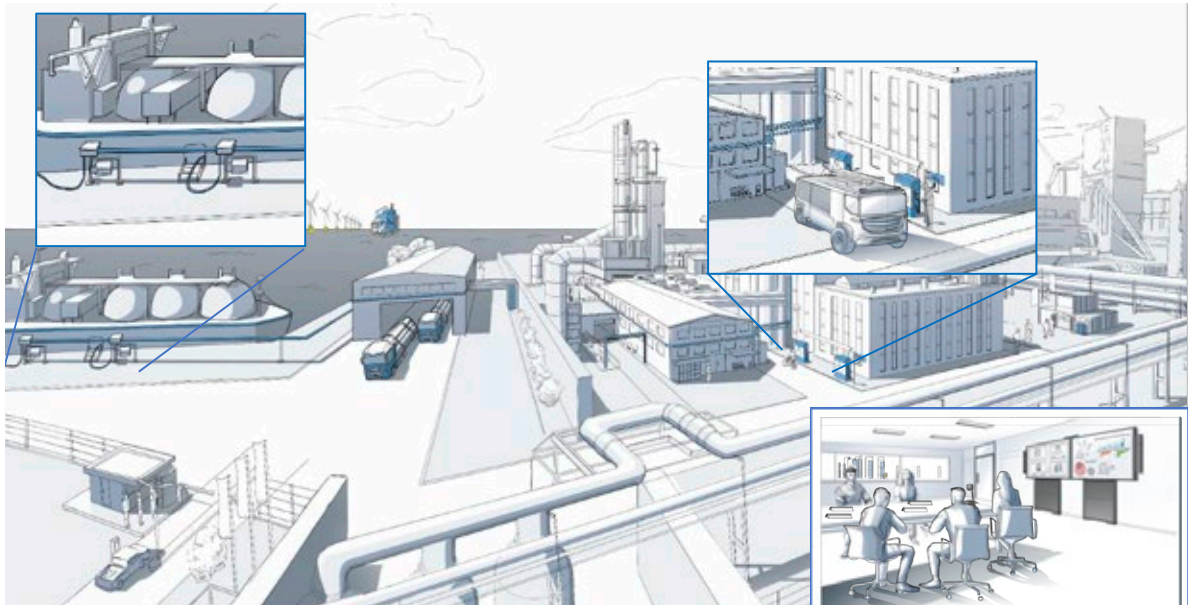
The landscape of risks, although broad, should not stand in the way of widespread ramp-up of hydrogen as a source of power. All these risks can be mitigated. Therefore, before joining the hydrogen economy, organisations need to conduct an individual risk assessment. This enables plant and operations managers to plan for safety and establish best practice as they introduce hydrogen use. There is no standard risk profile, and the risks manifest differently depending on the infrastructure. When Dräger conducts a risk assessment with stakeholders, the objective is to help organisations to understand on a fundamental level what it means to use hydrogen, to identify their specific safety challenges, define safety metrics, quantify risk and reduce it to an acceptable level. Gas measuring and warning systems are one key element of risk control which organisations need to engage with in accordance with legal and regulatory requirements and their own circumstances. Only after thorough analysis can the project proceed to designing and installing gas detection infrastructure, and training staff. Dräger is able to channel decades of expertise in gas detection technology into ensuring organisations gain the insights (and confidence) to work safely with hydrogen.

If hydrogen is to be stored, for instance, the assessment will explore planned storage locations; in alignment with the identified risk, Dräger experts will propose the specific type and placement of detectors. One key consideration is working out where the gas will go if it escapes: will hydrogen bubbles, for example, form undetected beneath ceilings? Efficient incident prevention also means integrating gas detectors into an internal alarm management system. Is an effective ventilation system in place which can be activated by an alarm? Advanced technology, such as flame and gas mapping, help to develop suitable solutions for specific organisational needs. It is also important to plan a rescue concept to flank preventive measures. This includes rescue and emergency training, with clear plans on the course of action, such as first aid, treatment and recovery. The number of users is also assessed (together with the type of staff training required).

REGULATORY FRAMEWORKS

Regulatory frameworks for working with hydrogen are especially strict, and companies also need to consider their compliance. In Germany , any company working with FCEVs, for example, is subject to rules for fuel cell storage and refills.

Transport companies running hydrogen-powered trams or buses need to observe rules for garaging their vehicles. Hydrogen sensors are mandatory to check for gas in hollow spaces such as wheel cavities. Tanks must be emptied outside. To prevent static discharge, precautions must be taken to ground components, for example by ensuring the ground in working areas is conductive. Large refineries and chemical plants that regularly handle flammable gases or chemicals will be familiar with the risks of improper grounding, but the same cannot be said for new users. In-depth knowledge of explosion protection requirements and standards is essential for selecting the right protections such as gas detection systems. Dräger's expert local contacts are familiar with international safety standards as well as national authority and production technology standards. There are also health and safety rules to consider, and HSE managers have a key responsibility for the safety of the employees. With its decades of experience in gas detection and personal protection, Dräger frequently helps customers steer a path through the plethora of HSE and plant safety regulations and advises on measures to take.



Safety solutions with Dräger

Gas detection systems are only as effective as the planning which goes in to them. Therefore, after the risk assessment comes the planning and project engineering stage. The projects that work best are those which can call on expert guidance throughout. This is why Dräger has established a global network of system centres with teams of specialists in planning, assembly and commissioning. From advising on and planning the gas detection systems, to installation and operational maintenance, Dräger provides end-to-end service, also integrating third-party products (such as horns) or existing solutions to create a seamless safety infrastructure. Through on-site assessments, customers know, for instance, exactly where to place sensors, how sensitive they have to be, and what happens in the event of an alarm.

All these details are difficult for organisations to resolve on their own, and doing so involves huge investment of time and effort. Having identified the specific challenges and risks, we accompany our customers on the rest of the project, with order management and project documentation as well as commissioning of the equipment and training of staff. This ensures organisations receive solutions and installations that are an excellent fit for their situation.

EXPLOSION PROTECTION

Due to the properties of hydrogen, explosion protection by early leak detection is key to ensuring plant and personal safety. Gas detection is regarded as the primary way to protect against explosion by preventing explosive atmospheres from building in the first place. Different detection technologies come into practice to build efficient protection layers.

Hydrogen detecting sensors – from ultrasonic leak detectors to flame detectors with ultraviolet and infrared sensors – provide instant alerts if anything goes wrong. A professional combination of the different technologies offers the highest possible safety level.

Dräger PointGard 2200
Flammable Gas Detector

Dräger Flame 2700
(Multi-IR) Flame Detector

Dräger Polytron(R) 8900 UGLD
Ultrasonic Leak Detector

Dräger X-am® 8000
Multi Gas Detector

Detection technology

CATALYTIC BEAD SENSOR (CATEX)

CatEx sensors detect flammable gases and vapours such as hydrogen below their lower explosive limit (100% LEL). They have good long-term stability and a fast response time. They are mainly used for continuous area monitoring of the ambient air.

FLAME DETECTORS

Hydrogen flames radiate energy mainly in the UV band, so UV flame detectors excel at fast detection of hydrogen flames. As they are susceptible to false alarms from other UV sources, they are best suited to locations that do not contain other potential UV sources i.e., indoor applications. For hydrogen flame detection UV sensors are often combined with an IR sensor in one device. This offers better (but not full) false alarm immunity capability than just UV detection alone.

Multi Infrared (MIR) is another option for hydrogen flame detection. Although standard IR devices cannot detect hydrogen, MIR devices use a combination of IR sensor filters and software analysis to detect flames and reduce false alarms. Specific MIR devices have been explicitly designed to detect the low-level radiation from hydrogen flames using unique sets of IR filters.

ULTRASONIC GAS LEAK DETECTION

Ultrasonic detectors “listen” to high-pressure leaks, and can detect even small leaks very fast. They serve as early warning area monitors: they respond earlier than conventional gas detectors because they register the sound of leaking gas instead of measuring the concentration of accumulated gas clouds.

ELECTROCHEMICAL SENSOR (EC)

EC sensors are a good choice when selective measurements of hydrogen on ppm concentration level are required. They offer advantages such as fast response, high accuracy, great stability and a long service life. This technology is useful for point leak detection and personal air monitoring.

Documentation requirements and smart data analytics

As compliance requirements become stricter, organisations are required to maintain detailed records – for example of measured gas values or alarms – to demonstrate adherence to safety standards. Paper-based documentation and reporting are neither efficient nor often secure enough to demonstrate compliance.

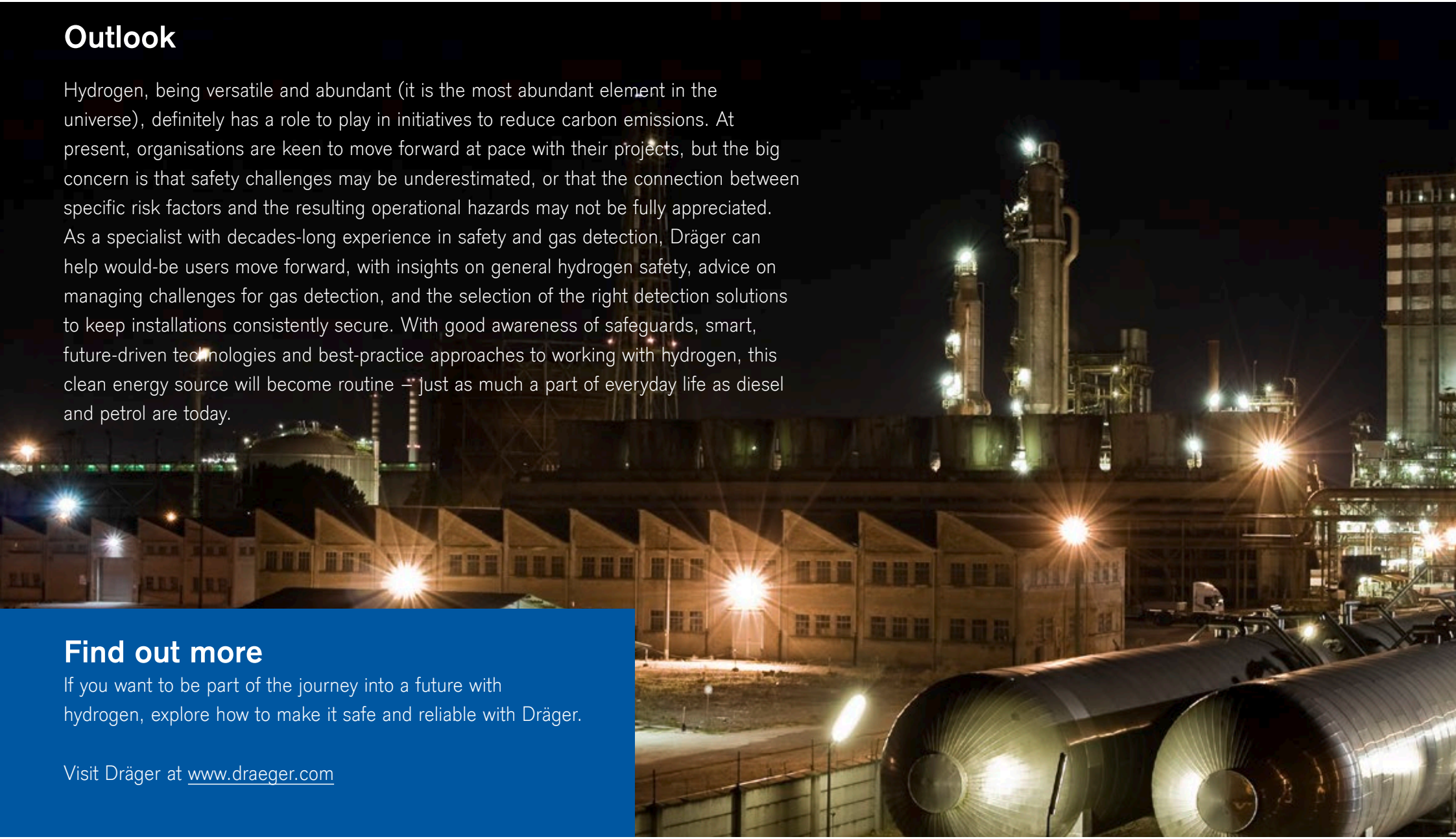
In a bid to raise efficiency of documentation tasks and make use of the large amount of data generated, organisations are turning to solutions with smart data analytics. Data captured by gas detectors are processed in a single, automated workflow that takes care of record keeping, and turns raw data into valuable insights for operational safety. The digital records are more accurate and can be made available faster during audits. Predictions and improvements can also be derived from data patterns. Impending failures can be prevented before they occur, for example, and leaks and defects can be detected before they lead to serious damage.

Dräger: trusted advisor for safety and gas detection

Dräger's experience in gas measurement technology, risk management and plant safety concepts takes organisations through the entire project – from greenfield planning through to installing and maintaining systems.

Outlook

Hydrogen, being versatile and abundant (it is the most abundant element in the universe), definitely has a role to play in initiatives to reduce carbon emissions. At present, organisations are keen to move forward at pace with their projects, but the big concern is that safety challenges may be underestimated, or that the connection between specific risk factors and the resulting operational hazards may not be fully appreciated. As a specialist with decades-long experience in safety and gas detection, Dräger can help would-be users move forward, with insights on general hydrogen safety, advice on managing challenges for gas detection, and the selection of the right detection solutions to keep installations consistently secure. With good awareness of safeguards, smart, future-driven technologies and best-practice approaches to working with hydrogen, this clean energy source will become routine – just as much a part of everyday life as diesel and petrol are today.



Find out more

If you want to be part of the journey into a future with hydrogen, explore how to make it safe and reliable with Dräger.

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