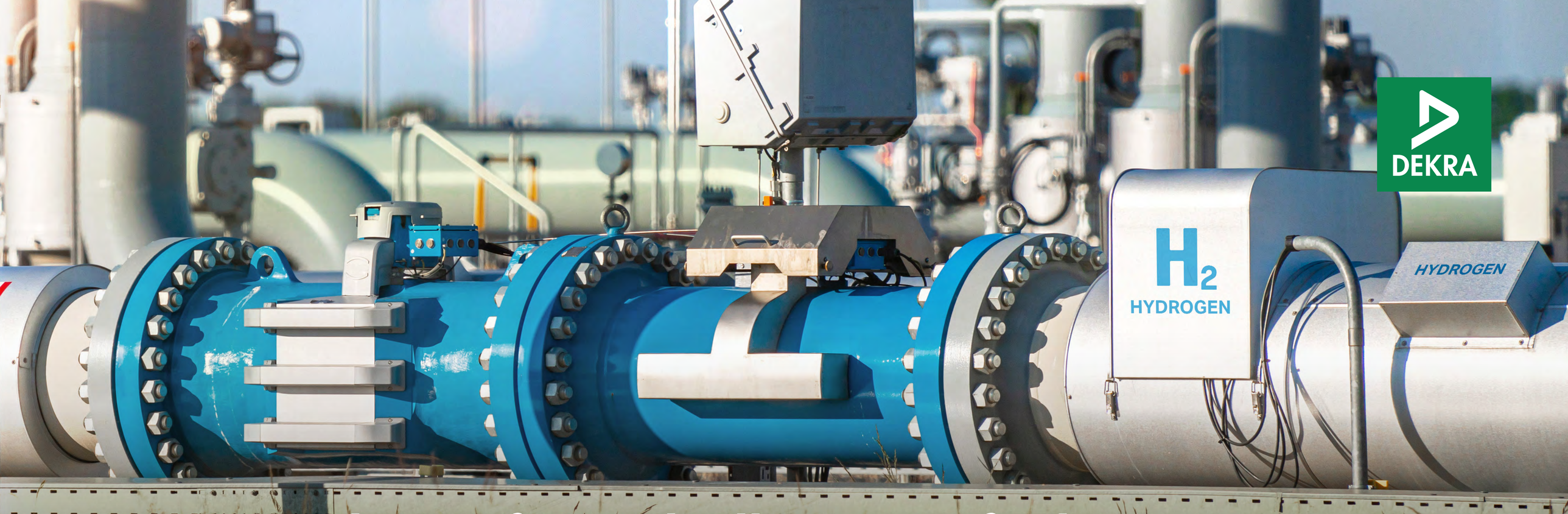

The Safety Challenges of Alternative Energy:
Are We Ready to Manage Risk Exposures Presented by Green Hydrogen?

White Paper

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Green hydrogen and its derivatives represent a promising sustainable form of decarbonized energy use. At DEKRA, we are convinced that a robust process safety model is essential to the sustainable development of the green hydrogen industry at every stage of the product life cycle, from the construction and operation of production facilities to its transport, storage, distribution, and use in the energy consuming mobility, industrial, and building heat sectors.

Green Hydrogen

Hydrogen that has been generated from renewable sources and energies is called green hydrogen. It serves as a fuel source and does not generate CO2, since it does not contain carbon. In addition, it may use little to no carbon-containing fuel in its production. In general, green hydrogen certificates are not standardized but have a CO2 threshold in their definition). Instead, the energy consumption of hydrogen simply generates water. Green hydrogen is a very versatile energy carrier, as it can be transformed into electricity or synthetic fuels and used for domestic, commercial, industrial, or mobility purposes. It represents a particularly important opportunity for sectors that are difficult to decarbonize, such as heavy transport as well as high-temperature processes in industry and aviation, where an electric solution is not available or not commercially preferable and a sustainable fuel is still needed.

Hydrogen Properties and Safety

Hydrogen is a colorless, odorless, nontoxic gas, but it is extremely flammable. Indeed, the ignition of hydrogen requires 15 times less energy than natural gas, and the range of concentration in the air at which hydrogen is flammable is 10 times greater than for gasoline. A hydrogen flame is almost invisible to the human eye.

It has a very low density, 14 times lighter than air and 22 times lighter than propane and diffuses very quickly. In case of leakage, it rises and disperses quickly (at more than 20 m/s).

Because of its low density in the gas and liquid states, extreme conditions are required to store hydrogen. In the gas phase it must be maintained at very high pressures (200 to 700 bar), and in the liquid phase, at cryogenic temperatures (-252.9 °C).

In addition, hydrogen is capable of diffusing even through solids, which entails both the loss of stored fuel that is poured into the atmosphere, as well as the possible embrittlement of the metals used to confine the element.

Safety Management in the Green Hydrogen Industry

As a counterpart to its favorable environmental properties, hydrogen poses quite a few challenges, in terms of safety. Given its properties, it is essential to address hydrogen's explosion risk by adopting appropriate measures, such as equipment suitable for use in classified atmospheres with the presence of hydrogen, ventilation, Hydrogen requires quite particular facilities and materials, as well as very strict asset management programs. Indeed, expertise is needed to ensure that the equipment design, mitigation, and administrative systems that support processes involving hydrogen are appropriate for the risks that are present.

Any facility using or producing hydrogen, even as a byproduct, should consider certain scenarios and factors when carrying out a hazard analysis or similar procedure. These include reactive chemistry concerns and the possibility of runaway reactions, mechanical integrity challenges, and the risk of a high temperature hydrogen attack (HTHA), and human risk factors often stemming from a lack of hazard awareness.

Industrial facilities that generate, process, and store hydrogen involve a certain level of risk to people, the environment, and assets. It is, therefore, important to have sufficient safety mechanisms, as well as adequate risk management, to prevent disasters and to minimize their potential consequences.

Given hydrogen's particular risk profile, safety measures must go far beyond mere compliance with legal obligations, industrial regulations, technical regulations, or design standards. It requires the experienced use of advanced tools for the identification, assessment, and management of risks, as support for administration and decision-making.

In hydrogen facilities, as elsewhere, process safety is integral to and must consider:

- Facility design, engineering, and construction
- Hazard assessment
- Process control and monitoring
- Stable operating procedures in suitable facilities
- Shutdown and startup procedures
- Change management
- Pre-boot management
- Contractor management
- Staff training
- Communication throughout the organization

Two facets of risk management in the industry are safety in design and safety in operations.

Safety in Design

At the design and engineering stage (conceptual, basic, and detailed), plants must be designed with inherent safety as the goal: to minimize internal and external risk. For example, inventory management and facility spacing are important aspects of safe design. Although facilities often try to design systems that prevent a fire or explosion, each facility must be designed with the assumption that ignition can occur in order to help minimize the impact of primary and secondary fires and explosions. Bulk inventories of hydrogen must be located taking into account surrounding facility buildings and units to help limit risk to the surrounding facility and personnel.

It is key, in the design phase, to carry out thorough risk analyses and to apply appropriate techniques to manage all possible hazards.

There are many tools (HAZID, HAZOP, SIL Analysis, LOPA, FMECA, QRA, BRA, FERA, Fire & Gas, ALARP, Bow-tie, ATEX, among others) that can be used, depending on the engineering phase, the project to be developed, the objectives pursued, and the risk management policy that the project's promoter and engineers have defined. Their application yields important safety benefits throughout the facility's lifecycle, such as:

- Identifying dangerous situations
- Evaluating damages
- Determining the probability of a disaster
- Assessing and quantifying risks

Safety in Operations

Process safety management systems that ensure assets are functioning properly are essential. The fundamental pillars of such a system are:

- Commitment to safety at every organizational level, from management to workers.
- An understanding of the risks and hazards arising from the hydrogen production process.
- Risk management tools to facilitate the monitoring of processes, as well as having reliable safety mechanisms in place.
- The ability to learn from experience by translating lessons learned into improvements.

Moreover, ignition source management via bonding, grounding, and ensuring that electrical devices meet applicable hazardous area classification requirements is basic to hydrogen safety in operations, as are leak and flame detection systems.

Finally, human factor assessments can close gaps in hazard awareness and provide step-by-step guidance for carrying out tasks. For process safety to be successful, it must be more than a management system. It must be a fundamental component of an organization's culture. DEKRA has created a solution to foster a positive process safety culture in order to protect people, the environment, and assets.

Organizational Process Safety Diagnosis (OPS)

The technical aspects of avoiding risks are important, but they cannot be implemented effectively without developing organizational competency, culture, and management systems. Facilities that best manage their risk recognize the importance of developing work processes and robust management systems at their facilities. The Center for Chemical Process Safety offers complementary resources to implement a risk-based process safety program that can be scaled based on the complexity of the process and the organization managing the risk. It is unique from other legal requirements in that it introduces a set of management systems in addition to organizational culture and competency-building components.

DEKRA offers an organizational process safety assessment solution that can be used to identify operational blind spots, benchmark management system, and culture against best practices, and helping develop a road map for continual improvement.

The risk-based process safety program helps to:

1. Build competency and skill set among all staff, including frontline workers, their supervisors, and technical support personnel procedures, operational excellence around procedures, and a robust asset integrity program.

2. Build a strong facility culture that is aware of the explosive properties of hydrogen and willing to stop work if conditions seem unsafe

3. Implement robust management systems that establish a technical basis of safety, hazard identification and risk assessments, safe work practices, emergency procedures, operational excellence around procedures, and a robust asset integrity program.

Conclusion and Recommendations

Green hydrogen is an energy vector that can contribute to the decarbonization of the planet. With such high stakes, its development must be accompanied by the highest levels of safety in design and engineering, as well as in operation and maintenance.

The starting point is the presence of knowledgeable, competent personnel prepared to meet the challenges of process safety for hydrogen plants. Secondly, the use of advanced tools for the identification, evaluation, and management of risks is key.

These make it possible to select the appropriate technologies and materials for the construction of the facility and to monitor and analyze risks during operations. They include HAZID, HAZOP, SIL, LOPA, QRA, BRA and FERA, among others. Finally, a Process Safety Management (PSM) system, such as DEKRA Organizational Process Safety, helps prevent adverse events.

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Arturo Trujillo

Arturo Trujillo is Global Director of Process Safety Consulting. His main areas of expertise are diverse types of process hazard analysis (HAZOP, What-if, HAZID), consequence analysis, and quantitative risk analysis. He has been involved in many projects over the last 35 years, especially in the oil and gas, energy, chemicals, and pharmaceutical industries.

DEKRA Process Safety

The breadth and depth of expertise in process safety makes us globally recognized specialists and trusted advisors. We help our clients to understand and evaluate their risks, and work together to develop pragmatic solutions. Our value-adding and practical approach integrates specialist process safety management, engineering and testing. We seek to educate and grow client competence to provide sustainable performance improvement. Partnering with our clients, we combine technical expertise with a passion for life preservation, harm reduction and asset protection. As a part of the world's leading expert organization DEKRA, we are the global partner for a safe world.

Process Safety Management (PSM) Programs

- Design and creation of relevant PSM programs
- Support the implementation, monitoring, and sustainability of PSM programs
- Audit existing PSM programs, comparing with best practices around the world
- Correct and improve deficient programs

Process Safety Information/Data (Laboratory Testing)

- Flammability/combustibility properties of dusts, gases, vapors, mists, and hybrid atmospheres
- Chemical reaction hazards and chemical process optimization (reaction and adiabatic calorimetry RC1, ARC, VSP, Dewar)
- Thermal instability (DSC, DTA, and powder specific tests)
- Energetic materials, explosives, propellants, pyrotechnics to DOT, UN, etc., protocols
- Regulatory testing: REACH, UN, CLP, ADR, OSHA, DOT
- Electrostatic testing for powders, liquids, process equipment, liners, shoes, FIBCs

Specialist Consulting (Technical/Engineering)

- Dust, gas, and vapor flash fire and explosion hazards
- Electrostatic hazards, problems, and applications
- Reactive chemical, self-heating, and thermal instability hazards
- Hazardous area classification
- Mechanical equipment ignition risk assessment
- Transport & classification of dangerous goods

We have offices throughout North America, Europe, and Asia.

For more information, visit www.dekra.us/process-safety

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Do you want to learn more? Contact our experts!

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