The Safety Challenges of Alternative Energy:

Are we ready to manage ***risk exposures*** presented by ***green hydrogen?***

PhD. Jesus Ceballos, Project Manager in Process Safety Management;
Michael D. Snyder, PE, CSP, CFEI, CFPS is the Vice President of Operational Risk Management for DEKRA North America;
Dr. Arturo Trujillo is Global Director of Process Safety Consulting

DEKRA On the safe side.

White Paper DEKRA Advisory and Training

Green hydrogen and its derivatives represent a promising sustainable form of decarbonised 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 CO_2, 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 standardised, but have a CO_2 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 decarbonise 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 colourless, odourless, non-toxic 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 state, 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.

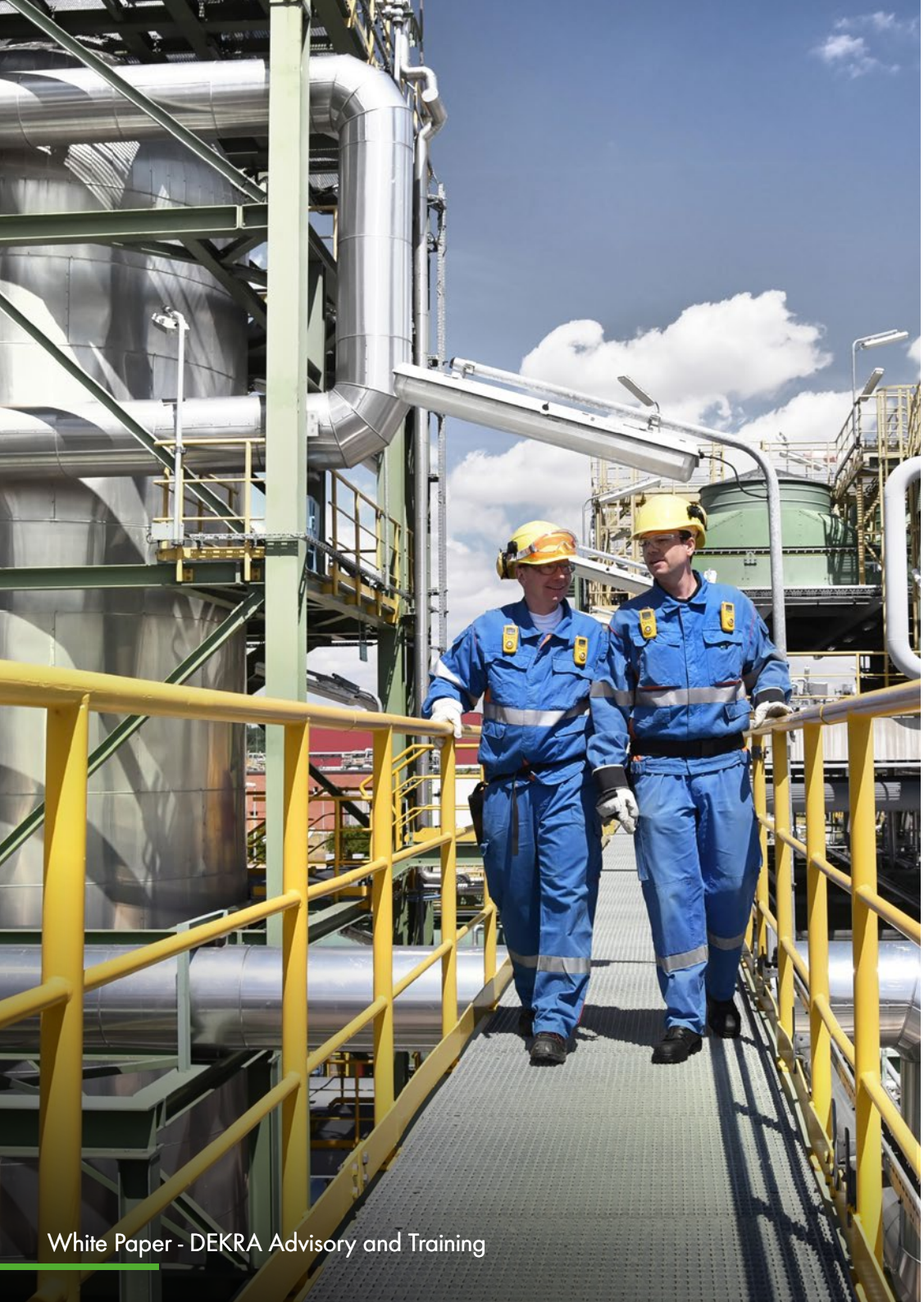
Safety Management in the Green Hydrogen Industry

As a counterpart to its favourable 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, etc. 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 by-product, 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 minimise 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 start up procedures
- Change management
- Pre-boot management
- Contractor management
- Staff training
- Communication throughout the organisation

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 minimise internal and external risk. For example, inventory management and facility spacing is one aspect of safe design. Although facilities often try to design systems that prevent a fire or explosion, the facility must be designed with the assumption that ignition can occur in order to help minimise 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 organisational 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 organisation's culture. DEKRA has created a solution to foster a positive process safety culture in order to protect people, the environment and assets.

Organisational Process Safety Diagnosis (OPS)

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

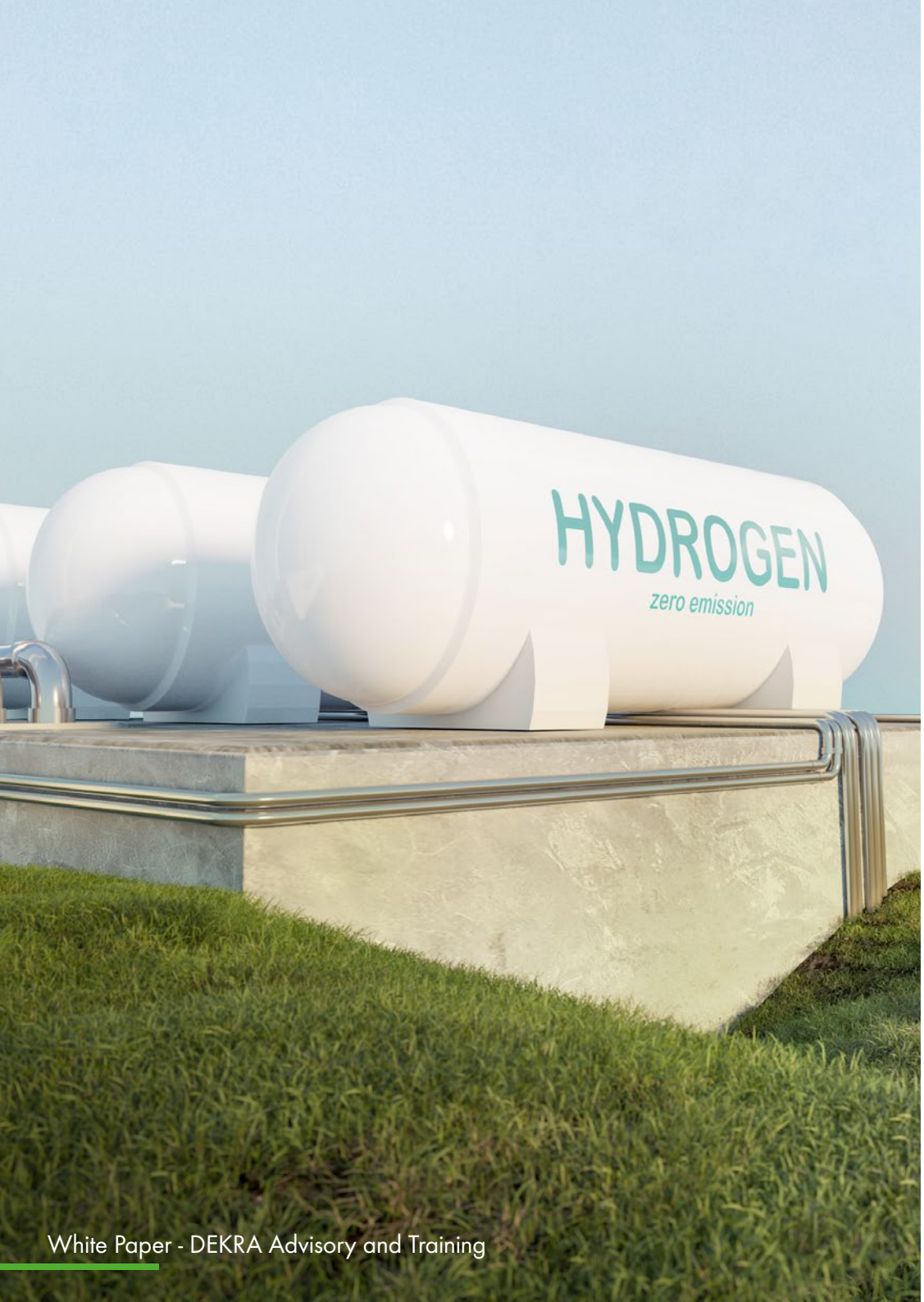
DEKRA offers an organisational process safety assessment solution that can be used to identify operational blind spots, benchmark management system and culture against best practices, and help develop a roadmap for continuous improvement.

The risk-based process safety program helps to:

1. Build the competency and skill development of all staff, including frontline workers, their supervisors, and technical support personnel

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 decarbonisation 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 analyse 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 Organisational Process Safety, helps prevent adverse events.

Do you want to learn more? Contact our experts!

PhD. Jesus Ceballos

Jesus Ceballos is a chemical engineer with a master´s degree in process engineering and a PhD in engineering. He works as a Project Manager for Process Safety Management at DEKRA Chile.

Michael D. Snyder

Michael D. Snyder, PE, CSP, CFEI, CFPS is the Vice President of Operational Risk Management for DEKRA North America and an advisor in chemical process safety testing and consulting services. He was previously the Global Director of Safety and Loss Prevention for Dow Corning Corp, responsible for leading the company's occupational and process safety programs. He current serves on the Center for Chemical Process Safety (CCPS) Governance Board, and is a former member of the National Fire Protection Association (NFPA) Standards Council.

Dr. Arturo Trujillo

Dr. 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 & gas, energy, chemicals and pharmaceutical industries.

Process Safety Advisory and Training Services

DEKRA Organisational and Process Safety is a behavioral change and process safety consultancy company. Working in collaboration with our clients, our approach is to assess the process safety and influence the safety culture with the aim of making a difference.
In terms of behavioral change, we deliver the skills, methods, and motivation to change leadership attitudes, behaviors, and decision-making among employees. Supporting our clients in creating a culture of care and measurable sustainable improvement of safety outcomes is our goal.
The breadth and depth of expertise in process safety makes us globally recognised specialists and trusted advisors. We help our clients understand and evaluate their risks, and we work together to develop pragmatic solutions. Our value-adding and practical approach integrate specialist process safety management, engineering, and testing. We seek to educate and grow client competence in order to provide sustainable performance improvement. Partnering with our clients, we combine technical expertise with a passion for life preservation, harm reduction and asset protection.
We are a service unit of DEKRA SE, a global leader in safety since 1925 with over 45,000 employees in 60 countries and five continents. As a part of the world's leading expert organisation DEKRA, we are the global partner for a safe world.

We have offices throughout North America, Europe, and Asia.
For more information, visit **https://www.dekra-uk.co.uk/en/process-safety-consulting/**
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