D 4.4

Guidelines and good practices for first responders

Under Review

The project is supported by the Clean Hydrogen Partnership and its members.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the Clean Hydrogen Partnership. Neither the European Union nor the Clean Hydrogen Partnership can be held responsible for them.

www.hypop-project.eu
info@hypop-project.eu

#HYPOPPROJECT

D 4.4	Guidelines and good practices for first responders
DELIVERABLE TYPE	Report
MONTH AND DATE OF DELIVERABLE	Month 28, 30/09/2025
WORK PACKAGE	WP 4
LEADER	ENVI
DISSEMINATION LEVEL	Public
AUTHORS	Mattia Miglietta
PROGRAMMA	HORIZON EUROPE
GRANT AGREEMENT	101111933
START	Jun.2023
DURATION	28 Months

Contributors

NAME	ORGANISATION
Mattia Miglietta	ENVI
NAME TWO HERE	ORGANISATION 2
NAME THREE HERE	ORGANISATION 3

Peer Reviews

NAME	ORGANISATION
Ilaria Schiavi	ENVI
María Panadero	CNH2

Revision History

VERSION	ORGANISATION	REVIEWER	MODIFICATIONS
1	ENVI	Ilaria Schiavi	First version for consortium's review
2	ENVI	Mattia Miglietta	Second version after comments from CNH2
3	ENVI	Ilaria Schiavi	Final version for upload

Index of Contents

Index of Tables

Index of Figures

Partners short names

ENVI	Parco Scientifico Tecnologico Per L'ambiente Environment Park Torino Spa
IMI	Institute For Methods Innovation
IME	Fundacion IMDEA Energia
APRE	Agenzia per la Promozione della Ricerca Europea
CNH2	Centro Nacional Del Hidrogeno
RIGP	Regionalna Izba Gospodarcza Pomorza
CLUSTER TWEED	Cluster Tweed
BH2C	Balkanski Vodoroden Klaster

Abbrevations

ATEX	*Atmosphères Explosibles* – EU directives for equipment & workplaces in potentially explosive atmospheres
BoP	Balance of Plant
EES	Emergency Shutdown systems
HAZID	Hazard Identification
HAZOP	Hazard and Operability Study
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
LEL	Lower Explosive Limit
LOI	Limiting Oxygen Index
LPG	Liquefied Petroleum Gas
PPE	Personal Protective Equipment
PSV	Pressure Safety Valve
WFMPT	Wet Fluorescent Magnetic Particle Testing

Executive Summary

HYPOP was created with a simple yet ambitious goal: to help citizens, public authorities, manufacturers and early adopters trust hydrogen technologies, especially in emerging sectors like mobility and residential where the transition is more complex. Specifically, safety, permitting and certification of hydrogen technology are in focus, with the aim of understanding if a common approach throughout Europe is possible. However, listening to stakeholders and analysing cases in different Countries reveals an uneven picture with respect to safety authorisations: rules are interpreted differently in different regions; there are varying levels of technical familiarity with the properties of H_2, and there appear to be fluctuations between prescriptive regulations and risk-based "performance" approaches. This translates into long and unpredictable authorisation processes, inconsistent safety margins (sometimes excessive, sometimes perhaps insufficient), higher indirect costs and, not infrequently, public mistrust.

The HYPOP safety guidelines supports a common approach and rest on two pillars: **technical actions** and **knowledge transfer for public awareness**.

On the technical side, the document provides baseline terminology and concepts to approach hydrogen safety and its enabling technologies, starting from general principles (basic properties of the gas, risk assessment, site selection) to specific points of attention for the single hydrogen technologies. Because hydrogen's **flammability and explosivity** is a defining hazard, we explicitly reference the **ATEX framework** (equipment/operations in potentially explosive atmospheres) and summarise the **most common risk-analysis methods** identified during HYPOP's stakeholder engagement (from qualitative HazID/HAZOP to quantitative tools). Building on these core blocks, we outline the **principal risks**, **preventive and mitigative measures**, and—where relevant—the **practical benefits** for stakeholders that emerge.

The second pillar addresses the **social and acceptance dimension**, offering recommendations and practical actions to tackle: (i) regulatory gaps or divergent interpretations (including between regions/local offices); (ii) limited practical experience of authorities with technical standards, risk methods and hydrogen specifics; (iii) defensive reliance on rules written for other fuels (natural gas/LPG) and partial application of other rules that do not fit hydrogen projects; (iv) iterative, slow procedures due to ad-hoc data requests; and (vi) public distrust.

These recommendations are consolidated into a proposal of **standard, step-by-step safety pathway**—from early authority engagement to proportionate risk assessment, ATEX zoning, barrier selection, and emergency planning—designed to **accelerate approval** while ensuring a **documented, robust safety case** for hydrogen projects.

1 About the project HYPOP

HYPOP – Hydrogen Public Opinion and Acceptance, is a project funded by the Clean Hydrogen Partnership under the European Horizon Europe programme (GA nr.101111933). Its overall objective is to raise public awareness and trust towards hydrogen technologies and their systemic benefits, focusing on mobility and residential applications.

The results presented in this document refer to one of the main foreseen outcomes of HYPOP project: the production of guidelines and good practices that will help to define more effectively how citizens, consumers/end users, and stakeholders can be involved in the implementation of Hydrogen technologies.

The document was built through the analysis of current practices and the interaction with many stakeholders. Target groups of the engagement activities were the technology manufacturers, the early adopters of such technologies and the public authorities (e.g., first responders, municipalities etc) involved in safety, permitting and certification procedures in the different EU countries.

2 HYPOP Guidelines documents

This document is part of a set of guidelines focusing each on one of the following:

- Safety (this document),
- Permitting (Deliverable D4.3) and
- Certification (Deliverable D4.5).

Safety is one of the pillars of the permitting framework, addressed in this D4.3, but it needs a specific focus as it encompasses both social and technical issues. Safety procedures often make reference to certification aspects and/or standards, which are covered in D4.5. Because of these existing links, wherever possible, cross-referencing within the three guidelines has been inbuilt to aid the users.

3 How to use HYPOP Safety Guidelines

Users of this Guidelines should refer to the Table below for a description of the content of this document. While it is recommended that Sections 4 and 5 should be read in full at least once, it might be possible to then refer just to the specific applications of interest described in Section 4.3. Section 6 provides an overall approach that could support interaction amongst the different stakeholders.

Table 1 Guide to the content of the HYPOP Safety Guidelines

Section	Content
4 - Basic principles of Safety of Hydrogen and Hydrogen technologies	It describes the **characteristics of hydrogen as a substance, highlighting their impact on safety.** Knowledge of these properties is essential for understanding basic prevention and mitigation measures. It describes **what a stakeholder must consider when evaluating a project involving individual hydrogen technologies** (the combination of multiple hydrogen technologies generally falls within industrial applications, mobility, etc., described in Sub section 4.3). In addition, there is a mention of the risk assessment and a **specific focus on the ATEX directive**, which must be taken into account by all technologies used in environments where hydrogen is used, as it relates to flammability and therefore to explosive phenomena that could involve people present in an industrial plant with hydrogen production and/or storage, in a refuelling station, whether fixed or mobile, and in residential applications.
4.4 - Interaction with planning: site selection and characterisation *Selecting a* **site for a hydrogen installation becomes an additional factor with significant weight, alongside the safety considerations for individual technologies.** Therefore, the site selection should be based on a multicriteria analysis that accounts for: • Land-use designations and urban-planning compatibility, including	This subsection brings together all safety information, starting with the basic properties of hydrogen, the operation and safety of individual technologies, ATEX analyses and risk analysis methods. This knowledge converges when multiple hydrogen technologies must be channelled into a specific application context. **The chapters of this sub section therefore provide a general approach to safety for different contexts, such as hydrogen production by electrolysis for industrial and other applications, for fixed and mobile refuelling stations, and for fuel cell systems installed in residential contexts.**

Section	Content
constraints for protected species or other environmental limits. • Distances from crowded areas and public buildings. Better avoid congested areas. • Availability of electrical power and water. (Water availability is a risk factor if the site is in a water-scarce area.) • Absence of obstacles that could promote gas stagnation. • Verification of fire brigade/emergency vehicle access and hydrant locations (linked to safety distances). • Interference assessment: overhead power lines, railways, heavy traffic flows, existing ATEX zones, other fuel tanks. More details about some of these aspects are included in deliverable D4.3. Safety approaches for Hydrogen Projects:	

Section	Content
Prevention and Mitigation Measures	
5 – Risk Assessment Methodologies	This chapter describes **what risk analyses are, why they are used and when**. It then provides general information on methodological approaches that should always accompany a hydrogen project, regardless of its application.
6 - HYPOP Recommendations and Actions to accelerate Acceptance and Safety procedures	It sorts the main criticalities, practical actions and recommendations, and the benefits of addressing them. **HYPOP proposes a standard procedure ("HYPOP Safety Guidelines") designed to facilitate interaction between public authorities and designers.** The latter will thus be able to submit hydrogen projects following a safety philosophy that is shared, understandable, and accepted by public authorities (e.g., first responders etc) and citizens in the shortest possible time.
7 – Methodology	It **describes the methodological approach** followed to collect the data necessary to produce the guidelines. It then provides an overview of the stakeholders who contributed, the type of research activities carried out and a graphic summary of the results obtained from the technical research on the safety requirements and barriers identified in Deliverable 2.1.
8 - Conclusions	It provides a recap of HYPOP research undertaken to develop the Safety Guidelines

4 Basic principles of Safety of Hydrogen and Hydrogen technologies

Safety is an intangible construct, open to interpretation and thus presenting limitations for both scientific understanding and practical implementation. In safety engineering, various definitions of safety are proposed. Below are some commonly cited definitions:

- *"Freedom from unacceptable risk to the outside from the functional and physical units considered"* — from the Online Electrotechnical Vocabulary[1];
- *"Freedom from risk which is not tolerable"* — from ISO/IEC Guide 51:2014[2], where risk is defined as the *"combination of the probability of occurrence of harm and the severity of that harm"*;
- *"Freedom from unacceptable risk"* — from ISO 11014:2009[3].

The safety of any installation is closely linked to the concept of risk, which, as defined above, arises from the combination of:

- The **likelihood** that a hazardous event will occur (accidental occurrence), and
- The **severity** of its consequences (how serious the potential damage may be).

This likelihood is not merely a theoretical probability — it also considers:

- How frequently one is exposed to the hazardous situation,
- Whether the harmful event actually occurs, and
- Whether it is possible to avoid or limit the damage (e.g., through alarm systems, safe distances, or staff training).

Hydrogen use entails some risks, linked to the characteristics of the substance itself, as detailed below. However, with proper safety protocols and risk mitigation measures, **hydrogen and hydrogen-based technologies are not inherently more dangerous than conventional fuels or other sustainable solutions alternative to fossil fuels**. Furthermore, these risks are not Country dependent. In other words, **hydrogen safety can and must be ensured in the same way across all EU countries**. This offers the opportunity to adopt **replicable solutions** across borders, leading to a streamlined bureaucratic process and reduced project costs.

The following sub sections aim to provide basic foundations to understand how to deal in general with hydrogen and with specific hydrogen technologies.

[1] https://www.electropedia.org/
[2] https://www.iso.org/standard/53940.html
[3] https://www.iso.org/standard/44690.html

4.1 Safety of Hydrogen: properties and comparisons with conventional fuels

Hydrogen is the lightest and smallest element and is a gas under atmospheric conditions (**standard temperature and pressure conditions, 25 °C and 1 atm).** Hydrogen is a colourless, odourless, tasteless, non-toxic, and non-poisonous substance. It is also non-corrosive, but it can embrittle some metals. Typical physical-chemical hydrogen properties are reported in the following table.

Table 2 Main properties of Hydrogen (some additional educational material[4])

Property	Value	Unit (SI)
Auto-ignition temperature	500	°C
Boiling point (1 atm)	−252.9	°C
Density (NTP)	0.08375	$kg\ m^{-3}$
Diffusion coefficient in air (NTP)	0.610	$cm^2\ s^{-1}$
Enthalpy (NTP)	3858.1	$kJ\ kg^{-1}$
Entropy (NTP)	53.14	$J\ g^{-1}\ K^{-1}$
Flame temperature in air	2045	°C
Flammable range in air	4.0 – 75.0	vol %
Ignition energy in air	2×10^{-5}	J
Internal energy (NTP)	2648.3	$kJ\ kg^{-1}$
Molecular weight	2.02	$g\ mol^{-1}$
Specific gravity (air = 1) (NTP)	0.0696	—
Specific volume (NTP)	11.94	$m^3\ kg^{-1}$
Specific heat, **Cp** (NTP)	14.29	$J\ g^{-1}\ K^{-1}$
Specific heat, **Cv** (NTP)	10.16	$J\ g^{-1}\ K^{-1}$
Thermal conductivity (NTP)	0.1825	$W\ m^{-1}\ K^{-1}$
Viscosity (NTP)	8.813×10^{-5}	$g\ cm^{-1}\ s^{-1}$

**NTP = 1 atm, 20 °C (normal temperature and pression conditions).*

Hydrogen can also exist in liquid form when specific temperature and pressure conditions are met (its boiling point is at −253 °C at 1 atm). The term *cryogenic hydrogen* is often used more generally to refer to hydrogen at extremely low temperatures (liquid hydrogen, therefore, is a cryogenic form).

[4] https://www.h2euro.org/hyfacts/2014/06/26/training-material/

Depending on the specific application, hydrogen is produced and used under different conditions and in its various physical forms.

Table 3 Typical hydrogen forms, operating conditions and applications

State	Temperature range	Pressure range	Typical applications
Gaseous (compressed)	Ambient (20-25 °C)	Up to 700 bar	Fuel cells for vehicles; industrial uses
Liquid (cryogenic)	Below – 252.87 °C	1 atm	Space propulsion; high density storage
Cryo-compressed	– 240 to – 253 °C	200 – 350 bar	Transport and distribution

The Table below includes further properties, useful for safe project development and management including, for example, ATEX zoning of installation sites, safety distances, gas and leakage detectors and protection systems.

Table 4 Useful parameters for safe project development and management (additional educational material[5])

Parameter	Deflagration	Detonation	Unit
Lower flammability limit	4.1	18.3	vol %
	3.6	16.1	g m^{-3} of air
Upper flammability limit	74.0	59.0	vol %
	67	51.8	g m^{-3} of air
Stoichiometric detonation value in air	—	29.53	vol %
Auto-ignition temperature	574	574	°C
Minimum ignition energy	0.02	≥ 10^7	mJ
Maximum flame temperature	2318	2318	K
Explosion energy	—	2.02	kg TNT m^{-3} (gas at NTP)
Burning velocity in air (concentration-dependent)	102 – 325	—	cm s^{-1}
Detonation velocity in air	—	1.48 – 2.15	km s^{-1}

[5] https://hyresponder.eu/e-platform/training-materials/educational-training/lecture-2-properties-of-hydrogen-relevant-to-safety/

The main properties of hydrogen that impact safety include:

- Relative vapour density
- Emissivity and Flame temperature
- Flammability range
- Diffusivity
- Boiling point

H_2 properties will be classified below based on their impact on safety:

- If an intrinsic property of hydrogen ensures greater safety for the environment and people, we refer to it as a **safety advantage**.
- If an intrinsic property of hydrogen requires **mitigation measures** to achieve the same level of safety as traditional fuels, we refer to it as a **safety disadvantage or drawback**.

4.1.1 Safety advantages

Relative vapour density

It refers to how heavy a gas or vapor is compared to air.

- If the value is **greater than 1**, the gas is **heavier than air** → it tends to accumulate in low areas (such as basements, or trenches).
- If the value is **less than 1**, the gas is **lighter than air** → it tends to rise and disperse upward.
- If the value is **equal to 1**, it behaves like air and tends to diffuse without a preferred direction.

IMPACTS ON SAFETY:
In the context of fuel safety, understanding relative vapor density is crucial for:
- Designing appropriate ventilation systems;
- Assessing the risk of accumulation in confined spaces;
- Determining the placement of gas leak detectors (e.g., high up for light gases like H_2, low down for heavier gases like propane).

Hydrogen is a molecule that is much lighter than air and other conventional fuels. Indeed, hydrogen is**:**

- **14 times lighter than air,**
- **6 times lighter than natural gas and**
- **57 times lighter than gasoline vapor**[6].

[6] https://h2tools.org/bestpractices/gaseous-gh2-and-liquid-h2-fueling-stations/hydrogen-compared-to-other-fuels

In outdoor applications (such as hydrogen vehicles and refuelling stations), hydrogen tends to disperse upwards very quickly, reducing the likelihood of contact or interaction with a spark. In enclosed spaces, hydrogen tends to accumulate immediately near the ceiling. In comparison, in the event of leaks fossil fuels, usually heavier, tend to accumulate and form wide combustible clouds, thereby increasing the risk of fire or explosion.

Emissivity and Flame Temperature

Radiant heat emitted by hydrogen flames is low compared to other conventional fossil fuels. **A lower thermal load reduces the likelihood of domino fires or structural damage to other components that may be present on the location.**

However, low emissivity makes the flames almost invisible to the naked eye and this, together with the fact that the flame temperature can reach 2400 °C, represents a risk. Despite this, in current hydrogen production, storage and use facilities it is unlikely that exposure will occur without emergency devices being activated. Normal mitigation measures include the application of minimum safety distances.

4.1.2 Safety drawbacks

Flammability range and Minimum Ignition Energy

Hydrogen has a peculiarity that makes it worthy of attention from public authorities responsible for ensuring the safety and health of citizens and from project developers responsible for ensuring the operation of neighbouring or directly related economic activities: its flammability.

It is important to consider also the limiting oxygen index (LOI), the minimum concentration of oxygen that will support flame propagation in a mixture of fuel, air, and nitrogen. No mixture of hydrogen, air, and nitrogen at NTP conditions will propagate flame if the mixture contains less than 5% by volume oxygen: $LOI_{H2} = 5$

The flammability range refers to the span of gas concentrations between the **Lower Flammability Limit (LFL)** and the **Upper Flammability Limit (UFL)**.

- The **LFL** is the **minimum concentration** of a combustible substance in a gaseous oxidizer (typically air) that can support flame propagation.
- The **UFL** is the **maximum concentration** at which combustion can still occur.

Hydrogen (and any gas) can ignite when its concentration in air falls **between the LFL and UFL**, **provided that an ignition source is present**.

IMPORTANCE FOR SAFETY:
In the context of fuel safety, it is important to monitor different ignition sources that can cause hydrogen flames:

- Electric sources: motors, switches, relays or mobile phones
- Static electricity
- Electric charge from equipment operation: from poorly earthed or non-conductive pipework
- Mechanical sources ad impacts: sparks from impacts
- Friction phenomena (rubbing surfaces)
- Thermal sources: hot surfaces etc
- Other open flame sources: naked flames and sparks from welding, burning or grinding
- Hot surfaces (e.g., an exhaust manifold)
- Vehicle exhaust
- Chemical sources

Given such ignition sources, a hydrogen property associated to flammability is the Minimum Ignition Energy (MIE). It is defined as the minimum electric energy needed to ignite a mixture of flammable substances and can vary according to temperature and pressure: MIE=0,017 mJ. This is less than one tenth that of other common fuels such as methane, LPG or petrol.

When the concentration of hydrogen in the air reaches 4% to 75% (the explosion limits), it can deflagrate under open fire, static electricity or high temperature (≥ 500 ° C). **This flammability range is much wider than other conventional fuels (e.g., gasoline has a flammable range of 1–7.6%, propane's range is 2.2–9.6%, and methane's range is 5.3–15%).**

Table 5 Flammability ranges of fuels vs H_2[7]

Fuel	Flash point (°C)	Flammable range in air (vol %)
Hydrogen	−231	4 – 75
Methane	−188	5.3 – 15
Propane	−104	2.2 – 9.6
Gasoline	−45	1 – 7.6
Methanol	11	6 – 36.5
Ethanol (70 %)	17	3.3 – 19
Kerosene	36	0.7 – 5
Jet fuel	60	0.7 – 5
Diesel	62	0.6 – 5.5
Biodiesel	130	0.6 – 6

[7] https://hyresponder.eu/e-platform/training-materials/educational-training/lecture-2-properties-of-hydrogen-relevant-to-safety/

Flashpoint temperature: The lowest temperature at which a fuel produces sufficient vapours on its surface to form an ignitable mixture with air (in this case, an ignition source is still needed).

Diffusivity

It quantifies the rate at which gas molecules move from a region of high concentration to a region of low concentration, following a concentration gradient. Although this property is linked to hydrogen's low relative vapour density—which shortens the duration an explosive atmosphere can persist—it cannot be considered an overall safety advantage.

> **IMPACTS ON SAFETY:**
> In the context of fuel safety, hydrogen can permeate many materials, making the formation of explosive mixtures more likely even in very confined spaces. Likewise, once such a mixture ignites, the flame front propagates much more rapidly precisely because of hydrogen's high diffusivity.

Boiling point

The boiling point is a fundamental property that directly affects safety and potential health risks in the event of direct contact with liquid hydrogen or hydrogen vapours. The **normal boiling point (NBP)** of hydrogen is approximately **20.3 K (−252.9 °C)**.

> **IMPACTS ON SAFETY:**
> Negative effects, deriving from rapid changes from liquid to other hydrogen forms like gas, can be:
>
> - **Direct skin contact** with liquid hydrogen can cause **cryogenic burns**. Similarly, **inhalation of hydrogen vapours** may lead to **respiratory issues such as asphyxiation**, due to displacement of oxygen in confined or poorly ventilated environments.
> - Significant hydrogen expansions, leading to a sharp increase in pressure and the possible **horizontal propagation** of the released hydrogen.

Mitigation measure: Proper ventilation, oxygen monitoring systems, and thermal insulation are essential mitigation measures to ensure safe handling of liquid/cryogenic hydrogen. Moreover, use special cryogenic containers, such as double-walled and vacuum-insulated vessels and select materials capable of withstanding extreme thermal stress without becoming brittle.

4.2 Safety of installation: basic principles of risk analysis and potentially explosive atmospheres – ATEX

For any installation, the project's safety assessment must include information on the risk analyses conducted for:

- the correct operation of the (hydrogen) technologies themselves;
- potential faults and cascading effects on other equipment;
- equipment located within the installation area;
- ageing phenomena that could compromise proper equipment performance;
- human errors due to improper use and maintenance of the various systems.

It is important to carry out Qualitative Risk Assessments (QRA) for cases that fall under the applicable national/local regulations, plus targeted QRAs for more complex situations in terms of technology used, site characteristics, or aspects not covered by existing safety rules (where present). For more information on the common risk assessment methodologies identified in HYPOP project check Section 5.

Risk analysis must be integrated with ATEX area classification, which involves:

- mapping Zones 1 / 2 around probable / occasional release points;
- defining the effective volume based on ventilation parameters;
- segregating non-Ex equipment;
- optimising the layout to minimise overlap between hazardous zones and egress routes.

Directive 2014/34/EU (ATEX) is the regulation most commonly applied to prevent and protect a site against accidental explosions[8]. This is particularly relevant for any installations using gas, including hydrogen technologies. When combined with the risk analyses described in the Section 5, ATEX documentation focuses on classifying explosion-hazardous areas. It is a prerequisite for designing and installing electrical systems and, more broadly, is essential for any overall safety assessment. For this reason—and given the characteristics outlined above—ATEX classification appears in the various safety reports that fire-protection engineers submit to the competent authorities.

What is the purpose of hazardous area classification?

- To support the "explosive atmosphere" risk assessment.
- To define the essential explosion-safety requirements for electrical and non-electrical products and for installations of the same in a hazardous area, ensuring they cannot ignite the identified explosive atmospheres.

[8] https://single-market-economy.ec.europa.eu/sectors/mechanical-engineering/equipment-potentially-explosive-atmospheres-atex_en

Who needs the hazardous area classification?
Depending on the national or local administrative structure, this classification is useful for many stakeholders, but in general it is required by:

- Those performing the explosive atmosphere risk assessment.
- The Health, Safety & Prevention Service.
- Anyone purchasing equipment (devices, machinery, etc.) for these areas.
- All personnel who work in or otherwise enter these areas.
- Workers who use tools or equipment there (e.g., maintenance crews).
- Regulatory and inspection bodies.

In general, an explosion can occur only when the following three elements coexist in the same place at the same time:

1. **A flammable gas or combustible dust (fuel);**
2. **Air, whose oxygen acts as the oxidizer (oxidizer);**
3. **An ignition source**—for example, a spark, an electric arc, or a high surface temperature (ignition).

Explosion safety is achieved when the probability of fuel, oxidizer, and ignition source coexisting is reduced to an acceptable level. Around each item of equipment in a hydrogen installation, areas are classified by determining the spatial extent of hazardous zones and the corresponding explosion risk. That risk is assessed—and, if necessary, reduced to acceptable limits—by acting on the emission sources, on the environment (ventilation, monitoring, etc.), and on potential ignition sources (both electrical and non-electrical).

Areas are divided into **Hazardous Zones** and **Non-Hazardous Zones** on the basis of the origin of the hazard (e.g., flammable gases, vapours, or mists; combustible dusts) and of operating characteristics such as containment systems, process equipment, and maintenance procedures.

- **Zone 0:** An explosive atmosphere is present continuously, for long periods, or frequently.
- **Zone 1:** An explosive atmosphere is likely to occur during normal operation, but only occasionally.
- **Zone 2:** An explosive atmosphere is unlikely to occur during normal operation and, if it does, will persist only for short periods.

This zoning method is also essential for selecting technologies that will not themselves become potential ignition sources.

4.3 Interaction with planning: site selection and characterisation

Selecting a site for a hydrogen installation becomes an additional factor with significant weight, alongside the safety considerations for individual technologies.

Therefore, the site selection should be based on a multicriteria analysis that accounts for:

- Land-use designations and urban-planning compatibility, including constraints for protected species or other environmental limits.
- Distances from crowded areas and public buildings. Better avoid congested areas.
- Availability of electrical power and water. (Water availability is a risk factor if the site is in a water-scarce area.)
- Absence of obstacles that could promote gas stagnation.
- Verification of fire brigade/emergency vehicle access and hydrant locations (linked to safety distances).
- Interference assessment: overhead power lines, railways, heavy traffic flows, existing ATEX zones, other fuel tanks.

More details about some of these aspects are included in deliverable D4.3.

4.4 Safety approaches for Hydrogen Projects: Prevention and Mitigation Measures

Below, the main safety risk sources associated with individual hydrogen production, storage, and use technologies are examined.

Understanding hydrogen's intrinsic properties is essential to operate plants safely. The aim of this section is to highlight the key safety aspects that should be considered. The section contains a review of the following hydrogen installations:

- Renewable Hydrogen Production through Electrolysis for Industrial applications (4.4.1)
- Compressed Hydrogen Storage for Industry and Mobility sectors (4.4.2)
- Hydrogen Refuelling Stations (4.4.3)
- Fuel cells for Energy and Residential sectors (4.4.4)

A hydrogen installation might contain elements from the systems described in this section (e.g., a HRS with on-site production and storage; an electrolyser with on-site storage, etc), hence the safety information provided within this guideline should be combined to cover all elements included.

4.4.1 Renewable Hydrogen Production through Electrolysis for Industrial applications

Renewable hydrogen can be produced using electricity produced from renewable sources such as solar, wind, and hydropower. This AC power is converted to DC to supply the electrolyser with a constant, unidirectional current. Electricity also feeds all the Balance of Plant (BoP) components that accompany the electrolytic stack to ensure efficient operation under design conditions, and overall plant safety.

The Balance of Plant may consist of:

1) Water management systems;
2) System for the energy supply;
3) Electrolyte recirculation and purification systems;
4) Gas purification systems for the electrolyser products;

Within the BoP are also included the monitoring and control systems that trigger safety functions. In general, monitoring, control and safety systems like Emergency Shutdown Systems (EES) are automated equipment that might trigger shutdown procedures. In the event of a detected leak or other emergency conditions, automated systems can initiate an immediate shutdown of relevant processes and equipment. Moreover, operators can manually trigger shutdown procedures if necessary, providing an additional layer of control during emergencies.

Electrolysis system has a core component which is a stack of **electrolytic cells**. As an example, PEM electrolysers operate at pressures between 15 and 30 barg and contain the following elements:

1) Membrane/Diaphragm;
2) Catalyst layer;
3) PTL (Porous transport layers);
4) Current collector/flow field (grids);
5) Bipolar plate.

No technology is risk-free. Therefore, the likelihood of a component malfunction leading to a hydrogen leak is not zero, though it is unlikely. Both manufacturers and system integrators are required to perform their own analyses and tests to ensure proper operation of system components, as well as of alarm and safety systems whose role is to activate in the event of different types of hazards. During normal electrolyser operation, several risks must be considered, and they can originate from multiple sources.

Below, by way of example, are possible risk sources, their description, and the necessary prevention and mitigation measures to be applied when the project under review includes on-site hydrogen production by electrolysis for all applications included industrial, mobility and residential ones. The focus is on the electrolytic cell but information on BoP is considered below as completing an integrated system (BoP+Stack).

Table 6 Failures, risks and prevention/mitigation measures for Electrolysis stack

Origin of the failure	Description of the Risk	Prevention/Mitigation measures
Variation of pression within the system	High pressures coming from failures can cause dangerous ruptures and leakages	• Evaluate redundant safety valves (PSVs) sized for "blocked-outlet," "fire exposure," and "thermal expansion" scenarios. • Consider rupture discs as a second line of defence, or in parallel with PSVs, on critical piping and vessels. • Ensure relief lines discharge to a vertical vent stack at height, equipped with a demister, check valve, and flame arrestor at the outlet.
Hydrogen and oxygen come into contact, creating a potentially explosive mixture	In this case, the risk stems from a malfunction of the component that keeps the two gases separated—the membrane. Ruptures or crossover of oxygen and hydrogen through the membrane can occur during certain transient phases (e.g., system start-up). All electrolysis systems have a specific membrane selectivity, but it is not absolute. Permeation effects can therefore lead to combustion or explosions inside the electrolytic cell, within piping, and in storage systems.	• Ensure the use of safety control systems with safety shutoff valves.
Hydrogen leakage outside the system	Hydrogen that permeates outside the electrolyser must be continuously monitored, and the explosive risk must be prevented by using forced air circulation.	• Use H_2 sensors referenced to the Lower Explosive Limit (≤ 25% LEL) and O_2 sensors (≥ 23% vol), with alarms at 10% LEL and a shutdown (forced plant stop) when the parameter exceeds, for example, > 25% LEL.

Origin of the failure	Description of the Risk	Prevention/Mitigation measures
		• Provide forced ventilation, specifying the required air changes per hour.
Leaks of hydrogen in the electrolyser's waste streams and associated systems (e.g., dryers...)	Hydrogen can also be released outside the electrolysis system through drain/vent streams from the dryer, the electrolyte, and venting lines. When the liquid phase is removed, the gaseous hydrogen can accumulate and reach flammability limits.	• Make sure the area where drains are performed is well ventilated and away from ignition sources. • Size and locate vent lines so that the gas is safely dispersed to atmosphere. • Electrolyte drain streams must also be handled in ventilated areas; additionally, use non-sparking tools and dispose of the caustic waste in accordance with hazardous-waste regulations.
Electric charges/sources	Electric charges that build up on the surface of an electrolyser component can act as an ignition source.	• Use equipment suitable for ATEX zones (it is essential to verify that all systems carry the CE mark).

Below are the various risks associated with potential causes of failure of BoP components that affect safety and the applicable prevention and mitigation measures.

Table 7 Risks associated with Hydrogen production BoP components that affect safety and the applicable prevention and mitigation measures

BoP component	Potential causes of failure and associated risks	Description of the Risk	Prevention/Mitigation measures
Water management system	Presence of contaminants, causing degradation/failure of parts with release of gases and/or liquids	• Contaminants of various kinds—ions, organic substances, particulates, etc.—may be present due to malfunctioning filtration, reverse osmosis, or deionization systems. These contaminants primarily cause	• Water quality monitoring (e.g., Total Organic Carbon—TOC—for organic contaminants, conductivity for dissolved ions); • Secondary containment for tanks to prevent the release of water and

BoP component	Potential causes of failure and associated risks	Description of the Risk	Prevention/Mitigation measures
		degradation of the membranes. • Wear of the water-quality management systems can introduce contaminants into the electrolyser or lead to gas and/or liquid leaks. • Corrosive phenomena can also affect stack materials, increasing the risk of hydrogen/oxygen and electrolyte leaks.	electrolyte from vessels and piping; • Use of Personal Protective Equipment (PPE) paired with clear procedures for handling chemicals; • Level sensors on tanks and sumps plus alarms when levels deviate from set limits.
System for the energy supply, rectifiers, transformers	• Grid disturbances; • Electric overload; • Wrong sizing; • Overheating, poor cooling; • Insulation ageing, degradation; • Corroded connections; • Vibration, mechanical shocks All the above might generate sparks, short-circuits, other electric phenomena	The presence of the failures indicated as examples may cause electric shocks, sparks, etc. These phenomena are dangerous for operators who come into contact with the instruments, but even more so, they create cascading risks (initiate fire or explosion), especially in ATEX areas.	• Consider panels for non-classified areas or with suitable IP/Ex; • Define periodic insulation tests; • Consider proper grounding and bonding
Electrolyte recirculation, as applicable	• Contaminants; • Micro-leaks; • Overpressure; • Mixing of gases.	• Membrane degradation can lead to contamination of the electrolyte and the cell, resulting in	• Conduct continuous monitoring with electrolyte replacement. At the same time, check

BoP component	Potential causes of failure and associated risks	Description of the Risk	Prevention/Mitigation measures
	All of the above can result in liquid/gas leakages.	increased heat and the release of unwanted gases. • Micro-leaks can cause caustic solutions to spill, which can cause burns. • Overpressure and unwanted gas mixing can cause internal explosions in the cell.	the filter replacement schedules • Identify the presence of secondary containments and provide flow/pressure sensors with alarms • Check the operation of automatic shut-offs for any electrolyte leaks from the pipes in case of activation of T/P detectors • Immediate purging/inerting in case of mixing and controlled discharge.
Gas purification systems	• Breakages • Overpressure • Malfunctioning of dryer system	• Breakages can cause micro-leaks from gas circuits (H_2/O_2) that can affect the safety of ATEX zones. • Possible overpressure can cause valves and flanges to break. • A malfunction of dryers/gas drying systems can also include condensed liquids containing hydrogen.	• Conduct periodic inspections to highlight any leaks • Ensure that components have certified sealing (PED + ATEX) • Ensure the presence of pressure safety valves (PSV) • Use materials resistant to embrittlement • Ventilated drains and controlled purge procedures

Safety must be ensured during operation to protect its components. **It is therefore recommended to carry out:**

- **Regular Maintenance**: Scheduled maintenance can be preventive and predictive with routine cleaning of electrolysers components and component replacement, if it is the case. This prevents contamination due to wear, corrosion or failure of components involved in gas and water/electrolyte handling.

- **Testing Protocols**: Regular testing of stored gases ensures that they meet required purity specifications before being utilized or distributed.

4.4.2 Compressed Hydrogen Storage for Industry and Mobility sectors

If the hydrogen project—whether industrial or a refuelling station—includes hydrogen storage, stakeholders should take into account the following risks and corresponding preventative/mitigating measures.

Hydrogen storage systems are the plant components that typically operate under the most demanding conditions in terms of pressures (e.g., pressures up to 700 bar). For this reason, their construction uses multiple materials designed to withstand typical degradation phenomena that could compromise material integrity and thus the safety of people and structures. Storage of hydrogen can be in gaseous, liquid, or solid form (e.g., metal hydrides). Below, we present safety risks and possible preventative and mitigating measures for compressed hydrogen storage systems, today's most widespread technology**.**

Given hydrogen's physic-chemical properties and the typical operating conditions of a storage system—high pressure and expected long service life—**the following table lists the three main risks associated with compressed hydrogen, which need to be addressed if a hydrogen project include a fixed or mobile (e.g., hydrogen bottles bundles) storage system.**

Table 8 Risks and prevention/mitigation measures for Compressed Hydrogen storage for Industry and Mobility

Description of the Risk	Prevention/Mitigation measures
Hydrogen embrittlement of metals is caused by hydrogen permeation. At high pressures, the hydrogen molecule (or atom after dissociation) is small enough to slip into lattice interstices and even replace atoms within the metal's crystalline structure. This process weakens chemical bonds, degrades mechanical properties, and thus leads to embrittlement.	• Verify that technical datasheets accompanying the documentation explicitly report the hydrogen-embrittlement behaviour of the metals used. • If the surroundings of the installation site require additional safety measures, consider design modifications to the component to prevent the creation of new ignition or failure sources. • Include fail-safe measures such as automated shutoff systems, venting systems, ventilation, and physical barriers to protect personnel and nearby equipment in case of ignition.
Hydrogen induced cracking: Defects or cracks within the material can be amplified by hydrogen especially when it is contained	• This corrosion phenomena can be prevented through inspection and testing by techniques like (also on-site): Wet

Description of the Risk	Prevention/Mitigation measures
in liquids that contact the material surface and then diffuse into it.	Fluorescent Magnetic Particle Testing (WFMPT), Ultrasonic testing methods, etc
High-temperature hydrogen attack: When the operating temperature exceeds 200 °C, materials tend to react strongly with hydrogen, which at high pressure and temperature penetrates the structure and, together with material impurities, forms gaseous species such as methane. As these gases propagate, they leave behind pores and other defects.	• It is essential to use metallic alloys compliant with API RP 941 – *Steels for Hydrogen Service at Elevated Temperatures and Pressures*. • Prevention relies on regular surface inspections and dedicated testing methods such as (also on-site): Phased Array Ultrasonic Testing (PAUT); Time-of-Flight Diffraction (ToFD); and Full Matrix Capture/Total Focusing Method (FMC/TFM).

4.4.3 Hydrogen Refuelling Stations

Hydrogen refuelling stations (HRS) are facilities where multiple hydrogen technologies operate in adjacent areas. Therefore, **the preventive and mitigating measures described for production and storage technologies—linked to possible risk scenarios—also apply to HRS, since these technologies can form part of the station.**

HYPOP suggests a general safety approach that can be applied, for example, to:

- HRS with on-site production;
- HRS without on-site production;
- Standard HRS with fixed or mobile storage (e.g., hydrogen bundles, tube trailers);
- Mobile HRS with integrated storage.

The following pillars outline the general steps that should be followed to ensure the safety of a hydrogen refuelling station project. In broad terms, these steps can be applied across the different cases mentioned; the level of attention depends on the number of hazardous elements present and on the context around the site perimeter. **More complex safety management designs—such as HRS with on-site electrolysis or containerized/mobile solutions—require greater focus and more detailed technical documentation from technology providers (e.g., risk analyses, safety and maintenance protocols etc) to support the design phase.** In any case, the baseline safety criteria are those indicated in Table 9.

If electrolysers or storage systems are present, please refer to Sections 4.4.1 and 4.4.2.

Engineering design and generic barriers

The design of the system must include an open, modular layout to ensure safety.

The safety information in the following table is a synthesis that considers the functional and physical connections among the various components found in a hydrogen refuelling station. For more in-depth details on individual technologies—such as electrolysers and storage systems—see Sections 4.4.1 and 4.4.2, which apply to HRS cases with on-site production and with mobile/fixed storage.

Table 9 Potential failures and detection and safety measures for HRS components

HRS affected component	Possible failure	Detection and Safety Measures
Production (further details on electrolyser in Table 6 and on BoP in Table 7)	• Undesired variation of pression and module overheating due to electric charges; • Contaminants from failures of the water management system; • Minor H_2 leaks; • ; • undesired gas mixing	• H_2, pressure and temperature sensors with trip setpoints; automatic unit shutdown and isolation; • water quality monitoring systems, secondary containment for tanks, use of PPE and level sensors on tanks • effective natural and/or forced ventilation; • scheduled inspections & preventive maintenance; • operator training to recognise anomalies
High-pressure gas (further details on material-related failures of storage check Table 8 – relevant also for compressors)	• Line over-pressure; • leaks at fittings/valves; • compressor overheating	• Pressure & temperature monitoring; • pressure relief valves to safe area; • automatic compressor shutdown; • H_2 leak detection; • ventilation and potential external cooling; • preventive maintenance
Dispenser (vehicle fuelling)	• Leak at coupling; • User misuse	• Functional pre-fuelling checks; • local H_2 detectors; • immediate shutdown & purge on leak; • guided operating instructions;

HRS affected component	Possible failure	Detection and Safety Measures
		• controlled access for authorised users
Electrical & control systems for the installation and its parts	• Ignition sources in classified zone; • safety system failure	• ATEX certified equipment; • physical segregation of panels; • diagnostics & self-tests; • selective shutdown and isolation of faulty circuits; • periodic inspections & functional testing; • documented management of change
Overall area & people (users, personnel)	• Unauthorised access; • delayed response; • poor emergency coordination	• Fencing and access control; • posted up-to-date emergency procedures; • regular drills with Fire Brigade; • remote monitoring & event logging; • continuous training & qualification; • ongoing review of lessons learned

Alongside design choices, HRS safety is ensured by multiple barrier types integrated into the plant and positioned at defined internal safety distances (electrolysis → compression → storage → dispenser).

Barrier types:

- **Passive (used where justified by QRA):** Reinforced-concrete walls, blast walls, fencing to prevent access by untrained/unauthorised personnel, etc.
- **Active:** Systems that trigger automatically when control parameters are exceeded (temperature/pressure/flow sensors with shutdown logic; combined gas + flame detection in compression and storage areas; fast shut-off valves—ESD—and depressurisation lines to an elevated vent stack for vertical dispersion).
- **Continuous:** Systems operating constantly to keep conditions within safe ranges, e.g., ventilation systems that prevent explosive atmospheres.

4.4.4 Fuel cells for Energy and Residential sectors

Fuel cells are electrochemical devices that, like batteries, supply electrical power for a range of end uses—from mobility to stationary applications in the energy and residential sectors. Fuel cells can operate as long as they are fed with hydrogen (or hydrogen-rich fuels) and until their components reach end of life.

There are several types of fuel cells that operate at different temperatures, use different materials, and serve different purposes. They can be distinguished by the nature of the electrolyte—liquid (and this can be acidic or alkaline) or solid—and by their operating temperatures.

As with other hydrogen technologies, chemical-related safety risks must be considered whenever a project includes a fuel cell to supply electricity in industrial, energy, or residential settings. Some fuel cells use electrolytes that contain corrosive or irritating agents. If the fuel cell is damaged, these substances could pose a health hazard. However, in a properly functioning, closed system, the likelihood of exposure is generally low.

The main fuel cell types are listed in the following table.

Table 10 Fuel cell types and applications (additional educational material[9])

Fuel cell	Type of electrolyte	Operational temperature	Applications
Polymer electrolyte membrane (PEMFC)	Fluorocarbon-based polymer (solid)	60-90 °C	Mobility/Stationary
Phosphoric acid fuel cells (PAFC)	Phosphoric acid film contained in a fluorocarbon matrix (liquid)	>150 °C	Stationary power generation, Micro-CHP residential
Alkaline electrolyte fuel cells (AFC)	Aqueous potassium hydroxide solution (liquid)	100 < T < 250 °C	Mobility
Solid Oxide fuel cells (SOFC)	Conductive ceramic (solid)	600 < T < 1000 °C	Stationary – Power-to-x
MCFC: Molten carbonate fuel cell	Molten lithium and sodium/potassium carbonates in a matrix	600 < T < 1000 °C	Stationary - Industry

The following table lists the risk scenarios and the **prevention/mitigation measures that should be considered—or specifically looked for—when reviewing the safety approach proposed by a project developer submitting a project to a public authority.**

[9] https://observatory.clean-hydrogen.europa.eu/learn-about-hydrogen/education-materials/hydrogen-basics

Table 11 Risks and prevention/mitigation measures for Fuel cell systems used in Energy and Residential applications

Origin of the failure	Description of the Risk	Prevention/Mitigation measures
H_2 leakage	Hydrogen can escape through micro-leaks or gasket/line failures, accumulate in enclosed spaces → fire/explosion.	Ensure the design includes: • Gas detectors + forced ventilation • Certified tightness of lines, flanges, fittings (ATEX/IECEx) Maintenance procedures must include inerting and purging before intervention.
Oxidant releases (O_2 or compressed air)	As with general leaks, a local increase in O_2 concentration can raise the likelihood of fire.	• Redundant overpressure piping and valves • Separation distances from combustible materials.
Overheating and hot surfaces	Malfunctions may drive areas/surfaces to temperatures causing burns or hazardous vapours (e.g., > 120 °C for PEM and up to 800 °C for SOFC).	• Provide thermal insulation and shielding • Verify thermostats/fuses and automatic shutdown above predefined safe temperatures.
Overpressure of stacks or gas/liquid vessels	Blocked valves, ice formation in components/lines, or uncontrolled reactions can cause overpressure and mechanical rupture.	Plant design must include: • Calibrated rupture disks and pressure relief devices (PRDs) • Continuous P/T monitoring with control logic to detect abnormal trends and trigger shutdown • Safe blow-down lines venting outside • For icing, check that thermal/humidity management is provided.
Electric hazard (low & high voltage)	Risk of electric shock, arcing, short circuits (especially in high-power stacks).	Check for: • IPxxB enclosures and safety disconnects • Ground-Fault Circuit Interrupters (GFCI) to trip on mA earth faults, preventing shock and fires

Origin of the failure	Description of the Risk	Prevention/Mitigation measures
		• Periodic insulation tests on cables, windings, equipment.
Material compatibility vs H_2 permeation	Wrong steel selection can induce hydrogen embrittlement in high-strength alloys.	• Ensure metal alloys are resistant (e.g., stainless steel 316L – Fe-Cr-Ni based; Inconel – Ni-Cr superalloys; Hastelloy – Ni-Mo and/or Ni-Cr-Mo superalloys).

In HYPOP, stakeholder engagement and the review of multiple best practices showed that **residential applications are still struggling to take hold across Europe. As a result, the available data are not yet sufficient to define a baseline safety approach for these contexts (as was done for HRSs). More demonstration projects and broader information sharing are needed to advance hydrogen's integration as a balancing resource for household energy use.**

Nevertheless, discussions with sector experts and the exchange of experiences within HYPOP allowed us to outline a general safety approach drawn from one of the best practices reported in Deliverables 2.1 and 2.2.

Considering the installation of a rSOC (reversible Solid Oxide Cell) system able to operate in SOEC mode to store surplus electricity by producing hydrogen, and in SOFC mode to generate electricity and useful heat the following method was adopted.

Methodological safety approach

Risk management should follow a HAZOP-type deviation–cause–consequence–safeguard logic:

1. Systematic identification of operating deviations.
2. Analysis of causes (instrument failures, spurious valve actions, operator error).
3. Evaluation of consequences disregarding existing protections (overpressure, H_2 release, fire/explosion).
4. Listing of existing safeguards (PSVs, interlocks, H_2 detectors, ventilation, EX-rated components).
5. Additional recommendations where residual risk exceeds acceptance criteria.

Examples of Critical events to be examined for this type of application should be:

- **E1 – Blocked compressor discharge:** risk of line overpressure and H_2 release → mitigated by PSVs to safe vent, pressure interlocks, H_2 gas detection at 10% LEL with forced ventilation + alarm, automatic depressurisation to safe vent.
- **E2 – Cooling failure:** excessive compressor temperature, membrane damage, internal/external H_2 leak → temperature and flow sensors with trips, EX-rated components (Zone 2), H_2 detectors.

- **E3 – Air ingress (low pressure):** formation of flammable mixtures in high-pressure storage → low-pressure trip, compressors housed in REI Grade I enclosure.
- **E4 – Small leaks (connections):** local H_2 release → gas detection + forced ventilation + alarm, EX Zone 2 components.

Cross-cutting measures

Natural high-level ventilation, gas detection (set at 10% LEL), selective shutdown, automatic forced ventilation, remotely actuated vent valves, optical/acoustic alarms, EX-certified equipment in classified Zone 2, rapid depressurisation systems.

5 Risk Assessment Methodologies

Table 12 WHAT, WHY and WHEN risk analysis is important for H_2 projects

WHAT? Risk analyses are methodological approaches—grounded in technical knowledge plus modelling/prediction tools—that help prevent and mitigate failures which could harm people or assets.
WHY? Component safety can be challenged by malfunctions or external events, potentially triggering cascading effects on nearby economic activities and public areas. Uncertainty due to knowledge gaps and unclear regulation often leads to "the stricter, the safer" thinking, which can slow innovation and make projects technically or economically unfeasible. For this reason, various methods are used to analyse risks from accidental events with different probabilities and severities. **Risk analysis is therefore a powerful tool that can be applied at multiple stages of a hydrogen project.**
WHEN? The main methods fall into two macro-categories: qualitative and quantitative techniques. **Qualitative risk analyses** are mostly used in the early project phases to quickly spot obvious hazards when detailed technical data are not yet available; they can also yield preliminary separation distances. **Quantitative techniques** add numeric inputs—failure rate data, ignition probabilities, weather statistics, population data, validated models—to refine and justify the safety design.

Below is a concise summary of the main risk analyses HYPOP identified from the best practices in Deliverable 2.1 and from interviews with various stakeholders and European hydrogen projects.

Table 13 Qualitative and Quantitative risk analyses identified from HYPOP best practices

Qualitative Techniques
HAZOP (Hazard and Operability Study): A systematic technique that examines one item (or node) at a time and describes the consequences of malfunctions. By identifying deviations and their causes—through guide words (e.g., *no/not; more; less; as well as*) linked to process parameters (e.g., flow, pressure, temperature)—it proposes corrective actions.
HAZID (Hazard identification): A multidisciplinary team exercise to identify potential hazards across a broad scope—project design, construction, installation, decommissioning, and proposed changes to existing operations. It is often a precursor or component of quantitative risk analyses.
What-If Analysis:

An approach that explores potential hazards and failure causes by posing “what if” questions and evaluating the resulting scenarios.
Failure Modes and Effects Analysis (FMEA): A semi-quantitative method that lists possible failure modes of a process/component and their effects, typically one by one without considering multiple simultaneous failures. Each failure is ranked (Risk Priority Number) by severity, occurrence, and detectability so actions can target the most critical issues first.
Quantitative Techniques
Quantitative Risk Assessment (QRA): An in-depth analysis combining fault tree outputs with modelling tools to quantify overall risk of a hydrogen facility or process—covering failure frequencies, ignition probabilities, and consequences.
Fault Tree Analysis (FTA): A graphical method that maps undesired top events and the combinations of basic events leading to them, assigning probabilities to estimate the likelihood of failure.

A broader set of qualitative, semi-quantitative, and quantitative techniques can be explored in the “EHSP Guidance on Hydrogen Safety Engineering – Guidance Document” published by the Clean Hydrogen Joint Undertaking[10].

[10] https://www.clean-hydrogen.europa.eu/system/files/2023-05/EHSP%20Guidance%20on%20Hydrogen%20Safety%20Engineering%20-%20v1-Final.pdf

6 HYPOP Recommendations and Actions to accelerate Acceptance and Safety procedures

In HYPOP, it was observed that **every hydrogen project must be assessed with respect to multiple factors: the installation site, the environment surrounding the plant perimeter, and the national and local regulatory framework**. Providing a safety guideline that offers a clear approach while remaining adaptable to the specific requirements and barriers across EU countries and applications will act as a driver to accelerate acceptance and the development of hydrogen projects. These guidelines also serve as an incentive for stakeholders in countries that are less advanced in the practical and regulatory development of the hydrogen sector and its industrial, mobility, and residential applications. The best practices, as well as the requirements and barriers drawn from the various regulatory frameworks of European countries that informed the development of these guidelines, can be consulted in detail both in the appendix to this document and in Deliverable 2.1.

Below, we summarize the main criticalities, practical actions and recommendations, and the benefits of addressing them. At the same time, HYPOP proposes a standard procedure ("HYPOP Safety Guidelines") designed to facilitate interaction between public authorities and designers. The latter will thus be able to submit hydrogen projects following a safety philosophy that is shared, understandable, and accepted by public authorities and citizens in the shortest possible time.

Table 14 HYPOP practical actions/recommendations and expected benefits

Issue	Practical Actions/Recommendations	Expected Benefit
Regulatory gaps or divergent interpretations (even between regions or local offices)	Shared "equivalent practices" compendium (co-created with authorities & operators)	• Baseline uniformity; • Less discretion
Low practical experience of authorities with technical standards, analysis methods, and hydrogen specifics.	Modular training (legal / technical / social) for officials & fire brigades	• Faster, better-justified decisions
Misuse and defensive reliance on regulations for other fuels (natural gas, LPG) that do not always match hydrogen's features.	Comparative property sheets + adaptation guidance	• Avoid unjustified over-design
Partial and inconsistent application of Seveso elements to small sub threshold plants, creating confusion.	Follow general safety principles (for SEVESO sub-threshold cases) + risk-based checklist	• Consistent treatment of small plants

Issue	Practical Actions/Recommendations	Expected Benefit
Iterative and slow process bring to lengthened timelines due to ad hoc data requests and unstructured clarification cycles.	Formal pre-consultation ("scoping meeting") before filing	• Fewer later integration requests
Public distrust	Early engagement (Q&A sessions) with simplified risk map	• Greater social acceptance, fewer objections

The **HYPOP Safety Guidelines** are therefore the result of stakeholder engagement and structured as a series of steps to be followed, accompanied by indications of errors and risks, recommendations and practical actions. All the technical information on safety of hydrogen, hydrogen technologies and the related prevention/mitigations measures described in this report are relevant to manage properly the following 6 steps (especially steps 2, 3 and 4).

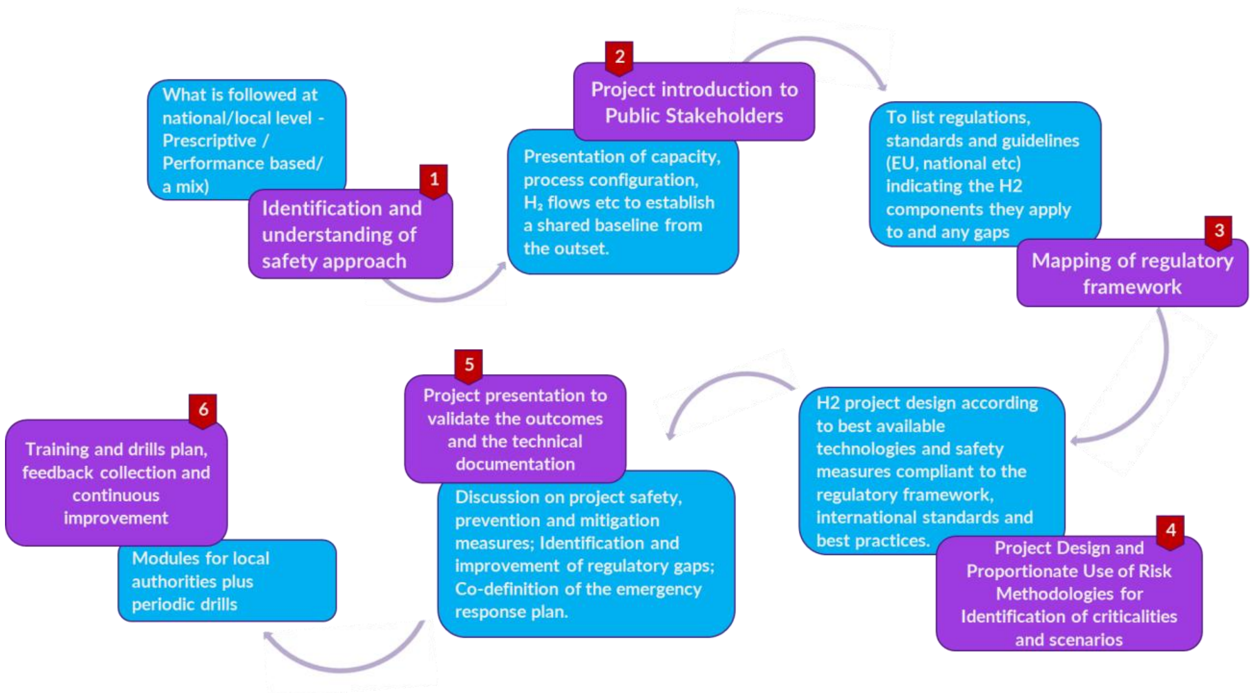

Figure 1 HYPOP Safety Guidelines

1) The first step is **to identify and understand the general safety approach followed at the national or local level (Prescriptive / Performance based).**

In some mobility and residential contexts, hydrogen projects are treated by regulations or competent authorities as industrial projects, and the corresponding requirements and approaches are applied. In the absence of practical experience or specific regulatory references, it is advisable to look to other countries or to established regulations for more familiar fuels and adapt those requirements. Based on this information, the appropriate safety approach can be determined.

Within HYPOP, case studies were identified that adopt two types of safety approaches—sometimes as alternatives, sometimes in a complementary way:

- **Prescriptive approach:** sets fixed rules (some examples reported below). It is typical of mature regulations or of rules originally written for other fuels (natural gas, LPG) and then "adapted" to hydrogen. International technical standards effectively become part of the prescriptive package once they are transposed into laws or decrees.

Examples of Typical Prescriptive Requirements

- Minimum distances between H_2 technologies (mainly hydrogen production and high-pressure storage) and site boundaries.
- Limits on pressure or capacity to trigger levels of passive protection.
- Specification of certified equipment in classified hazardous areas (ATEX).

- **Performance-based approach:** defines the safety objective (acceptable risk level) and leaves freedom in how to achieve it. Here, risk analyses come into play: they identify critical scenarios and support targeted choices for layout, barriers, and procedures.

Examples of typical Performance-based Requirements

- Safety distances resulting from modelling and simulation tools.
- Use of international standards for equipment, operations and maintenance.
- Use of prevention/mitigation measures and materials if justified by specific features of the installation site or as a result of risk assessments.
- Layout optimization via CFD simulation to reduce accumulation/stagnation zones.

In practice the two approaches **co-exist**: HYPOP identified that where rules are clear you apply tabulated requirements; where there are gaps or innovative cases you use performance-based approach to demonstrate an equivalent safety level.

Table 15 Strengths and Limitations of Prescriptive and Performance-based Approaches

Aspect	Prescriptive	Performance-Based
Decision speed	Fast if the case is "standard", analysis limited to some H_2 tech	Slower (analysis always needed for all the plant)
Innovation flexibility	Low (rigid constraints)	High (adaptable to new tech)

Aspect	Prescriptive	Performance-Based
Transparency for local authorities	High (simple rules)	Depends on quality of risk report and requires technical background
Over-engineering risk	Medium/High	Controllable (barriers sized to real risk)

Understanding this approach is essential to understanding what the preferred approach of national/local authorities towards a hydrogen project may be.

2) **Project introduction to Public Stakeholders**

The second step involves a concise presentation (purpose, capacity, process configuration, H_2 flows, user profile) to establish a shared baseline from the outset.

Engagement with public authorities is recommended from the earliest design phases, when the plant type, technologies, and installation site are still being defined. Potential technical criticalities (e.g., water availability; presence of other facilities handling hazardous substances; proximity to urban areas that impose construction constraints or require additional preventive/mitigative measures, etc.) and acceptance issues—especially among the public and local authorities (e.g., fire safety, environmental protection, etc.)—should be addressed early.

Table 16 Benefits from early project introduction to public authorities

Risks/Issues to be addressed	Benefits from taking action
Low awareness and technical knowledge of hydrogen among local authorities and citizens;	Citizens are informed and aware of local opportunities and the importance of local activities for sustainability.
Opposition to a project submitted late. Failure to submit an initial presentation before the application is submitted to the competent authorities may be risky.	Initial feedback from local authorities, even in the case of projects that comply with existing legislation, can speed up the entire procedure, avoiding delays or critical issues during the subsequent procedure.
Difficulty interpreting regulations or lack of knowledge of the existing regulatory framework	The authorities take preventive action by gathering information and suggesting regulations to be taken into consideration – essential in the event of regulatory gaps

The introduction of the project is only the first step in involving the authorities, which must be followed by further meetings with more detailed information about the security philosophy that is to be proposed.

3) **Mapping of regulatory framework (likely also in parallel with Step 2)**
Table listing regulations, standards and guidelines (EU, national, local, voluntary international) indicating the components they apply to and any gaps.

It is strongly recommended to examine the existing regulatory landscape. In most European countries, there are notable gaps and interpretive uncertainties; in the worst cases, hydrogen is not even mentioned in the regulations that put national and local strategy documents into practice. Occasionally, however, supplementary documents exist—sometimes treated by public authorities as quasi-official regulations—that compile the relevant framework and list the documentation required for hydrogen applications in industry, mobility and residential sectors. Where no such resource is available, stakeholders are advised to approach the public authorities and establish working groups capable of drafting an equivalent document. HYPOP identified that:

- **Guidelines provide clarity** by identifying bottlenecks, defining the role of authorities, and addressing regulatory gaps.
- **Guidelines act as accessible tools** to reach and engage a broader range of stakeholders.
- **Guidelines showcase best practices** across the EU, fostering trust and raising awareness among local authorities.
- **Guidelines strengthen cooperation** between stakeholders and authorities, as their development requires consensus and collaboration.

Key benefit: developing guidelines strengthens relationships with public authorities, builds trust, and brings to light regulatory gaps, binding requirements, and interpretative challenges. For examples and further detail on several of the guidelines reviewed in HYPOP, readers are encouraged to consult the Appendix of this document and HYPOP Deliverable 2.1.

4) **Techno-economic Project Design and Proportionate Use of Risk Methodologies for Identification of criticalities and scenarios:**

Hydrogen project design according to best available technologies and safety measures compliant to the regulatory framework, international standards and best practices.

Not every project requires a full Quantitative Risk Assessment (highest level of complexity identified in HYPOP). It is recommended to go for a proportional scale avoiding waste and keeps credibility:

- **Structured qualitative screening** (HazID + risk matrix) as minimum default baseline.
- **Semi-quantitative analysis** (e.g. in between qualitative and quantitative approaches, see Section 5) if decision uncertainty remains or moderate scenarios emerge.
- **Full QRA** only if:
    - dense layout / limited space;
    - high pressure equipment;
    - request for derogation from fixed safety distances from the regulations;
    - proximity to public buildings and crowd areas;
    - cumulative risks / domino potential.

5) **Project presentation to validate the outcomes from the first meeting's feedback and the technical documentation produced.**

Discussion on project safety, prevention and mitigation measures; identification and improvement of regulatory gaps; co-definition of the emergency response plan.

The discussion between authorities and designers should be based on at least the following **minimum documentation set**: Process Flow Diagram (PFD)/ Piping & Instrumentation Diagram (P&ID), layout, ATEX classification, scenario matrix, risk report, logic of safety control behind the emergency shutdown system (ESD) & detection philosophy, justified safety distances, etc.

Validation of the safety approach and the project may entail the **co-definition of preventive measures and barriers**, where required. In particular, more detail may be requested on monitoring, safety-parameter detection and related instruments, and the extent of ventilation. **Additional barriers**—such as containment walls—may also be required in the direction of sensitive areas and crowded public buildings.

This step is the moment for the public authorities to pose questions, and to discuss and collect gaps and observations from the designers, in order to improve their understanding and to shape more effective future regulations.

It is recommended that authorities **validate or co-define an emergency response plan.**

6) **Training and drills plan, feedback collection and continuous improvement**

Modules for local authorities (physical properties of H_2, differences vs NG / LPG, safety of H_2 technologies) plus periodic drills (leak, ESD, surrounding fire).

When necessary, it is recommended to develop a training plan that, through the dissemination of knowledge, also has a positive impact on permitting procedures in general. Operational preparation trains people, periodically tests procedures and systems (detection, evacuation, etc.) and creates a cycle of continuous improvement based on real evidence and feedback. This improvement can be measured through indicators such as: average time for additional information requests, overall permitting time; emergency response time, joint annual review of operation, maintenance and failures, etc.

Steps 5 and 6 are intended for this transition phase, in which hydrogen and hydrogen technologies will be used in emerging sectors and for those cases where there is little practical knowledge of hydrogen projects and low awareness. Once practical knowledge has spread across the various EU countries, there will be greater convergence and a more harmonised approach to hydrogen plant safety. Consequently, these steps could be maintained only if deemed necessary, otherwise it can result into iterative consultancies and higher project costs.

7 Methodology

HYPOP is based on stakeholders' engagement. The information that contributed to the final Safety guidelines for first responders were collected through the results from HYPOP national workshops and applying the same methodology used to gather information for the technical analysis of safety requirements and barriers of Work Package 2.

The **national workshops took place in Spain, Italy, Belgium, Poland, and Bulgaria, and their outcomes are presented (see Appendix).** Data were gathered primarily via online tools (e.g., Google Forms, Slido), and—in Italy and Belgium—supplemented by round-table discussions. The objective was to capture experiences from stakeholders across the hydrogen value chain, build an overall picture of those experiences, and compare similarities and differences between the workshop countries and the other countries analysed in the project.

Moreover, prevention and mitigation measures collected from best practices and the general safety approaches improved the final Recommendations and Practical actions of HYPOP guidelines described in Section 6. This was possible through the constant implementation of the research started in Work Package 2 on "Safety requirements and barriers" (a complement to WP2 data is provided in the Appendix). So, the same methodology was applied for this document. It is mainly based on the literature research of specific national/local regulations and guidelines, on the synergies with other projects working on regulatory topics (e.g., HYLAW project, GA nr. 737977 etc), and on the experience of stakeholders engaged by HYPOP partners. **The following table summarizes the main activities that characterize the mentioned methodology where safety and certification of hydrogen technologies are usually linked and the stakeholders who can benefit from each activity and topic are highlighted.**

Table 17 Activities carried out in Work Package 2 and 4 to get information on Safety approaches for H_2 projects

Type of activity	Stakeholders	Reference Topic
Analysis of regulatory frameworks in the EU target countries for the implementation of hydrogen projects (useful for technical recommendations and practical actions)	Manufacturers, early adopters, project developers, Public authorities	Safety
Literature and standards review about hydrogen technologies	Manufacturers	Safety and Certification
Interviews with stakeholders to get information on national/local safety approaches followed, on personal experiences (e.g., pilot and real projects), opinions and perception	Manufacturers, early adopters, project developers, Public authorities	Safety and Certification
Analysis of a restricted number of key projects/best practices (described in Deliverable 2.1)	Manufacturers, early adopters, project developers, public authorities	Safety and Certification

Type of activity	Stakeholders	Reference Topic
Organization of national workshops and an international workshop (activity linking WP2 and WP4)	Manufacturers, early adopters, project developers, public authorities	Safety and Permitting

The analysis has been performed in the following EU countries and the following table shows the type of stakeholders and experiences brought to the HYPOP guidelines.

Table 18 Contributors to HYPOP: EU projects, public authorities and private entities

Country	Type of Stakeholders	Reference and Experiences
HYPOP countries		
Belgium	Hydrogen cluster; Private company	• Waterstofnet - safety, permitting and certification; • Brussels airport- coordinator STARGATE project; • Technifutur – involved in several H_2 projects (Green SKHy, KnowWHY, HySCHOOL, …); • VITO - BAT study on H2 refueling station; • Sertius, permitting body in Belgium; • RESA, gas and electricity distribution network manager; • University of Bruxelles (ULB); • Colruyt group, Administration of the Walloon region (permitting and environment department)
Italy	Public authority; Private company; University	• Trieste port - safety and permitting, RENEWPORT project; • RINA Consulting - experts for safety and certification; • Tecnodelta - HYCARE project partner - certification; • ATENA Scarl - certification - H2ports project partner; • Uniparthenope - certification - FuelSOME project partner; • A2A company - safety and permitting - Valcamonica hydrogen project; • Tenova - safety and permitting - GrInHy 2.0 project;

Country	Type of Stakeholders	Reference and Experiences
		• Fondazione Bruno Kessler - safety, permitting and certification - coordinator SWITCH project; • UNI - Ente Italiano Normazione - certification - partner e-SHyIPS project; • SAGAT - safety, permitting and certification - TULIPS project partner
Spain	Private company, Association of companies	• Redexis (OCEANH2, GREEN HYSLAND projects); • Tecnalia (ARENHA project) • TECNIBERIA • Clúster Andaluz del Hidrógeno; • Plataforma Tecnológica Española del Hidrógeno
EU-13 Countries		
Bulgaria (HYPOP country)	Hydrogen association	• Balkan Hydrogen Cluster – safety and permitting
Poland (HYPOP country)	Private company;	• TUV SUD Poland - safety and certification experts;
Croatia	Research center; Public authority	• Energy Institute Hrvoje Pozar - environmental permitting - Interreg projects; • Ministry of Economy - safety; • Energy and Environmental Protection Institute (EKONERG) - permitting; • Green Sustainable Solutions - permitting.
Cyprus	Private Company; Public entity	• Future Fuels Ltd - coordinator of GreenH2CY project - safety and permitting; • Cyprus Energy Regulatory Authority - safety and permitting; • Trinomics
Czech Republic	Private company; Hydrogen cluster; Regional energy agencies; Regional agency	• ORLEN Unipetrol - expert in safety and permitting; • National Czech hydrogen technology platorm -expert in safety and permitting; • Energy Center of the Usti Region; • Energy Agency of the Zlín Region (EAZK); • Economic and social council of the Usti region;

Country	Type of Stakeholders	Reference and Experiences
		• DEVINN company - safety, permitting and certification - system integrators;
Estonia	Research center	• Metrology institute Metrosert - coordination of Hydrogen valley
Hungary	Private company	• PBN Advanced Management - SMART-HY-AWARE project partner - safety and permitting;
Latvia	**No information**	**No information**
Lithuania	Research center; Public authority	• Lithuanian renewable energy institute; Klaipeda State Seaport authority – safety and permitting; • Representative of Ministry of Transport - information on regulatory framework; • Research Council of Lithuania
Malta	National agency	• Malta council for science and technology
Romania	Hydrogen competence association	• Sustainable NGO - Permitting
Slovakia	Research center; Public authority	• Institute for public service development - partner in H2CE project; • Kosice regional authority - coordinator of EASTGATEH2 project - information shared on safety and permitting;
Slovenia	Research center; Private company	• Kemijski inštitut - H2GreenFuture Interreg project; • Holding Slovenske elektrarne d.o.o. - coordinator of NAHV, North Adriatic Hydrogen valley-safety permitting and certification;
Frontrunner countries		
France	Public authority; National Association; Private company	• Region Centre Val De Loire - public acceptance; • France Energies Marines - focused on safety, permitting and public acceptance for maitime sector; • ENGIE - saefty and certification experts - prenormative research in Thyga project; • France Hydrogen

Country	Type of Stakeholders	Reference and Experiences
Germany	Private company	• Hamurg airport - HyAirport project coordinator - safety and permitting; • Experts in safety and certification- information shared during Hytruck breakfast meetings; • NOW GmbH
Netherlands	Public authority; Private company	• Hydrogen hub Noord Holland-coordinator of Hydrogen Hub Noord-Holland valley - safety permitting and certification; • New Energy Coalition - LIHYP project - safety and permitting; • Nedstack fuell cell technology BV - safety and certification - GRASSHOPPER project partner; • KIWA - certification; NL Hydrogen
Switzerland	National Association;	• H2Mobiliteit - permitting.

Figure 2 Geographical coverage of the research on safety, permitting and certification topics

The following parameters have been used to perform a strength and weakness analysis capable to provide a comprehensive picture of the current readiness of EU regulatory framework. The main outputs of WP2 have been reported in the table. Further insights are included in HYPOP Deliverable 2.1 “Safety requirements and barriers” and Deliverable 2.2 “Permitting requirements and barriers”.

Table 19 Safety and Permitting parameters used to perform a strength and weakness analysis

Safety parameters	Permitting parameters
Availability of guidelines for safety evaluation	Evidence of existence of a regulatory framework for permitting
Evidence of implementation/adoption of risk assessment methodologies	Existence of H2 -specific procedures
Evidence of regulations, codes and standards guiding the safety approach to hydrogen	Evidence of permitting guidelines (for H2 technologies)
Application/adoption/evidence of performance-based approach and consequent requirements	Evidence of cooperation with and overall positive attitude towards hydrogen by public authorities
Application/adoption/evidence of prescriptive approach and consequent requirements.	

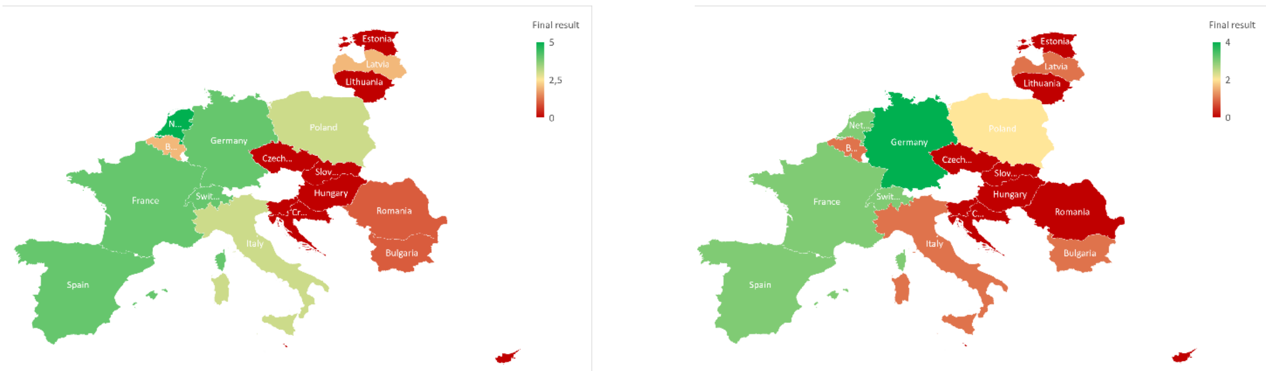

Figure 3 Strength and weakness map according to Safety parameters (on left) and Permitting parameters (on the right) from WP2

8 Conclusions

Hydrogen technologies are increasingly recognised as a pillar of Europe's decarbonisation pathway for industry, mobility and residential uses, complementing electrification and efficiency. Evidence gathered by HYPOP—best-practice analyses, stakeholder workshops, permitting case studies—shows, however, a fragmented safety landscape: divergent interpretations, uneven familiarity with the distinctive properties of H_2, and oscillation between prescriptive and performance-based approaches.

Perception and knowledge of stakeholders involved in the safety and permitting procedures are seen as drivers of hydrogen projects implementation. Hydrogen use is perceived by many as new, but hydrogen technologies have been used safely in several industrial applications since last century. New applications and emerging hydrogen technologies are being developed for mobility and residential applications. In these cases, safety approaches underpinning the regulatory framework must follow the pace defined by research and innovation and this is not an easy task. Indeed, common safety approaches associated to hydrogen technologies and hydrogen itself as a fuel are not fully developed. This uncertainty is reflected both at national and local levels in EU where safety requirements can result in barriers hindering the private investments and making more complex the work of both stakeholders involved in the procedures of granting and obtaining permits (e.g., public authorities vs businesses).

Current Problem: The current phase is marked by limited practical experience with hydrogen: many local authorities (first and foremost Fire Brigade Commands and the technical offices responsible for environmental matters, urban planning and accident prevention) are not supported from a regulatory framework hence struggle to interpret existing regulations (often conceived for other fuels) in their assessment of innovative solutions.

Objective: Reduce uncertainty and permitting timelines and increase knowledge and perception—while ensuring documented, equivalent safety levels—through a structured, replicable interaction pathway between the project proponent / HSE designer and the public authorities.

The fragmented safety landscape generates:

- Longer and less predictable permitting timelines.
- Unequal and diversified safety requirements in EU (over- or under-engineering).
- Increased development "soft costs" (iterative review cycles, repeated consultancy).
- Weakened public trust where transparency is low.

Recommendations included in **HYPOP guidelines can be resumed into two operational pillars that can drive day-to-day implementation and reproducibility:**

- **Technical Actions:** from mapping regulatory gaps to targeted adaptation and transfer of best practices from EU approaches; from different technical requirements (e.g., certification & ATEX compliance, Layout engineering & containerisation, Early detection and adaptive ventilation etc) to gradual standardisation of risk methodologies and a common safety approach.

- **Knowledge Transfer & Awareness Raising**: a continuous improvement process based on modular training for authorities and operators; creating a broad, standardized participatory ecosystem that strengthens interaction among stakeholders to build acceptance and counter misinformation.; organizing workshops between technical experts and public authorities to exchange views and align perspectives on safety; and co-creating emergency protocols with the fire brigade

Implementing this model will accelerate safe deployment, reduce administrative burden, and strengthen public trust—initiating a virtuous cycle between innovation and risk governance.

9 Appendix A

i. EU Guidelines

The following table includes some safety guidelines identified during HYPOP that can be taken into consideration to explore different approaches and start developing your own guidelines based on your approach to safety and by making changes or adaptations from other best practices.

Table 20 EU safety guidelines identified in HYPOP

Country	Impact	Topics	Sectors	Entities	Takeaways
Switzerland[11]	National	Safety/ Permitting	H_2 production	Association of H_2 producers, companies, national authority	The permitting framework is based on simplified interactions between public authorities where the exchange of information for different types of permits is led by a main authority. Two main permits needed, building and electrical. The building permit includes environmental authorizations like Environmental Impact Assessment if: • The storage of gas exceeds 50,000 m^3 or in the case of liquid storage if it exceeds 5,000 m^3;

11 https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://pubdb.bfe.admin.ch/de/publication/download/11554&ved=2ahUKEwiEu47S3N-OAxU8cvEDHQm-Hv4QFnoECAkQAQ&usg=AOvVaw2qMyiJ0ZB6GKrH3iWeuf5f

Country	Impact	Topics	Sectors	Entities	Takeaways
					• The operational area of the plant exceeds 5,000 m^2 or if chemical products are synthesized beyond 1,000 tons per year. Safety aspects: • harmonized standards at the intercantonal level as fire prevention; • legal reference for potentially explosive atmospheres, VUV (equivalent to ATEX 1999/92/EC)
Netherlands [12]	National	Safety	Mobility (Hydrogen refuelling stations, HRS)	H_2 experts engaged by authorities	Guidelines on safety of HRS (assessed by municipality or provinces) act as a regulation. Internal safety distances (up to 8,5 meters) are calculated through the application of a quantitative risk assessment-based methodology, a software (SAFETI-NL NL v6.5.4), and definitions and safety concepts from the European Industrial Gases Association (EIGA) IGC Doc 75/07/E "Determination of safety distances". The regulation (or guidelines) also recommends to consider mitigation measures like firewalls to reduce escalation, or the alteration of equipment design and/or operating conditions to reduce the severity and/or likelihood of the incident if the resultant safety distances are too large for design of the HRS.

12 https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://content.publicatiereeksgevaarlijkestoffen.nl/documents/PGS35/PGS%252035%2520voor%2520website%2520ondertekend.pdf&ved=2ahUKEwiuzPrr3N-OAxW4Q_EDHcHUMjYQFnoECBcQAQ&usg=AOvVaw05GoR5M1E9FmV_6igboHzr

Country	Impact	Topics	Sectors	Entities	Takeaways
Spain[13]	National	Safety	H_2 Production Mobility Residential	Companies' association	The guidelines point out the Spanish performance-based approach to safety describing: • the most relevant risk analysis methodologies, their function and goals and the stage of application in the project; • the identification of potential regulatory gaps at national level, recommendations from experts and presentation of international regulations, codes and standards (RCS) for safety of hydrogen installations. Key elements influencing safety of hydrogen installations are reported (also for on-site H_2 production): • definition of exclusion zones where access is limited; • safety distances and mitigation measures affected by explosion scenarios; • leakage of H2 in air requiring proper ventilation systems for all ATEX zones; • gas and fire detection systems.

[13] https://bequinor.org/general/guia-de-seguridad-del-hidrogeno-de-bequinor/

ii. Evidence of regulations for safety of H2 projects in EU

Below are some safety regulations identified in HYPOP, classified according to the type of safety approach and listing the main security requirements. For further information, please refer to Deliverable 2.1 of HYPOP.

Table 21 Existing EU safety regulations for H_2 projects

Country	H2 Application	Reference	Main requirements	Safety Approach
Italy	H2 production	Decree of 7 July 2023 by the Ministry of the Interior: "Technical rule for fire prevention for identifying risk analysis methodologies and fire safety measures to be adopted for the design, construction, and operation of hydrogen production plants through electrolysis and their storage systems."[14]	• Safety distances from 3 m to 5 m (P<10bar) • Safety distances from 15 m to 30 m (700 <P<1000 bar)	Prescriptive
Italy	HRS	Decree of 23 October 2018 by the Ministry of the Interior: "Technical rule for fire prevention for the design, construction, and operation of hydrogen distribution plants for motor vehicles;[15]	Safety distances from 12 m to 30 m	Prescriptive

[14] https://www.vigilfuoco.it/media/notizie/gu-decreto-7-luglio-2023-impianti-di-produzione-di-idrogeno-mediante-elettrolisi-e-relativi-sistemi
[15] https://www.gazzettaufficiale.it/eli/id/2018/11/05/18A07049/SG

Country	H2 Application	Reference	Main requirements	Safety Approach
Spain	HRS	Real Decreto 919/2006, de 28 de julio (ITC-ICG 5)[16]	ISO/TS 19880-1:2020 "Gaseous hydrogen - Fuelling stations - Part 1: General requirements	Performance
Spain	Residential	Real Decreto 656/2017, Reglamento de Almacenamiento de Productos Químicos y sus Instrucciones Técnicas Complementarias MIE APQ 0 a 10 [17] (MIE APQ-1; MIE APQ-5; MIE APQ-10.	• Based on storage quantity; • Safety distances between dangerous equipment - 3 m / 6 m or separation wall	Prescriptive
Poland	HRS	Regulation of the Minister of Climate and Environment of 21 October 2022 on detailed technical requirements for hydrogen stations (Journal of Laws 2022, item 2158)[18]	• standards ISO 1988-1 and EN ISO 17127 • standards ISO 19880-2 and EN ISO 17268	Performance

[16] https://www.boe.es/buscar/act.php?id=BOE-A-2006-15345#itcicg05
[17] https://www.boe.es/buscar/act.php?id=BOE-A-2017-8755
[18] https://www.gov.pl/web/klimat/rozporzadzenie-ministra-klimatu-i-srodowiska-w-sprawie-szczegolowych-wymagan-technicznych-dla-stacji-wodoru

Country	H2 Application	Reference	Main requirements	Safety Approach
Bulgaria	HRS + on-site H2 production	Regulation No RD-02-20-2 of September 28, 2020 on the “Conditions and Procedure for Design, Construction, Commissioning and Control of Hydrogen fuel vehicle filling stations”[19]	• Safety distances up to 15 m. • BDS ISO 16111 "Portable gas storage devices. Hydrogen absorbed in reversible metal hydride • BDS EN ISO 17268 "Connection devices for refuelling road vehicles with gaseous hydrogen (ISO17268:2012)". • BDS EN 17127 "Outdoor hydrogen refuelling points, dispensing gaseous hydrogen and	Prescriptive

[19] https://lex.bg/bg/laws/ldoc/2137206003

Country	H2 Application	Reference	Main requirements	Safety Approach
			including filling protocols"; • BDS EN 60079-10-1 "Explosive atmospheres. Part 10-1:Classification of areas. Explosive gas atmospheres".	
Czech Republic	HRS	Methodology for the construction and operation of compressed hydrogen filling stations for mobile devices [20](guideline applied officially)	Safety distances from 3 m to 8 m	Prescriptive
France	HRS	Arrêté du 22 octobre 2018 relatif aux prescriptions générales applicables aux installations classées pour la protection de l'environnement soumises à déclaration sous la rubrique n° 1416 (station de distribution d'hydrogène gazeux)[21]	Safety distances from 6 m to 14 m (reduction to max 10 m)	Prescriptive/Performance

[20] https://hzscr.gov.cz/clanek/metodika-vystavby-a-provozu-plnicich-stanic-stlaceneho-vodiku-pro-mobilni-zarizeni.aspx
[21] https://www.legifrance.gouv.fr/loda/id/JORFTEXT000037519292/

Country	H2 Application	Reference	Main requirements	Safety Approach
France	Residential	Arrêté du 12 février 1998 « general requirements applicable to classified installations for environmental protection subject to declaration under heading No. 4715).[22]	• Indoor safety distances 5 m • Outdoor safety distances 8 m	Prescriptive
Germany	HRS	*Genehmigungsleitfaden Wasserstoff-Tankstellen*[23]	• ISO 19880-1:2020 Gaseous hydrogen — Fuelling stations — Part 1: General requirements • TRGS 720: Hazardous Explosive Mixtures – General Information • TRGS 727: Avoidance of Ignition Hazards due	Performance

[22] https://www.legifrance.gouv.fr/loda/id/JORFTEXT000000571176

[23] https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.now-gmbh.de/wp-content/uploads/2022/03/NOW_Genehmigungleitfaden_H2-Tankstellen.pdf&ved=2ahUKEwibqrL0vt-OAxU_V6QEHabPPCEQFnoECAkQAQ&usg=AOvVaw1DDVCWjEDp6w9zjCd4ybOy

Country	H2 Application	Reference	Main requirements	Safety Approach
			to Electrostatic Charges • TRGS 745: Portable Compressed Gas Containers – Filling, Storage, Internal Transport, and Emptying	
Netherlands	HRS	PGS35 "Waterstofinstallaties voor het afleveren van waterstof aan voertuigen en werktuigen"[24]	• Safety distances from 2 m to 8,5 m • software (SAFETI-NL v6.5.4), • safety concepts from the European Industrial Gases Association (EIGA) • IGC Doc 75/07/E "Determination of safety distances"	Performance

[24] https://publicatiereeksgevaarlijkestoffen.nl/publicaties/pgs35/

Country	H2 Application	Reference	Main requirements	Safety Approach
Croatia	Industry, HRS, residential	Based on NFPA-2/2020 “Hydrogen technology code” (not national regulation)	• Safety distances from compressed hydrogen storage between 1,5 m to 14 m depending on the equipment involved.	Performance

iii. Basic references for Regulations, Codes and Standards (RCS)

The following table includes some basic RCS that could be checked. For further details on standards you are recommended to check both Deliverable 2.3 and D4.5 Certification Guidelines of HYPOP.

Table 22 Basic references for Regulations, Codes and Standards

Useful standards and regulations for hydrogen safety
Explosion protection: IEC/EN 60079 and ISO/IEC 80079;
ISO 22734 - Hydrogen generators using water electrolysis — Industrial, commercial, and residential applications: requires manufacturers of electrolysers to perform a risk assessment. Depending on the final placement location of the equipment, plant owners/operators may need to perform their own additional assessment on the hydrogen generator, applying zone classification using IEC 60079-10-1 or an appropriate national standard

ISO 19880 - Gaseous hydrogen — Fueling stations
Zone classification and ignition protection methods according IEC 60079, ISO/IEC 80079 and NFPA 2
ISO/TR 15916 — Basic considerations for the safety of hydrogen systems
Additional resources (with references)
Hydrogen and Fuel Cells Codes and Standards Database: https://h2tools.org/fuel-cell-codes-and-standards?search_api_fulltext=
EIGA guide: HYDROGEN PIPELINE SYSTEMS https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.eiga.eu/uploads/documents/DOC121.pdf&ved=2ahUKEwja-_uC4d-OAxVmVqQEHaObHnkQFnoECBUQAQ&usg=AOvVaw2Xm3-VobjG-Flg0-Bkki3n
EIGA guide: GUIDELINE FOR SMALL SCALE HYDROGEN PRODUCTION https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.eiga.eu/ct_documents/doc246-pdf/&ved=2ahUKEwja-_uC4d-OAxVmVqQEHaObHnkQFnoECBYQAQ&usg=AOvVaw1ue2JTdrcuiEf8Qz9O5yME
NFPA guide: fundamental safeguards for the generation, installation, storage, piping, use, and handling of hydrogen in compressed gas form https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://www.nfpa.org/codes-and-standards/nfpa-2-standard-development/2&ved=2ahUKEwi-1L724d-OAxW4KvsDHU5HIzYQFnoECAkQAQ&usg=AOvVaw3X4ls3hYFY0_tIrRBIw7D8

iv. HYPOP technical workshops

Technical workshop: Spain

The two workshops organized in Spain by Centro Nacional de Hidrogeno consisted of presentations on the HYPOP project and discussions with the audience composed by companies mainly. The most significant results of these workshops referred to the main challenges/barriers encountered for demonstrating safety of hydrogen technologies.

The main challenges and barriers have been summarized in the following categories:

- **Knowledge**: the lack of information and awareness (generally from the administrations), availability of previous infrastructures and lack of precedents were also shown as an issue.
- **Public opinion**: credibility, social awareness (fighting false myths, raising awareness in society that H2 has been with us for decades) and social issues.
- **Regulation and certification**: lack of specific regulation, lack of a unique specific regulation, certification, standardized best practices, homogeneity.
- **Environmental prevention.**
- **Techno-economic issues**: costs, economic issues, demand, use of the technology, machinery operating hours, anticipation of storage equipment degradation, facility design, storage, distribution, making H2 closer to people through HRS.
- **Safety**: low awareness about safety and the difficulty in detecting hydrogen leakages were other topic addressed. General aspects about this topic, like explosive zones, the range of flammability of the H2, the values of pressure in H2 generation and storage, lack of previous accident data (for validating safety level). Developing, disseminating and applying passive and active safety measures.

Technical workshop: Italy

The Italian workshop took place during the Hydrogen Expo Piacenza. The workshop was organized by ENVIPARK in collaboration with the Italian Hydrogen and Fuel Cell Association (H2IT) and was attended by private companies and public authorities.

A roundtable was held to discuss the main barriers experienced by stakeholders of the hydrogen sector in Italy. The main criticalities identified was the low experience and perception of public authorities towards hydrogen and the uncertainties regarding the interpretation and application of the existing safety regulations at national level.

Through the discussions, the main output from speakers and audience were collected to develop a likely safety authority engagement discussion. The main steps have been reported here:

- **Project introduction (Safety):** Present the project to the fire brigade command, making it easier to understand and accelerating the approval process.
- **Normative references:** Review with the fire brigades which ministerial decrees and regulations apply to each section of the installation.
- **Critical issues:** Analyse potential project criticalities and identify suitable mitigation measures.
- **Needs**: Implement existing safety regulations introducing specific conditions for each possible project size and technologies installed
- **Tools:** To require risk assessment and to specify which methodology is desired
- **Approach**: To reason on the likely of incident scenarios instead of gravity

Technical workshop: Belgium

CLUSTER TWEED organized an online workshop involving a company specialized in environmental and safety services; a private company which implemented a hydrogen project in the **food store chain**; a company dedicated to gas and electricity distribution network; and the **Free University of Brussels**. CLUSTED TWEED led a presentation focusing on the current situation in Belgium and neighbouring countries. The session finished with a brief Q&A session which highlighted how the primary issue when safety of hydrogen projects is addressed is not the technical aspect, but rather, the acceptance of the stakeholders in making it acceptable. Linked to an unclear administrative framework in Wallonia public authorities generally fear this new technology. As the administration lacks expertise in hydrogen, it often refers to SEVESO regulations, even for small projects. As there are no specific acceptance criteria, they follow the SEVERO criteria, which are very restrictive for hydrogen project like Hydrogen refuelling stations. All the participants agreed that **training and raising awareness among the authorities is essential**, and the industry can primarily join in the process.

Technical workshop: Bulgaria

The Bulgarian workshop was held at the Bulgarian Academy of Sciences in Sofia. Some of the participants were representatives of the following organizations: the State Agency for Meteorology and Technical Supervision, the Bulgarian Academy of Sciences, various universities, municipalities, and the National Fire and Civil Safety Services.

Due to the significant regulatory gaps in Bulgaria, the workshop addressed in general terms what were the main needs to be tackled. The National Fire Safety and Civil Protection Service informed participants of all the legal and regulatory requirements and practical examples relating to the production, storage and use of hydrogen. The participants then expressed their opinion that the state authorities should take a proactive approach and introduce legislative norms more quickly in order to enable businesses to adopt hydrogen on a large scale. As an example of the next steps that we will see for Bulgaria, a working expert group is going to be established specifically for hydrogen project permits. Participants expressed their hope that this group will provide positive momentum for hydrogen project and their permits.

Technical workshop: Poland

The workshop aimed to introduce the audience to HYPOP project (Hydrogen Public Opinion and Acceptance) and to initiate an in-depth, constructive interregional discussion on the potential and challenges related to the hydrogen economy. The meeting gathered representatives from various sectors—industry, public administration, and environmental expertise. This cross-sectoral presence ensured a holistic view of hydrogen economy development.

During the discussion session, participants shared experiences, needs, and challenges related to hydrogen project implementation. The following key issues were identified:

- Complexity and lack of transparency in administrative procedures; lack of uniform local standards
- Insufficient administrative competence in technical and legal aspects of hydrogen installations,
- Absence of coherent public communication tools and citizen engagement mechanisms,
- Untapped potential for synergy with EU-funded projects,
- The need for unified guidelines for the Pomeranian region.

v. Technical analysis of safety requirements and barriers: complement from HYPOP D2.1

The information provided in this section of the appendix is intended to supplement the technical analysis of safety requirements for hydrogen projects that appears in D2.1. This work was carried out (including in the case of permitting) in parallel with the organisation of stakeholder engagement workshops. **Further information, results and comparisons for other countries can be found in HYPOP Deliverable 2.1.**

CROATIA

Croatia currently does not have a dedicated legal framework for hydrogen in the industrial, mobility, or residential sectors. Existing regulations related to flammable gases, construction safety, and energy are applied, often in combination with EU directives. For mobility and industrial use, EU rules are followed, while in the residential sector hydrogen is still in the pilot phase.

The main challenges shared by stakeholders when dealing with hydrogen-related permits include:

- lack of a clear and specific legal framework;
- additional safety requirements;
- varying interpretations and procedures between municipalities and counties.

General safety requirements

The limit quantities of hazardous substances that must be stored at the installation site must be checked in accordance with **Annex IA of the Regulation on the Prevention of Major Accidents involving Hazardous substances (OG, 44/14, 78/15, 31/17, 45/17)**:

Table 23 Limit quantities of hazardous substances from Regulation on the Prevention of Major Accidents involving Hazardous substances

Serial number	Hazardous substance	Lower limit quantities of hazardous substances (in tonnes)	
		Small quantities	Large quantities
Annex IA, part 2			
15	Hydrogen	5	50

Moreover, since hydrogen is defined as a hazardous substance that, if leaked, can cause an explosive atmosphere and possible explosions, danger zones and safety distances have been defined. Since Croatian legislation currently does not contain regulations defining the safety distances of compressed hydrogen tanks from other buildings and fire sources, the **NFPA-2/2020 standard applies,** the values for which are given below:

Table 24 Safety distances from NFPA-2/2020 standard (from Croatia)

TYPES OF POTENTIAL OBJECTS IN THE VICINITY OF A COMPRESSED HYDROGEN TANKER ("TUBE TRAILER")	MINIMUM DISTANCE FROM A COMPRESSED HYDROGEN TANK (m)
FIRE-RESISTANT BUILDINGS	5,8
FLAMMABLE OR LOW-FLAMMABILITY BUILDINGS	5,8
PARKED VEHICLES	7,3
PUBLIC HIGHWAYS, RAILROADS, AND OTHER SURFACES OWNED BY THIRD PARTIES	14
LIQUID HYDROGEN TANKS	1,5
PLACES OF PUBLIC ASSEMBLY	14
OPEN CALLS	14
LIQUID OXYGEN TANKS	5,8
FLAMMABLE LIQUID TANKS	5,8
UNDERGROUND TANKS BREATHING VALVES	5,8
LIQUID COMBUSTIBLES	5,8

TYPES OF POTENTIAL OBJECTS IN THE VICINITY OF A COMPRESSED HYDROGEN TANKER ("TUBE TRAILER")	MINIMUM DISTANCE FROM A COMPRESSED HYDROGEN TANK (m)
FLAMMABLE SOLID MATERIALS (FUEL STORAGE) SOLIDS)	14
AIR COMPRESSOR INTAKES	14
OTHER STRUCTURES	14

CYPRUS

Stakeholders' engagement brought to the analysis of the main H_2 project active in Cyprus. The **GreenH2CY project** is one of the few initiatives in Cyprus that integrates the **production, storage, and use of renewable hydrogen specifically for road transport**. Funded under the **2022 Innovation Fund call**, the project aims to include on the same site:

- The installation and operation of a **2-megawatt (MW) Proton Exchange Membrane (PEM) electrolyser** consisting of two 1 MW electrolysis stacks (150 tons/year production capacity);
- A **hydrogen storage facility** made up of two storage units (2 × 500 kg);
- A **hydrogen refuelling station** at the same location.

Project stakeholders have been engaged in the **permitting process for over two years**, facing significant challenges due to the **lack of hydrogen-related education among authorities**, both at the local and national levels. In contrast, **public perception and community engagement have been very positive**, with the project being described as an opportunity to decarbonize the transport sector.

Future Fuels Ltd, the project coordinator, contributed these insights to the HYPOP project regarding **safety and permitting** procedures.

From a **safety perspective**, the **Fire Brigade** is the competent authority for issuing safety-related permits. Since there are **no specific technical guidelines or regulations for hydrogen**, the only known regulatory reference is the **SEVESO Directive**. However, due to its **inapplicability to small-scale pilot projects** (below the 5-ton threshold) and its **stringent safety requirements**, it was ultimately considered but **not applied**.

Instead, the procedure involved analyzing **existing guidelines for conventional fuels** and submitting a **safety report** to the Fire Brigade, including results of a **risk assessment** highlighting the **explosion risk of hydrogen storage** and the **required safety distances** between the storage unit and external site boundaries.

CZECH REPUBLIC

The **regional fire brigades** (at district level) are the **competent authorities for safety**. There are currently **no specific working groups** or **initiatives aimed at gathering best practices and shared experiences**. In practice, **each project is handled as a stand-alone case.**

At the moment, the practical experience for hydrogen mobility in the country relies on four 700 bar hydrogen refuelling stations: one in Ostrava operated by VÍTKOVICE, a.s., two (one in Prague and one in Litvinov) operated by ORLEN Unipetrol; and one close to Prague operated by ČEPRO, a.s.

A guideline for the development of Hydrogen refuelling stations exist in Czech Republic. It can be checked at the following link: https://hzscr.gov.cz/clanek/metodika-vystavby-a-provozu-plnicich-stanic-stlaceneho-vodiku-pro-mobilni-zarizeni.aspx.

The main features of the guidelines for hydrogen refuelling stations are reported as follows.

These guidelines have been prepared in the absence of an official regulation and therefore serve, in effect, as a de facto standard. They set out a methodology that establishes the basic conditions for constructing new compressed-hydrogen refuelling stations for mobile equipment, particularly for transport vehicles.

They also describe a range of methods—used individually or in combination—for accident prevention, damage mitigation, and emergency-response procedures should flammable or explosive atmospheres arise. The document was produced through collaboration between public and private bodies together with the independent certification organisation TÜV NORD, and it contains provisions on both fire safety and permitting procedures.

For site selection, design, construction, commissioning, operation, and maintenance, it draws on the experience of comparable plants and on the regulations for CNG and LPG, as well as on lessons learned from designing, building, operating, and maintaining the first (and so far only) compressed-hydrogen refuelling station in Neratovice, and on internationally recognised technical standards adopted by the Czech Republic. The document does **not** cover on-site hydrogen production or the use of liquid hydrogen. Nonetheless, the methodology addresses various station types—public or private, with slow- or fast-fill capability.

Structure of the guidelines

- **Definitions, terminology and applicable normative references**
- **Technical and administrative requirements for submitting a refuelling-station project**
- **Recommendations on site characteristics and station design**
- **Tests for system validation**

This structure reflects a **prescriptive safety approach**, giving clear guidance to the designer. The principal fire-safety references for developing a hydrogen refuelling station are:

- **ČSN 73 0802** (fire safety of non-production buildings)
- **ČSN 73 0804** (fire safety of production buildings)

Additional key reference: **ISO/TS 19880-1 – Gaseous hydrogen—Fuelling stations—Part 1: General requirements**.

General safety requirements

- The **minimum distance between dispensers** must prevent overlap of hazardous explosion zones.

- **All station components** must be protected against mechanical damage caused by motor-vehicle operations.
- **Hydrogen piping** must comply with **EN 13480-3 – Industrial metallic piping, Part 3: Design and calculation**.
- **Pressure storage vessels** must meet **EN ISO 11114-4 – Gas cylinders for the transport of gases, Part 4: Test methods for selecting steels resistant to hydrogen embrittlement**.
- **Dispensers** must be installed outdoors beneath a canopy made entirely of non-combustible materials (roofing included).

Table 25 Safety distances required in Czech Republic

Distance category	Distance (m)
From sources of heat and open flame	5
Fire- and explosion-risk zone created by storage and pressure equipment	5
From public roads and car parks	8
From buildings with open flame, combustible surfaces/buildings, and air-handling intakes	8
From LPG tanks and warehouses	8
From CNG and LNG equipment	8
From the compressor	3

Documentation required for planning and building approval (The detailed checklist is given in the guidelines; key references include):

- **Act No. 133/1985 Coll.** on fire protection (as amended)

- **Act No. 505/1990 Coll.** on metrology (as amended)
- **ČSN 1127-1** – Explosive atmospheres—Explosion prevention and protection—Part 1: Basic concepts and methodology
- **Decree No. 499/2006 Coll.** on building documentation (as amended)
- **Decree No. 169/2016 Coll.** on the scope of documentation for public-works contracts and the inventory of construction works, supplies and services, as amended by **Decree No. 405/2017 Coll.**
- **ISO 26142** – Hydrogen detection apparatus—Stationary applications
- **IEC 61000** – Electromagnetic compatibility (EMC)
- **ČSN 73 0810** – Fire safety of buildings—General provisions

Instead, there are no evidences of guidelines or specific regulations for hydrogen production plants, as indicated at the following link: https://observatory.clean-hydrogen.europa.eu/hydrogen-landscape/policies-and-standards/national-policy Nevertheless, some hydrogen production processes are envisaged in the country: Green Mine (2027, Most, Region of Ústí nad Labem) where an electrolyser will be built as part of the Green Mine project (annual production of 360 tonnes); a project where the hydrogen produced by an electrolyser is connected to PV excess of energy produced. The project should run on 2027 and it is managed by ORLEN Unipetrol (annual production of 4500 tonnes).

At the moment, there are only a few active hydrogen-related projects in the Czech Republic. There are some hydrogen refuelling stations (HRS) that have been built and are operational, as well as a project involving hydrogen production through electrolysers powered by a photovoltaic park. However, these projects share the characteristic of being located in **industrial areas**, often on **private company land**, particularly within the **chemical sector**. This influences both the **type of public authorities involved** and their **experience and perception** regarding such projects, while also highlighting a general **lack of experience** in public or urban contexts.

The hydrogen production project currently undergoing permitting is not encountering major difficulties in terms of safety procedures, primarily because it is situated near areas where chemical companies routinely operate with other explosive gases. The **only challenge** encountered was the need to implement **additional safety standards and measures** to address concerns raised by the **firefighters** due to the site's proximity to **railway lines**.

Currently, there are **no specific national or regional safety regulations** for hydrogen projects in the Czech Republic—neither for HRS without on-site production nor for hydrogen production facilities. For existing HRS, **standard regulations** for **natural gas and LPG refuelling stations** have been followed (together with the guidelines which function as a methodology). In addition, the installation of **gas detectors**, proper **ATEX zoning**, and a **risk analysis** are required. Some **prescriptive safety distances** are applied, but these can be **overridden through discussions with the fire brigade**, provided that **minimum safety criteria** are still met. This is generally possible thanks to the **technical competence and openness of the fire services**, who are accustomed to working in industrial settings.

LITHUANIA

One of the main representatives of the Port of Klaipėda project, currently the most advanced hydrogen initiative in Lithuania, was engaged and shared her opinion. The project calls for building an on-site hydrogen-production plant and refuelling station within the port. Equipped with a 1.25 MW electrolyser, the plant will produce about 531 kg of hydrogen per day and include on-site storage for 1,500 kg. Hydrogen will be dispensed through two units: one open to the public and one dedicated to fuelling the port's own vehicles (bunkering hybrid vessels used for waste collection and handling).

This initiative has also provided the opportunity to launch a working group aimed at drafting a national hydrogen regulatory framework for Lithuania.

At present, Lithuania has no specific hydrogen regulations. Consequently, all permitting procedures—covering safety, environmental, and other aspects—are being developed ad hoc in consultation with the relevant authorities. The entire permitting process has taken more than 2.5 years and is now in its final stages.

When the port authority began the process in 2023, it proposed two possible installation sites. One of them was rejected by the fire brigade because it was too close to an area used for handling fertilisers and therefore considered hazardous.

Key points on safety:

- A formal application was required to use German standards for safe plant construction and safe-work management. In particular, earlier this year the Minister of Energy issued a regulation permitting the use of German standards for the technical design of hydrogen-related projects. These are the applicable standards:
    - **Guidelines for the Installation of Hydrogen Refueling Stations** (*German: Genehmigungsleitfaden Wasserstoff-Tankstellen*);
    - **General Safety Requirements for Hydrogen Refueling Stations** according to ISO 19880-1:2020 (*English: Gaseous hydrogen — Fuelling stations — Part 1: General requirements*);
    - **Annex 1 of the German Hazardous Substances Ordinance** (*German: Gefahrstoffverordnung*);
    - **TRGS 720: Hazardous Explosive Mixtures – General Information** (*German: Gefährliche explosionsfähige Gemische – Allgemeines*);
    - **TRGS 727: Avoidance of Ignition Hazards due to Electrostatic Charges** (*German: Vermeidung von Zündgefahren infolge elektrostatischer Aufladungen*);
    - **TRGS 745: Portable Compressed Gas Containers – Filling, Storage, Internal Transport, and Emptying** (*German: Ortsbewegliche Druckgasbehälter – Füllen, Bereithalten, innerbetriebliche Beförderung, Entleeren*).
- A quantitative risk assessment (QRA) was requested; among other outcomes, it led to a requirement for a safety distance of roughly 5 m around the dedicated hydrogen pipelines. Lithuania's existing rules cover only 200-bar pressures, so the QRA was necessary for higher-pressure hydrogen service zones.
- No specific demand was made for concrete boxes or walls to separate equipment, except for a blast-mitigation wall protecting the terminal side.
- Additional safety distances are under discussion.
- A HAZOP study was required to identify all potential hazards.

- Public presentations were organised to answer community questions. Many came from environmental groups concerned about water consumption and explosion risk. Local authorities were repeatedly consulted, and reference examples from the UK and Japan were presented.

MALTA

In the case of Malta, there is no information found about the specific procedures for hydrogen neither general procedure. The following safety elements have been found:

- Act XXVII of 2000, as amended, Occupational Health and Safety Authority Act, Cap 424 of the Laws of Malta;
- S.L. 424.15Work Place (Minimum Health and Safety Requirements) Regulations;
- S.L. 424.19 Control of Major Accident Hazard Regulations;
- S.L. 424.29 Work Place (Minimum Health and Safety Requirements for Work at Construction Sites) Regulations repealed by legal notice 88 of 201

SLOVAKIA

HYPOP engaged a representative of the Košice Region in Slovakia. The regional authority began working on hydrogen roughly five years ago and helped draft a regional hydrogen strategy. The stakeholder joined as coordinator of the recently funded **EASTGateH$_2$ Valley**, which aims to install a total of **4 MW of electrolytic hydrogen production** together with a **hydrogen-refuelling station (HRS).**

Project timeline

The valley will be delivered in two main phases:

1. **Phase 1** – installation of the first 2 MW electrolyser (permitting now well advanced) and initial steps for the co-located HRS;
2. **Phase 2** – installation of the second 2 MW unit.

Key information shared on Safety topics:

- **No dedicated national hydrogen safety code** yet exists. A *custom*, *project-by-project* approach is therefore required.
- Sector associations and the Ministry of Economy are working on new legislation.
- For the current valley, safety requirements are assessed by the **Technical Inspection Authority** and the **City Council**, with support from the **Fire Brigade**, which helps prepare the Safety Management Plan and Risk Assessment included in the technical file.

www.hypop-project.eu
info@hypop-project.eu
#HYPOPPROJECT

Let's make the hydrogen revolution

Clean Hydrogen Partnership
Co-funded by the European Union