MultHyFuel

Deliverable 1.2

Permitting requirements and risk assessment methodologies for HRS in the EU (First version)

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Content

Acronyms

HRS	Hydrogen Refuelling Station
ALARP	As Low as Reasonably Practicable
EU	European Union
AFID	Alternative Fuels Infrastructure Directive
SEA	Strategic Environmental Assessment
CNG	Compressed Natural Gas
LPG	Liquefied Petroleum Gas
FCEV	Fuel Cell Electric Vehicle
QRA	Quantitative Risk Assessment

Executive Summary

Clean Hydrogen and Fuel Cell Electric Vehicles (FCEV) have developed significantly in the past years in order to respond appropriately to the challenges associated with the transition to a net zero carbon Economy.

Associated infrastructure, in particular, Hydrogen Refuelling Stations (HRS) have also developed to respond to the increasing needs for Hydrogen in the mobility sector. The need to mainstream Hydrogen in the mobility sector requires higher levels of accessibility of HRS in the public environment.

In response to these challenges, the MultHyFuel project proposes to study how hydrogen refuelling stations can be relevantly and safely integrated in close proximity, alongside other conventional and alternative fuels for the hydrogen mobility.

Deliverable 1.2 contains a comparative cross-country assessment of permitting requirements and public guidance on risk assessment methodologies covering HRS permitting across **14 European countries**, providing a **comprehensive cross-country review** of these elements and **gap analysis**. A strong network of national experts was involved in the process of gathering information from the different countries analysed (Austria, Belgium, Bulgaria, Finland, France, Germany, Hungary, Italy, the Netherlands, Norway, Poland, Spain, Sweden and the United Kingdom). In this report, an overview of the commonalities and gaps observed in the admistrative framework is presented, alongside relevant examples in the approach adopted by the different Member States. Towards the end of the project, a new and final version of this report will be published, containing updates and new findings that stem from the project implementation.

This report focuses mainly on permitting requirements, risk assessment methodologies commonly used, safety distances prescribed in legislation, equipment maintenance rules and mandatory/common practice mitigation measures applied.

Although only a few countries currently present HRS specific rules, other countries are also making efforts to develop such guidelines. Currently, most authorities will consult laws that target conventional or CNG reguelling stations and the handling of hydrogen in industry (not HRS specific) to make a permitting decision or define the right requirements.

1 Introduction

MultHyFuel proposes to study how hydrogen refuelling stations (HRS) can be relevantly and safely integrated in alongside other conventional and alternative fuels for the H_2 mobility. Work Package 1, in particular, focuses on a comparative cross-country assessment of permitting requirements and public guidance on risk assessment methodologies covering HRS permitting across **14 European countries**, providing a **comprehensive cross-country review** of these elements and **gap analysis**.

The production of hydrogen is subject to a significant number of requirements, most of which can be traced back to EU initiatives and directives in various fields which have then been embedded in national legislation. However, whilst the overall requirements are similar across all partner countries, significant differences in interpretation and implementation exist.

The approach taken for the co-location of hydrogen with other fuels is left to be defined on a national basis. This can have a variety of effects: in some cases it is straight-forward to co-locate hydrogen with other fuels and integrate hydrogen into a conventional forecourt, in others the provision of hydrogen can be subject to not insignificant minimum separation distances from other fuels, with a hydrogen dispenser needing to be either on an 'island' on its own or located away from the forecourt (or even not be permitted at all).

Deliverable 1.2 aims to contribute to the identification of relevant gaps in the current legal and administrative framework to be addressed based on the evidence and data produced as well as on identified best practices in this domain. A research framework was created and distributed among different national experts to collect as much information about the permitting and risk assessment requirements at the national level as possible. Towards the end of the project, a new and final version of this report (Deliverable 1.3) will be published, containing updates and new findings that stem from the project implementation.

The research framework was created to define the scope of the analysis and provide structure to the national experts' research. Specific questions were provided so that the real expectations of such analysis could be well understood by all participants. To keep the scope within an efficient frame, the focus of this framework is limited to < 5000kg H2-storage on-site. Topics like land use planning shall not be treated. On-site production of hydrogen fuel is also not included.

The experts conducting the research were selected based on their experience analysing national regulation in the field of hydrogen. Some of the associations had already been involved in similar projects, namely the Hylaw project in 2018 which identified the legislation and regulations relevant to fuel cell and hydrogen applications and legal barriers to their commercialisation.

The network of national experts can be found in Table 1. The national experts conducted their own research based on their own methodologies, which consisted mostly in the consultation of legislation and interviews with HRS operators and relevant authorities. This report summarizes the research's key findings, highlitghing the main commonalities and gaps found amongst the different countries. The analysis conducted focuses on the existing permitting requirements for HRS, the risk assessment methodologies, safety and separation distances, equipment maintenance intervals and existent mitigation measures on-site.

Table 1 - Network of national experts to be involved in WP1.

COUNTRY	ORGANIZATION	EU COVERAGE & REPRESENTATIVENESS
AT	Austrian Energy Agency	
BE	WaterstofNet vzw	
BG	Bulgarian Hydrogen, Fuel Cell and Energy Storage Association	
FI	VTT Technical Research Centre of Finland LTD	
FR	France Hydrogene	
DE	ZSW Center for Solar Energy and Hydrogen Research	
HU	MEBATERV BT.	
IT	H2IT - Italian Hydrogen and Fuel Cell Association	
NL	NEN	
PL	NEXUS Consultants	
ES	Aragon Hydrogen Foundation	
SE	Hydrogen Sweden	
UK	ITM Power	
NO	Greenstat	

2 Relevant European legislation

Despite the existence, or not, of HRS specific rules and laws at the national level, different European Directives and standards must be complied with by the different Member States. Before diving deep into the different national laws, it is useful to consider what European requirements do the Members States have to comply with. In the case of building an HRS, the most relevant Directives can be seen in Table 2.

Table 2 - Relevant european directives and standards for HRS.

Legislation	Definition
Directive 2014/94/EU **[1]**	Deployment of alternative fuels infrastructure. Setting technical specifications for alternative fuels refuelling stations.
Directive 2012/18/EU **[2]**	Also known as the SEVESO Directive, it concerns the control of major-accident hazards, mainly in the chemical and petrochemical industry, as well as in fuel wholesale and storage.
Directive 1999/92/EC **[3]**	Also known as the ATEX Workplace Directive, sets out the minimum requirements for improving the health and safety protection of workers potentially at risk from explosive atmospheres.
Directive 2014/34/EU **[4]**	Also known as ATEX Equipment Directive, on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres.
Directive 2014/68/EU **[5]**	On the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment
Directive 2001/42/EC **[6]**	The SEA – Strategic Environmental Assessment procedure can be summarized as follows: an environmental report is prepared in which

	the likely significant effects on the environment and the reasonable alternatives of the proposed plan or programme are identified.

The existence of Directives such as the ones presented in Table 2 does not make the permitting process uniform in every country. Specific risk assessment methodologies are not prescribed at the European level, and different approaches will therefore be taken by the different countries. It is also worth mentioning that, in some countries, these Directives do not have a permitting requirement attached to them but simply the potential for fines if the requirements are not met.

According to Directives 99/92/EC and 2014/34/EU, all countries must follow **ATEX** rules for zoning. ATEX is the name commonly given to these two European Directives for controlling explosive atmospheres. Employers must classify areas where hazardous explosive atmospheres may occur into zones. The classification given to a particular zone, and its size and location, depends on the likelihood of an explosive atmosphere occurring and its persistence if it does. The main purpose is to facilitate the proper selection and installation of apparatus to be used safely in that environment, taking into account the properties of the flammable materials that will be present. Hazardous areas are classified into zones based on an assessment of the frequency of the occurrence and duration of an explosive gas atmosphere, as follows:

- **Zone 0:** An area in which an explosive gas atmosphere is present continuously or for long periods;
- **Zone 1:** An area in which an explosive gas atmosphere is likely to occur in normal operation;
- **Zone 2:** An area in which an explosive gas atmosphere is not likely to occur in normal operation and, if it occurs, will only exist for a short time.

There are also European standards such as ISO 19880-1:2020 [7] that are frequently referenced by the Member States in their methodology. These define the minimum design, installation, commissioning, operation, inspection and maintenance requirements, for the safety, and, where appropriate, for the performance of public and non-public fuelling stations that dispense gaseous hydrogen to light duty road vehicles (e.g. fuel cell electric vehicles). Since this document is intended to provide minimum requirements for fuelling stations, manufacturers can take additional safety precautions as determined by a risk management methodology to address potential safety risks of specific designs and applications. Carried out by ISO/TC 197 - Standardization in the field of systems and devices for the production, storage, transport, measurement and use of hydrogen.

3 Existing permitting requirements for HRS

Chapter 3 presents an overview of the current permitting procedure inherent to the design and building of a new HRS in the different European countries included in this analysis. Commonalities found in the process are highlighted and gaps identified. The Chapter has been broken down into different sub-sections in order to best describe the general requirements and authorities involved, integration of hydrogen in a multi-fuel context, existent process guidance from the authorities to the operator and documents needed.

3.1 General procedure and authorities involved

Across the countries analysed, there are very few cases where hydrogen refuelling stations are specifically targeted and regulated in national legislation. In fact, specific HRS rules currently exist only in Germany, the Netherlands, France, Italy and Bulgaria.

In most countries, the permitting procedure followed for conventional refuelling stations is applied in combination with national rules concerning the handling of potentially hazardous substances, as is the case of hydrogen. However, these national rules are usually based on hydrogen applied to industry, hence they are not specific for refuelling activities. In many countries, compressed natural gas (CNG) specific rules for refuelling stations exist. In this case, as an alternative fuel that is often times considered an analogue for hydrogen in fire safety matters, CNG rules are followed by the authorities when permitting an HRS.

A significant number of countries, however, is currently taking efforts to shift the paradigm and develop HRS specific national permitting and safety rules and/or guidance, as is the case for Sweden or Austria. Specific guidelines on how to approach the existence of multiple conventional and alternative fuels in the same location is, however, non-existent in all countries. All isolated regulations existent for the different fuels need to be considered to build a multi-fuel HRS and different countries will therefore follow different procedures and requirements for permitting the construction of an HRS. This Section will show an overview of the general procedure followed and take a deeper look at some specific cases.

The general procedure for HRS deployment usually involves the regular building permits (that every building construction requires, no matter its purpose) and a special permit considering the handling of chemical substances potentially dangerous. Hence, the process usually involves around two different national authorities, including the local municipality and other safety-specific regulating bodies (e.g. Finnish Safety and Chemicals Agency, Norwegian Directorate for Civil Inspection, Hazardous Substances Authority in the UK, Fire Brigades, etc). In some cases, although only a few, the environmental authorities are also involved in the process (for example, in Bulgaria).

The authorities involved are usually very familiar with the permitting procedure when it comes to conventional refuelling stations, however the familiarity with HRS specific rules varies, even at the national level, depending on the authority's experience with handling hydrogen safety issues or the deployment of alternative fuels refilling stations such as CNG refuelling stations or HRS.

In countries such as Italy and Germany, local authorities in regions where HRS have already been deployed will, obviously, have more experience in the process. However, in most cases the deployment of an HRS is a completely new concept. Without failure, all countries agreed that the lack of HRS specific legislation and lack of experience from the authorities usually makes the process more difficult and time consuming, not to mention the level of subjectivity that it enables for the final decision on the permit.

3.1.1 Process subjectivity

In countries where the procedure is more flexible, authorities require that the project shall be "adequate", "done in a safe manner" or "satisfactory safe" instead of prescribing specified safety measures. In Norway, for example, it is up to the HRS operator to develop the project in a safe way.

When no specific rules are prescribed in legislation, what might be considered adequately safe is generally decided by the administrator handling the permit request. On the opposite side, there are some countries such as Italy that have specific requirements prescribed in their legislation, which gives more guidance to the operator but also less flexibility. Even in this case, however, there are exceptions where the operator can opt for an "engineering approach" (i.e. perform its own analysis), which enables for a degree of subjectivity. Still in Italy, local authorities may require additional fire protection measures to what is required in regulation. In Austria, where no HRS specific rules currently exist, German safety requirements may be used as a guideline during the permitting procedure, which increases the degree of subjectivity as well.

3.1.2 Different criteria

Within each country, the type of procedure to follow may differ according to different criteria such as the amount of hydrogen stored on-site, the openness of the refilling station to the public, and others. **In some cases, a permit may not even be needed and be replaced by a simple notification procedure.**

In **Norway**, the Norwegian Directorate for Civil Protection (DSB) must always be notified when a refuelling station is to be built, but a formal permit is only necessary if the HRS has **over 5 tonnes** of hydrogen storage or the hydrogen supply is done via pipeline with pressure above 16 bar. However, any HRS will need a permission to set up the buildings/facilities, as all other buildings/facilities/initiatives in Norway. These permissions are managed by the local municipalities. As part of this process the consideration zones (safety zones) should be assessed. Normally a QRA will be performed with predefined risk tolerance criteria defined by DSB.

In **Finland**, similarly, HRS with **under 2 tonnes** of hydrogen storage will only need to notify the regional rescue department and municipality, whereas going over this amount will require a permit from Tukes (Finnish Safety and Chemicals Agency). As both countries mentioned do not have specific HRS regulations, the requirements described refer to the handling and storage of hydrogen in general.

In **France**, a hydrogen station storing less than 100 kg must only be declared to the prefecture of its location under heading n°1416, whereas a station storing between 100 kg and 1 tonne will have to be declared under heading n°1416 and heading n°4715 simultaneously. Above **1 tonne** of storage, a declaration under heading n°1416 is needed and an authorization under heading n°4715.

In **Germany**, the amount of hydrogen stored on-site will change the regulations that must be followed in the permitting procedure:

- Storage **below 3 tonnes** will require a procedure according to the Ordinance of Industrial Safety and Health for construction and operation permit, as well as a building permit according to Federal State Building Regulations [8];
- Storage **over 3 tonnes** will involve a simplified permit procedure according to the Federal Immission Control Act [9], which includes the building permit as well (formal permit procedure is only needed when storage exceeds 30 tonnes of hydrogen, which is out of scope of the research).

In the **UK**, storage over **2 tonnes** will require consent from the Hazardous Substances Authority in accordance with the Planning Regulations. Storage above **5 tonnes** (or less if other dangerous substances are stored on-site such as LPG, gasoline, diesel) will transit within the scope of Control of Major Accidents Hazards (COMAH) Regulations [10] and need specific requirements.

For most countries, a **public fuelling station** will follow the same requirements that a non-public refilling station would. In Austria, however, public stations will need to follow the Austrian Trade Act [11] and non-public stations will not. In Italy, non-public stations will require the approval of less authorities to get the final permit and safety distances may differ.

It is also worth mentioning that in some countries, such as Italy, the presence of other fuels in the station (e.g. LPG, CNG, other) may limit the amount of hydrogen allowed to be stored on-site. This comes from Direttiva Seveso, normally applied for the big fuel depots, which prescribes a maximum quantity of all the different fuels present in the service station to get a maximum value in term of explosive risk. In this case if the service station includes fuels like LPG, CNG or LNG the cylinders hydrogen storage could be consequently limited.

It should be noted that another important criterion that greatly influences the procedure to follow in many countries is on-site production of hydrogen. However, this feature is out of scope of the current analysis and will not be discussed in this report.

3.1.3 Process duration

The permitting process can take, on average, around 5-6 months, although significant differences can be seen (from 2 months in Hungary or the UK to 12 months in Bulgaria). Some countries have specific regulated time limits for granting the permit after submission, but even in those situations the time limit can be, in practice, surpassed.

3.2 Type of integration in a multi-fuel context

With increasing demand for FCEV, HRS are required to be upscaled and co-located alongside conventional fuels in commercial and residential areas. Co-location of hydrogen with different fuels may, however, require specific safety measures.

Generally speaking, the approaches taken by the different countries vary significantly amongst the different countries. Some may be more conservative and do not allow the placement of a hydrogen dispenser in the same island as other fuels, while others do. This can come up as a challenge for operators who are trying to deploy multi-fuel HRS in different countries. With different criteria being applied all over Europe, the operator will not be able to apply the same design to all its stations. Every project will possibly require different layouts.

In most countries there are no rules explicitly stating whether one is or is not allowed to place the hydrogen dispenser on the same island as other fuels. In **Spain**, however, legislation clearly forbids this layout. In **Austria**, even though nothing is explicit in legislation, placing the hydrogen dispenser on the same island as other fuels has not been allowed so far. In **Germany**, this placement is allowed. In **France**, required safety distances between hydrogen dispensers and other fuels (5 m) may or may not allow you to place the hydrogen dispenser in the same island as other fuels, but they definitely do not allow you to use the same dispenser for different fuels in combination with hydrogen, and the same occurs in Hungary and Bulgaria. In France, these distances are currently being discussed and will possibly be reduced to 0m. In most countries, what determines whether the hydrogen dispenser can be placed right next to other fuels is the safety distances prescribed, which will be discussed in further detail in Chapter 5.

A hydrogen dispenser located in the same dispenser as other fuels is not allowed in some countries such as Spain, but it is allowed in others such as Germany. In most countries, however, no explicit rule exists concerning this aspect, but it is a feature that is usually allowed for CNG dispensing.

In **Belgium**, the hydrogen hoses that are to be deployed on multi-fuel refuelling stations are located on the same island as hydrogen dispensers but are typically installed separately from the non-hydrogen dispensers as it includes specific components relevant to hydrogen dispensing (meters, cooling, etc.). In fact, in **Belgium**, the common practice is to have the dispenser of hydrogen separated from the rest in such a way that it is possible for a FCEV to be refuelled at the same time that a conventional combustion engine vehicle is.

The same layout – same island/separate dispenser – is adopted in **Germany**. This is because, in general, combined arrangement of dispensing equipment in a potentially explosive area for fuels requires consideration of carry-over explosive atmospheres. In the case of a combination of a dispenser for hydrogen with other dispensers, all parts of the system must be designed for explosion group IIC (or IIB+H2) and for temperature class T3, as defined in Directive 2014/34/EU. The possible release quantity in the event of leaks from refuelling hose lines for gaseous fuels shall be limited to a harmless level. This is fulfilled for hydrogen if:

a) there is an automatic check of the connection of the refuelling hose to the refuelling connection of the motor vehicle so that refuelling is not started in the event of a leak,
b) there is automatic monitoring of the refuelling so that refuelling is stopped immediately in the event of a leak,
c) the hose is safely depressurised via a blow-off line by discharging the hydraulic fluid via the vent mast/chimney; and
d) after refuelling, the refuelling hose is pressure-free.

3.3 Process guidance

Only half of the countries analysed present public guidance for the operator regarding the permitting process and which documents must be delivered to the authorities, although several countries are currently employing efforts to develop said guidance. In most countries, the guidance includes which formalities must be undertaken to successfully conclude the permitting process (documents needed, duration of the process, authorities involved). Even some countries that currently have no HRS deployed (Bulgaria) have some sort of guidance and rules for HRS. However, because there are not enough studies on hydrogen safety in refuelling stations, such guidelines are often based on what is known for other gases, such as CNG, as is the case for this country.

In **Austria**, The Austrian Association for the Gas and Water Industry (ÖVGW) publishes technical norms that are not legally binding but build the Code of Good Practice. This association currently developing a technical norm for HRS that will also guide through the permission process. A draft can be found for ÖNORM EN 17127:2020 03 15 [12], on outdoor hydrogen refuelling points dispensing gaseous hydrogen and incorporating filling protocols, but it is not legally binding yet.

In **Germany**, where specific HRS rules apply, the National Organisation Hydrogen and Fuel Cell Technology (NOW GmbH) provided an approval guide for hydrogen refuelling stations. This guide is currently under revision for updated rules and references [13]. Some topics included in this guidance are the time schedule and the identification of the relevant approving authority: when should which document be transmitted and which arrangement with the contact persons be completed? Which steps are to follow during permitting process and construction.

Bulgaria, where there is also a specific Ordinance for HRS (RSHV – Conditions and Procedures for Design, Construction, Commissioning and Control of Refuelling Stations for Hydrogen Fueled Vehicles, Ordinance № RD-02-20-2 of September 28, 2020 [14]), does not have such a guide, but the Ordinance is available for the operator to see which requirements must be met when designing the station. This Ordinance includes technical requirements and control on HRS in respect to the minimum project characteristics concerning safety issues during design, construction and operation.

Although there are no specific HRS rules in **Belgium** (AFID requirements and ISO/TS 19880 standards are followed), there are a few studies that try to fill the gap regarding safety measures and distances (BAT - Best Available Technologies [15], Dutch PG35 [16] and EIGA Doc 15/06 [17]) and are complied with when submitting permitting documents.

3.4 Documents needed

The total amount of documents required by the entities varies from 2 to 9 between the different countries.

The process is the simplest in **Norway**, where only the risk assessment and the regular building documents are required (worth mentioning that in Norway, HRS with less than 5 tonnes of hydrogen stored do not need a permit, but simply need to notify the authorities and have the required documents available if inspection were to occur).

Risk assessment is mandatory for all Member States and in most countries it is a requirement to obtain a permit. In Hungary, for example, it is not, but safety measures and zone planning are required for the construction permit. In Spain, the technical project required for the permitting includes some safety aspects and the construction plan required in Poland includes technical evaluation.

4 Risk assessment regulations/methodologies

Different Directives and EU legislative acts impose set requirements for hydrogen refuelling stations. Directive 2014/94 (AFID - Alternative Fuels Infrastructure Directive), for example, sets technical specifications for these stations. Hydrogen refuelling points are also under the scope of Directive 2012/18/EU (SEVESO), in which all points storing over 5 tonnes must comply with lower-tier requirements and points storing above 50 tonnes must comply with upper-tier requirements (out of scope of the current analysis). **Even though these norms must be complied with by all Members States, risk assessment European methodologies are not common, and different approaches will therefore be taken by the different countries.** What is more, MultHyFuel focuses on the co-location of hydrogen next to other fuels. It is therefore important to assess how this feature is usually approached by from the risk assessment point of view in the different European countries.

Different common standards are usually followed by the European Member States. The most relevant is ISO 19980-1:2020 concerning Gaseous Hydrogen – Fuelling Stations. This document defines the minimum design, installation, commissioning, operation, inspection and maintenance requirements, for the safety, and, where appropriate, for the performance of public and non-public fuelling stations that dispense gaseous hydrogen to light duty road vehicles (e.g. fuel cell electric vehicles).

ISO 19980-1:2020 applies the following definition for risk assessment: "Risk assessment is the overall process of risk identification, risk analysis, risk evaluation, and risk mitigation. Use of risk assessment may allow station owners and designers to flexibly define station-specific mitigations that achieve an equal or better level of risk to those of prescriptive recommendations or to relax existing prescriptive mitigation measures as long as the total system risk remains below the selected tolerability threshold (risk acceptance criteria). (…) **The risk assessment should demonstrate that the mitigation measures employed are appropriate to achieve the desired level of risk of the station**."

In Annex A3.1, A3.2, ISO 19880-1:2020 standards also add: **"It may be possible to use quantitative risk assessment (QRA) and/or semi-quantitative (e.g., consequence-only) analysis instead of prescriptive requirements to allow the hydrogen fuelling station to use alternative methods which are of an equivalent, or higher, level of safety to the prescriptive requirements. Using QRA may allow (for instance using mitigation measures) for shorter safety distances and/or simplified station layout.** (…) A semi-quantitative risk assessment provides an intermediary level between the textual evaluations of qualitative risk assessment and the numerical evaluation of quantitative risk assessment, by evaluating risks with a score. Semi-quantitative risk assessment provides a structured way to rank risks (…) Risk assessment provides a framework to establish a common understanding of the system safety level based on robust science and engineering models."

Overall, there are no specific risk assessment requirements for the construction of HRS, in a multi-fuel context or not, aside from the general requirements provided by ISO/TS 19880, which include performing QRA or semi-quantitative analysis instead of relying on the prescriptive requirements. In most countries, different non-HRS-specific ordinances must be considered while performing the risk assessment, to make sure that specific requirements concerning explosive atmospheres and safety with hazardous substances are met. Overall, the operator usually has a high degree of freedom in terms of the risk assessment methodology applied, as long as risks are kept to a minimum. In some countries, however, common practices exist.

In **Belgium**, the standardised risk assessment practice involves sub-dividing the station into the different equipments (storage, vessels, …), which facilitates the process as there are also standardised guidelines for each component. However, these standards are not HRS specific. **Quantitative** risk assessment is the common practice in this country and guidelines on how to perform it are being developed. HRS components that are multi-element components, for example the electrolyser or steam reformer, are represented as a combination of standardized components.

Following ISO 19880, all 5 public HRS deployed in **Austria** had to submit a **HAZOP** study. According to this, risk management should consider:

- the nature of the hazards,
- the behaviour of hydrogen under the design and operating conditions,
- equipment design and operating conditions,
- installation design and location, including protection measures as well as

- specific targets (e.g., person, property, equipment) which are being protected from effects of potential hazards.

Still in Austria, other relevant national ordinances must also be complied with while performing a risk assessment. The Ordinance on Explosive Atmospheres [18] defines that an explosion detection concept must be written previously to the approval process, where the assessment of hazardous potential of hydrogen and mitigation measures must be defined. A potentially explosive atmosphere is deemed to exist in any case if 50% of the lower explosion limit can be reached. Employers must identify and assess the likelihood and duration of the occurrence of explosive atmospheres and potentially explosive places and the characteristic properties of the agents which may form explosive atmospheres. All these insights feed into an explosion protection document. This document must be drawn up before work is started. It must be kept up to date and be revised if significant changes are made. An Ordinance for CNG and LPG is also to be followed, in which there are specific guidelines to follow in terms of distances and mitigation measures.

In the **Netherlands**, an HAZOP study is not required for the permitting process but must be performed before the HRS initiates operation. For the permitting process, a QRA is necessary.

Similarly, risk assessment in **Germany** follows guidelines provided in EN ISO 12100-1 for machinery (now replaced by ISO 19880-1:2020), EN 61511 (functional safety), EN 1127-1 (Explosive atmospheres) and other relevant national regulations such as the Ordinance on Industrial Safety and Health [19], Hazardous Substances Ordinance [20] and Workplace Ordinance. Under this legislative framework, the HRS operator is required to carry out a risk assessment before selecting and procuring work equipment, carrying out activities with hazardous substances and setting up and operating workplace for the first time. Different materials exist to assist the operator in carrying out the risk assessment in conformity with the relevant ordinances.

In **Finland** risk assessment is required but no particular requirements in terms of methodology exist. The results must describe the typical and maximum possible accidents of the plant, as well as their consequences inside the plant, and the effects outside. In addition, the causes of the accidents, their probability or the circumstances and situations in which they may occur must be reported. Guidelines are provided by Tukes, the safety and chemicals agency.

In **Sweden**, a guidance for CNG refilling stations (TSA) [21] was published by the industry organization Swedish Gas Association. This is considered an established industry standard and if a compliance form is included in the permit application, further risk assessment is often considered unnecessary. The TSA has been referred to in permit applications for hydrogen, however, it is not the intended application. A TSA specific to hydrogen is on the way and expected to be published in 2022.

In **Hungary** and **Poland** there is no risk assessment required to obtain permit as long as guidelines (not HRS specific) are complied with. No HRS have been deployed yet in these countries. It is worth mentioning that in Hungary the risk assessment concerning hydrogen delivery and supply is the responsibility of the fuel supplier and not the HRS operator.

In **Norway**, no permitting is required for an HRS set-up within the scope of this analysis (under 5 tonnes of hydrogen storage), but for risk assessment purposes many operators choose to follow the same guidelines applicable to station where permitting is required. These QRA guidelines [22] include main requirements such as:

- **Identification of hazards** and unwanted events. All possible events at the facility should be assessed, including leaks and incidents related to all equipment. A detailed HAZID sheet with key words/lead words is given in Appendix A to the guideline. Based on the HAZID, a list of top events are established for further assessment;
- **Assessment of consequences** of all top events. For every scenario the consequences in terms of fatality for humans is assessed based on harm criteria for radiation and explosion pressure.
    - Harm criteria for explosion pressure is now on hearing. The suggested harm criteria is 400 mbar representing 50% probability of fatality for people inside a building

  General guidelines are given for use of empirical tools and CFD tools, but there are no requirements for use of different tools in specific scenarios.
- **Assessment of the leak frequency**, ignition probability and hence fire and explosion frequencies:
    - Leak frequencies are suggested estimated based on HyRAM-model, with an exception for filters;
    - Ignition probabilities are suggested in the revised QRA guidelines, available in Norwegian [23];
- **Establishment of risk picture** in terms of 10^{-5}, 10^{-6} and 10^{-7} iso-contours for individual fatality risk per annum;
- **Comparison with risk acceptance criteria.** The risk tolerance criteria applicable for QRAs are described in the Safety of Systems Handling Flammable, Reactive, Pressurized and Explosive Substances [24];
- **Identification of possible risk reducing measures.**

In **Italy,** a full risk assessment analysis is only needed if the operator wishes to apply different requirements (for example, different safety distances) than the ones prescribed by Ministerial Decree 7/8/2018 [25]. In this case, the operator opts for the engineering approach, where different requirements exist for different components, and they follow a specific national directive.

In the **UK**, for COMAH specific installations (out of scope, as it considers storage of over 5 tonnes of hydrogen), a comprehensive HAZID is necessary, and a HAZOP study is often used together. A qualitative or semi-quantitative judgement is then made about which hazards can be treated qualitatively or need quantification. In the UK, this means showing that the risk is not intolerable (against individual risk criteria, and societal risk measures for major hazards) and that it is ALARP – As Low as Reasonably Practicable (a balance between putting more resources into reducing risk and the benefit gained from further risk reduction measures). This is often demonstrated qualitatively or by approximate and conservative quantification. The starting point for ALARP is that the safety measures required by relevant standards are implemented first. ALARP looks at whether further risk reduction is also needed.

5 Safety or separation distances

Every site where explosives are stored must ensure that the relevant separation distances are maintained in order to avoid accidents and mitigate the possible effects of one. In some countries, specific safety distances concerning refuelling stations are already well described in legislation, while in others it is the operator's responsibility to perform risk assessment and guarantee that the area is safe.

As there are no HRS specific regulations in most of the countries, specific prescribed safety distances in legislation are also mostly non-existent. **In most cases, it is the operator's responsibility to perform their own risk assessment evaluation and define these distances. However, some guidelines do exist, as there are national regulations that establish certain minimum requirements for hydrogen storing/dispensing, even if they are not specifically targeting refuelling activities. Once more, CNG guidelines are sometimes used if they exist, as well as EU Directives. All Member States must comply with ISO/TS 19880, which does not define any safety distances but recommends that a QRA is performed in order to calculate them. A risk assessment methodology is proposed on the Annex A from the standards. Other national legislations that prescribe safety distances are industrial safety regulations.**

In the following sub-sections, it is the author's intention to present the different safety distances respected in the different countries. To avoid the necessity to explain the context in which such distances were prescribed, the general procedure followed by each country will firstly be presented. This is information that must be taken into account when interpreting the distances required in every country, as some of them come from CNG specific rules, other come from conventional refuelling stations rules, or other.

5.1 General procedure by country

In **Germany**, recommended safety distances for HRS exist mainly in the TRBS 3151 [26] document. However, they are often defined by the manufacturer in their own way, typically based on regulations of their country of origin or international documents. If the operator opts for shorter distances than the ones recommended in the guidelines TRBS 3151, he does it on his own risk. The manufacturer is then out of liability claims.

In **Finland**, the safety distances of flammable gas storage units shall be determined based on the effects of thermal radiation and pressure effects caused by the combustion of a gas cloud, which ignites immediately or with a delay in the event of a leak. According to the recommendations given by the Finnish Safety and Chemicals Agency (Tukes) the safety distances are based on the effects of possible accidents. Which accident scenarios are selected as starting points to determine the safety distances, depend on the local conditions of each installation or site (e.g. location of other sites, terrain) and technology (e.g. tank sizes, placement).

In **Norway**, no prescribed distances of any sort exist and the operator assumes total responsibility. However, there are general requirements such as:

- Following the ALARP requirement, equipment is to be separated to reduce risk as far as reasonable practicable;
- ATEX zoning must be respected.

Still in Norway, the necessary separation distances do not depend on the size of the HRS or flow rate of the dispenser, unless larger HRS results in potentially more severe incidents, requiring larger separation distances to meet the risk tolerance criteria, or larger ATEX zones.

In **Belgium**, prescribed distances exist for gas storage systems in VLAREM II. As a flammable gas, hydrogen falls into the scope of such legislation. Hydrogen, natural gas, gasoline, diesel and LPG all fall into the scope of group 1 in such legislations, and the same safety distances are therefore prescribed for all of them. Although these distances are not HRS specific, HRS guidelines being developed currently will potentially be based on them. These distances will be further discussed in the following sub-sections.

In **Austria**, once more, there are no specific regulations but national laws are to be considered. As a result of the lack of regulations, the experts are somewhat free to make their own decisions. For example, the fire brigade can define protective radii around HRS, but these are not defined by law and thus differ for each HRS. The Ordinances to consider are the Pressure Vessel Installation Ordinance, the Austrian Norm on the installation of pressure vessels (specified specific protection areas), Ordinance on Explosive Atmospheres (VETAX), Natural Gas Fuelling Systems (which describes the safety zones according to VETAX for CNG fuelling stations and is most often applied to HRS) and Liquefied Petroleum Gas Filling Stations Ordinance 2010.

Regarding CNG rules in Austria, the most important definitions are:

- Compressor units: Must be in buildings or enclosure. The entire enclosure is defined as Zone 1. The area around their openings (0.2 meters to the side and 1 meter above) is defined Zone 2;
- Gas storage: Must be in a building. The entire building is said to be Zone 2.
- Dispensers: inside the protective housing: Zone 1;
- Outside the protective housing: 0.2 m around the protective housing and at least 1 m above: Zone 2

Additionally, it is defined:

- Dispensers shall not be located within the explosion zones according to VEXAT of gas storage facilities and shall be located so that vehicles being refuelled do not have to pass through these zones.
- Dispensers shall be located at least 8 m from buildings made of combustible materials and from above-ground storage tanks for combustible materials.
- Dispensers shall be at least 5 m away from openings of buildings made of non-combustible building materials which are not used for the accommodation of facilities of the gas storage. These distances can be reduced by providing a protective wall.

Regarding the Liquified Petroleum Gas Filling Stations Ordinance, the following rules are of relevance:

- HRS may only be built outdoors and only on land that is well naturally ventilated.
- The ordinance defines two kinds of safety distances. The first one is the so-called “operating range”. That is the range that can be reached horizontally at a working height of approx. 0.8 m plus 2 m with the nozzle. Additionally, the safety zone system of VATEX is to be applied whereby Zone 0 is not allowed to exist in LPG filling stations. The entire area inside the protective housing of the dispenser containing components that carry gas is potentially explosive and is considered Zone 1. The potentially explosive area extends to a distance of 0.2 m around the protective housing from the top of the protective housing to the ground, unless otherwise specified by the manufacturer; it is considered Zone 2. Additionally, there is a cone-shaped Zone 2 around the dispenser with the top of the cone extending along the top edge of Zone 1 and the base at the ground at a distance of 1 m from Zone 1. The potentially explosive area around the nozzle during the filling process has the shape of a sphere with a radius of 0.5 m and is to be assigned to Zone 1.
- Publicly accessible dispensers must be installed in such a way that the potentially explosive areas do not have to be entered during refuelling operations.

- The potentially explosive areas around gas containers and pumps must be secured against access by unauthorised persons.
- The provisions of the Pressure Vessel Installation Ordinance (mentioned before) apply to the installation of gas containers regarding the fire protection zone. If protection against fire loads is provided exclusively by means of protective distances, the minimum distance between the container and fire loads and the property boundaries of the operating facility must not be less than 5 metres.
- Motor vehicles must maintain a minimum distance of 3 m from the liquid gas container during refuelling.
- At locations where tank vehicles fill containers, a potentially explosive area with a radius of at least 5 meter of the base circle around the tank vehicle during the filling process must be kept free.
- There must be no ignition sources within safety zone. There must be no drains, cavities or openings to lower-lying rooms, cellars, etc. in the operating range of the liquid gas delivery hoses or in potentially explosive atmospheres.
- Dispensers must be at least 8 m away from buildings made of combustible building materials and at least 5 m away from openings in buildings made of non-combustible building materials.
- If the filling station has a capacity of below 3,000 kg, they are referred to as “compact”. Compact installations must be at least **10 m away from** dispensers for other liquid fuels and at least 5 m away from areas not used for the operation of the LPG filling station or from property boundaries. Compact installations shall be located in a separate part of the installation suitable for the refuelling of motor vehicles. In the case of non-public installations, the authority may, upon application by the owner of the installation, reduce the distance from at least 10 m to dispensers for other liquid fuels to 5 m in accordance with local conditions (potential hazards in the vicinity of the dispensers, such as storage of materials or substances or traffic routes).
- Underground tanks must not be capable of being driven over by motor vehicles or trailers, nor must they be wholly or partially built over.
- Temporary fire loads, especially vehicles when using the filling station: A distance of 3 metres must be maintained between vehicle and pressure vessel.

In **Bulgaria**, the safety and separation distances on the territory of a multi-fuel station are described in Ordinance N° RD-02-20-2 of September 20, 2020 on the Conditions and Procedures for Design, Construction, Commissioning and Control of Refuelling Stations for Hydrogen Fuelled Vehicles (RSHV). In **Spain**, some national regulations do prescribe the different safety distances included in this report, however they are based on industrial safety regulations. In **Sweden**, different general national rules apply, as well as CNG specific rules. In **Italy**, the safety distances are prescribed for general fire safety. The same definitions are taken for the legislation of the hydrogen station, based on ATEX zoning.

In **France**, safety distances depend greatly on the dispenser flow-rate and will be further discussed in the following sub-sections. The safety distances applicable to the storage area may vary if the installations contain more than 1 ton of hydrogen. The prefect may ask in his authorisation order for more restrictive measures than the general prescription orders initially provided to control the risks of installation. In fact, these safety distances were adopted at the beginning of the hydrogen mobility applications and efforts to update them are currently being made.

In **Hungary**, legislation exists on **supervision of pressure equipment**, filling equipment, low-capacity compressed gas filling equipment and periodic inspection of autogas vessels. This legislation defines the most important terms, technical expressions relevant to all pressure equipment, and filling station including hydrogen refuelling stations. The Technical Safety Regulation (TSR) forms the Annex 2 of the Ministerial Decree. Technical Safety Regulation is a set of technical specifications containing the technical safety conditions for the construction, relocation, commissioning, entry into service, operation, modification, repair and periodic inspections of the negotiated pressure equipment, filling stations including Hydrogen Filling Stations. Its point No.4. describes the rules for gas vehicle filling stations but includes only a few hydrogen-specific prescriptions. Most of this part of the TSR is "tailored" at present on LPG (autogas) and CNG (compressed natural gas) fuels. Directly hydrogen related parts of TSR are deriving mostly from the AFID directive, and these are mostly references to the ISO standards (for e.g. ISO/TS 19880: Gaseous hydrogen - Fuelling stations). Other piece of legislation important to consider is the National Fire Protection Codes, with minimum required distance between the fuelling station structures and adjacent structures not belonging to the service station and minimum required distance between the filling station structures.

In the **Netherlands**, a QRA is mandatory but safety distances are not defined in it. There are fixed safety distances prescribed and they must be followed by the operator. Only distances that are not prescribed in legislation, such as protection distances (see sub-sections below), are defined by the operator himself while conducting a proper risk analysis. For restriction distances, for example, operators refer to ATEX zoning.

In **Italy**, HRS specific rules exist in the Ministerial Decree 23/10/2018 which also include some prescribed safety distances. When these distances are respected, an additional risk analysis is not required. If the operator only some punctual different safety distances than the ones prescribed, a qualitative risk assessment can be performed to propose some compensating mitigation measures. If a significant number of different safety distances are to be applied, risk analysis, through the engineering approach, must be provided, following a different Decree, Ministerial Decree 9/5/2007. In this case, the professional applying the engineering approach is directly responsible.

Similarly, in **the Netherlands**, prescribed safety distances may be reduced if relevant mitigation measures (such as the additional of a fire wall) are in place. Correct mitigation measures should be discussed between the authorities and safety experts.

In **Poland**, safety distances will be mostly based on regulations for conventional refuelling stations and Directive 94/63/EC – Control of volatile organic compound emissions resulting from the storage of petrol and its distribution from terminals to service stations, Directive 98/34/EC - laying down a procedure for the provision of information in the field of technical standards and regulations and Directive 2009/126/EC - Stage II petrol vapour recovery during refuelling of motor vehicles at service stations. In the following sub-sections, distances applied in pre-existing building plants that are not official have been considered, even though they can only be treated as an estimation of what authorities will ultimately approve as a standard.

5.2 Restriction Distances

Restriction distances refer to distances from, or area around, hydrogen equipment where certain activities are restricted or subject to special precautions. These are distances meant to protect the hydrogen equipment against other activities and constructions around, which are considered the hazard in this case. The hydrogen equipment to be protected from a potential area of flammable/explosive atmosphere can be the compression unit, the storage unit, the dispenser, any sparking equipment and outdoor discharge for relief valves or vents.

Most countries do not present any prescribed mandatory general restriction distances for hydrogen equipment.

The exceptions are Hungary and Poland. In Hungary, the Ministerial Decree NGM (2/2016 [I.5]) recommends a safety distance of 15 m between the hydrogen equipment and potential flammable atmospheres around it. It also recommends a distance of 20 m between hydrogen equipment and public railways.

In Poland, however, these safety distance would be 2.35 m between the compression and storage units and flammable areas, 5 m between the dispenser and flammable areas and 20 m around sparking equipment and outdoor discharge valves. These distances, however, come from regulation on conventional fuelling stations and European directives, they are not hydrogen specific.

Around **sparking equipment, Belgium** legislation requires 3-7.5 m safety distance and **Spain** 10 to 35 m. Including **Polish** requirements of 20 m safety distance, we can see that this is a topic in which the different countries have very different requirements.

Around **outdoor discharge for relief valves or vents**, **Belgium** prescribes a minimum distance of 1 meter, while **Finland** prescribes a distance of 4.5 m, or 9 m in the blowing direction. In **France**, distributors' vents should be located above the highest point of the station's equipment. Other vents should be located as far as possible from inhabited buildings and aerations and at least 1 m above the highest point of the installation. For liquid hydrogen there must be no obstacle above the vent in an area delimited by a half sphere of 20 m whose center is a point at 3 m under the top of event.

5.3 Installation Layout Distances

Installation layout distances refer to the minimum distance between the various sub-systems that are part of the hydrogen installation, required to prevent units from causing damage to one another in case of incidents. Many countries present different installation layout distances, even if most refer to CNG rules.

Required distances between the hydrogen **storage unit** and other hydrogen sub-system vary between 3 m to 20 m, with an outlier of 80 m in Poland. In some countries, prescribed distances can be reduced, if:

- the storage container is protected against impermissible heating during at least 30 minutes of exposure to fire in **Germany**;
- and the effects of thermal radiation are prevented by a protective wall in **Finland**.

In **Sweden**, distances concerning the storage unit depend on the existence of protective barriers as well and the amount of gas, but these are the CNG specific rules that are usually applied in HRS as well. Liquid hydrogen might require higher distances, up to 100 m.

Between the **compressor** and other hydrogen sub-systems, minimum distances vary between 0.2 m and 12 m. Again, protective barriers can reduce the required distance between the sub-systems. In Sweden, CNG rules are applied and the required safety distances depend on the amount of gas in the following way:

- Between 60 and 1000 L of gas – 3 m
- Between 1000 and 4000 L of gas – 6 m
- Above 4000 L of gas – 12 m

5.4 Clearance and Protection Distances

Clearance distances refers to the minimum distance required between the different installation units to prevent them from causing damage to one another in case of accidents, which includes personnel, storage equipment, other buildings inside the station, etc. This section will also include protection distances between the hydrogen equipment and other possible hazards and sources of damage such as private or public roads to avoid chances of being hit by a vehicle.

Concerning the **presence of combustibles above ground** such as a gasoline storage equipment, minimum distances required in most countries are around **10 m**.

In Italy, such distances depend on the type of fuel around. Minimum distance between hydrogen equipment and other fuels is 15 m for gasoline/diesel tanks, 30 m for LPG tanks (15 m for LPG dispensers) and 22 m for CNG systems (12 m for CNG dispensers).

In **France**, protection distances between hydrogen equipment and other fuels depend on the dispenser flow-rate. For a flow-rate of 120 g/s, any equipment that may contain hydrogen must be at least 14 m from any storage, implantation, flammable material, or fuel other than hydrogen. For a 60 g/s flowrate, the distance is reduced to 10 m, which can be further reduced to 8 m if relevant mitigation measures are applied such as an anti-snatching system designed to steer the gas flow to more than 45 degrees upwards. For a 20 g/s flow-rate, the required distance is 6 m. If the distance cannot be respected, the operator must set up a full wall without openings, built with fire-holding characteristics REI120 materials and whose height exceeds the highest point of the distribution area, except the vent, but being at least 3 m high.

Most countries do not include any prescribed distances between the hydrogen equipment and **liquid oxygen storage**.

Distances between hydrogen equipment and **other buildings inside the plant** vary significantly. In Germany, all safety distances must be around 3 m. Both Hungary and Italy present distances of 5 m, although for Hungary it increases to 15 m if the building is made of combustible material. Belgium applies a distance of 8 and both Bulgaria and Poland apply 10 m. In Bulgaria, if the building is made of combustible material the distance increases to a range between 30 m and 50 m. In Finland it ranges between 10 to 25 m, from CNG rules. In Spain it ranges between 5 and 30 m (or 8-30 m for buildings made of combustible material) but it concerns cryogenic vessels only. If buildings are made of combustible material, distances increase. In Poland, if the building is made of combustible material, the safety distance increases from 10 m to 25 m.

Minimum required distances between hydrogen equipment and a **public/private road** range between 2 m and 19 m between the countries that present prescribed distances. It is worth mentioning that, in Sweden, no specifications are available for HRS but CNG guidance recommends that the distance varies according to the road's speed limit, ranging from 10 m at 60 km/h and 25 m at 110 km/h.

5.5 External Risk Zone

External risk zone refers to the distance or area outside the fuelling station which has to be protected against hazards caused by the hydrogen installation.

In most countries, HRS need to be situated at least 15 m from any residential buildings. While in Finland the distance reduces from 50 m from residential buildings to 25 m from public buildings such as offices, in Hungary the opposite occurs: 15 m are required between the facility and residential buildings and 30 m are required if the building is public. However, if the public building is a place of public assembly (e.g. a school/hospital), the distance in Finland will be 50 m. In Hungary it will be 30 m. In Belgium, the distance will also increase from 27 m in residential buildings to 38 m in places of assembly.

Mild distances are required between the facility and parking lots, ranging from 3 to 15 m.

A few countries also present prescribed distances between the hydrogen site and a voltage line. While in Hungary the distance can range between 1 m and 40 m, in Spain it ranges between 10 m and 15 m.

6 Equipment maintenance

Most maintenance intervals of a HRS are defined in detail by the technology providers, due to the specific technical solutions they provided. Nevertheless, especially for safety of relevant components within the HRS, some maximum intervals can be defined in national regulations. From the 14 countries analysed in this report, only 1 (Austria) presents specific maintenance intervals for hydrogen equipment that do not rely solely on supplier's advisory, but rather national legislation. All the others either present no guidance at all or rely on the supplier's advisory on when to perform maintenance on the equipment.

Nevertheless, the range and average maintenance interval for each piece of equipment can be seen in the table below:

Table 3 - Inspection/maintenance intervals for the different hydrogen elements in the HRS.

Equipment	Inspection interval range (years)	Inspection interval average (years)
Dispenser	1-4	2
Storage	1-6	3
Compressor	1-5	3
Piping and distribution	2-10	5
Safety valves	0.5-2	1
Hoses	1-5	2
Pre-cooling equipment	1-4	2
Vaporizer	1-4	2

In **Austria**, regulations concerning intervals and contents of maintenance stem mainly from three sources: Ordinance on Explosive Atmosphere [18], Pressure Equipment Monitoring Ordinance [27] and Electrical Protection Ordinance [28]. The Technical Inspection Agency (TUV) must first approve all HRS. This approval includes an installation document that specifies inspection and maintenance intervals. The operator of an HRS must keep records of all maintenance and inspection measures. However, again the surveyed experts highlighted that an analogy is drawn between LPG filling stations and liquid hydrogen, but most of all between CNG filling stations and gaseous hydrogen. It is also worth mentioning that pressure vessels (storage unit) and pipelines are divided into different test levels according to the Pressure Equipment Monitoring Ordinance. Depending on the test level (test level 1 to test level 4), different test intervals are required.

It is worth mentioning the specific minimum intervals prescribed in German regulation, under the Ordinance on Industrial Safety and Health:

Section 4, No. 5.3: The inspection period for the pressure system to be determined by the employer as part of the risk assessment shall not exceed 10 years.

Section 4, No. 5.8, Table 1: Maximum Inspection Periods for

Element	External inspection	Internal inspection	strength testing
Pressure Vessels	2 years	5 years	10 years
Piping	5 years	-	5 years

Section 4, No. 7, Table 12, Nr. 7.14: Maximum inspection period for pressure vessels for gases or gas mixtures, which do not have a corrosive effect to pressure-retaining walls is 10 years.

Section 4, No. 7, Table 12, Nr. 7.27: Maximum inspection period for pressure systems for filling land, water or air vehicles with gases for use as fuel is 5 years.

According to TRBS 1201-2, Nr. 6.6.3, the function of Safety Relief Valves has to be checked with every external inspection.

7 Regulated mitigation measures

Additionally to the application of adequate protection distances surrounding the installation's equipment, other mitigation measures can be put in place with the goal of limiting the impacts of hazards. As it has been seen already in this report, the existence of such mitigation measures can even reduce the required safety distance surrounding the equipment. In this chapter, the different mitigation measures required by law in the different countries analysis will be discussed.

Mitigation measures to improve system safety are included in ISO 19880-1:2020 to be complied with by all Member States. All ATEX zones must be well ventilated. A common practice is also to add fire protection walls which allow to reduce safety distances, and buildings inclosing and surrounding possibly explosive atmosphere must be made of non-combustible materials.

7.1 Measures against fire and domino effects

In **Austria**, only a certain electrical equipment is allowed in the surroundings of potentially explosive atmospheres. For example, only sheathed cables and lines (thermoplastic thermoset elastomer sheath or mineral insulated metal sheath) may be used. In **Finland**, the refuelling station's electrical main centre shall be located on its own space. The electrical space must be separated from the compressor unit and the gas storage by a gas-tight wall, if located in the same container or building. Internal electrical and instrumentation cables are recommended to be placed and enclosed at floor level to reduce the fire load in case of gas leak or fire.

In **Italy**, operators are asked to collocate all dangerous elements (in practice all elements of an HRS) in "boxes", that is, at least two sides must be protected with walls of steel reinforced concrete or other materials with similar mechanical properties. Specific measures for the different pieces of equipment are also found in national guidelines:

- The areas in which the dangerous elements of the plant are placed, with the exception of the supply units, must be fenced for a height of not less than 1.8 m so that such elements are inaccessible, and tampering can be prevented. This fence must be placed at a distance from the elements of the system that allows safe operation.

- **Compressor:** The compressor must have an emergency shut-off device that stops its operation when the pressure on the suction side drops below the minimum supply pressure. Each compressor must be equipped with a safety system to prevent overpressure as well as a system of relief valves for emergency depressurization. The compressors must be placed in boxes with walls in concrete or other non-combustible material with adequate mechanical resistance such as to ensure the containment of any splinters projected towards external buildings.

- **Storage unit**: Each gaseous hydrogen storage unit must have the following safety requirements: the support structure, if present, must be incombustible and have at least R60 fire resistance characteristics or be protected in order to guarantee performance equivalent to R60; have safety devices that prevent the pressure from exceeding the design value, regardless of the storage temperature; have a safety device, thermally activated, which intervenes in case of exceeding the design temperature of the shell; each storage unit must be isolated from the rest of the system by means of emergency shut-off valves. The storage units must be placed in a special box as for the compressors. If the total volume of the deposit is greater than 6000 Nm^3, the box must be divided into portions delimited by walls built in reinforced concrete, or in other non-combustible material of adequate mechanical resistance, with construction characteristics of the artefacts such as to guarantee mitigation only perimeter. The storage units must be arranged inside each box in such a way as to limit the risks of direct impact of a possible release from one unit to the adjacent one. The storage units must be positioned at such a distance from each other and from the walls of the box as to guarantee the carrying out of surveillance and maintenance operations.

7.2 Barriers to the process flow

Some technical barriers to the process flow may also be added to limit the accidental scenarios. This is the case for Austria, where different regulations for LPG and CNG refuelling stations state that:

- A device must be provided to prevent the permissible operating pressure from being exceeded at maximum flow rate.
- Dispensing hoses and pipe sections that can be shut off on both sides must be protected against excess pressure by pressure relief valves.
- All parts of the filling station, such as tanks, pumps, pipelines, dispensers and dispensing equipment, etc., must be electrically conductively connected to each other and earthed in such a way that electrostatic charges are safely discharged.
- All CNG filling stations need at least the following installations to avoid or limit hazards:
    - Upstream pressure monitoring: switches the compressor off if the pressure exceeds or falls below a certain level.

- Shut-off devices
- Instrumentation and control protective devices
- Safety valves
- Blow-off and expansion lines
- Device for limiting the filling pressure
- Devices for emergency shutdown.

In **Germany**, the maximum flow-rate is dependent on the used refuelling protocol. For SAE J2601-HRS it is limited to 60 g/s. For HD refuelling protocol currently under development by CEP, to 120 g/s. Higher flows may be allowed in future with new protocols, e.g. out of the PRHYDE-project.

Other measures required in **France** include:

- On the compressor:
  - A pressure measurement device must be linked to an automatic shutdown system in case of overpressure or low pressure at suction.
  - A valve is positioned at the exhaust with a venting placed high up.
  - A temperature measurement device should ensure that the compressor is working properly.

- The distribution line must be equipped with:
  - A flow regulator to limit the rise in temperature in the vehicle's tank.
  - A positive isolation valve.
  - A safety valve.
  - A hydrogen detector in the distribution unit and a detection system that detects any abnormal pressure drop or rise and triggers an emergency shutdown.

- The distribution connector must be:
  - Specific to a given flow and pressure.
  - Equipped with a check valve or equivalent device preventing any air entrance.

In **Finland**, additional measures are required:

- The dispenser gas hoses must be of suitable length and intended for use (suitable for CNG use and for temperatures to - 40 °C). A break away valve is required (shuts off the gas flow in the event of a hose failure).
- The gas line between the storage and the dispenser must be equipped with a closing device to prevent gas leak in the case of pipe breakage.
- All metallic structures must be connected to ground. All the main equipment (gas storage facilities, pipelines, exhaust pipes etc.) must be grounded and connected to equipotential bonding. Equipment and buildings should be protected from lightning by connecting lightning protection to main earthing.
- The dispenser must be equipped with temperature compensated filling system. Temperature compensation may be in connection with the compressor unit.

In **the Netherlands**, HRS specific guidelines state that in case of power cut, all valves are in safe mode. Moreover, specific technical safety measures for hydrogen installations are also mentioned. It is stated that burdening of the installation is turned to safe mode when it overpowers the design limits. Oxygen should not be able to penetrate the hydrogen-carrying parts of the installation. Hydrogen should not be able to accumulate in any part of the installation.

7.3 Protection from collision

To protect the hydrogen equipment from collision, some countries rely solely on safety distances, while others add some collision barriers as a way to mitigate effects of future accidents.

In **France**, specific measures must be taken to protect the hoses from physical damage. It must be:

- Equipped with an anti-snatching out system.
- Equipped with a safety device in case of snatching or bursting.
- Protected from abrasion and folding.
- Installed in such a way that no vehicle can ride on it.
- Installed so that it does not touch the ground.
- Changed in case of deterioration.

In many countries, all the equipment except the dispenser (which needs to be used by the consumer) must have restricted access to personnel only. It is also common practice to have a fence 1.8 m high surrounding the areas where this equipment is installed.

7.4 Other obligations

As a general rule, all refuelling stations must be built in a well-ventilated area, outdoors. If some of the equipment is allocated in closed spaces, ventilation is needed, as well as gas detection. Emergency shutdowns are required in every country, as stated in ISO 19880-1:2020. The system must be activated through detection or manual activation.

A pre-alarm shall be triggered at a maximum of 20% of the lower explosion limit (LEL). At a maximum of 40% of the lower explosion limit (LEL), an emergency shutdown must switch off the hydrogen compressor and close the valves of the associated auxiliary systems. If technical ventilation is required, it must be switched on automatically when the emergency shutdown is triggered.

As a general rule, the type of fire extinguisher is not prescribed in European standards and they are usually recommended by local fire authorities. Fire class C extinguishers are usually the recommendation for gaseous hydrogen.

In **Austria**, a fire class ABC approved fire extinguisher has to be available at CNG filling stations. At LPG filling stations, at least two portable fire extinguishers suitable for fighting liquefied gas fires, which are permanently easily accessible and ready for use, each with a capacity of at least 6 kg or 9 litres, shall be available in the immediate vicinity of each liquefied gas dispenser and each liquefied gas dispensing device (first extinguishing aid). Only fire extinguishers that have been sealed and tested in accordance are considered ready for use. The place of installation of fire-fighting equipment must be marked with the appropriate signs.

8 Conclusions

With the information gathered from a strong network of national experts, it was possible to get a deep understanding on the permitting requirements and risk assessment methodologies followed in Europe regarding the deployment of HRS in a multi-fuel context.

All Member States must comply with specific European Directives and most of them follow the same standards. Even if the permitting requirements sometimes do not specifically check for the adherence to said directives, disobeying to them may lead to fines if due inspection occurs.

Most countries currently lack specific regulation that target the dispensing of hydrogen in refuelling stations, as this is still new equipment that has not been targeted in regulations. For the HRS currently deployed, the permitting procedure follows existent guidelines on conventional fuelling stations combined with industrial hydrogen requirements or CNG specific regulation. Most countries agree that the lack of specific regulations increases the level of subjectivity in the permit decision.

In many countries, the permitting procedure depends greatly on the amount of hydrogen stored on-site. The limit amount of hydrogen that may change the procedure, however, varies between 1 and 5 tonnes between the different countries.

The co-location of hydrogen in proximity with other fuels is handled very differently amongst the different countries. While in some countries it is completely forbidden to place a hydrogen dispenser in the same island as other fuels, in other countries this layout is allowed. Sometimes, specific regulation does not exist on this topic but the authorities consider best practice not to allow the layout, for safety reasons. In some countries, even placement of the hydrogen dispenser at the same dispenser as other fuels is allowed. Deeper analysis on the safety issues related to the placement of hydrogen in proximity with other fuels is clearly a common gap between all the countries.

There is no clear guidance on risk assessment methodologies among the different countries. Current standards state that a quantitative or semi-quantitative risk assessment must be performed and due safety distances must come as an output of such assessment. However, different countries make use of different national/European laws to guide them on further practicalities during risk assessment.

Regarding safety distances adopted in the different countries, different approaches are endorsed, also related to the different risk assessment guidelines followed. While in some countries safety distances are the sole responsibility of the risk assessment carried out by the operator and complete freedom is given, specific requirements are existent in most countries, even if they usually target the handling of hydrogen in industrial processes or conventional/CNG refuelling stations.

Equipment maintenance requirements are usually left for the manufacturer to prescribe. While piping and distribution systems can usually go a little longer without inspection (5 years on average), the most sensitive equipment are the valves, which should undergo maintenance, on average, every year. However, some countries do include some mandatory maintenance intervals prescribed in national legislation.

In many countries, adding specific barriers such as fire safety walls allow for a decrease in safety distances around the different equipment. In fact, fire walls are a common mitigation measure applied during the construction of HRS. Another important feature mentioned by most of the countries was the mandatory emergency shutdown that is activated both through gas detection and manually.

Many of the countries analysed in this deliverable have several HRS already deployed in their territory. However, there was a general consensus that clear guidance on the permitti ng procedure is sometimes lacking and, most of all, specific safety rules for hydrogen in the context of refuelling are non-existent or in need of further development, which is normal considering how new the application of hydrogen in mobility is. Most of the countries pointed out how useful it would be to have more knowledge on hydrogen safety related to its dispensing as they are now trying to develop HRS specific guidelines, which also emphasizes the importance of the work carried out in the MultHyFuel project. With the legislative and administrative commonalities and gaps identified in this report in mind, work carried out in the different work packages of the project will try to fill the knowledge gap on hydrogen safety and, this way, contribute towards a more harmonized permitting process in Europe.

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What is MultHyFuel?

The goal of MultHyFuel is to contribute to the effective deployment of hydrogen as an alternative fuel by developing a common strategy for implementing Hydrogen Refueling Stations (HRS) in multi-fuel contexts, contributing to the harmonization of existing laws and standards based on practical, theoretical and experimental data as well as on the active and continuous engagement of key stakeholders.

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Further information can be found under https://www.multhyfuel.eu.

For feedback on the MultHyFuel project or the published deliverables, please contact info@multhyfuel.eu.

The MultHyFuel Consortium