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Pre-normative research for safety of hydrogen driven vehicles and transport through tunnels and similar confined spaces

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Report on critical analysis of RCS for tunnels and similar confined spaces

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Summary

Current international regulations, codes or standards (RCS) provide no specific guidance for evaluating the appropriateness of conventional mitigation technologies, safety management and first responder intervention strategies in case of an accident with a hydrogen vehicle or transport. This urges for new or updates to RCS. Based on the results of a questionnaire implemented from October until December 2019, this report presents the critical analysis of existing (national) RCS to identify and analyze gaps for inherently safer use of hydrogen (H2) in tunnels and similar confined spaces.

Hydrogen can be considered both as a gas and a fuel. In most countries hydrogen is considered a gas with regards to production, transport and storage and national regulations, codes or standards for hydrogen in general are the same for all flammable gasses. Some countries also consider hydrogen as a fuel, but mostly in RCS related to Hydrogen Refuelling Stations. Although hydrogen has lots of similarities with other alternative fuels, no existing regulations, codes or standards on other alternative fuels can be directly translated for hydrogen. However, RCS for LNG could be used as a useful starting point.

Perspectives for first responders in tunnels or confined spaces (CS) are not hydrogen specific, but the same as for any other dangerous goods. For example, first responders cannot immediately enter a tunnel in case of an accident where dangerous goods class 2 are being transported. In addition, no common specific training is provided for accidents with hydrogen.

All responding countries have implemented the ADR and RID[1]. However, national safety requirements often go beyond the minimum requirements in EU legislation. Only generic (not hydrogen specific) aspects are taken into consideration, e.g. escape routes, sprinklers and ventilation. Risk assessment only has generic requirements and the methodology is established by national authorities. In risk analysis, Hydrogen Powered Vehicles (HPV) are mostly not yet integrated.

Apart from Norwegian ferries, all national responses confirm that there are no common RCS for hydrogen transport in relation to confined spaces. Existing RCS being mentioned mostly relates to Hydrogen Refuelling Stations. There are no specific requirements for HPV in national regulations, codes or standards for tunnels or confined spaces. The only mentioned exceptions are examples of airports and the Channel Tunnel. Lack of national regulations, codes or standards related to HPV maybe also have to do with the many forms and characteristics of CS.

There are no specific national construction regulations concerning the transport of hydrogen, or any alternative fuel. In addition, only generic aspects are taken into account for the construction of confined spaces, like sprinklers and ventilation. In most countries local regulations may affect the technical design of confined spaces and may differ from place to place. Different regulations, codes or standards may apply based on the type of CS. These do not take into consideration the fuels of the vehicles that may be parked there.

[1] ADR: European Agreement Concerning the International Carriage of Dangerous Goods by Road;
RID: Regulation concerning the International Carriage of Dangerous Goods by Rail.

Based on the input coming from the filled in questionnaires, a draft contents for recommendations have been drawn up for new or updated regulations, codes or standards for tunnels and similarly confined spaces to timely address hydrogen specific hazards and associated risks. These recommendations are, in random order:

- Develop hydrogen-specific standard operation procedures and tactics for first responders;
- Availability of Vehicle Identification Number in any type of incident/accident;
- Adaptation of RCS on ventilation specific for hydrogen; and
- Include hydrogen safety in the methodology for tunnel design.

These recommendations will be further elaborated in deliverable D6.10 “Recommendations for RCS” of Task 6.4.

Keywords

Questionnaire, Recommendations, Regulations, Codes, Standards, Hydrogen Safety, Tunnels, Confined Spaces

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Nomenclature and abbreviation

ADN	European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways
ADR	European Agreement Concerning the International Carriage of Dangerous Goods by Road
ALARP	As Low As Reasonably Practicable
CBG	Compressed Bio Gas
CNG	Compressed Natural Gas
CS	Confined Spaces
H2	Hydrogen
HPV	Hydrogen Powered Vehicles
ICE	Internal Combustion Engine
ISO	International Standardization Organization
LBG	Liquefied Bio Gas
LNG	Liquefied natural gas
M	Milestone
NEN	Dutch Standardization Organization
QRA	Quantitative Risk Assessment
RCS	Regulations, Codes, Standards
RID	Regulation concerning the International Carriage of Dangerous Goods by Rail
SDO	Standards Developing Organization
SOP	Standard Operation Procedures
VIN	Vehicle Identification Number

Definitions

Accident is an unforeseen and unplanned event or circumstance causing loss or injury.

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1. Introduction

Serious fires in some road tunnels in the Alpine countries during the years 1999 and 2001 triggered the issuing of the European tunnel safety directive 2004/54/EC. National implementations of this directive were due by 2019. Neither this directive nor any other regulations, codes and standards (RCS), e.g. PIARC Committee on Road Tunnels "Fire and smoke control in road tunnels" (1999), NFPA 502 "Standard for Road Tunnels, Bridges, and Other Limited Access Highways", NFPA 130 "Standard for Fixed Guideway Transit and Passenger Rail Systems" provide specific guidance for evaluating the appropriateness of conventional mitigation technology, e.g. ventilation, water sprays or fog, foams, etc., safety management and first responders' intervention strategies and tactics in case of a tunnel incident/accident if hydrogen vehicle or hydrogen delivery transport is involved. Thus, the deployment of hydrogen powered vehicles, the growth of hydrogen transportation and the increase in traffic infrastructure, which is established in tunnels or in similar confined spaces, urges new or updated RCS for tunnels and similarly confined spaces to timely address hydrogen specific hazards and associated risks.

Based on the results of a survey implemented from October until December 2019, this report presents the critical analysis of existing (national) regulations, codes or standards (including the activities of Standards Developing Organizations (SDOs) for other alternative fuels) to identify and analyse gaps for inherently safer use of hydrogen in tunnels and similar confined spaces. Based on results of this analysis a draft Table of Contents of the recommendations to different stakeholders, including regulators and SDOs, will be proposed (see Task 6.4 "Recommendations for RCS" for further elaboration) as part of the implementation of this project.

The remainder of the report is structured as follows: Section 2 describes the methodology and gives a general description of the participants; Sections 3 and 4 contain the results of the survey and general outcomes and suggestions; Section 5 presents a draft table of contents of recommendations for regulations, codes or standards; and Section 6 concludes with next steps. The Appendices include the template of the survey and a list of contacted organizations.

2. Methodology

2.1 General description

To be able to analyze existing (inter)national RCS with regards to the safety of hydrogen in tunnels and similar confined spaces, a questionnaire was produced to obtain the needed information on hydrogen and to find out what the similarities and differences are with regulations, codes or standards on alternative fuels and batteries. HyTunnel-CS partners were asked to share this questionnaire with their target audience (M1.1) to have them fill it in. All the filled in questionnaires were automatically received by NEN and shared with the HyTunnel-CS Partners, based on the country where the response came from. Based on all these national responses on the questionnaire, the national HyTunnel-CS partners made a first analysis of the results and based on this, proposed recommendations for regulators and SDOs. This report was written based on these analyses including a draft Table of Contents of the recommendations for regulators and SDOs.

2.2 Preparation of questions

The preparation of the questions for the questionnaire was performed by NEN, with input based on the knowledge of project partners. The last version of the questionnaire was agreed during the second HyTunnel-CS project meeting in Karlsruhe (Germany) in September 2019.

The questionnaire is divided into different subjects:

- H2 specific hazards and associated risks (compared to other alternative fuels)
- H2 Transport
- H2 Transport in Tunnels
- H2 Transport in Confined Spaces
- H2 Powered Vehicles in Tunnels
- H2 Powered Vehicles in Confined Spaces; and
- Suggestions for H2 specific RCS

The target audience were given the opportunity to explain each given answer in the questionnaire. This led to the identification of various and different answers containing interesting elements, which serve as a basis for recommendations for new or updated regulations, codes or standards at the end of this report.

2.3 Target audience (M1.1)

The target audience was part of M1.1. The list of contacts that have been established can be found in Annex II, and includes experts from other hydrogen projects, research institutions, governmental organizations, consultancies, standardization bodies, NGOs and association/networks.

Of all the responses to the questionnaire, next to coming from (inter)national contacts from HyTunnel Partners, responses also came from non-Partner countries Austria, Portugal and Sweden. See Figure 1 below.

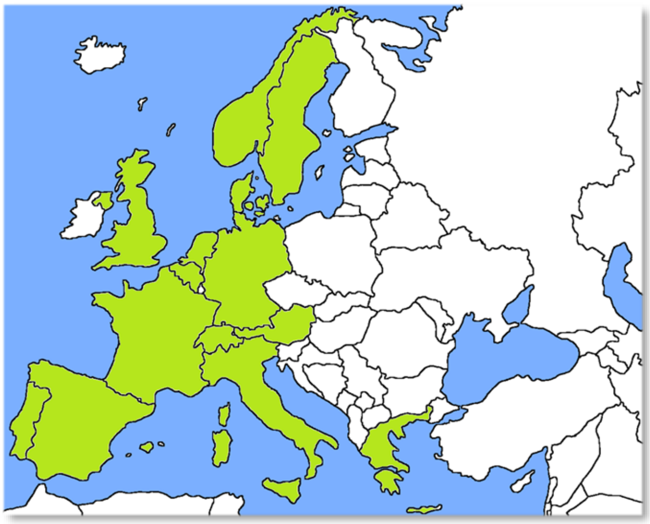

Figure 1. Map of national responses to the questionnaire (in green).

2.4 IT tools

For the questionnaire, the online survey and feedback tool Questback was used. Questback offers online data collection and analysis solutions, create statistics and export the resulting data to other applications (www.questback.com).

3. Questionnaire

3.1 Disclosure

This section of the report (chapter 3) reflects and summarizes the main outcomes of the questionnaire, per topic. It is solely based on the combined results of the national reactions to the survey questions.

The effectiveness of the used methodology to obtain the needed information was reliant on the participation of the project partners to identify and facilitate the identification of relevant RCS via their national network. Whilst a range of relevant organisations were identified and contacted, it was a demanding task getting these organisations to complete the questions - in part due to issues identifying the right people to engage with, but also due to limited resources to follow up the contacts.

Therefore, it is uncertain whether a complete view of all the relevant RCS has arisen. Based on the national reactions to the survey questions, some areas were identified where there is limited RCS. Hence, it is recommended for future work to look at these areas in more detail to see if any RCS does exist.

3.2 Hydrogen specific hazards and associated risks

Is hydrogen treated as any other alternative fuel (LNG, LPG, CNG, Batteries) in national Regulations, Codes and Standards (RCS)?

According to the national responses, there is a distinction between national RCS for hydrogen as a gas and hydrogen as an alternative fuel.

Gas

In, for example, Great Britain, with regards to production, transport and storage, hydrogen is treated as a hazardous industrial gas, and is considered in the same way as other industrial gasses. All aspects of hydrogen related hazards are covered already, but as a hazardous substance, not a fuel. RCS classification of hydrogen itself needs to be amended to cover its use as a fuel.

The response from Switzerland is in line with this, where there is no specific legislation for hydrogen. Rather, legislation applies to carriage and storage of dangerous substances. Naturally, hydrogen related risks may not be higher than risks of other energy-technologies.

Also, the Norwegian regulation of safety and security is the same for all flammable gasses. Hydrogen is considered as such, even though its use is not widespread.
The same counts for Portugal, where there are no specific regulations, codes or standards for hydrogen storage, transportation and use as vehicle combustible, or any other specific gasses. Rather, there are general regulations for "gasses"; compressed, liquefied or cryogenic.

Alternative fuel

In Europe, an important regulation is the Directive 2014/94/EU on the “deployment of alternative fuels infrastructure”, better known as Alternative Fuels Infrastructure Directive (AFID). It obliges member states to build infrastructure for alternative fuels when they are missing. In the end it should be possible to use alternative fuels throughout the EU .

In Spain, national RCS do not consider hydrogen as equal to other alternative fuels due to its greater risks of explosion. However, there is no specific national RCS apart from the transposition of EU Regulation 79/2009 on type-approval of hydrogen powered motor vehicles and the above mentioned AFID.

In Great Britain, on the other hand, LNG, CNG, electric and hydrogen are all alternative fuels in the national Alternative Fuels Infrastructure Regulations 2017. In other countries, most existing national regulations, codes or standards on hydrogen as an alternative fuel are on regulations for refuelling stations.

In the Netherlands, regulations for refuelling stations follow the same principles: for each fuel an equal level of individual risk and group risk. The regulations address specific hazards and therefore may be different for the different fuels. Some activities need a permit, for others a notification is sufficient. Dedicated national documents exist per fuel, in the PGS-series (Hazardous Substances Publication Series).

In Italy, national RCS also concerns around the fire safety of hydrogen refuelling stations and corresponds to ISO 19880 (Gaseous hydrogen - Fuelling stations). Every fuel has a national fire safety standard for its use in refuelling stations.

3.2.1 Similarities

Similarities between hydrogen and other alternative fuels

On the question what the similarities are between hydrogen and other alternative fuels, the following examples were given:

- Hydrogen is a flammable gas, lighter than air (like natural gas), and kept in pressurized containers;
- Need for cautions and need for more experienced users;
- Hydrogen is compressed gas, as CBG, or liquefied as LBG[2]; and
- Hydrogen has a lot of specific energy, and there is a greater risks of explosion than for fossil fuels.

3.2.2 Differences

Differences between hydrogen and other alternative fuels

Based on the responses, the most important differences between hydrogen and other alternative fuels include:

- Hydrogen is odourless, colourless and non-toxic;
- Hydrogen flames are not visible, heat radiation is much less;
- Hydrogen is very reactive and can experience detonations if mixed with air and ignited. The cloud that is generated by a leak in a hydrogen tank is much more flammable and a lot easier to ignite than for natural gas;
- Hydrogen does not pollute;
- Hydrogen requires more demanding safety systems for handling, use and transport. It has an increased range of explosion limits

3.2.3 Directly translated

Are there national RCS for (specific) alternative fuels that can be directly translated to Hydrogen?

In general, respondents confirm that they do not know of any specific existing national RCS on other alternative fuels that could be directly translated to hydrogen. Mostly because there aren't any regulations, codes or standards for any alternative fuel in the first place. Both the responses coming from Great Britain and the Netherlands, for example, state that it is not possible for existing national RCS for other (specific) alternative fuels to be directly translated, given the different levels of hazard involved.

However, in the Netherlands existing RCS for LNG is being taken as a starting point and possibilities to adjust it for hydrogen is being analysed. During the period of 2013 – 2017 there has been a national "LNG Safety Program", which resulted in regulations (Interim law on LNG safety distances), codes (PGS-33 for LNG refuelling stations) and handbooks for permits for LNG refuelling stations. A similar national program for hydrogen safety starts in 2020.

[2] CBG = Compressed Bio Gas; LBG = Liquefied Bio Gas.

3.3 H2 transport

In this section of the questionnaire focus was on issues related to hydrogen transport in tunnels, confined spaces and perspectives for first responders. The different questions are expressed in the grey bars. The combined responses to the questions are detailed below.

3.3.1 ADR and RID

Are the ADR and RID nationally implemented?

Directive 2008/68/EC of the European Parliament and of the Council on the inland transport of dangerous goods, transposes ADR, RID and ADN into the EU’s internal law, including for national transport. Hereby harmonizing the provisions on the carriage of dangerous goods by road, rail and inland waterways. All national responses, including those of non-EU members Norway and Switzerland, confirm national implementation of ADR, RID and ADN.

3.3.2 Tunnel length

How does national RCS subdivide tunnels in terms of length?

In all the national responses to the questionnaire it is confirmed that national codes are implemented regarding safety in road tunnels of 500m or more on the European road network, therewith following the mapping of the European Directive 2004/54/EC on minimum safety requirements for tunnels in the trans-European road network. For train tunnels, this length also applies, but often in relation to the internal regulation of the infrastructure manager.

In Greece, for example, road tunnels (according to Presidential Decree 230/2007) are structures longer than 500m. In Italy, for rail tunnels they follow National Decree n. 28/10/2005 above 500m. Likewise, in Austria tunnel safety law must be observed for tunnels longer than 500m.

However, in many countries, as function of the length, the traffic intensity and the fact that a tunnel is unidirectional or bidirectional, a more detailed regulation applies for road tunnels. In Germany, for instance, according to “Regulations for the equipment and operation of road tunnels” (RABT 2016, Section 0.5), risk analysis should be done for a tunnel longer than 400m (see Figure 2). In the Netherlands a quantitative risk analysis should be carried out for tunnels longer than 250m.

INFORMATIVE SUMMARY OF MINIMUM REQUIREMENTS

Tunnel Category: **Congested Unidirectional**

KEY
○ Not Mandatory for all Tunnels
■ Final decision after predetermined risk analysis conducted
● Mandatory for all Tunnels

Origin of guideline	Category	Tunnel Length (M)									
		<400m	400-500m	500-600m	600-800m	800-1000m	1 000 - 1200 m	1200 - 1500 m	1500-3000m	>3000m	Comment
DIRECTIVE (EU)	Mechanical ventilation	○	○	○	○	○	●	●	●	●	May be varied if risk assessment demonstrates acceptable in special circumstances
	Special provisions (fresh air ducts and/or smoke extraction)	○	○	○	○	○	●	●	●	●	May be varied if risk assessment demonstrates acceptable in special circumstances
Germany (D)	Mechanical ventilation	○	●	●	●	●	●	●	●	●	Detailed decisions about smoke extraction etc driven by requirements of fire case.
	Special provisions (fresh air ducts and/or smoke extraction)	○	●	●	●	●	●	●	●	●	Detailed decisions about smoke extraction etc driven by requirements of fire case.
Switzerland (CH)	Mechanical ventilation	○	○	○	○	●	●	●	●	●	Lower Risk -Ventilation decisions driven by risk analysis .
		○	○	○	●	●	●	●	●	●	Higher Risk - Ventilation decisions driven by risk analysis
	Special provisions (fresh air ducts and/or smoke May extraction)	○	○	○	○	■	■	■	●	●	. Lower Risk -Ventilation decisions driven by risk analysis
		○	○	○	■	●	●	●	●	●	Higher Risk - Ventilation decisions driven by risk analysis

Figure 2. Simplified summary of EU, D and CH Guidelines for unidirectional congested tunnels of differing lengths[3].

3.3.3 H2 transport in tunnels

What are the perspectives for action of first responders in tunnels?

In general, national responses on the questionnaire mention the recognizability of goods transported; structural reliability; and type of tunnel ventilation, as being most important perspectives for action. In addition, ADR and the emergency plan of the tunnel are referred to in national responses.

However, perspectives for action of first responders are not per se hydrogen-specific. In Switzerland, for example, perspectives for hydrogen related incidents are the same as for any other dangerous goods.

Road tunnels

In Italy, the selection of the best rescue strategy is strongly related to the situational analysis (kind of accident, number of involved people/vehicles, kind of transported goods and their sensitivity, site characteristics, etc.). In Spain, Royal Decree 635/2016 Article 3 defines a list of basic actions to consider in the organisation of the civil protection under the frame of dangerous goods incidents. In Greece, requirements in Presidential decree 230/2007 should be followed. In general, first responders cannot immediately enter a tunnel if there is an accident with a vehicle that is transporting a dangerous good and the safety situation is still unclear.

The Norwegian response elaborates on this. National “Act on Protection against Fire, Explosion and Accidents with Dangerous Substances” and the international “Fire and Explosion Protection Act”, although not specific for tunnels, are important sources for the perspectives for action of first responders. According to the latter act, first responders must carry out a risk and vulnerability analysis so that the fire brigade is best adapted to the tasks it can be faced with. Before smoke or chemical diving (working under protective breathing

[3] Dix, A., Professor of Engineering, Safety Standards For Road And Rail Tunnels – A Comparative Analysis, *Queensland University of Technology*, p273.

apparatus) is implemented, the emergency manager and a necessary number of qualified smoke or chemical divers and sufficient equipment must have arrived at the damage site and the personnel's safety in carrying out the effort must be assessed. Requirements for training of the Norwegian crews have been set according to the tasks they can be assigned to.[4]

In Great Britain, guidance is provided to regional fire services by National Operational Guidance. But there does not appear to be national RCS or any other guidelines covering hydrogen-specific first responder training. In the Netherlands, the Institute for Safety (IFV) has developed six protocol cards for first responders who have to deal with accidents with hydrogen. However, these are not specific for tunnels or confined spaces. One of the cards is for hydrogen related general procedures. The others for accidents with refueling stations, fuel tanks, local production of hydrogen, trucks powered by hydrogen and hydrogen road transport (not tunnels).

Rail tunnels

Based on the national responses to the questionnaire, most of the perspectives for action of first responders for rail tunnels are the same as for road tunnels. Naturally, the RID and the tunnel emergency plan is referred to.

In Austria, specific knowledge of the location by tunnel operators is required. In the United Kingdom, all Network Rail tunnels are required to have an emergency plan (This is the common standard in all industrialized countries). These are developed by the operations teams within each route. If hydrogen was to be used or transported through the tunnels, then this would need to be incorporated into the plan so that those attending an emergency are aware there could be hydrogen present within the tunnel.

In the Netherlands, there is no specific training program for first responders in rail tunnels. Fire brigades who deal with railway tunnels organize tunnel exercises together with the National Railway Management organization, but not on a regular basis.

3.3.4 Construction of tunnels

Which aspects have to be taken into account in the construction of tunnels?

Based on the input coming from the questionnaires, no specific distinction is made in the regulations with regard to construction requirements and facilities for the different ADR tunnel categories. There are many ‘generic' aspects that must be taken into account in the construction of tunnels, for example:

- Emergency exits/Escape routes: In Switzerland, the distance between exits in road tunnels is 300m maximum and for new rail tunnels 500m max. In Italy and the Netherlands this distance in road tunnels is 250m maximum. In general, National Railway Management organizations have their own guidelines for requirements for escape routes. In Great Britain, for example, for existing rail tunnels there are no requirements on escape routes as majority of tunnels were built in the 1800s or early 1900s and as such have no provision for this. Most are just brickwork arches and some of them have ventilation shafts. New Tunnels are required to be compliant with the Safety in Rail Tunnels Technical Specification for Interoperability, which includes the bullets below;

[4] Norwegian Fire and Explosion Protection Act (2002), §4-9 Smoke or chemical diving.

- Drainage for toxic liquids;
- Lighting (normal, safety and emergency/evacuation);
- Carbon Monoxide detector;
- Fire resistance;
- Emergency phones;
- Hydrants;
- Evacuation signage;
- Communication systems for emergency services;
- Ventilation: In Spain, for example, longitudinal ventilation is forbidden in bi-directional tunnels unless a risk analysis shows that it works properly. Austria is looking at the possibility of creating a standard for the ventilation system in tunnels. The importance of this is apparent in the input coming from Belgium: Sprinklers will suppress the fire, but you need proper ventilation as well. Otherwise the cloud of hydrogen will not disperse and the explosion risk and size will only increase. However, ventilators are not explosion-proof themselves either.

However, questionnaire responses from Italy and Greece show that there are no specific national construction regulations concerning the transport of hydrogen (or any other alternative fuels) in road or rail tunnels.

In Sweden, the National Transport Agency has been authorised to issue regulations regarding safety in road tunnels on the government authority level, and issues mandatory provisions and general recommendations regarding safety in road tunnels. These regulations do not factor in alternative fuels in vehicles, and the responsibility for managing these risks is placed on tunnel managers. There is, however, a general recommendation that is relevant to the risk of explosion, which relates to longitudinal ventilation in tunnels of longer than 1000m: The average air speed of the cross-section of a tunnel should be at least 3 m/s during heat release rates of up to 100 MW. This reduces the risk of larger vapour clouds being formed.[5]

3.3.5 Risk assessment

What requirements are there relating to risk assessment study?

Based on the input coming from the filled in questionnaires, there are generic requirements for risk assessment topics, such as traffic strength, accidents, ventilation, fire escapes, vehicle participation, dangerous goods participation in accidents in general. Norway, Italy and Great Britain indicate that (full) risk assessment study is always mandatory for both rail and road tunnels. Minimum requirements must be integrated by ALARP (As Low As Reasonably Practicable) risk analysis to demonstrate the compliance with safety objectives. In Greece, like in most other countries, the specific methodology that should be followed, is established by either the national Tunnel Administrative Authority or a Ministry. In Greece, for example, there are “Guidelines for Risk Analysis of Dangerous Goods Transportation through Road Tunnels” according to Presidential Decree 230/2007 of the Ministry of Infrastructure, Transportation and Utilities.

[5] Gehandler, J., Karlsson, P., and Vylund, L., Risks associated with alternative fuels in road tunnels and underground garages, *SP Report*, 2017:14, p38.

In Spain, recently the Ministry of Development has published a methodology that aims to ensure uniformity, reliability and consistency of this risk analysis. Before to the publication of this methodology, it has been elaborated the Operating Manual for the Media Fanega tunnel which contains a risk analysis that complies with the methodology promulgated by the Ministry of Development.[6]

In the Netherlands, the “Additional Road Safety Tunnels Act” (Warvw[7]) stipulates that a quantitative risk assessment (QRA) should be carried out for tunnels > 250m. This calculates the risks of fires and accidents with hazardous substances. The QRA model has primarily been developed to assess the risks caused by bulk transport of hazardous materials (like fuels), but is also being applied to assess the risks of fires of heavy duty vehicles powered by new fuels,

3.3.6 Additional requirements

Additional requirements in national RCS on Hydrogen transport

In general, national responses to the questionnaire indicate that there are no additional requirements in national RCS on hydrogen transport, apart from Directive 2008/68/EC on the inland transport of dangerous goods and the tunnel restriction codes of the ADR (or RID in case of rail transport), given effect by national legislations.

In ADR, road tunnels are categorized A, B, C, D or E based on hazard assessment of transport. The tunnel category indicates the substances that are not allowed to transport. A tunnel can be assigned to more than one tunnel category. This can depend on the hours of the day or day of the week. The transport of hydrogen in tanks is prohibited through tunnels of categories B, C, D and E; and in cylinders through tunnels of categories D and E.[8]

Examples of tunnel restrictions were given by both Great Britain and the Netherlands. Hydrogen vehicles are not permitted in the tunnels under Heathrow airport or Schiphol airport, nor on the Eurotunnel (Le Shuttle).[9] For the railway tunnel at Rijswijk a prior request for permission has to be submitted to the fire brigade and mayor.

Confined Spaces

Apart from Norway, where there are specific RCS for transporting dangerous goods on ferries, all national responses confirm that there are no specific regulations, codes or standards for hydrogen transport in relation to confined spaces.

3.3.7 Conclusions

Hydrogen can be considered both as a gas and a fuel. In general, hydrogen is considered a gas and national RCS for hydrogen overall are the same for all flammable gasses. Some countries

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[6] Jiménez, P., Safety in tunnels. *ResearchGate* (2013), vol. 4, p43-51.
[7] “Wet aanvullende regels veiligheid wegtunnels”. Available from: https://wetten.overheid.nl/BWBR0019516/2015-07-01 [Accessed 26.12.19].
[8] European Agreement concerning the International Carriage of Dangerous Goods by Road (2019), *United Nations*, §1.9 Transport restrictions by the competent authorities.
[9] “Unsure which fuel-type your vehicle uses?” Available from: https://www.eurotunnel.com/uk/travelling-with-us/vehicles/fuel-types/ [Accessed 26.12.19].

also consider hydrogen as a fuel, but mostly in national RCS related to Hydrogen Refuelling Stations. Although hydrogen has lots of similarities with other alternative fuels, no regulations, codes or standards can be directly translated for hydrogen. However, RCS for LNG could be used as a starting point.

Perspectives for first responders in tunnels are not hydrogen specific, but the same as for any other dangerous goods. For example, first responders cannot immediately enter a tunnel in case of an accident where dangerous goods class 2 are being transported. Only little specific training is provided for accidents with hydrogen. In the Netherlands, Hydrogen Protocols for first responders have been developed, but these are not tunnel or CS specific.

All countries have implemented the ADR and RID. Still, national safety requirements often go beyond the minimum requirements in EU legislation. Safety requirements for the construction of road tunnels seem to be somewhat stricter than for rail tunnels. Only generic (not hydrogen specific) aspects are taken into consideration, e.g. escape routes, sprinklers and ventilation. There are no specific national construction regulations concerning the transport of hydrogen, or any alternative fuel. Some examples of additional requirements for hydrogen transport in tunnels are given for the Channel Tunnel and tunnels near airports.

Risk assessment only has generic – not hydrogen specific - requirements and the methodology is established by national authorities. In the Netherlands, however, the QRA includes heavy duty vehicles powered by alternative fuels.

Apart from Norwegian ferries, all national responses confirm that there are no RCS for hydrogen transport in relation to confined spaces. Later in this report, regulations, codes or standards for hydrogen powered vehicles in relation to CS will be discussed.

3.4 H2 propulsion

This part of this report deals with hydrogen propulsion-related questions from the questionnaire. This section is divided into questions about tunnels and confined spaces in relation to perspectives for action of first responders, requirements in national RCS, different types of confined spaces and other aspects of hydrogen specific hazards and associated risks.

3.4.1 Perspectives for action of first responders

What are the perspectives for action of first responders?

Next to the perspectives mentioned in §3.2.3 on hydrogen transport, which also apply to hydrogen powered vehicles (HPV), for the latter there are some additional perspectives for action of first responders.

For instance, as showed by the Belgian response to the questionnaire, logically first responders need to be able to assess what kind of fuel is being used by the vehicle. In this context, the importance of the international standard - ISO 17840 "*Road Vehicles – Information for first and second responders*" is mentioned frequently in national responses to the questionnaire. In Part 4 of this standard, propulsion energy identification is addressed. In addition, the

International Association of Fire and Rescue Services (CTIF) is working on a new standard to put stickers with the symbol for each type of alternative fuel on the car.

From the Swiss response follows that the availability of a Vehicle Identification Number (VIN) in any type of incident / accident is a precondition for hydrogen-specific action taken by first responders. However, national standard operation procedures (SOP) for emergency services are not yet hydrogen specific.

In Sweden, the smartphone apps "Fordonskoll" ("Swedish license plates") and "CRS" (Crash Recovery System) can be used to determine whether the vehicle is powered by an alternative fuel. However, its use requires the license plate to be visible and identifiable, which is not always the case.[10] The same is true for stickers.

Confined spaces

In the different national responses to the questionnaire, there are no differences in RCS mentioned, based on the type of confined space.

Specific perspectives for action of first responders in confined spaces follow from the Belgian response to the questionnaire. If there is a risk for explosion in a confined space (based on risk assessment performed at the scene), first responders typically do not enter without ventilating first. Sprinklers will extinguish the fire, but there is a need for proper ventilation. Otherwise the cloud of hydrogen will not disperse and the explosion risk and size will only increase.

3.4.2 Requirements in national RCS

What specific requirements are there in national RCS regarding hazard risks related to HPV in tunnels and confined spaces?

In general, the national responses to the questionnaire are that no specific regulations apply for tunnels and confined spaces that are used by HPV. The ADR, for instance, is about hydrogen transportation. When it comes to RCS related to HPV, national responses mainly refer to European regulations and standards on hydrogen refuelling stations. Some examples that are given are:

- Directive 2014/94/EU on the deployment of alternative fuels infrastructure (AFID);
- Italian Ministry of Interior Decree of 23 October 2018 concerning the fire safety of hydrogen refuelling stations. It provides similarities with:
- ISO 19880 Gaseous hydrogen - Fuelling stations;

However, none of the regulations, codes or standards mentioned here are specifically related to tunnels or confined spaces.

Tunnels

In the Netherlands, no specific regulations apply for tunnels that are used by HPV. In addition, HPV have not yet been elaborated in QRA models, but they will be in the near future. Furthermore, up till now, there are no hydrogen powered trains in the Netherlands. The first train is expected spring 2020, but there are no tunnels on its track.

[10] Gehandler, J., Karlsson, P., and Vylund, L., Risks associated with alternative fuels in road tunnels and underground garages, *SP Report*, 2017:14, p45.

In Great Britain, the civil engineering standards do not have any differences with regards to transport of hydrogen or use of hydrogen powered vehicles in tunnels. The only known exception is the earlier mentioned example of hydrogen powered or transporting vehicles not permitted in the tunnels under Heathrow airport, nor in the Eurotunnel (Le Shuttle). The latter, however, is not hydrogen specific. For safety reasons Le Shuttle is not able to transport vehicles powered by ANY flammable gasses, including but not limited to: BiFuel, Autogas, Hydrogen, LPG, CNG or CGH2.[11]

Confined spaces
Based on the German and Greek response to the questionnaire, there are also no specific stipulations on HPV in confined spaces, like car parks. As indicated earlier, in Norway there are specific laws for ferries, but these are on hydrogen transport and not on propulsion. In Portugal there also are no specific RCS for hazard risks related to HPV, because as a country they don't have any HPV yet.

The lack of specific national RCS for hazard risks related to HPV in confined spaces probably also has to do with the many forms and characteristics of confined spaces. This will be further discussed below.

3.4.3 Confined spaces

Which aspects regarding hydrogen have to be taken into account in the construction of confined spaces?

In general, national responses to the questionnaire indicate that they are not aware of the existence of specific regulations, codes or standards on hydrogen that must be taken into account in the construction of confined spaces. RCS concerning the construction of hydrogen refueling stations is mentioned, but this is not regarded as a CS. No specific distinction is made in the regulations with regard to construction requirements and facilities.

Generic aspects
More generic aspects that are mentioned in the filled in questionnaires, like the ones from Belgium and Italy, that have to be taken into account in the construction of confined space, are sprinklers an ventilation. The Belgian response states that although sprinklers will extinguish the fire, you need proper ventilation as well. Otherwise the cloud of hydrogen will not disperse and the explosion risk and size will only increase. In Italy there are also minimum electrical equipment requirements for confined spaces with possibility of vapor clouds formations.

Generic RCS
Examples of more generic RCS applying to the construction of confined space are also given. In Spain, depending on the use of the confined space, the possible gasses, fire protection and other industrial safety topics, different regulations may apply, e.g. Technical Buildings Codes, and national Decrees on Chemical Products Storage and Fire Safety. Eurocodes and the ATEX directive are mentioned. The ATEX directive consists of two EU directives that describe which

[11] "Unsure which fuel-type your vehicle uses?" Available from: https://www.eurotunnel.com/uk/travelling-with-us/vehicles/fuel-types/ [Accessed 26.12.19].

equipment and workspace are permitted in an environment with an explosive atmosphere. In Great Britain, legislation to carriage and storage of dangerous substances is applied.
In Sweden, 'Boverket ('the Swedish National Board of Housing, Building and Planning'), is responsible for regulations regarding the construction of buildings. The regulations of Boverket do not, however, take into consideration the fuels of the vehicles that may be parked in a garage within a building, although explosion loads can be factored into an analytical design process or the applying Eurocodes in relation to the load-bearing capacity of a building.[12]

Local
In general, local regulations may affect the technical design of the confined space. In the Netherlands, on municipal level specific local regulations exist. In theory, these kind of regulations could include specific rules for vehicle parking in confined spaces. As far as the Dutch respondents to the questionnaire know, no municipality has applied any of such specific rules for vehicle parking in confined spaces so far. As of 2021, in every municipality these regulations will be written down in the "Omgevingsplan" (the Integrated Local Environment And Planning Proposal), under the "Omgevingswet" (Environment and planning act). Until 2021, these kind of rules form part of the "Algemene Plaatselijke Verordening" (General Local Regulation).
A Spanish example is given for underground garages. The local regulations related to ventilation of the city of Zaragoza is different compared to other cities, and also the fire protection regulations.

Design
The Swiss response (and several other national responses) to the questionnaire makes clear that in principle no changes in the construction of CS should be necessary. The response from Sweden states that as vehicles are generally replaced more frequently than buildings, it is preferable that efforts to increase safety be directed towards rescue services and vehicles rather than implementing safety measures in CS, as these are more difficult to implement for existing structures.[13]

3.4.4 Differences in RCS

Are there differences in national RCS in the type of confined space?

As mentioned earlier, confined spaces can differ hugely from one to another, and based on the classification, a huge variety of regulation, codes and standards may apply. Additionally, the regulations that may affect will be dependent on different administrative bodies, at national, regional or even local level. In general, respondents confirm that there are no differences in national RCS in the type of confined space. Mostly because there are no specific hydrogen regulations, codes or standards in the first place.

Underground parking
General RCS are mentioned. The Spanish response notes that while the introduction of alternative powered vehicles in Spain is still limited, the car park spaces are designed with

[12] Gehandler, J., Karlsson, P., and Vylund, L., Risks associated with alternative fuels in road tunnels and underground garages, *SP Report*, 2017:14, p36.
[13] Idem, p43.

general purpose spaces for current ICE[14] vehicles. The relevant regulations (such as the local regulation for ventilation of parks in Zaragoza), does not consider novel fuel cell applications.

Underground car parks have a specific code of practice for the design and operation in United Kingdom (BS 7346-7:2013). Ventilation requirements are given as 6 Air Changes per Hour (ACH) in normal working operation and 10 ACH in the event of fire. However, also in this case, no reference is given to the type of vehicle.

Service stations
In Spain, hydrogen suppliers must be separated from the rest, but there are no specific requirements. In the Netherlands, rules for business-related storage and maintenance are being discussed.

Ferries
As indicated earlier in this report, in Norway there are specific laws for ferries. But these are on hydrogen transport and not on propulsion.

3.4.5 Risk assessment

What requirements are there relating to risk assessment study?

The national responses to the questionnaire show that the requirements do not much differ from the generic requirements mentioned earlier in § 3.2.1 on hydrogen transport in tunnels.

In the Netherlands the QRA model for tunnels has primarily been developed for fuel transport, but is also being applied for heavy duty vehicles powered by new fuels. Hydrogen vehicles have not yet been elaborated in the model, but will be in the near future.
In Italy the risk assessment study must specifically consider the risks due to the materials. These specific risks due to the nature of the material (or fuel) are added to the minimum ones.
In Portugal every building or infrastructure has to implement fire safety mitigation and planning actions, and to do that, the engineer has to do a risk assessment study.

First responders
In the international Fire and Explosion Protection Act, requirements for training of the crews have been set according to the tasks they can be assigned to. In accordance with the requirements, based on risk analysis, the fire department with tunnels and confined spaces must be trained to be able to implement efforts. Since there are function-based regulations, it is the individual municipality / fire and the rescue services that define their own requirements in relation to the individual tunnel or confined space.

3.4.6 Conclusions

Perspectives for action of first responders is overall the same as for hydrogen transport. An example of an additional perspective is propulsion energy identification. In Sweden, there is an app developed for this purpose, but this has its limitations. Another example is that the confined space has to be ventilated first before entering.

[14] Internal Combustion Engine

There are no specific requirements for HPV in national regulations, codes or standards for tunnels or confined spaces. Existing national RCS being mentioned mostly relates to Hydrogen Refuelling Stations or transport. In risk analysis, HPV are not yet integrated. The only mentioned exceptions are certain airports and the Channel Tunnel. Lack of national regulations, codes or standards related to HPV maybe also have to do with many forms and characteristics of confined spaces.

Only generic aspects are taken into account for the construction of CS, like sprinklers and ventilation. Different regulations, codes or standards may apply based on the type of confined space. These do not take into consideration the fuels of the vehicles that may be parked there. In general, local regulations may affect the technical design of confined spaces and may differ from place to place.

Confined spaces differs hugely from one to another, and based on the classification, a huge variety of regulation, codes and standards apply. However, based on input from several responses to the questionnaire, it is preferable that efforts to increase safety be directed towards rescue services and vehicles, instead of changes to the construction of CS.

4. General outcomes and suggestions

Based on the responses to the questionnaire, hydrogen is (still) viewed as a new perspective fuel. Respondents indicate that there is little experience with the subject, especially with propulsion.

Where there is a reasonable amount of RCS for transport, there is little for propulsion. Given the fact that the use of hydrogen vehicles is increasing, respondents see a good chance that regulations will prove necessary regarding the use of tunnels and confined spaces, like parking garages.

Often there is no national coordination of hydrogen regulations. In addition to the lack of experience, the opinion is that it also has to do with a great deal of variation in options. Confined spaces, for example, differ hugely from one to another, and based on the classification, a wide variety of (local) regulations, codes and standards may apply.

4.1 Suggestions

As a final question in the questionnaire, respondents were asked for suggestions for hydrogen specific RCS that is currently insufficient/missing.

Which (other) aspects of hydrogen specific hazards and associated risks in tunnels and confined spaces, should be covered by RCS, but at the moment is not?

Some national responses point out that before we can fully answer the question what (other) aspects of hydrogen-specific hazards and associated risks in tunnels and confined spaces should be covered in regulations, codes or standards, more insight is needed in the “new safety risks” to be able to determine whether an adjustment of current RCS is necessary. Hereby confirming the importance of the deliverables of the HyTunnel-CS project. Still, some valuable suggestions were made by the national respondents. In random order, a selection of the most important ones follows below.

- There is already a reasonable amount of regulations, codes and standards for hydrogen transport, therefore focus should be on developing RCS for HPV;
- Develop hydrogen-specific standard operating procedures and tactics for first responders (This will shorten the intervention time, which increases the chances of survival of the victims, and strives for optimum safety for first responders at the scene of the incident.)
- (Better) national hydrogen safety coordination;
- Availability of Vehicle Identification Number VIN in any type of incident;
- Develop a hydrogen-specific ventilation standard;
- Include hydrogen safety in the methodology for tunnel design;
- Reserving and marking certain spaces in underground garages for use by HPV.

5. Draft content for recommendations for new or updated RCS

Based on the input coming from the filled in questionnaires, including the suggestions mentioned above, draft content for recommendations has been drawn up for new or updated RCS for tunnels and similarly confined spaces to timely address hydrogen specific hazards and associated risks. These recommendations follow below, in random order.

5.1 Develop hydrogen-specific standard operation procedures and tactics for first responders

Rescue operations are much more at risk in both underground garages and tunnels. At this moment, however, there are no hydrogen-specific standard operating procedures (SOP) and tactics for first responders available. Therefore, hydrogen-specific standard operating procedures and tactics for first responders should be developed. These should be compatible and harmonized throughout Europe (especially for tunnels in border areas). This shortens the intervention time, which increases the chances of survival of the victims, and strives for optimum safety for first responders at the scene of the incident.
These recommendations for operation procedures and tactics for first responders will be developed within D5.4. “Harmonised recommendations on response to hydrogen accidents”. The identification of RCS where these recommendations may be included and to which parties these recommendations will be forwarded to, will be part of D6.10 “Recommendations for RCS".

5.2 Availability of Vehicle Identification Number in any type of incident/accident

There should be a European standard, or even law, for marking cars according to the fuels that they use. The 2019 international standard ISO 17840 “Road vehicles – information for first and second responders”, should therefore be adopted by CEN. Part 4 of this standard, for example, specifies the symbols that will be used to assist rescue services in quickly identifying the type of fuel that a vehicle uses. Next to useful tools like the use of data transmission technology (e.g. E-call), an app and stickers, reserved and marked parking spaces in underground garages is seen as an important means for the inherently safer use of hydrogen in tunnels and similar confined spaces.

5.3 Adaptation of RCS on ventilation specific for hydrogen

Proper Ventilation is regularly mentioned in the questionnaire as being very important in the context of hydrogen safety. No specific distinction is made in the regulations with regard to construction requirements and facilities such as ventilation for the different ADR tunnel categories, nor for the transport of hydrogen. As a function of the confined space, often different regulations related to ventilation apply, varying from national to local regulations.
In addition, tunnels and confined spaces may contain a number of hidden elements behind the brickwork. These include potentially voided areas of unknown size/shape. As hydrogen is a very light/small gas there is potential for it to seep through cracks in the linings and build up in these voids. This would lead in turn to potentially dangerous levels of hydrogen. Therefore, regulations need to be adapted for the alternative fuels and for future developments. This particularly involves regulations/standards for ventilation, which should be triggered by gasses, such as hydrogen gas and hydrogen fluoride, which are emitted by HPV. Earlier, other European programs have already been implemented on this subject, e.g. Hyindoor project. The results of the tests performed by the HyTunnel-CS project partners could provide valuable new information for recommendations for new or updated RCS.

5.4 Include hydrogen safety in the methodology for tunnel design

According to respondents to the questionnaire and e.g. the 2019 JRC Technical Report on 'Standardization needs for the design of underground structures', there are no European tunnel design standards or harmonized guidelines at European level. Thus, tunnel design in Europe is carried out based on national knowledge and experience, as well as parts of the EN Eurocodes. The EN Eurocodes are a set of European Standards which provide common rules for the design of buildings and other construction works to check their strength, stability and fire resistance. There are no parts devoted to the design of tunnels, as the Eurocodes do not explicitly include all underground structures. In addition, the lack of methodology for determining design and operating requirements for tunnels many times leads to an expensive over-design for tunnel works without the expected increase in safety levels. A possibility for hydrogen safety to be included in the methodology for tunnel design lies in adding tunnels (most common types of underground structures) in EN Eurocodes. The results of the HyTunnel-CS project could provide valuable substantiation for this.

6. Next steps

6.1 Table of contents

This draft content for recommendations for regulators and SDOs was agreed on during the third HyTunnel-CS project meeting in Aussois, France in February 2020. A final Table of Content of the recommendations for RCS will be prepared by NEN in consultation with partners as milestone M6.4. The recommendations for RCS will then be further elaborated as deliverable D6.10 of Task 6.4. Here, one could think of elaboration of recommendations, identification of RCS where these recommendations may be included, incorporation of relevant outcomes and recommendations from other deliverables of this project, and to which parties these recommendations will be forwarded to.

6.2 List of relevant RCS

In the progress of delivering this report, a list of related RCS was compiled relevant for the different Work Packages of the HyTunnel-CS project. The list is not complete, but a continuing work in progress and will expand in the course of the project. A complete list will be part of D6.10 of Task 6.4. The list can be found in Annex 3 of this report.

Annex 1 - Survey Template

Hydrogen specific hazards and associated risks
1a. Is hydrogen being considered as any other alternative fuel (LNG, LPG, CNG, Batteries) in national RCS? (RCS = Regulations, Codes and Standards) **1b.** What are similarities? (max 5) **1c.** What are differences? (max 5)
2. Are there national RCS (Regulations, Codes and Standard) for (specific) alternative fuels that can be directly translated to H2?
H2 Transport (via tubes on road and rail)
1. Is the ADR (European Agreement concerning the International Carriage of Dangerous Goods by Road) nationally implemented?
2. Is the RID (Regulation concerning the International Carriage of Dangerous Goods by Rail) nationally implemented?
For this project, we make a division of tunnels based on length. There are two categories: **a. Long structures, enclosed on four sides, for the benefit of road / rail / shipping. Examples are: underwater tunnel; land tunnel.** **b. Short structures, enclosed on four sides, for the benefit of road / rail / shipping. Examples are: aqueduct; underpass.**
3. How does national RCS subdivide tunnels in terms of length? (e.g. <500m = short tunnel)
H2 Transport in Tunnels Please specify the requirements in national RCS (Regulations, Codes and Standards) regarding **hazard risks of H2 transport in tunnels**.
1. What are the perspectives for action of first responders in tunnels (e.g. recognisability of what is being transported, training)? a. For road tunnels b. For rail tunnels c. Are there differences in national RCS in the type of tunnel (short/long/other categories)?
2. Which aspects have to be taken into account in the construction of tunnels (e.g. ventilation, sprinklers, direction bleed valve)? a. For road tunnels b. For rail tunnels c. Are there differences in national RCS in the type of tunnel (short/long/other categories)?
3. What are the requirements relating to escape routes (e.g. self-evacuation principle)? a. For road tunnels b. For rail tunnels c. Are there differences in national RCS in the type of tunnel (short/long/other categories)?
4. What requirements are there relating to risk assessment study?
5. What additional (in addition to ADR/RID) requirements are there in national RCS regarding H2 transport itself and external risks to the transport in tunnels? a. For road tunnels b. For rail tunnels c. For boat tunnels

H2 Transport in Confined Spaces: Please specify the requirements in national RCS (Regulations, Codes and Standards) regarding **hazard risks of H2 transport in confined spaces** (e.g. parkings, service stations, Train depots, Ferries).
1a What are the perspectives for action of first responders in confined spaces (CS)?
1b Are there differences in national RCS in the type of cs (e.g. ferries)?
2a Which aspects have to be taken into account in the construction of CS (e.g. ventilation, sprinklers, direction bleed valve)?
2b Are there differences in national RCS in the type of CS?
3a What are the requirements relating to escape routes (e.g. self-evacuation principle)?
3b Are there differences in national RCS in the type of CS?
4 What requirements are there relating to risk assessment study?
5 What additional (in addition to ADR/RID) requirements are there in national RCS regarding H2 transport itself and external risks to the transport in CS (e.g. remise with a (hydrogen) refuelling station)?
H2 Propulsion (cars, busses, trains, etc.) in Tunnels: Please specify the requirements in national RCS regarding **hazard risks of H2 Powered vehicles in tunnels**:
1. What are the perspectives for action of first responders in tunnels (e.g. recognizability of car type, training)? a. For road tunnels b. For rail tunnels c. Are there differences in national RCS in the type of tunnel (short/long/other categories)?
2. Which aspects have to be taken into account in the construction of tunnels (e.g. ventilation, sprinklers, direction bleed valve)? a. For road tunnels b. For rail tunnels c. Are there differences in national RCS in the type of tunnel (short/long/other categories)?
3. What are the requirements relating to escape routes (e.g. self-evacuation principle)? a. For road tunnels b. For rail tunnels **c.** Are there differences in national RCS in the type of tunnel (short/long/other categories)?
4. What requirements are there relating to risk assessment study?
5. What additional requirements are there in national RCS regarding H2 Powered vehicles itself and external risks in tunnels? a. For road tunnels b. For rain tunnels c. For boat tunnels
H2 Propulsion (cars, busses, trains, etc.) in confined spaces
1. What are the requirements in national RCS regarding hazard risks of H2 Powered vehicles relating to: a. Parkings b. Service stations c. Train depots d. Ferries

e. Other CS	
2. What additional requirements are there in national RCS regarding H2 Powered vehicles itself and external risks (e.g. electric cars) in confined spaces?	
The deployment of hydrogen powered vehicles and hydrogen transportation	
1. Does considering hydrogen as any other alternative fuel hinder the deployment of hydrogen powered vehicles and/or hydrogen transportation in certain aspects? a. With regards to tunnels b. With regards to confined spaces	
2. Which other aspects of hydrogen specific hazards and associated risks in tunnels and confined spaces should be covered by national RCS, but at the moment is not?	

Annex 2 - Contact list (M1.1)

Country	**Organization**
EU/International	**CEN/CLC/JTC6 Hydrogen in Energy Systems** WG3 Safety
	HySAFE - Safety of Hydrogen as an Energy Carrier
	International Association Of Fire & Rescue Services (CTIF)
	International Energy Agency - Hydrogen Task 37 - Hydrogen Safety Task
	ISO/TC 92 Fire Safety WG 15 Road Tunnel Fire Safety
	ISO/TC 197 Hydrogen technologies
	International Tunnel Safety Platform (ITA COSUF)
	SDO Tunnel: research and development (German and International) STUVA Studiengesellschaft für unterirische Verkehrsanlagen
	United Nations Economic Commission for Europe - GTR No. 13 - Hydrogen and Fuel Cell Vehicle Safety (UNECE) Sub group safety
Austria	**Austrian Fire Brigade Association** (Österreichische Bundesfeuerwehrverband)
Belgium	**Brandweerzone Centrum**
	Hulpverleningszone Noord-Limburg
	NBN Bureau voor Normalisatie
	Kenniscentrum Civiele Veiligheid (KCCE)
Denmark	**Dansk Standard**
France	**AFNOR**
	Centre d'Études des Tunnels (CETU)
	Direction régionale de l'Environnement, de l'Aménagement et du Logement (DREAL)
	L'Institut national de l'environnement industriel et des risques (INERIS)
	TÜV
Germany	**Bundesanstalt für Materialforschung und -prüfung** (BAM)
	German Coordination road tunnel construction and regulation (Bundesanstalt für Straßenwesen)
	German Institute for Standardization (DIN)

	German National Coordination Fire Services (Deutscher Feuerwehrverband e. V. (DFV) Bundesgeschäftsstelle)
	Ludwig-Bölkow-Systemtechnik GmbH (LBST)
	National Organisation Hydrogen and Fuel Cell Technology (NoW GmbH)
Greece	**ELOT**
	General Directorate Of Social Infrastructure - Ministry Of Infrastructure And Transport
	Hellenic Committee for Tunnels And Underground Works
Italy	**Ministry Of Home Affairs- National Fire Service Department**
	Ministry of Infrastructures and Transport Tunnel Safety Committee
	UNI
Netherlands	**DON Bureau**
	Instituut Fysieke Veiligheid (IFV)
	Kennisplatform Tunnelveiligheid
	Steunpunt Tunnelveiligheid RWS
	TNO
	Twynstra Gudde
Norway	**Norwegian Directorate for Civil Protection**
	Norwegian Maritime Authority
	Norwegian Tunnel Safety Cluster
	Standard Norge
	University of South-Eastern Norway
Portugal	**Alcabideche Fire Department**
Spain	**ADIF (**Spanish Administrator of Railway Infrastructures)
	AESF (Spanish Railway Safety Agency)
	AETOS: Spanish Association of Tunnels and Underground Works
	Aragón Hydrogen Foundation
	Consortium Bielsa-Aragnouet Tunnel
	IDOM
	Ministerio de Fomento (Ministry of Development)
	Prointec S.A.U. (civil engineering company)
Sweden	**SP Sveriges Tekniska Forskningsinstitut** (Technical Research Institute of Sweden)
Switzerland	**ASTRA (**Road authority Switzerland)
	Bundesamt für Verkehr (Railroad Authority Switzerland**)**
	EDA Schweizerisches Seeschifffahrtsamt (Maritime authority)
	FKS (Swiss National Coordination Fire Services)
	International Fire Academy Switzerland (IFA)
	SNV (Swiss Association for Standardization)
	Vereinigung Kantonale Brandschutzbehörden
UK	**Arriva Rail North**
	BPD (British parking association)
	BSI PVE/3/8 - Gas containers - Hydrogen technologies
	FTA (Freight Transport Association)

	ITM Power
	Network Rail
	ORR (Office of rail and road)
	UK FCH Association

Annex 3 - List of RCS

Organization	Committee	RCS
ISO	TC197 Hydrogen technologies	**ISO/TR 15916:2004** Basic considerations for the safety of hydrogen systems; **ISO/TS 20100:2008** Gaseous hydrogen — Fuelling stations; ISO 26142:2010 Hydrogen detection apparatus — Stationary applications; **ISO 19882:2018** Gaseous hydrogen — Thermally activated pressure relief devices for compressed hydrogen vehicle fuel containers
	TC22 Road vehicles SC21 electric road vehicles	**ISO 23273-2:2006** Fuel cell road vehicles — Safety specifications — Part 2: Protection against hydrogen hazards for vehicles fuelled with compressed hydrogen
	TC22/SC 36 Safety and impact testing	**ISO 17840** Road Vehicles – Information for first and second responders
	TC 92/SC 2 Fire containment	**ISO 22899:2007** Determination of the resistance to jet fires of passive fire protection materials; **ISO 6944-1:2008** Fire containment — Elements of building construction — Part 1: Ventilation ducts; **ISO 21925-1:2018** Fire resistance tests — Fire dampers for air distribution systems — Part 1: Mechanical dampers; **ISO/DIS 23693** Determination of the resistance to gas explosions of passive fire protection materials
	TC 92/SC 4 Fire containment	**ISO/TR 16576:2017** Fire safety engineering — Examples of fire safety objectives, functional requirements and safety criteria; **ISO 16732-1:2012** Fire safety engineering — Fire risk assessment; **ISO/CD TR 17886** Fire safety engineering — Design of evacuation experiments; **ISO/CD 20710** Fire safety engineering — Active fire protection systems

	ISO/TC 58/SC 4 Operational requirements for gas cylinders	**ISO 10961:2019** Gas cylinders — Cylinder bundles — Design, manufacture, testing and inspection; **ISO 11625:2007** Gas cylinders — Safe handling
	TC20 Aircraft and space vehicles	**ISO 2685:1998** Aircraft — Environmental test procedure for airborne equipment — Resistance to fire in designated fire zones
IEC	TC 105 Fuel Cells	**IEC 62282-5-1 (2007-02) Ed. 1.0** Fuel cell technologies – Part 5-1: Portable fuel cell power systems – Safety
CEN/CLC	TC 192 - Fire and Rescue Service Equipment	**EN 1846-2:2009+A1:2013** Firefighting and rescue service vehicles - Part 2: Common requirements - Safety and performance; **EN 1846-3:2013** Firefighting and rescue service vehicles - Part 3: Permanently installed equipment - Safety and performance; **EN 1366-1:2014** Fire resistance tests for service installations - Part 1: Ventilation ducts
	JTC 6/WG 3 - Hydrogen Safety	**pNWI** Hydrogen in confined spaces
	CEN/TC 23 - Transportable gas cylinders	**EN ISO 11439:2013/prA1** Gas cylinders - High pressure cylinders for the on-board storage of natural gas as a fuel for automotive vehicles; **FprEN ISO 19884 Gaseous hydrogen -** Cylinders and tubes for stationary storage; **prEN ISO 11114-2** Gas cylinders - Compatibility of cylinder and valve materials with gas contents - Part 2: Non-metallic materials
	CEN/TC 268 - Cryogenic vessels and specific hydrogen technologies applications	**EN 1797:2001** Cryogenic vessels - Gas/material compatibility
	TC 250 Structural Eurocodes	**EN 1990:2002 Eurocode** - Basis of structural design; **Eurocode 3** - Design of steel structures - Part 1-2: General rules - Structural fire design
BSI	FSH/25	**BS 7346-7:2013** Components for smoke and heat control systems. Code of practice on functional recommendations and calculation methods for smoke and heat control systems for covered car parks
NEN		**NPR 6095-1:2012** Smoke and heat control systems - Part 1: Guidelines on design and installation of smoke and heat exhaust

		installations and smoke control systems in car parks; **NEN 2443:2013** Design standards and recommendations on parking facilities for passenger cars; **NEN 6098:2012** Smoke control systems for powered smoke exhaust ventilators in car parks
IFV	6 Protocol Cards	First responders dealing with hydrogen accidents
Norway	Ministry of Justice and Emergency Management	Fire and Explosion Protection Act

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