RH2INE PROGRAM: SUB-STUDY 1A: SAFETY FRAMEWORK CONDITIONS & SUB-STUDY 1B: SAFETY AND REGULATORY ANALYSIS

SuAc 1.1d & SuAc A1-2 & B1-2 Regulatory & Standards Gap Assessment

RH2INE Consortium

Report No.: 10247894-4, Rev. 2
Document No.: 11I1RCRW-4
Date: 2021-03-24

Project name:	RH2INE program: Sub-study 1a: Safety framework conditions & Sub-study 1b: Safety and Regulatory analysis	Det Norske Veritas B.V. Energy Systems Risk Management Advisory Zwolseweg 1 2994 LB Barendrecht Netherlands Tel: +31 (0) 10 2922600 VAT No.: NL008585635B01
Report title:	SuAc 1.1d & SuAc A1-2 & B1-2 Regulatory & Standards Gap Assessment	
Customer:	RH2INE Consortium (Province Zuid-Holland, Ministry of Economic Affairs, Innovation, Digitalisation and Energy of North Rhine-Westphalia, the Port of Rotterdam, Duisport and RheinCargo)	
Customer contact:	Sub-study 1a: J.C. Boon (Port of Rotterdam) Sub-study 1b: SJ. Kelderman (Provence Zuid-Holland)	
Date of issue:	2021-03-24	
Project No.:	10247894 & 10254098	
Organisation unit:	Risk Management Advisory Rotterdam	
Report No.:	10247894-4, Rev. 2	
Document No.:	11I1RCRW-4	

Applicable contract(s) governing the provision of this Report:

Objective: this report identifies the gaps in land-based & water-based regulations and standards for the use of hydrogen on board of-, bunkering hydrogen and onshore systems supplying hydrogen to maritime and inland navigational vessels. Recommendations are formulated to enable the development of a regulatory framework for the use of hydrogen for propulsion, bunkering of hydrogen and required infrastructure in the Rhine-Alpine corridor.

Prepared by:	Verified by:	Approved by:
Dennis van der Meulen Senior Consultant	Gerard Nankman Senior Consultant	Rob van der Spek Head of Risk Management Advisory NL, digital lead region CEMEIA
Jürgen Hofman Principal Consultant		

DNV Distribution:

☒ OPEN. Unrestricted distribution, internal and external.

☐ INTERNAL use only. Internal DNV document.

☐ CONFIDENTIAL. Distribution within DNV according to applicable contract.*

☐ SECRET. Authorized access only.

*Specify distribution:

Keywords:

Hydrogen, Regulations, Standards, Gap Assessment, Inland Waterway Transport

Rev. No.	Date	Reason for Issue	Prepared by	Verified by	Approved by
0	2021-01-26	Draft report	D. van der Meulen	G. Nankman	R. van der Spek
1	2021-02-18	Draft report, incorporated results Sub-study 1b, SuAc A1-2 & B1-2	D. van der Meulen J. Hofman	G. Nankman	R. van der Spek
2	2021-03-24	Final report: conversion to new DNV report template & minor textual changes	D. van der Meulen J. Hofman	G. Nankman	R. van der Spek

Table of contents

ABREVIATIONS

ABS	American Bureau of Shipping
ADN	International carriage of dangerous goods by inland waterways
ADR	International carriage of dangerous goods by road
AENOR	Spanish standardisation body (Asociación Española de Normalización y Cerficifación)
AFID	Alternative Fuels Infrastructure Directive
AFNOR	Association Francaise de Normalisation
APTU	Uniform Rules concerning the Validation of Technical Standards and the Adoption of Uniform Technical Prescriptions applicable to Railway Material intended to be used in International Traffic
Arbo	Dutch decree on labor conditions (“Arbeidsomstandighedenbesluit”)
ASME	American Society of Mechanical Engineers
ATEX	“Appareils destinés à être utilisés en ATmosphères Explosives” (French for Equipment intended for use in Explosive Atmospheres)
ATMF	Uniform Rules concerning the Technical Admission of Railway Material used in International Traffic
Bal	Dutch decree activities in living environment that will come into force in 2022 (“Besluit activiteiten leefomgeving”)
BAT	Best Available Technique
BauG	German Federal Building Law
BauGB	German Federal Building Code
BBergG	German Federal Mining Act
BetrSichV	German Operational Safety Regulation (“Betriebssicherheitsverordnung”)
Bevi	Dutch decree on external safety of facilities (“Besluit externe veiligheid inrichtingen”)
Bevt	Dutch decree on the transportation of hazardous substances
BinSchStrO	German inland waterway ordinance
BinSchUO	German Inland water vessel investigation ordinance
Bkl	Dutch decree quality living environment that will come into force in 2022 (“Besluit kwaliteit leefomgeving”)
BlmSchG	German Federal emission protection law (“Bundesemissionschutzgesetz”)
BImSchV	German Federal control regulation (“Bundesimmissionsschutzverordnung”)
Bor	Dutch decree on the general provisions for environment (“Besluit omgevingsrecht”)
BPR	Dutch inland shipping police regulation
Brzo	Dutch decree on risk of major accidents (“Besluit risico’s zware ongevallen”)
BSI	British Standards Institute

BV	Bureaus Veritas
BVGS	Dutch decree on the transportation of hazardous substances
BVR	The Dutch inland shipping regulation (binnenvaartregeling)
Bvr	Dutch decree safety regions (“Besluit veiligheidsregio’s”)
CCC	Carriage of Cargoes and Containers
CCNR	Central Commission for the Rhine
CEN	European Committee for Standardization
CENELEC	Committee for standardisation of electrotechnical standards (Comité Européen de Normalisation Electrotechnique)
CESNI	Central European Committee for Inland Navigation Standards
CEVNI	European Code for Navigation on Inland Waterways
CFD	Computational Fluid Dynamics
CIM	Uniform Rules concerning the Contract of International Carriage of Goods by Rail
CIS	Commonwealth of Independent States
CIV	Uniform Rules concerning the Contract of International Carriage of Passangers by Rail
CNG	Compressed Natural Gas
CO2	Carbon dioxide
CUI	Uniform Rules concerning Contracts of use of Infrastructure in International Rail Traffic
CUV	Uniform Rules concerning Contracts of use of Vehicles in International Rail Traffic
DIN	Deutsche Institut für Normung
DS	Dansk Standard
EC	European Commission
ECA	Emission Controlled Area
EEG	German Renewable Energy Law (“Gesetz für den Ausbau erneuerbarer Energien”)
EIA	Environmental Impact Assessment
EIGA	European Industrial Gases Association
EMSA	European Maritime Safety Agency
EN	European Norm
EnWG	German Energy Industry Act (“Energiewirtschaftsgesetz”)
ERPG	Emergency Response Planning Guidelines
ESD	Emergency Shutdown
ES-TRIN	Technical Requirements for Inland Navigation vessels

ETSI	European Telecommunications Standards Institute
EU	European Union
EuGH	European Court (“Gerichtshof der Europäischen Union“)
EVS	Estonian Centre for Standardization
FAL	Facilitation Committee
FC	Fuel Cell
FMEA	Failure Mode and Effect Analysis
FP	Fire Protection
GGVSEB	German dangerous goods decree for road, rail and inland waterways
GH2	Gaseous Hydrogen
GHLV	Gaseous Hydrogen Land Vehicle
H2	Hydrogen
HRS	Hydrogen Refuelling Stations
HTW	Human element, Training and Watchkeeping
HZN	Croatian Standards Institute
IACS	International Association of Classification Societies
IAPH	The International Association of Ports and Harbours
IEC	International Electrotechnical Commission
IED	Industrial Emissions Directive
IGC	International Gas Carrier Code
IGF	International Code of Safety for Ships using Gases or other Low-Flashpoint Fuels
III	Implementation of IMO Instruments
IMDG	International Maritime Dangerous Goods Code
IMO	International Maritime Organization
IPPC	Integrated Pollution Prevention and Control
ISO	International Organization for Standardization
ITC	Inland Transport Committees
IWT	Inland Waterway Transport
KAS	German commission of plant safety (“Kommission für Anlagensicherheit”)
KR	Korean Register of Shipping
LEG	Legal Committee
LFL	Lower Flammable Limit

LH2	Liquid hydrogen
LNG	Liquefied natural gas
LR	Lloyd's Register of Shipping
LST	Lithuanian Standards Body
LVS	Latvian Standard Ltd.
MCCAA	Malta Competition and Consumer Affairs Authority
MEA	Membrane-Electrode Assembly
MEPC	Marine Environment Protection Committee
MSC	Maritime Safety Committee
NBN	Bureau de Normalisation/ Bureau voor Normalisatie (Belgium)
NCSR	Navigation, Communication, Search and Rescue
NEN	Dutch Standardization Institute (Nederlands Normalisatie-instituut)
NFPA	National Fire Protection Association
NMA	Norwegian Maritime Authority
NQIS/ELOT	National Quality Infrastructure System (Greece)
Ob	Dutch environmental decree that will come into force in 2022 ("Omgevingsbesluit")
OTIF	Intergovernmental Organisation for International Carriage by Rail
PED	Pressure Equipment Directive
PEFC	Polymer Electrolyte Fuel Cell
PEM	Proton Exchange Membrane
PGS	Dutch guidelines for dangerous goods
PKN	Polish Committee for Standardization
PoR	Port of Rotterdam
PPR	Pollution Prevention and Response
QRA	Quantitative Risk Assessment
Revi	Dutch arrangement on external safety of facilities ("Regeling externe veiligheid inrichtingen")
RH2INE	The Rhine Hydrogen Integration Network of Excellence
RID	Regulation concerning the international Carriage of Dangerous goods by Rail
RIVM	Dutch National Institute for Public Health and the Environment (Rijksinstituut voor Volksgezondheid en Milieu)
RPN	Regulations for Rhine navigation personnel
RPR	Police regulations for navigation of the Rhine

ROG	German Federal Regional Planning Act
RVIR	Rhine Vessel Inspection Regulations
SAE	Society of Automotive Engineers
SchSG	German ship safety law
SDC	Ship Design and Equipment
SFS	Finnish Standardization body (Suomen Standardisoimisliito r.y.)
SGMF	The Society for Gas as a Marine Fuel
SIMOPS	Simultaneous Operations
SIS	Swedish Standards Institute
SOFC	Solid Oxide Fuel Cell
SOLAS	International Convention for the Safety of Life at Sea
SSE	Ship Systems and Equipment
STS	Ship-to-ship
TC	Technical Committee
TCC	Technical Co-operation Committee
TMB	Technical Management Board
TPED	Transportable Pressure Equipment Directive
TRAS	German technical rules plant safety (“Technische Regeln Anlagensicherheit“)
TRBS	German technical rules operational safety (“Technische Regeln Betriebssicherheit”)
TTS	Truck-to-ship
UK	United Kingdom
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNI	Italian standardisation body (“Ente Nazionale Italiano di Unificazione”)
US	United States
UVPG	German Environmental impact assessment act (“Gesetz über die Umweltverträglichkeitsprüfung”)
Wabo	Dutch law on the general provisions for environment (“Wet algemene bepalingen omgevingsrecht”)
WG	Work Group
Wm	Dutch law on environmental management (“Wet milieubeheer”)
WVGS	Dutch law on the transportation of hazardous substances
Wvr	Dutch law safety regions (“Wet veiligheidsregio’s”)

EXECUTIVE SUMMARY

Introduction

The Rhine Hydrogen Integration Network of Excellence (RH2INE) is an international programme and consists of public and private parties. Its global aim is to implement hydrogen as a fuel in the inland waterway transport (IWT). This report is the result of:

- "Sub-activity 1.1d: Identification of gaps in regulations and standards for the use of hydrogen on board of-, and the supply of hydrogen to inland navigational vessels" of the tender "Sub-study 1a: Safety framework conditions" issued by the Port of Rotterdam Authority (PoR) on behalf of the RH2INE consortium;
- "Sub-activity (A/B) 1&2: Identification of land-based regulations and standards (1) and identification of gaps (2) for systems supplying hydrogen to vessels in the Netherlands (A) and Germany (B) of the tender "Sub-study 1b: Safety and Regulatory analysis" issued by the Provence of Zuid-Holland in the Netherlands on behalf of the RH2INE consortium.

A huge effort has already been put on the coordination of regulation, codes and standards for the use of and supply of hydrogen to vehicles (e.g. Hydrogen Refueling Stations, HRS). For application of hydrogen in shipping, further pre-normative work will be needed to close the gaps within current regulations, codes and standards.

This sub-activity report provides an overview of current applicable regulations, standards and guidelines for distribution (transport), bunkering of hydrogen, on-board storage & use of hydrogen in fuel cells and onshore systems (e.g. bunker stations) for the supply of hydrogen to vessels. Gaps are identified and recommendations to solve these gaps are formulated.

Objective

The objective of this study is to identify the gaps in land-based & water-based regulations and standards for the use of hydrogen on board of-, bunkering hydrogen and onshore systems supplying hydrogen to inland navigational vessels. Recommendations are formulated to enable the development of a regulatory framework for the use of hydrogen for propulsion, bunkering of hydrogen and required infrastructure for the supply of hydrogen to inland navigational vessels in the Rhine-Alpine corridor.

Methodology & Scope

Regulations are presented that are applicable for seagoing vessels (maritime) and inland navigational vessels. This report addresses the water-side (on-board use) and the bunkering operation/interface and land-based regulations for the required land-based systems & infrastructure (e.g. related to construction, operation and permitting of bunker stations & swapping of containers at container terminals etc.). Relevant national legislation and standards are identified for the Netherlands and Germany.

The scope of the study is limited to the use of compressed gaseous hydrogen & liquid hydrogen on board of ships. The use of hydrogen carriers (e.g. methanol, ammonia) is considered to be a long-term scenario (10-20 years) for inland shipping (see Sub-activity report 1.1b) and is therefore not considered in the regulatory analysis.

The study provides an overview of the current legislation & regulations on an International, European, National (Netherlands/Germany) and local level (Ports & Harbours). This is followed by an inventory of relevant existing standards & guidelines and in development. The existing gaps found in regulations, standards & guidelines are identified and described. The approach is summarized and displayed in the figure on the next page.

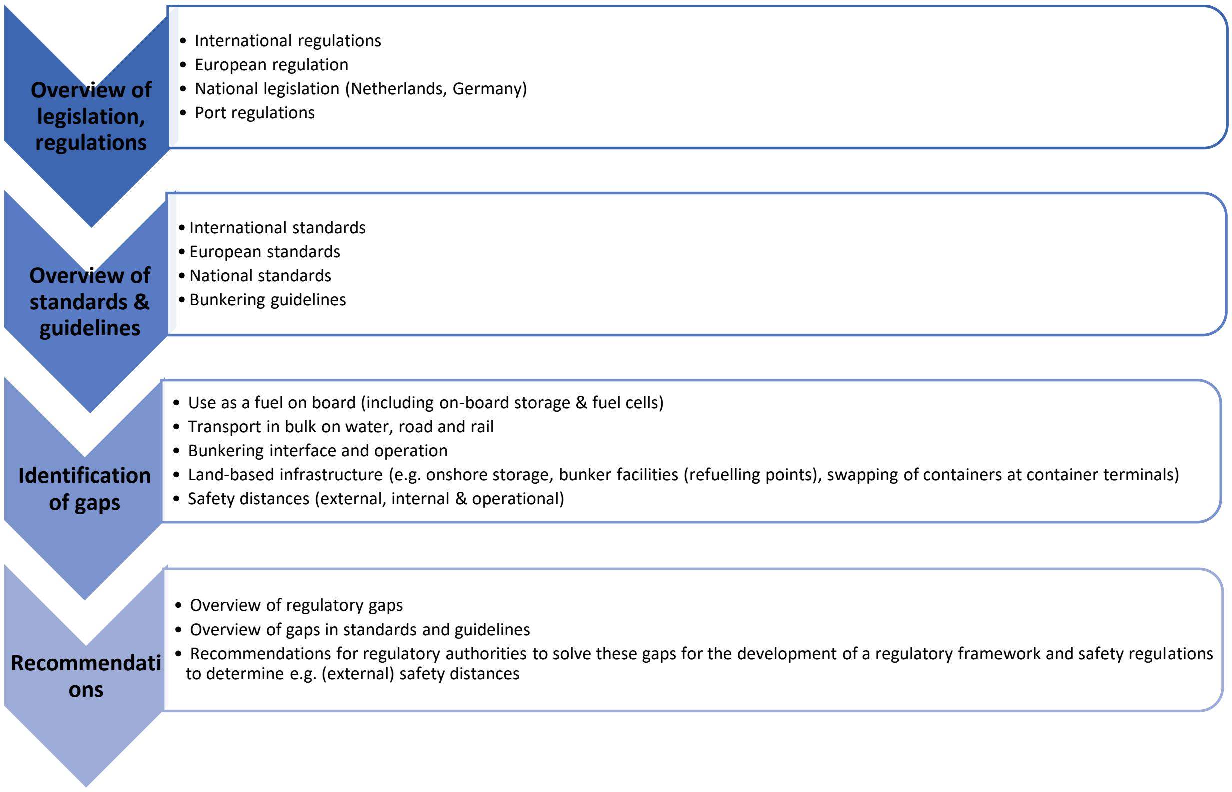

Figure 1: Methodology identification of gaps in regulations and standards and recommendations for development of regulatory framework

The identified gaps are classified under three categories:

Legal Gap (L):

Legal gaps are gaps for the supply and use of hydrogen in inland shipping that severely limit or even block the use of hydrogen as propulsion for ships. These gaps are typically gaps in legislation and regulations.

Harmonization Gap (H):

Harmonization gaps are gaps in the International or EU-wide harmonization of methods, rules, guidelines, provisions and safety aspects for hydrogen. Examples are standards for refuelling points and bunkering procedures.

Knowledge Gap (K):

Specific knowledge gaps are points where more research is needed in the implementation and development of the technology and use of hydrogen to be able to develop regulations.

The gaps are presented and sorted according to their key area of relevance. Therefore, the gaps have been categorized by topic, such as: bunkering, on-board storage, fuel cell system etc. and in some cases also by code/regulation where the gaps exist (e.g. IGF Code, ES-TRIN).

Identified gaps

The identified gaps for regulations and standards for the use and transport of hydrogen on board of-, and bunkering hydrogen to maritime and inland navigational vessels are presented in the table below.

Table 1: Identified gaps for water-based regulations & standards

Gap No.	Gap description	Gap category
IGF code: International code of safety for ships using gases or other low flashpoint fuels		
1a	Use of fuel cells is not regulated by IMO. Technical provisions for fuel cells are missing in the IGF Code.	L, K
1b	Detailed and prescriptive requirements for storage (including swappable systems/containers) and use of hydrogen as fuel in ships are missing. Provisions for bunkering gaseous & liquid hydrogen (bunker station shipside etc.) are also missing.	L, K
ES-TRIN: European Standard laying down Technical Requirements for Inland Navigation vessels		
2a	The ES-TRIN provides general provisions for low flashpoint fuels (Ch. 30; Appendix 8) but specific construction requirements regarding hydrogen-fuelled vessels and related fuel cell systems are lacking.	L, K
2b	Detailed and prescriptive requirements for storage (including swappable systems/containers) and provisions for bunkering gaseous & liquid hydrogen (bunker station shipside etc.) are missing.	L, K
Central Commission for the Rhine (CCNR)		
3	Regulations for the use of hydrogen as a fuel on board inland navigation vessels are lacking. Hydrogen-fuelled vessels are currently not allowed to operate on inland EU waterways. An exemption statement is required that can be requested at national authorities or the CCNR, depending on the operating area. Special requirements of the CCNR are to be observed if an inland vessel will be operating in EU inland waters. RPR contains instructions aimed at conventional fuel bunkering but does not cover the possibility of bunkering hydrogen. Bunkering of hydrogen on inland waterways controlled by CCNR is currently not allowed.	L
Legislation in the Netherlands		
4a	Bunkering of hydrogen on inland waterways in the Netherlands is currently not allowed. Exemptions could be made possible based on special permissions from the competent authority.	L
4b	“Basisnet”, a nationwide appointed network for the transportation of dangerous goods, does not consider transportation of hydrogen in bulk. It must be noted that there are no limits for the transport of (mobile) tank-containers on waterways in Basisnet because the associated transport risk is considered to be very low. The probability of a leak in a container is very small that it will not contribute to the external safety risks /8/. This seems to imply that there will be no limits applicable for the transport of swappable hydrogen tube-containers on waterways with container vessels to container terminals.	L, K
Legislation in Germany		
5	Bunkering of hydrogen on inland waterways in Germany is currently not allowed. Exemptions could be made possible based on special permissions from the competent authority.	L
Port & Harbour Regulations		
6a	Specific rules and regulations for hydrogen liquid tankers (including bunker vessels), hydrogen-fuelled vessels and hydrogen bunkering activities (truck-to-ship & ship-to-ship) are lacking the port bye-laws of EU Ports & Harbours.	L, K
6b	Audit & Accreditation criteria for hydrogen bunker operators do not exist.	L, K
Bunkering		
7	Rules for bunkering liquid hydrogen do not exist for the shipside of the bunker process.	L, H, K
8	Bunkering procedures & checklists for liquid hydrogen do not exist.	L, H, K
9	International standards for hydrogen refuelling points and bunkering for maritime and inland vessels do not exist.	L, H, K
10	Bunkering procedures & checklists for gaseous hydrogen do not exist.	L, H, K
11	An EU harmonized approach for risk assessment (including criteria) for non-Seveso hydrogen small scale establishments and bunkering activities (e.g. truck-to-ship, ship-to-ship) is lacking.	L, H
12	Indicators for determining common operational safety distances for hydrogen bunkering are currently missing.	L, H
13	Safety requirements for simultaneous hydrogen bunkering and loading / unloading or passenger embarking / disembarking processes are missing.	L, H, K
On-board storage		
14	Qualification for (swappable & fixed) on-board storage pressure tanks with compressed hydrogen gas is lacking. Rules and requirements for use of swappable containers on board ships do not exist.	L, H, K
15	There is a lack of understanding of failure modes for liquid hydrogen tanks.	K

Gap No.	Gap description	Gap category
Fuel cell system		
16	There is insufficient understanding of the safety aspects concerning release of hydrogen within the fuel cell system.	L, H, K
17	Ventilation requirements for fuel cell rooms are not validated for hydrogen.	L, H, K
18	Fuel cells open for new arrangement and vessel design solutions challenge existing rules & regulations.	L, K
19	Knowledge basis for requirements for handling of liquid hydrogen in piping to fuel cell system is lacking.	L, K
Ship life phases		
20	There is a lack of best practices, procedures, codes or similar regarding safe handling of on-board hydrogen and fuel cell installations in all the life phases of a ship. Crew training requirements for use of hydrogen in shipping do not exist.	L, H
Hydrogen safety		
21	There is insufficient understanding of hydrogen safety aspects for rules development.	L, K
22	There is a lack of understanding of properties and conditions affecting safety of liquid hydrogen in shipping applications.	L, K

The identified gaps in land-based regulations and standards for establishments/systems supplying hydrogen to vessels in **the Netherlands** are given in the table below.

It must be noted that the Dutch legal framework for regulating land-based establishments & activities will change considerably in 2022. A new Environmental law (“Omgevingswet”) is foreseen to come into force on the 1st of January 2022. Existing laws like Wabo & Wm will be replaced by a new environmental law (“Omgevingswet”). Brzo & Bevi will cease to exist and be replaced by new decrees: “Besluit activiteiten leefomgeving” (Bal), “Besluit kwaliteit leefomgeving” (Bkl) and “Omgevingsbesluit” (Ob). These new laws and decrees are taken into account in the gap analysis. This means that identified gaps in the existing laws are verified to check whether the same gaps are also present in the new legislation.

Table 2: Identified gaps for land-based regulations & standards in the Netherlands

Gap No.	Gap description	Gap category
PGS guidelines		
23	A PGS guideline for the safe design and operation of a hydrogen bunker station is missing (see paragraph 3.3.2.2)	L, K
24	Guidelines for maintenance and repairing hydrogen fuel engines / fuel cell systems on inland vessels are missing in PGS 26.	L, K
Bevi		
25	Small-scale hydrogen bunker stations (less than 5 ton storage, Brzo lower-tier threshold) & truck-to-ship bunkering is currently not regulated by Bevi / Bkl as they are not defined as categorial establishments / activities.	L, H
QRA calculation guidelines		
26	A specific QRA calculation guideline for hydrogen bunker stations is missing.	L, H
27	The QRA calculation guideline for container terminals is included in the Reference Manual /9/, module C, chapter 5 does not seem to specify failure scenarios for compressed hydrogen tube-containers nor containers with cylinders.	L, H

The identified gaps in land-based regulations and standards for establishments/systems supplying hydrogen to vessels in **Germany** are given in the table below.

Table 3: Identified gaps for land-based regulations & standards in Germany

Gap No.	Gap description	Gap category
BImSchG / BauG		
28	BImSchG is missing adequate treatment of hydrogen (e.g. a specific hydrogen related BImSchV).	L
12. BImSchV		
29	12. BImSchV does not provide adequate treatment of hazards due to very low temperature or very high pressure hydrogen.	L
30	Technical details providing TRBS guidance for the specific hazards of hydrogen and hydrogen bunkering installations or stations for vessels are missing.	L, K
BetrSichV		
31	Treatment of the specific hazards of liquid hydrogen in the BetrSichV and in the associated TRBS are missing.	L, K
KAS-18 ("TA Abstand")		
32	A technical guideline for definition of safety distances ("TA Abstand") is missing (hazards of hydrogen should be taken into account).	L, K

Recommendations are given to solve the gaps (reference is made to paragraph 5.2 in this report). In cases where the gaps are not yet solved, and no concrete actions to deal with the gaps are identified, work has been undertaken to attempt to suggest possible actions to deal with the identified gaps.

Conclusion

In general, it can be concluded that regulations for the use of hydrogen on board of-, and bunkering of hydrogen to inland navigational vessels are lacking. Currently, hydrogen-fuelled vessels are only allowed to operate on inland waterways based on an exemption given by national authorities or the CCNR. However, ES-TRIN is currently being updated with technical requirements and rules for inland navigational vessels with fuel cell systems.

Sub-activity report 1.1b Hydrogen bunkering scenarios concluded that the use of swappable containers with compressed gaseous hydrogen is the most feasible scenario for inland shipping in the short-term (upcoming 1-5 years). However, rules and requirements for use of swappable containers with gaseous hydrogen on board ships do not exist. It is recommended that these are also considered in the current update of ES-TRIN to speed up the introduction of hydrogen in inland waterway transport.

Hydrogen bunkering standards, procedures & checklists do currently not exist. The most recent development is that CEN/CENELEC (working group CEN/TC 268/WG 5) considers developing European standards for refuelling points and bunkering of gaseous compressed hydrogen, liquefied hydrogen, methanol and ammonia for both maritime and inland waterways hydrogen-fuelled vessels.

With regards to gap assessment for regulations & standards for the permitting of land-based systems (such as hydrogen bunker stations) in the Netherlands and Germany: no major gaps have been found in the laws as they are generic and cover the permitting of any installation with hazardous goods, including hydrogen. Most gaps are related to missing technical guidelines that are needed by regulators to verify if the technical and (external) safety requirements are met, thereby resulting in a more efficient permitting process.

Finally, there is a general insufficient understanding of hydrogen safety aspects. Comprehensive safety studies are needed to develop regulations, codes and standards.

1 INTRODUCTION

The world fleet is large with 115,000 ships and it will grow in the years to come, with more than 30% up to 2030. The International Maritime Organization's (IMO) goal of halving CO2 emissions from shipping by 2050 will lead to a significant restructuring over the next thirty years. The IMO targets and national decarbonization policies are expected to be fundamental drivers for developing low and zero emission technologies in the maritime industry. Next to IMO's goals, the European Union formulated its goals for all sectors in the European Green Deal. It is necessary to find and integrate low-emission propulsion fuels, such as hydrogen, in every part of the transport sector. Hydrogen could significantly reduce emissions, but implementation in inland shipping is new. Hydrogen is the only available zero emission solution for longer distances and high energy needs, but it will remain expensive, especially in the short term. To bring costs down it is absolutely necessary that authorities push for hydrogen technology to be used in vessels and that safety rules & regulations are standardized, which do not exist today.

The Rhine Hydrogen Integration Network of Excellence (RH2INE) is an international programme and consists of public and private parties. Its global aim is to implement hydrogen as a fuel in the inland waterway transport (IWT). On behalf of the consortium of the RH2INE programme, the Port of Rotterdam Authority (PoR) is taking the lead on Sub-study 1a: Safety framework conditions. The Provence of Zuid-Holland is in the lead for Sub-study 1b: Safety and Regulatory analysis.

Sub-study 1a specifically focusses on the water-based safety and regulations related to technical and operational aspects of hydrogen bunkering and transport scenarios for inland navigational vessels. Sub-study 1b covers the land-based regulations and standards for systems supplying hydrogen to vessels in the Netherlands and Germany.

Sub-study 1a comprises of four sub-activities:

- Sub-activity 1.1a: Identification of hydrogen containment systems for transport and propulsion on board of in-land navigational vessels;
- Sub-activity 1.1b: Identification of hydrogen bunkering scenarios for inland navigational vessels;
- Sub-activity 1.1c: Demand study hydrogen bunkering of inland navigational vessels;
- Sub-activity 1.1d: Identification of gaps in regulations and standards for the use of hydrogen on board of-, and the supply of hydrogen to inland navigational vessels.

This report focusses on sub-activity 1.1d: *Identification of gaps in regulations and standards for the use of hydrogen on board of-, and the supply of hydrogen to inland navigational vessels*.

Sub-study 1b comprises of three sub-activities:

1. Identification of land-based regulations and standards for systems supplying hydrogen to vessels in the Nether-lands and Germany;
2. Identification of gaps in land-based regulations and standards;
3. Guidance for external safety distances and other mandatory safety distances;

This report covers sub-activity 1&2: *Identification of land-based regulations and standards (and gaps) for systems supplying hydrogen to vessels in the Netherlands and Germany*.

A huge effort has already been put on the coordination of regulation, codes and standards for the use of and supply of hydrogen to vehicles (e.g. Hydrogen Refueling Stations, HRS). For application of hydrogen in shipping, further pre-normative work will be needed to close the gaps within current regulations, codes and standards. This sub-activity report provides an overview of current applicable regulations, standards and guidelines for distribution (transport), bunkering of hydrogen, on-board storage & use of hydrogen in fuel cells and onshore systems (e.g. bunker stations) for the supply of hydrogen to vessels. Gaps are identified and recommendations to solve these gaps are formulated.

2 SCOPE & METHODOLOGY

2.1 Scope

The scope of the study is limited to the use of compressed gaseous hydrogen & liquid hydrogen on board of ships. Sub-activity report 1.1b Hydrogen bunkering scenarios /1/ concluded that the use of swappable containers with compressed gaseous hydrogen is the most feasible scenario for inland shipping in the short-term (upcoming 1-5 years) and in the mid-term (5-10 years) bunkering of liquid hydrogen. The on-board use of & bunkering of hydrogen carriers (e.g. methanol, ammonia) is considered to be a long-term scenario (10-20 years) and is therefore less relevant (urgent) to address in this study.

Regulations are presented that are applicable for seagoing vessels (maritime) and inland navigational vessels. This report addresses the water-side (on-board use) and the bunkering operation/interface and land-based regulations for the required land-based systems & infrastructure (e.g. related to construction, operation and permitting of bunker stations & swapping of containers at container terminals etc.). Relevant national legislation and standards are identified for the Netherlands and Germany. EU directives such as Pressure Equipment Directive (PED) and regulations related to Hazardous Area Classification (ATEX) are generally applicable to all industrial installations, including hydrogen installations. Because minor implementation differences exist on a national level, these are not analysed in detail.

The inventory of regulations & legislation is not meant to be exhaustive, but rather focuses on those items which are considered relevant for the use & supply of hydrogen to inland vessels. Generic legislation such as labour laws is not assessed because it does not contain any specific requirements and is applicable to operations in general.

The gap analysis takes into account the two different on-board storage solutions: fixed tanks or swappable containers. All bunkering configurations are considered such as truck-to-ship (TTS), ship-to-ship (STS), bunker station to ship & swapping of containers at container terminals.

2.2 Methodology

The first step of the study approach is to provide an overview of the current legislation & regulations on International, European, National (Netherlands/Germany) and local level (Ports & Harbours), which are relevant for the use of and supply to hydrogen on board of seagoing and inland navigational vessels. The use & supply refers to:

- Use of hydrogen as a fuel for propulsion (including storage in fuel tanks and fuel cells);
- Supply (transport) of hydrogen in bulk via waterways, road and rail;
- Bunkering of hydrogen;
- Supply via land-based systems i.e. bunker facilities (refuelling points), swapping of containers at container terminals.

The next step is to provide an overview of relevant existing standards & guidelines and those currently in development.

Based on the inventory, the gaps in regulations & standards for the safe use of, and supply of hydrogen are identified. Recommendations are formulated to enable the development of a regulatory framework for the use of hydrogen for propulsion, bunkering of hydrogen and required infrastructure in the Rhine-Alpine corridor. The approach is summarized and displayed in Figure 2.

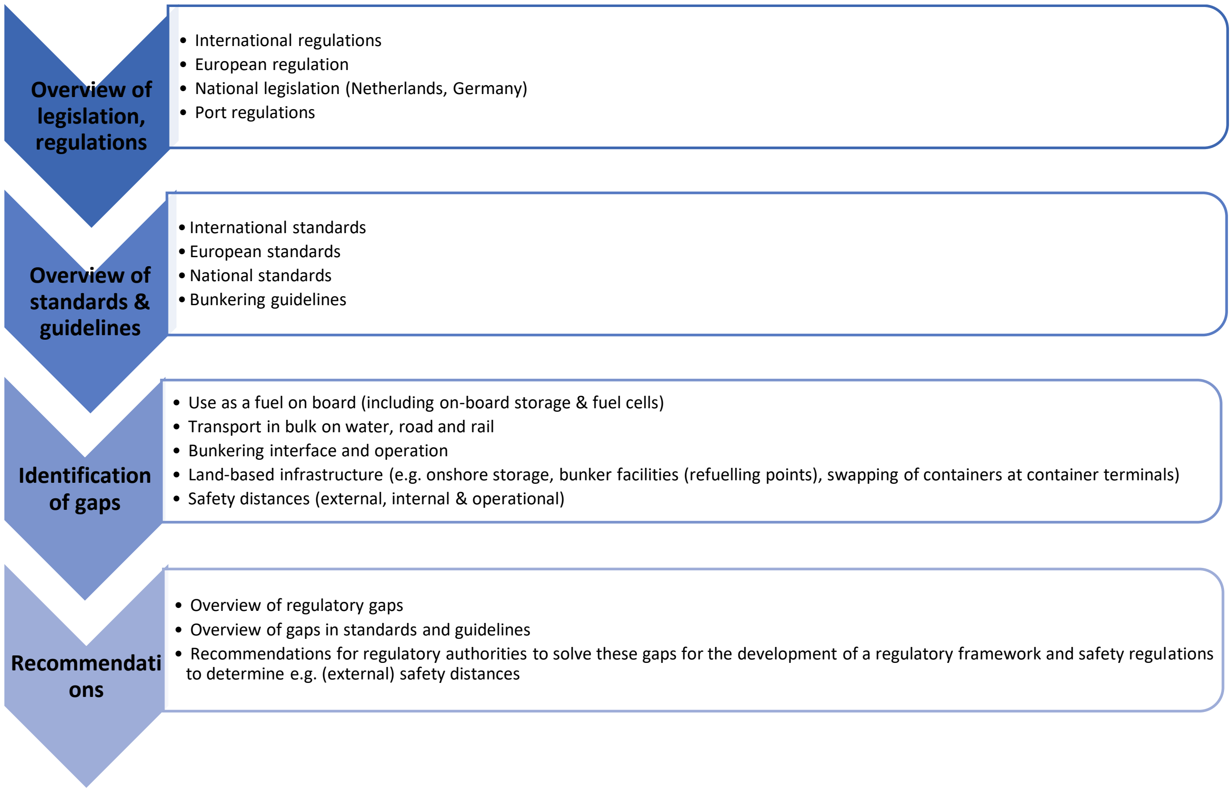

Figure 2: Methodology identification of gaps in regulations and standards and recommendations for development of regulatory framework

DNV has involved different employees in this study with relevant knowledge about rules & regulations. One is the DNV representative in the Dutch Hydrogen Safety and Innovation Program, Working Group (WG 3) Hydrogen legislation and regulations. The German representative at the IMO for the further development of the IGF Code (Interim Guideline for Fuel Cells) and also responsible for the DNV Class Rules for Fuels Cells (Pt. 6, Ch. 2, Sec. 3) also contributed. One of the employees represents the Norwegian Flag at the IMO for the development of the Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk and is currently working on the approval of hydrogen fuel installations and hydrogen development projects. Specific expertise about applicable (land-based) regulations and guidelines/standards in the Netherlands and Germany is covered by involving specialists from DNV offices situated in the Netherlands and Germany.

3 OVERVIEW OF RELEVANT ORGANISATIONS & REGULATIONS

Different organisations are active in the development of standards, regulations and guidelines related to supply and use of hydrogen in shipping. Some are focusing on one specific working domain, e.g. only maritime issues, whereas others deal with a broader range of aspects.

This chapter presents a brief overview of the main organisations and regulations at an International, European, National (Germany & The Netherlands) and Local level (Port & Harbour Authorities).

3.1 International

3.1.1 International Maritime Organisation (IMO)

IMO is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships. IMO is the global standard-setting authority for the safety, security and environmental performance of international shipping. Its main role is to create a regulatory framework for the shipping industry that is fair and effective, universally adopted and implemented.

In other words, its role is to create a level playing field so that ship operators cannot address their financial issues by simply cutting corners and compromising on safety, security and environmental performance. This approach also encourages innovation and efficiency.

Shipping is a truly international industry, and it can only operate effectively if the regulations and standards themselves are agreed, adopted and implemented on an international basis. IMO is the forum at which this process takes place.

IMO measures cover all aspects of international shipping – including ship design, construction, equipment, manning, operation and disposal – to ensure that this vital sector remains safe, environmentally sound, energy efficient and secure.

Figure 3 shows an overview of the structure and different sub-committees of IMO.

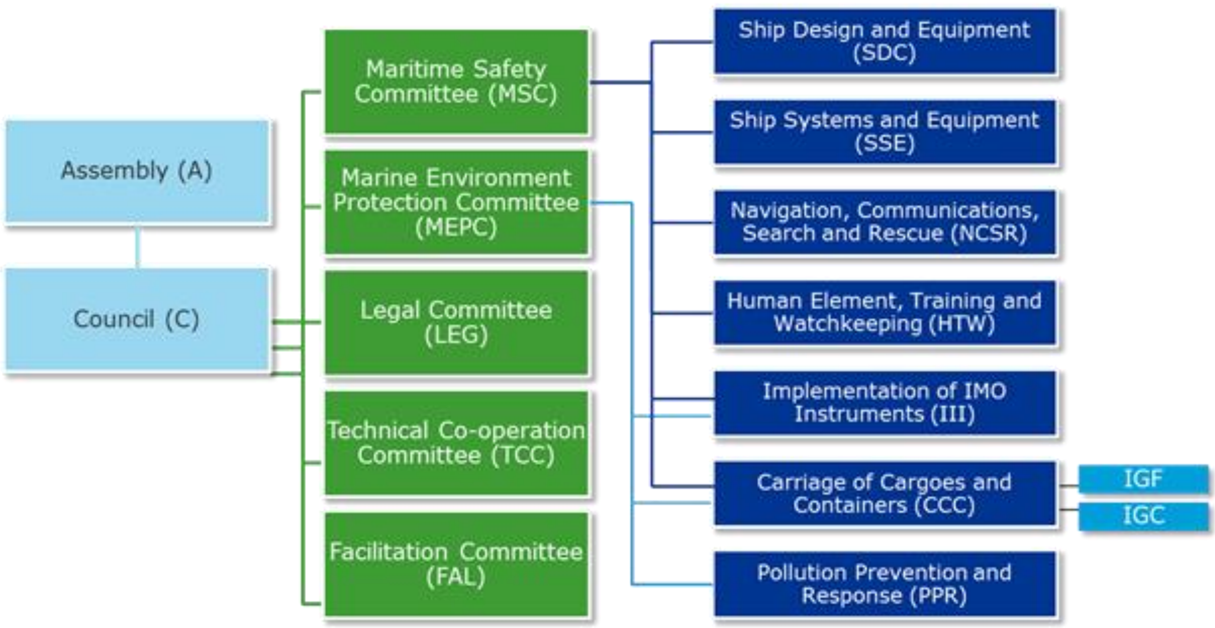

Figure 3: IMO organisational structure

The Maritime Safety Committee (MSC) is the highest technical body of the Organization. It consists of all Member States. The functions of the MSC are to “consider any matter within the scope of the Organization concerned with aids to navigation, construction and equipment of vessels, manning from a safety standpoint, rules for the prevention of collisions, handling of dangerous cargoes, maritime safety procedures and requirements, hydrographic information, log-books and navigational records, marine casualty investigations, salvage and rescue and any other matters directly affecting maritime safety”.

At international level IMO is the responsible body for drafting, discussing, approving, publishing and maintaining the main regulatory instruments that will be important for use of hydrogen in fuel cell systems in ships. The most relevant convention and codes of IMO are explained below. It must be noted that IMO has not yet developed specific regulations for the use of hydrogen as a fuel on board seagoing vessels[1].

International convention for the safety of life at sea (SOLAS)

The SOLAS convention defines as an international agreed minimum requirement for the construction, equipment and operation of ships. Flag States must ensure that these minimum requirements are met. It is generally regarded as the most important of all international treaties concerning safety of (merchant) ships. The most important chapters related to hydrogen are:

Chapter II-1 - Construction - Subdivision and stability, machinery and electrical installations

This chapter specifies amongst other things the requirements for generators for electrical power generation.

Chapter VII – Carriage of dangerous goods

The chapter requires carriage of dangerous goods to be in compliance with the relevant provisions of the International Maritime Dangerous Goods Code (IMDG-code). Part C requires that the construction of ships carrying liquefied gases in bulk and gas carriers to comply with the requirements of the International Gas Carrier Code (IGC Code).

Chapter II-2 – Fire protection, fire detection and fire extinction; Part B – Prevention of fire and explosion

Regulation 4.2.1.1 states that no oil fuel with a flashpoint of less than 60 °C shall be used. The use of hydrogen as a fuel is not covered by the SOLAS convention.

IMO has developed requirements for vehicle carriers carrying motor vehicles with compressed hydrogen in their tanks for their own propulsion as cargo (SOLAS II-2 reg. 20.1). This is the part relevant to fuel cells. The IMO sub-committee on Fire Protection (FP) agreed to introduce new requirements for electrical equipment and wiring, ventilation and gas detection. Entry into force was on 1 January 2016.

International code of safety for ships using gases or other low flashpoint fuels (IGF Code)

The IGF Code will, at international level, provide the necessary regulatory certainty for the adoption of hydrogen as a fuel, by ships designed and built in compliance with the code.

The IGF Code development resulted in adoption by the MSC committee in June 2015, meaning that the code was formally approved. The IGF Code entered into force on 1 January 2017. The IGF Code was initially adopted only for natural gas and internal combustion engines at MSC95 June 2015. The IGF Code is mandatory for all gases and other low flashpoint fuels. However, it only contains detail requirements for natural gas (LNG or CNG) as fuel. For other gases and low flashpoint fuels, the IGF Code Part A requires the alternative design method in accordance with SOLAS Regulation II-1/55 to be used demonstrating an equivalent level of safety.

A phase 2 development of the IGF Code initiated by IMO and the CCC (Carriage of Cargoes and Containers) subcommittee is currently developing technical provisions for methyl-/ethyl- alcohols as fuel and fuel cells. Fuel cells will

[1] IMO does have regulations for ro-ro vessels that have hydrogen-fueled vehicles on board.

be a new part (Part E) to be included in the IGF Code, at its first revision, due to take place within the 4-year cycle for SOLAS revisions.

The regulations for fuel cells was initially intended to be included in the IGF Code Part A-1 applicable for natural gas as fuel, but it was decided to extend the scope by including the fuel cell regulations in a separate Part E in the IGF Code, meaning that any gases (such as hydrogen) or other low flashpoint fuels can be used as fuel for the fuel cells, not only natural gas.

It should be noted that the fuel cell regulations under development in IMO will cover the fuel cell installation, but not the fuel storage and fuel supply system. If the fuel cell is using other gases or low flashpoint fuels than natural gas (covered by Part A-1 of the Code), the alternative design approach must be used in accordance with Part A of the Code for the fuel storage and fuel supply system until specific provisions for these aspects are developed for each of the low-flashpoint fuels in question.

International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)

The IGC defines the requirements for the construction and operation of gas carriers and is part of SOLAS Chapter VI, Part C. The IGC Code was the first code to regulate the use of gas as a ship fuel, in this case for gas carriers (use of boil-off gas (methane) as a fuel). This Code is kept under review, considering experience and technological development, as in practical terms, any developments into the IGC Code are relevant for consideration also in the IGF Code. However, IMO principles mean that a specific ship should relate to only one code, meaning either the IGC or the IGF Code. The development of the IGF Code and IGC Code is separated, which is seen on issues such as those concerning tanks below accommodation. The IMDG code also contains requirements for the transport of hydrogen (discussed further below).

As the IGC Code is specific for gas carriers and their fuel systems, its relevance for fuel cells in shipping is limited to the potential use of fuel cells and related fuels in gas carriers. The IGC Code covers hydrogen in the scope of the code. The CCC subcommittee in IMO has discussed introduction of requirements for carriage of liquefied hydrogen in bulk in this code and has developed interim recommendations that are included in resolution MSC.420 (97). This resolution is approved by MSC 97 and incorporated in IGC in 2016.

International Maritime Dangerous Goods Code (IMDG code)

The IMDG code is an international guideline to the safe transportation or shipment of dangerous goods or hazardous materials in packed form (e.g. containerized) by water on vessel. The IMDG Code is intended to protect crew members and to prevent marine pollution in the safe transportation of hazardous materials by vessel. Governments around the world adopt these rules for use in national regulations.

Current regulations prohibit the transport of compressed and liquid hydrogen on passenger vessels and for liquid hydrogen storage should be on deck only.

3.1.2 International Organisation for Standardisation (ISO)

ISO is an independent, non-governmental organization made up of members from the national standards bodies of 165 countries[2]. These national standards bodies make up the ISO membership and they represent ISO in their country. The ISO is also involved in the development of standards for the shipping industries and closely works together with the IMO.

[2] www.iso.org

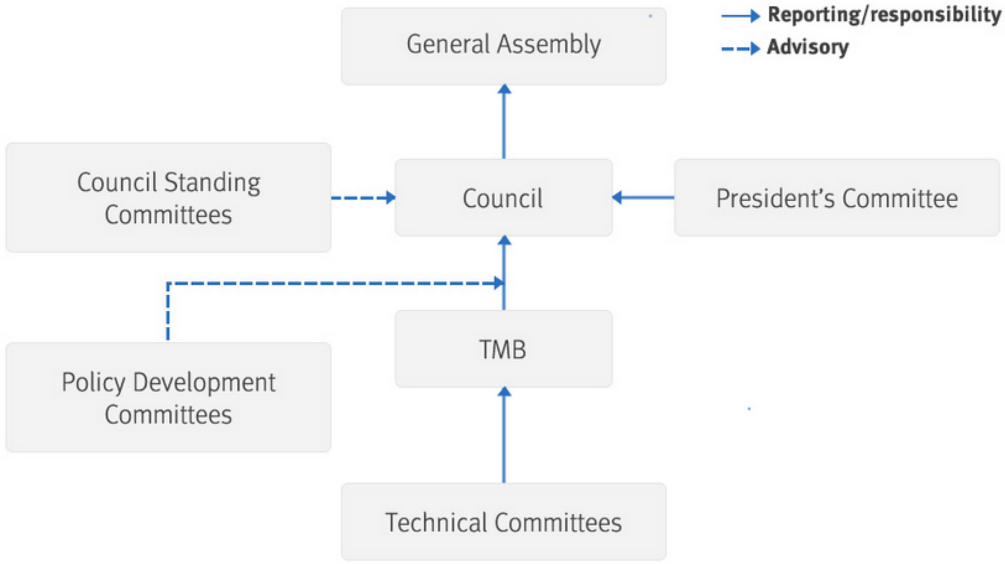

Figure 4: ISO governance structure (source: ISO)

The management of the technical work is taken care of by the Technical Management Board (TMB). This body is also responsible for the technical committees that lead standard development and any strategic advisory boards created on technical matters.

Relevant standards that ISO has developed are described in chapter 4.

3.1.3 International Electrotechnical Commission (IEC)

The IEC is a worldwide, independent, not-for-profit membership organization that develops state-of-the-art, globally relevant International Standards for electrical, electronic and information technologies.

Relevant standards that IEC has developed (e.g. IEC 62282 - Fuel cell technologies) are given in chapter 4.

3.1.4 Classification Societies

Seagoing ships are designed to and built under the class rules of a Classification Society. Most classification societies have also developed rules for vessels intended for operation on inland waterways. The objective of ship classification is to verify the structural strength and integrity of essential parts of the ship's hull and its appendages, and the reliability and function of the propulsion and steering systems, power generation and those other features and auxiliary systems which have been built into the ship in order to maintain essential services on board. Classification Societies aim to achieve this objective through the development and application of their own rules.

Classification societies, such as ABS, BV, DNV, KR & LR, have developed rules for fuel cell (FC) systems in shipping. These cover aspects such as design principles, material requirements, arrangement and system design, fire safety, electrical systems, control monitoring and safety systems, manufacture, workmanship and testing. For example, according to the DNV Fuel Cell Rules (Pt.6 Ch. 2 Sec. 3) storage of compressed flammable gases as hydrogen (above 10 bar) below deck will normally not be accepted, but exceptions are possible on a case by case basis. Above deck storage will be less challenging. Storage of hydrogen in enclosed spaces leads to requirements with respect to ventilation, ex-equipment etc. Specific DNV rules for swappable storage systems do not exist and there are some specific concerns with swappable systems. Reference is made to RH2INE Sub-study 1a, sub-activity report 1.1b: Hydrogen bunkering scenarios /1/ (chapter 7) for more information.

Some classification societies also develop bunkering guidelines and recommended practices (see paragraph 4.3.3), although guidelines for bunkering hydrogen have not been developed yet.

3.1.5 Industry bodies

3.1.5.1 The International Association of Ports and Harbours (IAPH)

The IAPH is promoting the interest of ports worldwide through strong member relationships, collaboration and information-sharing that help resolve common issues, advance sustainable practices and continually improve how ports serve the maritime industries. The IAPH publishes best practices and has developed LNG bunker checklists and audit and accreditation tools to recognize good LNG bunkering operators. Similar checklists and tools for bunkering hydrogen have not yet been developed.

3.1.5.2 The Society for Gas as a Marine Fuel (SGMF)

SGMF is a non-governmental organisation (NGO) that promotes safety and industry best practice and encourage training within the industry in the use of gas as a marine fuel. They are widely recognised as the leading experts in the use and adoption of low flashpoint fuels for shipping and the ensuing supply infrastructure. They have released safety guidelines for LNG bunkering. Similar safety guidelines for bunkering hydrogen are currently not in development, most likely because relevant ISO standards do not exist.

3.1.5.3 International Association of Classification Societies (IACS)

IACS is a technically based non-governmental organization that currently consists of twelve member marine classification societies (including DNV). IACS makes a contribution to maritime safety and regulation through technical support, compliance verification and research and development. They have several publications of which the most relevant one the IACS LNG bunkering Guidelines (No. 142), which was published in June 2016. Similar safety guidelines for bunkering hydrogen are currently not being developed.

3.2 European

3.2.1 European Commission (EC)

The European Commission represents the interests of the European Union (EU) as a whole. It proposes new legislation to the European Parliament and the Council of the European Union, and it ensures that EU law is correctly applied by member countries[3]. The Commission has the right of initiative to propose laws for adoption by the European Parliament and the Council of the EU (national ministers). In most cases, the Commission makes proposals to meet its obligations under the EU treaties, or because another EU institution, country or stakeholder has asked it to act.

Before making proposals, the Commission consults widely so that stakeholders' views can be taken into account. In general, an assessment of the potential economic, social and environmental impact of a given piece of legislation act is published along with the proposal itself.

Once EU legislation has been adopted, the Commission ensures that it is correctly applied by the EU member countries. In 2014, the EC Alternative Fuels Infrastructure Directive (AFID) was adopted. The AFID sets out minimum requirements for the building-up of alternative fuels infrastructure, including recharging points for electric vehicles and refuelling points for hydrogen (an appropriate number of points need to be in place by end 2025), to be implemented by means of Member States' national policy frameworks, as well as common technical specifications for such recharging and refuelling points, and user information requirements.

The existing legal framework allows the Commission to request one or several European standardisation organisations to draft a European standard or European standardisation deliverable. European standards are adopted by the European standardisation organisations, namely CEN, CENELEC and ETSI.

The EC has is responsible for several directives or decisions that are relevant for maritime, inland water and/or onshore hydrogen activities. Of main relevance are the following:

[3] http://ec.europa.eu

Inland transport of dangerous goods (2008/68/EC)

This EC directive establishes a common regime for all aspects of the inland transport of dangerous goods, by road, rail and inland waterway including the activities of loading and unloading and the transfer to or from another mode of transport. The directive refers to the annexed regulations of UNECE conventions ADN & ADR (see paragraph 3.2.3) and RID[4]. Whereas ADN, ADR & RID are applicable to safe international transport of dangerous goods, this directive extends the ADN, ADR & RID rules to apply also for national transport in the EU. Reference is made to paragraphs 3.2.3 & 3.2.4 for more information.

Directive laying down technical requirements for inland waterway vessels (2006/87/EC)

Annex II of this EC directive integrally includes the CCNR Rhine Vessel Inspection Regulation (see paragraph 3.2.6). It includes inland waterway vessel requirements for certification, carrying dangerous goods and inspections.

Seveso III - Directive on the control of major-accident hazards involving dangerous substances (2012/18/EU)

The Seveso III directive includes obligations of the operator and requirements for measures to prevent and inform about major-accident with dangerous substances. Transport and temporary storage of dangerous goods including loading and unloading is specifically excluded from this directive.

All onshore establishments which hold more than 5 tonnes of hydrogen fall under the scope of Brzo (Dutch decree on risk of major accidents) and need to establish a major accident prevention policy. In addition, operators of high tier establishments holding more than 50 tonnes of hydrogen need to establish a safety report before construction is commenced. The safety report must include identification of major hazards, a quantitative risk assessment and necessary measures to prevent such accidents, a safety management system and an emergency plan.

Environmental Impact Assessment directive (EIA) - on the assessment of the effects of certain public and private projects on the environment (2011/92/EU)

The initial EIA Directive (85/337/EEC) is in force since 1985 and applies to a wide range of defined public and private projects, which are defined in Annexes I and II. All projects listed in Annex I are considered as having significant effects on the environment and require an EIA. For projects listed in Annex II, the national authorities have to decide whether an EIA is needed. This is done by the "screening procedure", which determines the effects of projects on the basis of thresholds/criteria or a case by case examination. However, the national authorities must take into account the criteria laid down in Annex III. The EIA Directive of 1985 has been amended three times, in 1997, in 2003 and in 2009. The initial Directive of 1985 and its three amendments have been codified by directive 2011/92/EU of 13 December 2011. Directive 2011/92/EU has been amended in 2014 by directive 2014/52/EU. Hydrogen is not specifically mentioned in Annexes I & II of the EIA, although it must be considered when it used in an industrial installation for the production of electricity.

Industrial Emissions Directive (IED) - Integrated Pollution Prevention and Control (IPPC) (2010/75/EU)

The IED defines obligations with which industrial activities with a major pollution potential must comply. It establishes a procedure for authorizing these activities and sets minimum requirements to be included in permits, particularly in terms of pollutants released. The directive replaces 2008/1/EC. Since this regulation is not applicable for hydrogen land-based installations, this directive will not be further evaluated at the national level.

Pressure equipment directive (PED) (97/23/EC)

The Pressure Equipment Directive (97/23/EC) was adopted by the European Parliament and the European Council in May 1997. From 30 May 2002 the pressure equipment directive is obligatory throughout the EU. The purpose of PED is to harmonise national laws of Member States regarding the design, manufacture, testing and conformity assessment of

[4] The RID is published by the Intergovernmental Organisation for International Carriage by Rail (OTIF) and not the UNECE

pressure equipment and assemblies of pressure equipment. The Directive concerns items such as vessels, pressurised storage containers, heat exchangers, steam generators, boilers, industrial piping, safety devices and pressure accessories. Pressure equipment and assemblies above specified pressure (at least 0,5 barg and depending on the pressurized volume - at least 0,1 l) must meet essential safety requirements covering design, manufacture and testing; satisfy appropriate conformity assessment procedures and carry the CE marking. This directive is very commonly applied to onshore installations in the EU and does not contain specific features which will influence the development of hydrogen land-based installations in the Rhine corridor. It is therefore not further analysed at a national level.

ATEX directive 2014/34/EU (ATEX 114)

ATEX derives its name from the French title of the 94/9/EC directive “Appareils destinés à être utilisés en ATmosphères Explosives” (French for Equipment intended for use in Explosive Atmospheres). ATEX 114 concerns the equipment and protective systems intended for use in potentially explosive atmospheres. ATEX 114, which is dedicated to the manufacturer, replaces the former ATEX 95 on the 20th of April 2016. This directive is very commonly applied to onshore installations in the EU. The national implementation of ATEX does not contain specific features that will influence the development of hydrogen land-based installations in the Rhine corridor. It is therefore not further analysed at a national level.

ATEX directive 99/92/EG (ATEX 153)

ATEX 153 (formally known as ATEX 137) requires that 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 it persistence if it does. ATEX 153 is applicable to onshore hydrogen installations. Because of the same reason given for ATEX 114 (see above), it is not further analysed at a national level.

3.2.2 European Committee for Standardisation (CEN)

CEN, the European Committee for Standardization, is an association that brings together the National Standardization Bodies of 33 European countries[5]. CEN is one of three European Standardization Organizations (together with CENELEC and ETSI) officially recognized as competent in the area of voluntary technical standardisation. The European Union (EU) Regulation (1025/2012) which settles the legal framework for standardisation, has been adopted by the European Parliament and by the Council of the EU, and entered into force on 1 January 2013.

CEN provides a platform for the development of European Standards and other technical documents in relation to various kinds of products, materials, services and processes. CEN supports standardisation activities in relation to a wide range of fields and sectors.

The European standards are developed by Technical Committees (TC) which consists in of a panel of experts and is established by the Technical Board. Under each Technical Committees several working groups (WG) may exist in which the experts develop the EU standards for e.g. the gas industry.

To meet the requirements of the Alternative Fuels Infrastructure Directive, CEN/CENELEC considers developing standards on gaseous compressed Hydrogen, liquefied hydrogen, methanol and ammonia refuelling points and bunkering for maritime and inland waterways hydrogen-fuelled vessels. This is currently still at proposal stage (end 2020) and the work is covered by CEN/TC 268/WG 5. The scope of the proposed standards is further described in paragraph 4.3.2.

[5] www.cen.eu

3.2.3 United Nations Economic Commission for Europe (UNECE)

The UNECE is one of five regional commissions of the United Nations[6] (UN). UNECE's major aim is to promote pan-European economic integration. To do so, it brings together 56 countries located in the European Union, non-EU Western and Eastern Europe, South-East Europe and Commonwealth of Independent States (CIS) and North America. All these countries dialogue and cooperate under the aegis of UNECE on economic and sectorial issues.

The most relevant contribution related to the hydrogen supply chain is the work of the Transport Division which is guided by the mandates and work programmes of the UNECE Inland Transport Committees (ITC) and its subsidiary bodies. The ITC provides a pan-European intergovernmental forum to create tools for economic cooperation and to adopt international legal instruments on inland transport. Furthermore, they provide an international legal framework and technical regulations for development of international road, inland water, rail and dangerous goods transport. Regulations for transport of dangerous goods via road, inland water and rail are covered in three different European Agreements of which the first two are maintained by the UNECE:

1. The transport of hazardous goods by road is covered in the European Agreement concerning the International Carriage of Dangerous Goods by Road, commonly known as ADR (‘*Accord européen relatif au transport international des marchandises dangereuses*’). The ADR is translated and included in the national legislation of the applicable countries. The Agreement itself is short and simple. The key article is the second, which describes that, excluding some excessively dangerous goods, other dangerous goods may be transferred internationally in road vehicles subject to compliance with the conditions laid down in Annexes A (packaging and labelling) and B (construction, equipment and operation of the vehicle carrying the goods in question);

2. The transport of hazardous goods by inland waterway is covered by the European Agreement concerning the International Carriage of Dangerous Goods by Inland waterways, known as ADN. The ADN is published together with the Central Commission for the Navigation of the Rhine (CCNR). The provisions annexed to the ADN concern dangerous substances and articles, provisions concerning their carriage in packages and in bulk on board inland navigation vessels or tanks vessels, as well as provisions concerning the construction and operation of such vessels;

3. The transport of hazardous goods by rail is covered by the RID (“Règlement concernant le transport international ferroviaire des marchandises dangereuses”) - the European Agreement concerning the International Carriage of Dangerous Goods by Rail. The RID is published by the Intergovernmental Organisation for International Carriage by Rail (OTIF) and not the UNECE.

All agreements cover regulations for the transport of compressed & liquid hydrogen. In addition, several hydrogen carriers are also covered (e.g. methanol, ammonia, hydrogen in a metal hydride storage system).

3.2.4 Intergovernmental Organisation for International Carriage by Rail (OTIF)

The OTIF mainly focuses on the further development of rail transport law. 48 States are Members of OTIF at the present time. The following areas are dealt with[7]:

- contracts of carriage for the international carriage of passengers and goods (CIV and CIM);
- carriage of dangerous goods (RID);
- contracts of use of vehicles (CUV);
- contract on the use of railway infrastructure (CUI);
- validation of technical standards and adoption of uniform technical prescriptions for railway material (APTU);

[6] www.unece.org
[7] www.otif.org

- procedure for the technical admission of railway vehicles and other railway material used in international traffic (ATMF).

3.2.5 Central European Committee for Inland Navigation Standards (CESNI)

The CESNI is the European Committee for drawing up standards in the field of inland navigation and is created under the auspices of the Central Commission for the Navigation of the Rhine (CCNR).

Its mission shall include in particular:

- adopting technical standards in various fields, in particular as regards vessels, information technology and crew, to which the respective regulations at the European and international level, including those of the European Union and the CCNR, may refer with a view to their application;
- deliberating on the uniform interpretation and application of the said standards, on the method for applying and implementing the corresponding procedures, on procedures for exchanging information, and on the supervisory mechanisms among the Member States;
- deliberating on derogations and equivalences of technical requirements for a specific craft;
- deliberating on priority topics regarding safety of navigation, protection of the environment, and other areas of inland navigation.

The CESNI developed the ES-TRIN, which is the European Standard laying down Technical Requirements for Inland Navigation vessels. The standard lays down the uniform technical requirements necessary to ensure the safety of inland waterway vessels. It includes provisions regarding shipbuilding, fitting out and equipment for inland waterway vessels, special provisions regarding specific categories of vessels such as passenger vessels, pushed convoys and container vessels, provisions regarding vessel identification, model of certificates and register, transitional provisions as well as instructions for the application of the standard.

The ES-TRIN provides general provisions for low flashpoint fuels (Ch. 30; Appendix 8) and is currently under revision by working group CESNI/PT/FC to include more specific construction requirements regarding hydrogen-fuelled vessels and related fuel cell systems.

3.2.6 Central Commission for the Rhine (CCNR)

The CCNR is an international institution which addresses all the issues concerning inland navigation[8]. It promotes the development of close cooperation with the other international organisations working in the field of European transport policy and with non-governmental organisations active in the field of inland navigation. The objectives of the CCNR are to ensure efficient, safe and environmentally friendly transport of the Rhine as well as ensuring sustainable development. The CCNR cooperates with the UNECE and other river commissions.

CCNR has a regulatory role for navigation on the Rhine and the main relevant regulations developed by CCNR are the RVIR, RPR and RPN, which are described further down.

The CCNR has not yet developed specific regulations for the use of hydrogen as a fuel on-board inland navigation vessels. Hydrogen-fuelled vessels require an exemption statement that can be requested by national authorities or the CCNR, depending on the operating area. Special requirements of the CCNR are to be observed if an inland vessel will be operating in EU inland waters.

However, the CCNR & CESNI have commissioned a working group (CESNI/PT/FC) at the start of 2020 that is currently developing technical requirements and rules for inland navigational vessels with fuel cell systems (see previous paragraph).

[8] www.ccr-zkr.org

Rhine vessel inspection regulations (RVIR)

The CCNR technical rules and requirements for inland waterway vessels are captured in the RVIR. The Rhine inspection regulations, which are only legally applicable on the Rhine itself, have become Europe's technical reference base for the construction of new inland vessels, irrespective of whether they are intended for use on the Rhine or somewhere else. The regulation has been transposed into national regulations, was adopted by UNECE and was integrally included in EU directive 2006/87/EC.

Police regulations for navigation of the Rhine (RPR)

The Rhine police regulations are drawn up by the CCNR police regulations committee. The police regulations settles the markings and lights to be displayed by vessels and convoys, the rules for meeting, crossing, overtaking and berthing of vessels as well as the waterway signs, the allowed dimensions of vessels and convoys and the water protection against pollution to keep by navigation. The observance of the rules by navigation is supervised by the national water polices of the Rhine riparian states. RPR contains instructions aimed at conventional fuel bunkering but does not cover the possibility of bunkering hydrogen.

On a pan-European front, the UNECE adopted a recommendation with a view to harmonising inland navigation rules. The rules arising from this recommendation constitute the European Code for Navigation on Inland Waterways (CEVNI). The CEVNI Code was largely inspired by the CCNR's RPR. Many of its provisions are either identical or equivalent.

Regulations for Rhine navigation personnel (RPN)

With Resolution 2010-I-8-Annex 1, the Central Commission has adopted the RPN, which came into force on 1 July 2011. The Regulations for Rhine navigation personnel includes all the pre-existing Rhine regulations for navigation personnel.

The regulations cover the qualifications of personnel, particularly the skills required of boat masters and the manning requirements of crews. Furthermore, it contains the Rhine navigation certificate regulations adopted in June 2007. The annexes mainly contain model certificates and the list of documents issued by non-member states that have been recognised by the CCNR as valid for the Rhine.

For vessels that carry dangerous goods, a crew member on board must be in possession of a certificate of special knowledge of ADN.

3.3 National

3.3.1 Standardisation Organisations

Most of the European countries have established national standardisation bodies which develop their own national regulatory instruments and as well as represent national standardisation interests e.g. as a member of ISO and CEN. Table 4 gives an overview of the different national standardisation bodies for Emission Controlled Area (ECA) countries and potential future ECA countries. However, all 30 CEN members are obliged to adopt European standards as substitutes for their former national standards. Most of formerly relevant national standards have been integrated in or substituted by CEN European Standards.

Table 4: National standardisation bodies[9]

Country	Organisation	Acronym
Belgium	Bureau de Normalisation / Bureau voor Normalisatie	NBN
Croatia	Croatian Standards Institute	HZN
Cyprus	Cyprus Organization for Standardisation	CYS
Denmark	Dansk Standard	DS
Estonia	Estonian Centre for Standardisation	EVS

[9] http://standards.cen.eu/

Country	Organisation	Acronym
Finland	Suomen Standardisoimisliitto r.y.	SFS
France	Association Française de Normalisation	AFNOR
Germany	Deutsches Institut für Normung	DIN
Greece	National Quality Infrastructure System	NQIS/ELOT
Italy	Ente Nazionale Italiano di Unificazione	UNI
Latvia	Latvian Standard Ltd.	LVS
Lithuania	Lithuanian Standards Board	LST
Malta	The Malta Competition and Consumer Affairs Authority	MCCAA
The Netherlands	Nederlands Normalisatie-instituut	NEN
Poland	Polish Committee for Standardization	PKN
Spain	Asociación Española de Normalización y Certificación	AENOR
Sweden	Swedish Standards Institute	SIS
United Kingdom	British Standards Institution	BSI

The scope of this study is limited to the Netherlands and Germany as per the scope of Sub-study 1b (see paragraph 2.1). Therefore, the relevant work activities & norms published by the Dutch institute NEN ("Nederlands Normalisatie-instituut") and the German institute DIN ("Deutsches Institut für Normung") are provided in the paragraphs below.

3.3.1.1 NEN (Netherlands)

The relevant hydrogen initiatives, activities and developments where NEN is involved in are described below.

Hydrogen and fuel cells standards committee

This National Hydrogen and Fuel Cells Committee is the point of contact for Dutch stakeholders. The committee is responsible for national standard development activities and the Dutch contribution to the relevant technical committees of IEC, ISO and CEN. These are the global standards committees ISO / TC 197 "Hydrogen technologies", IEC/TC 105 "Fuel cell technologies" and the European standards committee CEN/CLC/TC 6 "Hydrogen".

H_2Platform

The H_2Platform is a growing partnership between the Ministries of Infrastructure and Water Management and Economic Affairs and Climate and organizations and companies involved in hydrogen. The H_2Platform organizes plenary platform meetings. Knowledge and innovation tables are used to exchange knowledge and form vision and advice on specific subjects. Current topics are: 'Hydrogen sustainability', 'Sustainable hydrogen economy', 'Infrastructure and market development', 'Utility vehicles' and the 'Hydrogen Safety Innovation Program'. NEN is coordinator of the Hydrogen Safety Innovation Program and is a member of the core team.

Hydrogen Safety Innovation Program

The Hydrogen Safety Innovation Program comprises the subjects that are preconditions, and must therefore be given priority, for the implementation of hydrogen in the public domain, among other things. The safety program aims to systematically check whether all safety aspects have been mapped out across the entire value chain, its interpretation of whether adequate measures are available and implemented in regulations. Different parts of the value chain are covered: storage and transhipment and transport and distribution of hydrogen (including bunkering). A number of essential horizontal subjects have also been identified for the safety program, such as legislation and regulations, international knowledge transfer and instructions / protocols to competent authorities such as municipalities and safety regions. In the context of knowledge transfer, the safety program also provides communication to the parties involved. Where necessary, scientific publications are processed into readable instructions that can be used in the workplace. The purpose of the safety program is to arrive at nationally coordinated measures and instruments for safety aspects and risks, to ensure uniformity at national level for authorities and operators (e.g. guidelines and protocols, etc.). Legislation and regulations are also an important pillar in the safety program. Bunkering of hydrogen is addressed in the various working groups within the program.

PGS guidelines

NEN develops so-called PGS (Publicatiereeks Gevaarlijke Stoffen) guidelines, which provide requirements & provisions for the safe design and operation of an installation (e.g. PGS 35 for HRS). Reference is made to paragraph 3.3.2.2 for more information.

Norms

NEN has adopted the hydrogen standards developed by IEC/CEN/ISO described in chapter 4. So far, no specific Dutch amendments were made to the standards.

3.3.1.2 DIN (Germany)

The relevant hydrogen initiatives, activities and developments where DIN is involved have a focus on truck systems or road operated vehicles. A small part of the activities is devoted to ship operations.

The ongoing activities are thematically similar or identical to those of NEN. In particular, the following revisions are ongoing:

- DIN EN 17127: Gaseous Hydrogen: tank filling system - part 1: general requirements;
- DIN EN ISO 17269: Connecting equipment for the refuelling of land-based vehicles with gaseous hydrogen;
- DIN ISO 19880-1: Design and test of ship transfer jetties for liquified hydrogen.

Further to that, DIN is presently involved in the following working groups, e.g.:

- CEN / CLC/ JTC 6 / WG 3: Safety of Hydrogen
- ISO / TC 8 / SC 2 / WG 12: Marine liquefied hydrogen transfer arms
- ISO / TC 197 / WG 29: Basic considerations for the safety of hydrogen systems

DIN has adopted the hydrogen standards developed by IEC/CEN/ISO described in chapter 4. No specific German amendments were made to the standards, so far.

3.3.2 Legislation in the Netherlands

An overview of the relevant water-based and land-based laws and regulations in the Netherlands and the related European regulations (as far as applicable) is presented in Table 5 and Table 6, respectively and further described below.

3.3.2.1 Water-based

An overview of relevant maritime, inland water, transportation and traffic laws and regulations in the Netherlands is presented in the table below.

Table 5: Overview of relevant maritime, inland water, transportation and traffic laws and regulations (primarily water-based)

Dutch legislation		Application area		
Title	*Contains transposition of (parts of)*	*Maritime*	*Inland water*	*Onshore*
Shipping traffic law (scheepvaartverkeerswet)	International convention for the safety of life at sea (SOLAS) CCNR police regulations for navigation of the Rhine (RPR)	X	X	
Inland shipping law (binnenvaartwet)	Directive laying down technical requirements for inland waterway vessels (2006/87/EC) Rhine vessel inspection regulations (RVIR) CCNR police regulations for navigation of the Rhine (RPR)		X	
Inland shipping police regulation (Binnenvaartpolitiereglement) (BPR)	CCNR police regulations for navigation of the Rhine (RPR)		X	
Law on the transportation of hazardous substances (wet vervoer gevaarlijke stoffen, WVGS) - Decree on the transportation of hazardous substances (besluit vervoer gevaarlijke stoffen, BVGS) - Decree on external safety of transportation routes	EU directive inland transport of dangerous goods (2008/68/EC) European agreement concerning international carriage of dangerous goods by inland waterways (ADN) European agreement concerning the international carriage of dangerous goods by rail (RID) European agreement concerning international carriage of dangerous goods by road (ADR)		X	X

Shipping traffic law (scheepvaartverkeerswet)

The shipping traffic law forms the basis for all traffic rules in shipping. It contains general rules for safe and smooth shipping traffic in the Netherlands. The law is applicable to all types of ships for both inland and maritime waters. This regulation is further elaborated on in separate rules and decrees. Relevant in this context are the following.

The Act of Mannheim concerns the freedom of inland shipping traffic on the river Rhine. Under this act the CCNR Rhine vessel inspection regulations and Rhine police regulations are implemented on the river Rhine in the Netherlands.

The "decree for routing and notification systems for ships on open sea near the Dutch shore" contains a transposition of sections of the IMO SOLAS treaty.

Inland shipping law (binnenvaartwet)

The inland shipping law has come into force on 1 July 2009 and combined three existing Dutch laws for inland shipping with the implementation of the European directive 2006/87/EC (see also section 3.2.1), CCNR RVIR and the RPR, see also paragraph 3.2.6.

The inland shipping regulation (binnenvaartregeling, BVR) falls under the inland shipping law and contains the technical requirements such as implementation of RVIR in appendix 1.1 and technical requirements for bunker stations in appendix 3.8. Appendix 3.8 covers conventional bunkering & bunkering of LNG only and need to be updated to make bunkering of hydrogen possible on Dutch inland waterways. Exemptions could be made possible based on special permissions from the competent authority.

Inland shipping police regulation (binnenvaartpolitiereglement, BPR)

BPR contains the shipping traffic rules for the Dutch inland waters, with exemption of several rivers including the Rhine corridor (Boven-Rijn, Waal, Pannerdensch Kanaal, Neder-Rijn, Lek). On the Rhine corridor the Rhine police regulations are applicable.

Law on the transportation of hazardous substances (wet vervoer gevaarlijke stoffen, WVGS)

The law on transportation of hazardous substances aims to prevent harm or nuisance to people, animals and the environment during transport of hazardous substances and implements the EU directive inland transport of dangerous goods (2008/68/EC). This law is applicable to the transport of dangerous goods over land, rail as well as inland waters and it also covers the loading and unloading of dangerous goods. The following legislation is related to the law on transportation of hazardous substances:

Decree on the transportation of hazardous substances (besluit vervoer gevaarlijke stoffen, BVGS)

The decree on the transportation of hazardous substances is an elaboration of the law on the transportation of hazardous substances and contains specific technical regulations per type of transport. The UNECE ADN and ADR (see paragraph 3.2.3) and the OTIF RID (see paragraph 3.2.3 & 3.2.4) are implemented in this decree. The decree has two underlying arrangements ('regelingen') containing rules for the transport dangerous good over inland waterways ("Regeling vervoer over de binnenwateren van gevaarlijke stoffen") and transport with seagoing vessels ("Regeling Vervoer gevaarlijke stoffen met zeeschepen"). The first arrangement states that compliance is needed with e.g. ADN and the latter states that compliance is needed with e.g. the IMDG code. The specific rules related to hydrogen are incorporated in the ADN and IMDG code.

Law on base transportation network (wet basisnet)

The law on transportation of hazardous substances has been amended to accommodate the implementation of the law on base transportation network (wet basisnet). "Basisnet" is a nationwide appointed network for the transportation of dangerous goods. Within certain boundaries this transportation over land, water or rail is guaranteed. The law on base transportation network sets regulation aimed at determination and containment of the (external safety) risks related to the transportation of dangerous goods.

The National Institute for Public Health and the Environment ("Rijksinstituut voor Volksgezondheid en Milieu"), the RIVM, has started an investigation in 2020 into the risks and effects of hydrogen and how they can be best modelled for Basisnet considering the transport of hydrogen via rail, road and water[10]. Also hydrogen carriers, such as ammonia, methanol and formic acid will be taken into account. Transport risks are currently calculated with use of the Reference Manual Transport Risk Analysis /8/.

It must be noted that there are no limits for the transport of (mobile) tank-containers on waterways in Basisnet because the associated transport risk is very low. The probability of a leak in a container is very small that it will not contribute to the external safety risks /8/. This means it is expected that there will be no limits applicable for the transport of swappable hydrogen tube-containers on waterways with container vessels to container terminals.

Decree on external safety of transportation routes (besluit externe veiligheid transportroutes, Bevt)

This decree is part of a set of regulations related to law on base transportation network. It is setup similar to the decree on the external safety for facilities (besluit externe veiligheid inrichtingen, see below). The decree regulates the external safety of transportation activities. Individual and societal risk criteria are used in this decree.

3.3.2.2 Land-based

Regulatory framework

[10] Source: https://magazines.rivm.nl/2020/07/magazine-omgevingsveiligheid/effecten-duurzame-energiebronnen-op-omgevingsveiligheid (accessed on 5-2-2021)

The current regulatory framework relevant for land-based establishments & activities in the Netherlands is presented in Figure 5. It must be noted that the Dutch legal framework for regulating land-based establishments & activities will change considerably in 2022. A new Environmental law ("Omgevingswet") is foreseen to come into force on the 1st of January 2022. Existing laws like Wabo (Dutch law on the general provisions for environment) & Wm (Dutch law on environmental management) will be replaced by a new environmental law the "Omgevingswet". Brzo & Bevi ("Besluit externe veiligheid inrichtingen") will cease to exist and be replaced by new decrees: "Besluit activiteiten leefomgeving" (Bal), "Besluit kwaliteit leefomgeving" (Bkl) and "Omgevingsbesluit" (Ob). These new laws and decrees are not described in detail, but are taken into account in the gap analysis. This means that identified gaps in the existing laws are verified to check whether the same gaps are also present in the new legislation.

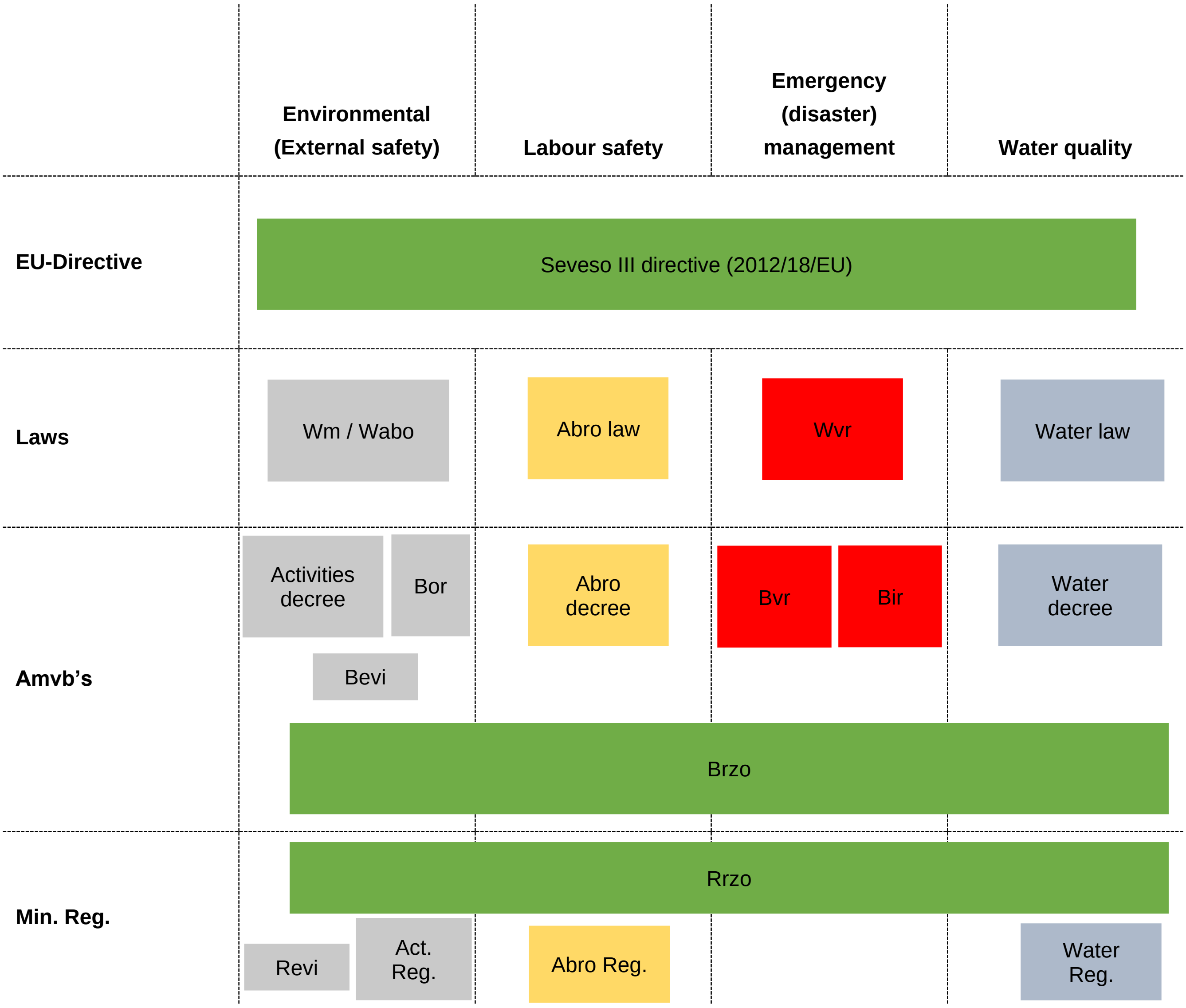

Figure 5: Regulatory framework in the Netherlands for land-based establishments and activities[11]

[11] Source : https://aandeslagmetdeomgevingswet.nl/publish/pages/180612/2020091420_seveso_toezicht_onder_ow.pdf

The focus of this report is to identify gaps in relevant environmental laws related primarily to external safety of land-based establishments & activities with hydrogen. Labour & water quality laws are therefore not considered. Laws related to emergency management are generic and therefore not further discussed below.

Legislation

Table 6 shows the current legislation applicable for land-based establishments and activities with hazardous goods, focussing on the most relevant environmental laws related to external safety (see also Figure 5).

Table 6: Overview of relevant environmental and hazardous goods laws in the Netherlands (land-based)

Dutch legislation		Application area		
Title	*Contains transposition of (parts of)*	*Maritime*	*Inland water*	*Onshore*
Law on the general provisions for environment (wet algemene bepalingen omgevingsrecht, Wabo)	-			X
Law on environmental management (wet milieubeheer, Wm) - Decree on general rules for environmental management of facilities, activities decree (Besluit algemene regels voor inrichtingen milieubeheer, activiteitenbesluit)	Industrial emissions directive (IED) - integrated pollution prevention and control (IPPC) (2010/75/EU)			X
Decree on risk of major accidents (Besluit risico zware ongvallen, Brzo) Decree on external safety of facilities (Besluit externe veiligheid inrichtingen, Bevi)	Seveso III - Directive on the control of major-accident hazards involving dangerous substances (2012/18/EU)			X

These laws are further described underneath.

Law on the general provisions for environment (wet algemene bepalingen omgevingsrecht, Wabo)

The law on the general provisions for environment was implemented on October 1, 2010. This law integrated about 25 permits, exemptions and notifications into one environment permit. Environmental permit requirements are not specifically regulated in this law, but in the law on environmental management as described below.

Law on environmental management (wet milieubeheer, Wm)

The law on environmental management was implemented on March 1, 1993. The law is aimed at the prevention of nuisance and protection of the environment. Since October 2010, the Wabo law (see above) is the legal basis for the related permit. Companies with a hydrogen land-based installation (e.g. onshore storage, HRS, bunker station) and related operation have to comply with this law and require a permit. Regulations apply to, for instance, noise and vibration energy, waste materials, odour, air emissions, discharging liquids, transport management, soil protection and hazardous substances. The following decree forms the basis for environmental regulations:

Decree on general rules for environmental management of facilities, activities decree (Besluit algemene regels voor inrichtingen milieubeheer, activiteitenbesluit)

The environmental management decree forms the basis for the environmental regulations. Depending on the activities of a facility, it will be classified in one of three categories pursuant to the activities decree. Type A does not require an environmental management notification or an environmental permit; type B requires and environmental management notification; Type C requires an environmental permit. Hydrogen onshore storage, HRS and bunker stations etc. are classified as Type C.

For facilities that contain hazardous substances the activities decree refers to the so-called PGS (Publicatiereeks Gevaarlijke Stoffen) guidelines, which provide requirements & provisions for the safe design and operation of an installation. These guidelines are considered to represent Best Available Techniques (BAT). These guidelines are used by the authorities and industry to prove conformity to the regulation by complying with the requirements of PGS. Relevant guidelines in relation to hydrogen are briefly outlined below.

PGS 35 is a guideline for hydrogen delivery installations for road vehicles (HRS). It offers uniformity of regulations that are important for the granting of permits, and the guidance and transparency it provides for the granting of permits for the construction and operation of a hydrogen delivery installation.

A guideline for the design and operation of a hydrogen bunker station to ship is currently not (yet) under development. However, the equivalent PGS guideline for LNG bunker stations (PGS 33-2) has been published in 2014. Depending on the market developments and the need for regulations for bunker stations, it is expected that a similar guideline will eventually be developed for hydrogen bunker stations ('PGS 35-2').

PGS 26 is a guideline for safe stalling, maintenance and repairing CNG and LNG road vehicles. Although the guideline is written for road vehicles, the new environmental legislation in 2022 (Bal) specifies that PGS 26 is also applicable for the maintenance and repair of fuel engines of e.g. maritime & inland vessels. The PGS program council is currently considering to include hydrogen in PGS 26.

PGS 15 is a guideline for the storage of packed dangerous goods. Chapter 10 specifies provisions for the storage of (tank)containers at e.g. container terminals and inland terminals in particular, which are relevant when hydrogen (tube)containers will be bunkered at inland container terminals. This guideline does not contain substance specific requirements for e.g. hydrogen. The requirements related to storage of (tank)containers with hazardous goods in the stack is primarily based on the ADR classification, which covers flammable gasses such as hydrogen.

Decree on risk of major accidents (Besluit risico zware ongevallen, Brzo)

The decree on risk of major accidents (Brzo) is a transposition of the Seveso III directive (2012/18/EU). Brzo integrates legislation on occupational safety, external safety and disaster relief in one legal framework.

In accordance with Seveso III, all onshore establishments which hold more than 5 tonnes of hydrogen fall under the scope of Brzo and need to establish a major accident prevention policy. In addition, operators of high tier establishments holding more than 50 tonnes of hydrogen need to establish a safety report before construction is commenced. The safety report must include identification of major hazards, a quantitative risk assessment (QRA) and necessary measures to prevent such accidents, a safety management system and an emergency plan.

Decree on external safety of facilities (Besluit externe veiligheid inrichtingen, Bevi)

The decree on external safety of facilities (Bevi) sets safety requirements to companies that pose a threat to people outside of the premises of that company. The decree contains risk acceptance criteria for location-specific risk and societal risk, which should be evaluated in a QRA. The criterion for location-specific risk is 10^{-6}/year and is applicable to vulnerable objects such as residential areas, hospitals etc. The distance to the 10^{-6}/year contour is the external safety distance. Note: the new 2022 legislation, Bkl, also contains a new concept: focus areas ("aandachtsgebieden") that need to be calculated. These areas will determine where additional measures are required to protect occupants indoors against harmful effects.

The Bevi decree forces land-based authorities to take into account these external safety requirements in environmental permit procedures. The Bevi decree is applicable to all activities that fall under the previously mentioned Brzo, e.g. for onshore establishments that hold more than 5 tonnes of hydrogen.

Next to Brzo establishments, Bevi also defines categorial (Bevi) establishments, such as an LPG refuelling station for road vehicles (Article 2.1.e) or container terminals with hazardous good (Article 2.1.b), for which specific safety requirements exist. For instance, for LPG refuelling stations fixed eternal safety distances are specified in Revi (therefore a QRA is not needed) depending on annual LPG throughput. For container terminals, a specific QRA calculation methodology must be applied. Small-scalle establishments with hydrogen (HRS, bunker station etc.) are not defined as categorial Bevi establishments, therefore no specific requirements exist. However, fixed external safety distances for HRS are given in the new 2022 legislation Bkl, see further below.

QRA calculation guidelines under Bevi

Bevi/Revi specifies that a QRA must be developed for e.g. Brzo establishments based on the Reference Manual Risk Assessments Bevi (current version is 4.3, 1st of January 2021) /9/ developed by the RIVM and making use of DNV's software program Safeti-NL 8 (current version 8.3). This manual provides information about possible failure scenario's, failure frequencies and how to model the consequences & risk. The manual is based on and is the successor of the most well-known and world-wide accepted guideline for the execution of quantitative risk assessment: the 'purple book'. Together with the other 'coloured books' (yellow, green and red) the guideline forms valuable reference material for safety studies. The books are written by Dutch Government (RIVM) with support from the research institute TNO. The coloured books have become obsolete and are not kept up-to-date anymore since 2005.

The Reference Manual Risk Assessments Bevi is not specifically written for hydrogen, it has generic applicability. For instance, the manual does not specify hydrogen-specific failure frequencies for e.g. storage in tube-containers, but rather specifies generic failure frequencies for pressurized onshore storage or pressurized vessels on trailers, which could be derived based on failure data of storage vessels that are very different in design compared to (compressed or liquid) hydrogen containment systems.

The RIVM has developed calculation guidelines for specific installations, e.g. container terminals, LNG refuelling stations and LNG bunker stations. These guidelines also contain case studies. Similar guidelines for hydrogen installations (e.g. bunker stations) do not exist. However, the RIVM has written a memo on risk and effect distances of HRS /10/. Based on these results the Ministry of Infrastructure and Environment has decided to include fixed external distances for HRS (30 m or 35 m depending on the supply of hydrogen via pipeline or trailer, respectively) in the new 2022 legislation (Bkl) and not to develop a specific QRA calculation guideline for HRS. However, there is still a need to develop a QRA calculation guideline for hydrogen bunker stations supplying hydrogen as a fuel to (inland) vessels, because the way of calculating the risk of hydrogen releases differs compared to other substances (e.g. related to ignition probability[12], outflow modelling).

The QRA calculation guideline for container terminals is included in the Reference Manual /9/, module C, chapter 5. This guideline does not specify failure scenarios for hydrogen containers in particular. The scenarios are related to hoisting and storage of tank-containers, either with gas or liquid. The assumptions related to gas tank-containers are actually based on liquified gas (inventory 20 m^3 and a liquid head of 2 m is assumed) and do not seem to be applicable for e.g. pressurized hydrogen gas in tube-containers. In addition, the design and strength (e.g. wall thickness of the tube/cylinder) of such containers is very different to a liquefied gas tank-container and therefore the failure scenarios & frequencies may not be appropriate.

3.3.3 Legislation in Germany

3.3.3.1 Regulatory framework

Germany is a federation consisting of 16 federal states ("Länder"). The relation between the national federal administration and the states are regulated within the so-called "constitutional law" (Grundgesetz).

[12] For instance, RIVM memo /10/ assumes an immediate ignition probability of 1 for gaseous hydrogen and 0.9 for liquid hydrogen. These specific parameters should be captured in a QRA calculation methodology for hydrogen installations, such as bunker stations.

Germany has implemented European legislation in a wide range of laws and regulations which do not focus on hydrogen in particular. As such, hydrogen issues are addressed only in general, based on the main property of hydrogen, e.g. hydrogen being a hazardous substance.

In consequence, all laws and regulations apply which are common for hazardous substances in general. The applicable framework is shown in Figure 6:

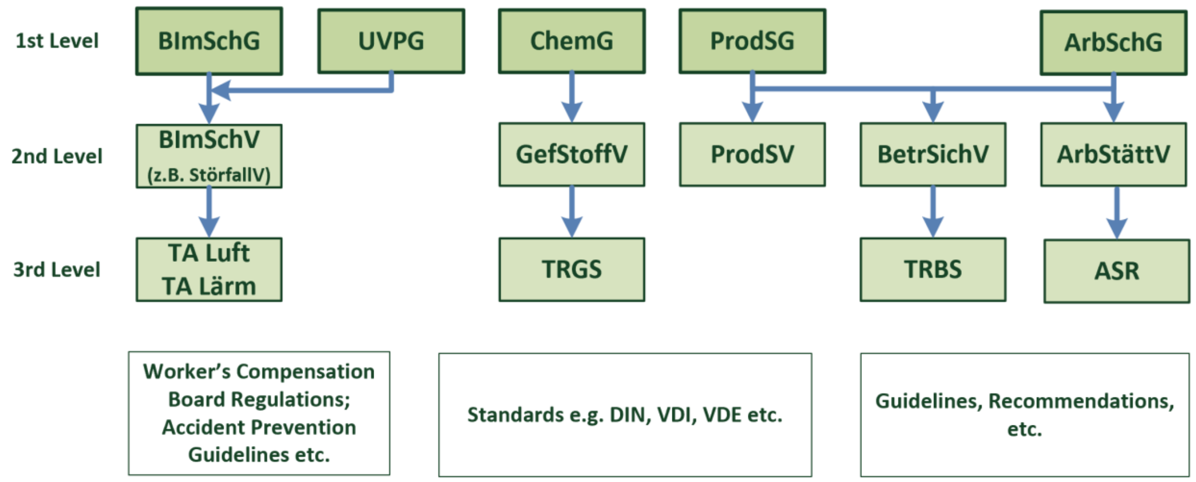

Figure 6: German Framework of Laws, regulations, guidelines and standards

The framework has a three-layered structure where *laws* are representing the first layer. A key role in the law layer has the Federal Immission Control Act (BImSchG = Bundes-Immissionsschutzgesetz) which sets a legal framework for all activities potentially leading to immissions of hazardous or harmful substances.

Further relevant laws in this layer are

- UVPG = Environmental Impact Assessment Act (Gesetz über die Umweltverträglichkeitsprüfung),
- ChemG = Chemicals Act (Chemikaliengesetz),
- ProdSG = Product Safety Act (Produktsicherheitsgesetz) and
- ArbSchG = Labour Protection Law (Arbeitsschutzgesetz).

The second level is the *regulation* level. Regulations ("Verordnungen") are detailing the corresponding laws and provide detailed prescriptions for the execution. A representative of this level are the "Bundes-Immissionsschutzverordnungen" (BImSchV; Federal Immission Control Regulations (ordinance)). This is a set of approx. 50 regulations which control the execution of the legal framework, regulate the range of facilities to which they apply and set general boundary conditions (also for different areas of immissions like hazardous substances, noise, environmental pollutions etc.).

The most relevant regulation for hazardous substances is the 12. BImSchV which is commonly known as "Störfallverordnung" (StörfallV), i.e. the Major Accident Regulation.

An overview of the relevant German water-based and land-based laws and regulations and the related European regulations (as far as applicable) is presented in Table 7 and Table 8, respectively and further described below.

3.3.3.2 Water-based

An overview of relevant maritime, inland water, transportation and traffic laws and regulations in Germany is presented in the table underneath.

Table 7: Overview of relevant German maritime, inland water, transportation and traffic laws and regulations (primarily water-based)

German legislation		Application area		
Title	*Contains transposition of (parts of)*	*Maritime*	*Inland water*	*Onshore*
Ship safety law (Schiffsicherheitsgesetz) (SchSG)	International convention for the safety of life at sea (SOLAS) CCNR police regulations for navigation of the Rhine (RPR)	X		
Inland water vessel investigation ordinance (Binnenschiffs Untersuchungs Ordnung) (BinSchUO)	Directive laying down technical requirements for inland waterway vessels (2006/87/EC) Rhine vessel inspection regulations (RVIR)		X	
Inland waterway ordinance (Binnenchifffahrtsstrassenordnung) (BinSchStrO)	CCNR police regulations for navigation of the Rhine (RPR)		X	
Gefahrgutverordnung Straße, Eisenbahn und Binnenschifffahrt (GGVSEB)	EU directive inland transport of dangerous goods (2008/68/EC) European agreement concerning international carriage of dangerous goods by inland waterways (ADN) European agreement concerning the international carriage of dangerous goods by rail (RID) European agreement concerning international carriage of dangerous goods by road (ADR)		X	X

These laws and regulations are further described underneath.

Ship safety law (Schiffsicherheitsgesetz) (SchSG)

The Ship Safety Act applies primarily in maritime shipping, i.e. on seagoing ships that use German shipping routes. However, the provisions of the law also apply to inland waterway vessels that operate in waters on which maritime traffic law applies.

Inland water vessel investigation ordinance (Binnenschiffs Untersuchungs Ordnung) (BinSchUO)

The Inland water vessel investigation ordinance implements the CCNR RVIR and EU directive (2006/87/EC) for the river Rhine in Germany.

Inland waterway ordinance (Binnenschifffahrtsstrassenordnung) (BinSchStrO)

Requirements for the navigation on the waterways are covered by the BinSchStrO. Hydrogen bunkering is not covered but could be made possible based on special permissions from the competent authority.

Under the regime of the inland waterway ordinance, the decree for adoption of the River Rhine Police Regulations implements the RPR for the river Rhine in Germany.

Dangerous goods decree for road, rail and inland waterways (Gefahrgutverordnung Straße, Eisenbahn und Binnenschifffahrt) (GGVSEB)

The UNECE ADN and ADR (see paragraph 3.2.3) and the OTIF RID (see paragraph 3.2.3&3.2.4) are implemented in the dangerous goods decree for road, rail and inland waterways.

3.3.3.3 Land-based

An overview of relevant German environmental and hazardous goods laws and regulations is presented in the table underneath.

Table 8: Overview of relevant German environmental and hazardous goods laws and regulations (primarily land-based)

German legislation		Application area		
Title	*Description / contains transposition of (parts of)*	*Maritime*	*Inland water*	*Onshore*
Federal emission protection law (Bundesemissionschutzgesetz) (BlmSchG), Hazardous Incident Ordinance (12. BlmSchV; "Störfallverordnung")	Seveso III - Directive on the control of major-accident hazards involving dangerous substances (2012/18/EU)			X
Environmental impact assessment act (Gesetz über die Umweltverträglichkeitsprüfung) (UVPG)	Environmental Impact assessment directive (EIA) - on the assessment of the effects of certain public and private projects on the environment (2011/92/EU)			X
Renewable Energy Law (Gesetz für den Ausbau erneuerbarer Energien; EEG; 2017)	Addresses the procedures and the capacity extensions for renewable energies (of marginal interest only)	X	X	X
Energy Industry Act (EnWG) (Energiewirtschaftsgesetz; Gesetz über die Elektrizitäts- und Gasversorgung, Law on the supply of electricity and gas)	Addresses energy political aspects (of marginal relevance only)	X	X	X
4. BlmSchV (Verordnung über genehmigungsbedürftige Anlagen, i.e. the regulation on facilities subject to authorisation)	Prescribes for which facilities a permit procedure is required as well as the extent of the procedures		(X)	X
9. BlmSchV (Verordnung über das Genehmigungsverfahren)	Regulation on the procedure to obtain an operating permit for the facilities described in the 4. BlmSchV		(X)	X
12. BlmSchV („Störfallverordnung"; Hazardous Incident Ordinance; Major Hazards Regulation)	Implements 2012/18/EU (Seveso III; control of major-accident hazards involving dangerous substances		(X)	X
Betriebssicherheitsverordnung (BetrSichV; Operational Safety Regulation))	Implement directive 89/655/EWG as replaced by 2009/104/EG; it addresses the safety of all machinery and other working equipment as required by health protection. Replaces the former Druckbehälterverordnung (pressurized vessel regulation) and applies to pressurized vessels as potentially used for hydrogen service.		(X)	X

The Federal Immission Control Act (BImSchG)

The objective of the BImSchG is to protect against harmful environmental effects by air pollution, noise, vibrations and other operations. To achieve this, the BimSchG bridges the gap to other areas of legislation by requiring e.g. in § 50: "Bei raumbedeutsamen Planungen und Maßnahmen sind die für eine bestimmte Nutzung vorgesehenen Flächen einander so zuzuordnen, dass schädliche Umwelteinwirkungen und von schweren Unfällen im Sinne des Artikels 3 Nummer 13 der Richtlinie 2012/18/EU in Betriebsbereichen hervorgerufene Auswirkungen auf die ausschließlich oder überwiegend dem Wohnen dienenden Gebiete sowie auf sonstige schutzbedürftige Gebiete, insbesondere öffentlich genutzte Gebiete, wichtige Verkehrswege, Freizeitgebiete und unter dem Gesichtspunkt des Naturschutzes besonders wertvolle oder besonders empfindliche Gebiete und öffentlich genutzte Gebäude, so weit wie möglich vermieden werden". (Translation: In the case of spatially significant planning and measures, the areas intended for a specific use are to be assigned to one another in such a way that harmful environmental impacts and serious accidents within the meaning of Article 3 number 13 of Directive 2012/18/EU in operational areas on those exclusively or predominantly used for living areas and other areas in need of protection, in particular publicly used areas, important traffic routes, leisure areas and, from the point of view of nature conservation, particularly valuable or particularly sensitive areas and publicly used buildings, are avoided as far as possible.)

According to the jurisdiction of the European Court (EuGH), this has to be taken into account into the provisions of the Federal Building Law (BauG) (§§ 9, No. 23c and 24, 34) and ensure safety distances as regulated in BImSchG §3, i.e. these requirements have to be taken into account already on the level of urban land use planning and in particular in all building activities.

In consequence, all prospective operators of facilities within the scope of the BImSchG have to take into account that safety distances ("Achtungsabstände") have to be observed. These safety distances depend on the hazardous substances engaged in the activity, their mass and state in which they are processed. To calculate the safety distances, a recommendation of the Kommission für Anlagensicherheit (KAS; commission of plant safety) of the federal government has been devised (KAS-18)[13] which describes all details of the required calculation (both in the initial phase where no detailed knowledge is available as well as in a later planning phase when detailed knowledge is available.

The KAS-18 recommendations are based on a deterministic procedure representing the hazardous substance inventory by a single leak of a defined diameter (typically 25 mm) and using state-of-the-art release, atmospheric dispersion, fire and explosion models to calculate the toxic and flammable consequences in terms of ERPG-2 values, heat radiation and explosion overpressure and their range to certain limit values to derive the safety distances.

These safety distances are implemented in the urban land use plans by the local authorities and are mandatory for the permits of all newly planned facilities.

As KAS-18 is a recommendation (which nevertheless has become a de facto standard for the time being), presently an official guideline (technical guideline for safety distances ("TA Abstand") is in the discussion phase but it is open when and whether this will be published.

Environmental impact assessment act (Gesetz über die Umweltverträglichkeitsprüfung) (UVPG)

The UVPG and the Environmental Impact Assessment Act addresses the range of facilities for which an EIA is required. It applies in particular to new facilities or modification projects.

Within the UVPG, the term "environment" covers a very wide range of environmental goods to be protected, i.e.:

- people (in particular health),
- animals and plants as well as biodiversity,
- soil and water,
- air, climate and landscape as well as
- cultural heritage and other tangible goods etc.

The responsible authority decides on the necessity of an EIA and fixes details and depth of the EIA. There is an obligation for an EIA for new projects as wells as projects with a risk of major accidents.

As a result of the EIA, a detailed report has to be delivered to the authority allowing formal public objections.

[13] KAS-18: Leitfaden: Empfehlungen für Abstände zwischen Betriebsbereichen nach der Störfallverordnung und schutzbedürftigen Gebieten im Rahmen der Bauleitplanung - Umsetzung § 50 BImSchG; Kommission für Anlagensicherheit beim Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit; 2. überarbeitete Fassung; November 2010.

In Germany, the EIA Directive is transposed in the Environmental Impact Assessment Act (UVPG), the Federal Mining Act (BBergG) and the relevant ordinance on EIA (UVP-V Bergbau), the Building Code (BauGB), the Federal Regional Planning Act (ROG), and the law of the German Länder. Environmental impact assessment is integrated into the procedures for the authorisation of projects. The need for an EIA within the spatial planning procedure is decided by Länder regulation. Since March 2010, Federal legislation requires an EIA for the spatial planning procedure, if not already required by Länder legislation. The EIA act defines that if an EIA has taken place within the spatial planning procedure, the EIA within the subsequent authorization procedure can be restricted to additional impacts or other significant impacts.

The Renewable Energy Law (EEG)

The Renewable Energy Law (Erneuerbare-Energien-Gesetz EEG; Gesetz für den Ausbau erneuerbarer Energien, 2017) is addressing energy political aspects and is therefore not relevant in the context of safety related aspects. The same applies to the EnWG.

The Energy Industry Act (EnWG)

The Energy Industry Act (Energiewirtschaftsgesetz; Gesetz über die Elektrizitäts- und Gasversorgung, Law on the supply of electricity and gas) is addressing energy political aspects as well and is therefore not relevant in the context of safety related aspects.

Regulations

The 12. BImSchV (Störfallverordnung)

The requirements of the BImSchG for hazardous facilities are further detailed in the major hazard regulation (12. BImSchV, "Störfallverordnung", StörfallV; present version dated 15.03.2017) which applies to all major hazard facilities and prescribes required actions in case that the hazardous substance inventory exceeds certain limits.

If the lower limit (column 4 of app. I; for hydrogen (no. 2.44) this limit is 5,000 kg) is exceeded, the operational area ("Betriebsbereich") belongs to the "lower class" ("untere Klasse") and the general requirements (basic duties ("Grundpflichten") of the StörfallV apply, i.e. the requirements of §3 to §8.

In the case that upper limit (column 5 of app. I; for hydrogen (no. 2.44) this limit is 50,000 kg) is exceeded, the operational area ("Betriebsbereich") belongs to the "upper class" ("obere Klasse") and the extended requirements (extended duties ("erweiterte Pflichten") of the StörfallV apply, i.e. the requirements of §9 to §12. The latter includes the requirement to supply a safety report ("Sicherheitsbericht") which usually is an extended document including a detailed hazard analysis with a model simulation of a set incidents resulting from such hazards and a concept for incident prevention and mitigation. In addition, § 10 requires the presentation of an emergency preparedness plan, whereas § 11 a detailed information of the public about the existing hazards and how the public should react in case of incidents. The safety report is usually available for concerned parties and has to be brought up to date every 5 years.

Further regulations associated with the BImSchG which might be of relevance for hydrogen related operations are:

4. BImSchV: (Verordnung über genehmigungsbedürftige Anlagen, i.e. the regulation on facilities subject to authorisation) defining the range of facilities for which an operating permit is required.

9. BImSchV: Verordnung über das Genehmigungsverfahren, i.e. the regulation on the procedure to obtain an operating permit.

37. BImSchV: Verordnung zur Anrechnung von strombasierten Kraftstoffen und mitverarbeiteten biogenen Ölen auf die Treibhausgasquote (Ordinance on the offsetting of electricity-based fuels and processed biogenic oils against the greenhouse gas quota)

38. BImSchV: Verordnung zur Festlegung weiterer Bestimmungen zur Treibhausgasminderung bei Kraftstoffen (Ordinance laying down further provisions on greenhouse gas reduction in fuels)

The Betriebssicherheitsverordnung (BetrSichV)

Whereas the BImSchG and the UVPG as well as the associated regulations are of prime importance for any hydrogen related activities other legal branches shown in Figure 6 may be relevant as well.

At foremost position, the *Betriebssicherheitsverordnung* (BetrSichV; Operational Safety Regulation) has to be mentioned. It is the realisation of European law (directive 89/655/EWG as replaced by 2009/104/EG) in German law and addresses the safety of all machinery and other working equipment as required by health protection. As such, it replaces the former Druckbehälterverordnung (pressurized vessel regulation) and applies to pressurized vessels as potentially used for hydrogen service.

The BetrSichV requires that

- a thorough hazard analysis is performed for all working equipment (machinery, vessels etc.) also in abnormal operational states,
- details on incident preventive measures and mitigation means are provided,
- proper maintenance provisions are stated and documented and
- appropriate training of personnel is ensured.

Hence the requirements of the BetrSichV are in line with the requirements of the StörfallV (as far as it is applicable).

<u>Technical Guidelines</u>

TRAS

Associated to the 12. BImSchV are the technical rules „plant safety“ („Technische Regeln Anlagensicherheit“, TRAS) which are developed under the guidance of the KAS.

This set of technical rules is slowly developing and covers aspects of specific hazards, e.g. heavy rainfall and flooding (TRAS 310) or safety related rules for ammonia based refrigeration systems (TRAS 110)

So far, no TRAS is available addressing the specific hazards related to hydrogen and also not for hydrogen bunkering installations / stations for vessels.

TRBS

Associated to the BetrSichV are various guidelines (called TRBS, i.e. “Technische Regeln Betriebssicherheit”, technical rules operational safety) of which the TRBS 3151 (“Vermeidung von Brand-, Explosions- und Druckgefährdungen an Tankstellen und Gasfüllanlagen zur Befüllung von Landfahrzeugen”, avoidance of fire, explosion and pressure hazards at gas stations and gas filling systems for filling land vehicles) is the most relevant in the hydrogen context.

The TRBS 3151 defines the state of the art for all operations associated to high pressure flammable gases in particular with respect to:

- construction and storage conditions,
- explosion protection
- fire protection,
- lightning protection (Blitzschutz)
- collision protection,
- shutdown provisions and
- regular testing intervals.

For the manufacturer, certain standards and laws regarding structural safety must also be observed when building hydrogen filling stations. The manufacturer has to carry out acceptance tests, which are checked by a "notified body", usually on the basis of ISO 19880 and VdTÜV Merkblatt 514. Although these texts are not legally binding for the operator of a hydrogen site, the operator should use them as information source.

3.4 Local (Ports & Harbours)

Port & Harbour Authorities have Management bye-laws to ensure safety and the environment in the port and its surroundings and the quality of services in the port. Each port or harbour has its own bye-laws. These bye-laws sets out the powers of the harbour master and provide rules & regulations for the orderly control of such matters as navigation, mooring and handling of goods and cargo.

For example, specific rules are developed by the Port of Rotterdam Authority for LNG harbours, LNG tankers (inc. LNG bunker vessels), LNG-fuelled vessels, floating LNG fuelled electricity generation and LNG bunkering activities (truck-to-ship & ship-to-ship). The rules are related to e.g. passing distances for (inland & seagoing) LNG-fuelled vessels when they are being bunkered, risk assessment requirements for executing parallel activities when bunkering, the mandatory use of bunker checklists (by IAPH) and other safety requirements.

In addition, the Port of Rotterdam has developed a bunker map to indicate suitable LNG ship-to-ship bunker locations in the port. This map is based on a quantitative risk study in which external safety distances for several LNG ship-to-ship bunkering scenarios are calculated. Also nautical conditions (risk of collision etc.) were taken into account in the development of the map.

Similar rules & regulations for hydrogen tankers, hydrogen-fuelled vessels and hydrogen bunkering etc. do currently not exist but would need to be developed for each Port & Harbour in the Rhine corridor. The development of a hydrogen bunker map would require a quantitative risk assessment of the feasible hydrogen bunker scenarios identified in sub-activity report 1.1b. To this end, RH2INE Sub-study 1b, SuAc A3&B3 will include such a risk assessment to get insight in the external safety distance for these scenarios. More detailed studies might be required later to account for future developments in the bunkering process. Alternatively, risk studies can also be conducted on a case-by-case basis.

For Germany, as an example the Allgemeine Hafenverordnung (AHVO; general harbour regulation) of the state of North-Rhine-Westphalia can be addressed.

It covers the general operation of a harbour and the regulations for cargo handling (in particular the handling of hazardous goods and water pollutant). It does not address individual substances as hydrogen.

Local harbours may have additional regulations as e.g. the harbour of the city of Cologne, Duisburg, Neuss and Düsseldorf. Usually the local regulations refer to the state regulations and add provisions for the local conditions. The local harbour regulations are not substance specific either.

4 OVERVIEW OF RELEVANT STANDARDS/GUIDELINES

4.1 Fuel cells

IEC & ISO have developed rules and standards to cover safety and test requirements of fuel cells primarily for road vehicles and small stationary power systems. The first larger number commercial developments of fuel cells are as power sources for stationary applications for the heat and power supply with up to 1.4MW electrical output /2/. Based on these developments the IEC reviewed and expanded their technical specifications to fuel cell technologies in all applications including but not limited to stationary power, transportation, portable power and micro power applications. The IEC 62282 - Fuel cell technologies and ISO 16110 - Hydrogen generators series are recognized to be relevant for maritime applications and have been widely adopted in Germany, EU, Korea, Canada, South Africa and China, as additions to the national rules.

The most relevant standards are enlisted and briefly described below.

IEC 62282-1:2012 "Terminology"

The first part of the standard series provides uniform terminology in the forms of diagrams, definitions and equations related to fuel cell technologies in all applications.

IEC 62282-2:2012 "Fuel cell modules"

This part provides the minimum requirements for safety and performance of fuel cell modules with or without an enclosure which can be operated at significant pressurization levels or close to ambient pressure. It applies to fuel cell modules with any kind of electrolyte chemistry.

IEC 62282-3-100:2012 "Stationary fuel cell power systems - Safety"

This standard is applicable to stationary fuel cell power systems intended for indoor and outdoor commercial, industrial and residential use in non-hazardous areas, with or without the ability to recover useful heat. It applies to all kind of fuels like natural gas and other methane rich gases, fuels from oil refining, liquids and hydrogen rich gaseous. Although this part does not cover propulsion fuel cell power systems, it is applicable to marine auxiliary power systems.

IEC 62282-3-200:2015 "Stationary fuel cell power systems – Performance test methods"

This part covers operational and environmental aspects of the stationary fuel cell power systems performance for systems with an electrical output of over 10 kW (systems with less than 10kW are dealt with IEC 62282-3-201).

IEC 62282-3-300:2012 "Stationary fuel cell power systems – Installations"

This part provides minimum safety requirements for the installation of indoor and outdoor stationary fuel cell power systems in compliance with IEC 62282-3-100.

IEC 62282-7-1:2010 "Single cell test methods for polymer electrolyte fuel cell (PEFC)"

This Technical Specification describes standard single-cell test methods for polymer electrolyte fuel cells (PEFCs). It provides consistent and repeatable methods to test the performance of single cells and cell components, including membrane-electrode assemblies (MEAs) and flow plates. This Technical Specification is also available for fuel suppliers to determine the maximum allowable impurities in fuels.

IEC 62282-7-2:2014 "Single cell and stack performance tests for solid oxide fuel cells (SOFC)"

This standard describes test methods for a single cell and stack that is to be employed in power generation systems using solid oxide fuel cells (SOFCs), but is not applicable to small button cells that are designed for SOFC material testing and provide no practical means of fuel utilization measurement. It is to be used for data exchanges in commercial transactions between cell manufacturers and system developers.

ISO/DIS 14687-3:2014 “Hydrogen Fuel – Product Specification — Part 3: Proton exchange membrane (PEM) fuel cell applications for stationary appliances”

This standard specifies the quality characteristics of hydrogen fuel in order to assure uniformity of the hydrogen product for utilisation in stationary proton exchange membrane (PEM) fuel cell power systems. The purpose of this part is to establish an international standard of quality characteristics of hydrogen fuel for stationary fuel cells.

BS EN 17124:2018 “Hydrogen fuel. Product specification and quality assurance. Proton exchange membrane (PEM) fuel cell applications for road vehicles”

This document specifies the quality characteristics of hydrogen fuel and the corresponding quality assurance in order to ensure uniformity of the hydrogen product as dispensed for utilization in proton exchange membrane fuel cell road vehicle systems.

Both ISO/DIS 14687-3 and BS EN 17124 standards are not applicable to fuel cell applications for maritime and inland vessels.

ISO 16110-1:2007 “Hydrogen generators using fuel processing technologies - Safety”

Part 1 of this standard applies to packaged, self-contained or factory matched hydrogen generation systems with a capacity of less than 400 m3/h at 0 °C and 101,325 kPa, intended for indoor and outdoor commercial, industrial, light industrial and residential use. It applies to hydrogen generators using one or a combination of different fuels like natural gas and other methane-rich gases, fuels derived from oil refining, fossil fuel sources (e.g. methanol) and gaseous mixtures containing hydrogen gas. Hydrogen generators are referred to as devices that convert a fuel to a hydrogen-rich stream of composition and conditions suitable for the type of device using the hydrogen. This device can be a fuel cell power system, or a hydrogen compression, storage and delivery system. It aims to cover all significant hazards, hazardous situations and events relevant to hydrogen generators, with the exception of those associated with environmental compatibility.

These guidelines contain information on the individual components of a fuel cell as well as on the structure of a fuel cell system. Even if the primary applications are road vehicles and stationary power supplier, these guidelines may be consulted to orient fuel cell design for use on ships. In particular the regulation of different fuels, simplifies adaption to the environmentally conditions on a ship.

Since 2008 fuel cells for maritime and other purposes in Germany have been certified according to DIN EN 62282-2 which is based on the IEC 62282-2 standard. Furthermore, the existing class guidelines for fuel cell systems on ships of the DNV /3/ and of other classes /4/, /5/ contain references to the IEC standards and recommend test procedures (manufacturer and sea-trial) based on these standards.

4.2 Hydrogen storage

ISO/TR 15916 “Basis considerations for the safety of hydrogen systems”

ISO/TR 15916 gives a very useful overview of safety relevant properties and related considerations for hydrogen. Annex C gives a good and very relevant overview of low temperature effects of hydrogen on materials, and the document also suggest suitable material selection criteria including how to consider hydrogen embrittlement.

Compressed gas hydrogen storage

European standards covering pressure vessels used for pressures exceeding 0.5 bar are harmonised with the Pressure Equipment Directive (PED). EN 1252-1:1998 on storage tank materials, EN 1797:2001 on gas/material compatibility, and EN 13648 part 1, 2, and 3 on safety devices for protection against excessive pressure are some of the standards related to hydrogen storage.

ISO 15399 Gaseous Hydrogen - Cylinders and tubes for stationary storage. This standard covers cylinders and tubes intended for the stationary storage of gaseous hydrogen of up to a volume of 10,000 l and a pressure of 110 MPa, of seamless metallic or composite construction.

The EIGA-code of practice IGC 15/06 covers storage of gaseous hydrogen. IGC 15/06 on gaseous hydrogen, compression, purification, and filling into containers and storage installations at consumer site shall serve as a guide for designers and operators of gaseous hydrogen stations and reflect the best practices currently available. It includes issues such as safety of personnel, operations instructions, protection and emergency situations.

There are also some relevant American standards/ guidelines, e.g. through the American Society of Mechanical Engineers (ASME) and the National Fire Protection Association (NFPA). US standards are not harmonised with EC directives, but they can still be used for practical purposes as long as there is no conflict with the European regulations.

Liquid hydrogen storage

The IGC- and IGF Codes cover storage of liquefied gas on board ships in bulk. The IMDG code covers storage of liquid hydrogen & compressed hydrogen in packed form (e.g. containerized). The defined C-tank rules for storage of liquefied gas in bulk will in principle cover hydrogen cooled to liquefied form. Additional considerations will however be required due to the properties of hydrogen including the low storage temperatures.

ISO/TC 220 – Cryogenic vessels

This is a standard for Cryogenic vessels developed for land-based application. Set of standards in the field of insulated vessels (vacuum or non-vacuum) for the storage and the transport of refrigerated liquefied gases of class 2 of “Recommendations on the Transport of Dangerous Goods - Model regulations - of the United Nations”, in particular concerning the design of the vessels and their safety accessories, gas / materials compatibility, insulation performance, the operational requirements of the equipment and accessories.

Detection of leaks

ISO 26142:2010 Hydrogen detection apparatus - Stationary applications. This standard defines the performance requirements and test methods of hydrogen detection apparatus that measure and monitor hydrogen concentrations in stationary applications. The standard cover hydrogen detection apparatus used to achieve the single and/or multilevel safety operations, such as nitrogen purging or ventilation and/or system shut-off corresponding to the hydrogen concentration. The requirements applicable to the overall safety system and the installation requirements are excluded. This standard sets out only the requirements applicable to a product standard for hydrogen detection apparatus, such as precision, response time, stability, measuring range, and selectivity and poisoning. This standard is intended to be used for certification purposes.

4.3 Hydrogen bunkering & refuelling points

The land side part of the bunkering operation is not part of the IGF Code. Therefore, other standards for safe bunkering of the relevant fuels are needed to support the implementation of bunkering technology for use in maritime and inland shipping. The ships side of the bunkering operation (from the bunkering flange on the ship side) is covered by the IGF Code.

4.3.1 Existing standards

EN 17127:2018 “Outdoor hydrogen refuelling points dispensing gaseous hydrogen and incorporating filling protocols” defines the minimum requirements to ensure the interoperability of hydrogen refuelling points, including refuelling protocols that dispense gaseous hydrogen to road vehicles (e.g. Fuel Cell Electric Vehicles) that comply with legislation applicable to such vehicles. The safety and performance requirements for the entire hydrogen fuelling station, addressed in accordance with existing relevant European and national legislation, are not included in this document. The standard is not applicable for maritime and inland waterways hydrogen-fuelled vessels.

ISO technical committee 197 Hydrogen technologies, offering standardisation in the field of systems and devices for the production, storage, transport, measurement and use of hydrogen. The ISO TC 197 also includes a hydrogen bunkering procedure for airports.

The standard ISO 20519 “Ships and marine technology – Specification for bunkering of gas fuelled ships” covers aspects as vessel and transfer system design requirements, emergency release system (breakaway) and emergency shut-down system, hoses, bunkering connections. Although it is a standard for gas fuelled ships, the standard appears to focus on LNG. It is not applicable for bunkering of liquid hydrogen.

The guideline ISO/TS 18683:2015 - Guidelines for systems and installations for supply of LNG as fuel to ships. ISO/TS 18683 was developed to clarify the aspects of bunkering of LNG fuel in a port environment. The standard gives guidance on the minimum requirements for the design and operation of the LNG bunkering facility, including the interface between the LNG supply facilities and receiving ship. The standard provides requirements and recommendations for operator and crew competency training, for the roles and responsibilities of the ship crew and bunkering personnel during LNG bunkering operations, and the functional requirements for equipment necessary to ensure safe LNG bunkering operations of LNG-fuelled ships. The standard is applicable to bunkering of both seagoing and inland trading vessels. It covers LNG bunkering from shore or ship LNG supply facilities and it proposes methodology to calculate operational safety zones during bunkering.

The development of a similar guideline for bunkering hydrogen is currently being proposed at CEN/CENELEC. More information is provided in the following paragraph.

4.3.2 New developments

CEN/CENELEC considers developing standards on gaseous compressed hydrogen, liquefied hydrogen, methanol and ammonia refuelling points and bunkering for maritime and inland waterways hydrogen-fuelled vessels. This is currently still at proposal stage (end 2020) and the work is covered by CEN/TC 268/WG 5. For each type of fuel there will be a separate standard. The standard shall describe the technical specifications for the refueling points for maritime and inland waterways vessels. The standard will include the technical specification for the refueling system, including the nozzle and connection, male and female flanges, their geometry, dimensions and fail-safe features. In addition, the standard shall include the relevant functional requirements for the different equipment necessary for the bunkering operation, procedures, responsibilities and risk assessment scope taking into consideration the specific hazards in handling and bunkering. The standard will be made in cooperation with the international maritime organizations to ensure the interoperability of the connection in other ports outside the European Union.

The standard will be written for both seagoing and inland vessels, but a European standard for seagoing vessels is not very useful (ISO standard would be more appropriate). Furthermore, the scope is very similar to that of ISO 20519:2017 and ISO/TS 18683 for LNG bunkering. Industry bodies, such as IACS, SGMF and IAPH (see paragraph 3.1.5) could develop more practical and detailed guidance based on these standards. For instance, the bunkering guidelines they have developed for LNG bunkering are described in the following paragraph.

4.3.3 Bunkering guidelines

Over the last years, several guidelines designed to handle LNG bunkering have been published:

- IACS LNG bunkering Guidelines (No. 142) was published in June 2016. The document provides recommendations for the responsibilities, procedures and equipment required for LNG bunkering operations and sets harmonised minimum baseline recommendations for bunkering risk assessment, equipment and operations
- The Society for Gas as a Marine Fuel (SGMF) has released the “LNG Bunkering – Safety Guidelines” (Feb 2015). The document includes chapters on LNG hazards, safety systems, bunkering and specific safety guidance for truck-to-ship, ship-to-ship and bunker station to ship bunkering;

- The International Association of Ports and Harbours (IAPH) issued checklists for bunkering LNG truck-to-ship, ship-to-ship and bunker station to ship;
- Bureaus Veritas (BV) has published LNG Bunkering Guidelines;
- DNV developed recommended practice DNV-RP-G105: Development and operation of liquefied natural gas bunkering facilities provides guidance to the industry on development, organizational, technical, functional and operational issues in order to ensure global compatibility and secure a high level of safety, integrity and reliability for LNG bunkering facilities. This recommended practice provides a more in-depth practical implementation of the guidance outlined in ISO/TS 18683.

Similar guidelines for bunkering gaseous or liquid hydrogen do not exist.

4.3.4 Bunkering of gaseous hydrogen

Bunkering of gaseous hydrogen (via hose) is very different from bunkering liquid hydrogen or liquid hydrogen carriers (see also Sub-activity report 1.1b Hydrogen bunkering scenarios).

For bunkering of compressed hydrogen gas, experience and standards used in land-based applications could be relevant. A starting point will be the currently available systems for filling of hydrogen on hydrogen cars, trucks and buses, but one must be careful as filling installations for vessels could be quite different (see sub-activity report 1.1b). It must be noted that it is a misconception that maritime bunkering will be similar to automobile/truck dispensing. Vehicle dispensing at Hydrogen Refuelling Stations (HRS) include compression, cooling and very high pressures that limit the maximum flow possible. For bunkering vessels the use of a compressor or cooling is not necessarily needed and lower pressures could be used using different methods (pressure balancing with cascade filling) and thereby possibly achieving higher flow rates. Upscaling issues will definitely need to be addressed, considering the temperature requirements for safe hydrogen refuelling as too high temperatures in the receiving tanks must be avoided.

SAE J2601 is an industry standard on the protocol for fuelling road vehicles developed by SAE (Society of Automotive Engineers). It gives tables of ramp-up rate of the tank pressure during fuel transfer but its target is limited to transfers of relatively small amounts. It appears to be the only published fuelling protocol for fuelling of hydrogen vehicles up to 700 bar tanks. The SAE J2602 can be a starting point, but current ongoing standardisation initiatives should also be consulted.

Other relevant standards related to vehicles fuelling installations are:

ISO 17268:2012 "Gaseous hydrogen land vehicle refuelling connection devices"

This standard defines the design, safety and operation characteristics of gaseous hydrogen land vehicle (GHLV) refuelling connectors consisting of, as applicable, a receptacle and a protective cap (mounted o vehicle), and a nozzle. It applies to refuelling connectors which have working pressures of 110 bar, 250 bar, 350 bar and 700 bar.

ISO/TS 19880-1:2016 "Gaseous hydrogen – Fuelling stations – Part 1: General requirements"

This standard recommends the minimum design characteristics for safety and, where appropriate, for performance of public and non-public fuelling stations that dispense gaseous hydrogen to light duty land vehicles (e.g. Fuel cell Electric Vehicles). The recommendations are in addition to applicable national regulations and codes, which can prohibit certain aspects of this standard. ISO/TS 19880 is applicable to fuelling for light duty hydrogen land vehicles, but it can also be used as guidance for fuelling buses, trams, motorcycles and forklift truck applications, with hydrogen storage capacities outside of current published fuelling protocol standards, such as SAE J2601.

It provides guidance on elements of a fuelling station as hydrogen production/delivery system, delivery of hydrogen by pipeline, liquid hydrogen storage, hydrogen purification systems, as applicable and gaseous hydrogen dispensers.

5 GAP ASSESSMENT

5.1 Introduction

The objective of this chapter is to identify and describe the existing gaps found in legislation, regulations, standards & guidelines. In cases where the gaps are not yet solved, and no concrete actions to deal with the gaps are identified, work has been undertaken to attempt to suggest possible actions to deal with the identified gaps. The gaps have been classified under three categories:

Legal Gap (L):

Legal gaps are gaps for the supply and use of hydrogen in inland shipping that severely limit or even block the use of hydrogen as propulsion for ships. These gaps are typically gaps in legislation and regulations.

Harmonization Gap (H):

Harmonization gaps are gaps in the International or EU-wide harmonization of methods, rules, guidelines, provisions and safety aspects for hydrogen. Examples are standards for refuelling points and bunkering procedures.

Knowledge Gap (K):

Specific knowledge gaps are points where more research is needed in the implementation and development of the technology and use of hydrogen to be able to develop regulations. Recommendations formulated for these gaps are suggestions for improvement.

In the following paragraphs, the gaps are presented and sorted according to their key area of relevance. Therefore, the gaps have been categorized by topic, such as: bunkering, on-board storage, fuel cell system etc. and in some cases also by code/regulation where the gaps exist (e.g. IGF Code, ES-TRIN).

A study carried out by DNV evaluated remaining European Maritime Safety Agency (EMSA) gaps for completing an EU-wide framework for marine LNG distribution, bunkering and use /6/. Many of the gaps and recommendations identified in this study are also relevant for hydrogen. These relevant gaps are included in the overview in the next paragraph with specific reference to the EMSA gaps.

5.2 Overview of identified gaps & recommendations

This paragraph provides an overview of the identified gaps & recommendations for regulations & standards related to the water-side (i.e. on-board use & bunkering interface) and land-based systems for the supply of hydrogen to inland navigational vessels in the Netherlands and Germany.

5.2.1 Water-based regulations & standards

Table 9 provides an overview of the main gaps identified for regulations and standards for the use and transport of hydrogen on board of-, and bunkering hydrogen to maritime and inland navigational vessels. Some of the gaps that require further explanation are detailed in the following paragraph. Reference is made to the relevant paragraphs were the gaps are detailed or where the background is explained. It must be noted that some gaps also have relevance for land-based systems, such as bunker stations (e.g. Gap No. 9 & 11).

Table 9: Gaps & recommendations water-based regulations & standards

Gap No.	Gap description	Recommendations	Gap category	Reference
IGF Code: International code of safety for ships using gases or other low flashpoint fuels				
1a	Use of fuel cells is not regulated by IMO. Technical provisions for fuel cells are missing in the IGF Code. For specific gaps related to the fuel cell system, see under "fuel cell system" below.	Finish the ongoing development under IGF Code for detailed and prescriptive requirements for fuel cells as power generating equipment in ships. For specific related to the fuel cell system, see under "fuel cell system" below.	L, K	Par. 5.3.1
1b	Detailed and prescriptive requirements for storage (including swappable systems/containers) and use of hydrogen as fuel in ships are missing. Provisions for bunkering gaseous & liquid hydrogen (bunker station shipside etc.) are also missing. For specific gaps related to on-board storage and bunkering rules (ship side) see further down.	Integration into IGF Code is needed. Requirements for storage & use of hydrogen as a fuel must be developed. At the moment only the alternative design approach can be applied. Detailed safety studies should be undertaken to provide input to the required development. Specific attention should be given to requirements for swappable systems for storage on board. For specific recommendations related to on-board storage & bunkering rules see further down	L, K	Par. 5.3.1
ES-TRIN: European Standard laying down Technical Requirements for Inland Navigation vessels				
2a	The ES-TRIN provides general provisions for low flashpoint fuels (Ch. 30; Appendix 8) but specific construction requirements regarding hydrogen-fuelled vessels and related fuel cell systems are lacking. For specific gaps related to the fuel cell system, see under "fuel cell system" below.	Finish the ongoing revision of ES-TRIN by working group CESNI/PT/FC. For specific recommendations related to the fuel cell system, see under "fuel cell system" below.	L, K	Par. 3.2.5
2b	Detailed and prescriptive requirements for storage (including swappable systems/containers) and provisions for bunkering gaseous & liquid hydrogen (bunker station shipside etc.) are missing For specific gaps related to on-board storage and bunkering rules (ship side) see further down.	Requirements for storage & use of hydrogen as a fuel must be developed. At the moment only the alternative design approach can be applied. Detailed safety studies should be undertaken to provide input to the required development. Specific attention should be given to requirements for swappable systems (e.g. tube-containers / containers with cylinders) for storage on board. For specific recommendations related to on-board storage & bunkering rules see further down.	L, K	Par. 3.2.5
Central Commission for the Rhine (CCNR)				
3	Regulations for the use of hydrogen as a fuel on board inland navigation vessels are lacking. Hydrogen-fuelled vessels are currently not allowed to operate on inland EU waterways. An exemption statement is required that can be requested at national authorities or the CCNR, depending on the operating area. Special requirements of the CCNR are to be observed if an inland vessel will be operating in EU inland waters. RPR contains instructions aimed at conventional fuel bunkering but does	Finish the ongoing revision of ES-TRIN by working group CESNI/PT/FC and develop vessel inspection regulations in RVIR. Develop regulations for hydrogen bunkering in RPR.	L	Par. 3.2.6

Gap No.	Gap description	Recommendations	Gap category	Reference
	not cover the possibility of bunkering hydrogen. Bunkering of hydrogen on inland waterways controlled by CCNR is currently not allowed.			
Legislation in the Netherlands				
4a	Bunkering of hydrogen on inland waterways in the Netherlands is currently not allowed. Exemptions could be made possible based on special permissions from the competent authority.	Update the inland shipping law (binnenvaartwet): 1. Include the technical requirements from (updated) RVIR in appendix 1.1 (see gap 3) 2. Include technical requirements for bunker stations in appendix 3.8. Appendix 3.8 covers conventional bunkering & bunkering of LNG only and need to be updated to make bunkering of hydrogen possible on Dutch inland waterways.	L	Par. 3.3.2
4b	“Basisnet”, a nationwide appointed network for the transportation of dangerous goods, does not consider transportation of hydrogen in bulk. It must be noted that there are no limits for the transport of (mobile) tank-containers on waterways in Basisnet because the associated transport risk is considered to be very low. The probability of a leak in a container is very small that it will not contribute to the external safety risks /8/. This seems to imply that there will be no limits applicable for the transport of swappable hydrogen tube-containers on waterways with container vessels to container terminals.	Determine maximum allowable limits for transport of hydrogen and hydrogen carriers via road, rail and water. Follow developments of RIVM who launched an investigation in 2020 into the risks and effects of hydrogen and how they can be best modelled for Basisnet.	L, K	Par. 3.3.2
Legislation in Germany				
5	Bunkering of hydrogen on inland waterways in Germany is currently not allowed. Exemptions could be made possible based on special permissions from the competent authority.	Update the Inland waterway ordinance (Binnenchifffahrtsstrassenordnung) (BinSchStrO) to include regulations for bunkering hydrogen	L	Par. 3.3.3
Port & Harbour Regulations				
6a	Specific rules and regulations for hydrogen liquid tankers (including bunker vessels), hydrogen-fuelled vessels and hydrogen bunkering activities (truck-to-ship & ship-to-ship) are lacking the port bye-laws of EU Ports & Harbours.	Develop rules & regulations for hydrogen tankers (bunker vessels), hydrogen-fuelled vessels and hydrogen bunkering. Take into account (not exhaustive): passing distances for (inland & seagoing) hydrogen-fuelled vessels when they are being bunkered, risk assessment requirements for executing parallel activities when bunkering, the use of bunker checklists and other safety requirements.	L, K	Par. 3.4

Gap No.	Gap description	Recommendations	Gap category	Reference
		In addition, consider developing a bunker map with suitable (ship-to-ship) liquid hydrogen bunker locations taking into account external safety and nautical conditions. Detailed quantitative risk assessments are needed to develop the map. This is nice to have and the need for a bunker map would depend on market developments. Suitable locations can also be determined on a case-by-case basis (with means of location-specific risk assessments etc.)		
6b	Audit & Accreditation criteria for hydrogen bunker operators do not exist.	The IAPH could develop audit and accreditation tools to recognize good hydrogen bunkering operators as they also have done for LNG (only needed when market becomes more mature).	L, K	Par. 3.1.5.1
Bunkering				
7	Rules for bunkering liquid hydrogen do not exist for the shipside of the bunker process.	Bunkering rules for the shipside liquid hydrogen bunkering process need to be developed. Rules need to be incorporated in relevant regulations & codes (i.e. IGF, ES-TRIN) Risk studies and a qualification process are needed to develop rules. Performa review of experiences and standards for bunkering of liquid hydrogen onshore and verify applicability of current approach and rules for bunkering of LNG.	L, H, K	Par. 5.3.2
8	Bunkering procedures & checklists for liquid hydrogen do not exist.	Bunkering procedures for liquid hydrogen can be developed by organisations such as IACS, SGMF or class societies once the relevant international (ISO/CEN) bunkering standards/guidelines have been published (see gap 9). Bunkering checklists for different bunkering configurations (Truck-to-Ship (TTS), Ship-to-Ship (STS), bunker station to ship etc.) can be developed by IAPH.	L, H, K	Par. 4.3.3
9	International standards for hydrogen refuelling points and bunkering for maritime and inland vessels do not exist.	CEN/CENELEC considers developing standards on gaseous compressed Hydrogen, liquefied hydrogen, methanol and ammonia refuelling points and bunkering for maritime and inland waterways hydrogen-fuelled vessels. Work will be covered by CEN/TC 268/WG 5. However, a European standard for maritime (seagoing) vessels is not very useful. It is therefore recommended that ISO develops a technical hydrogen bunkering standard/guideline.	L, H, K	Par. 4.3.2
10	Bunkering procedures & checklists for gaseous hydrogen do not exist.	Review applicability of land-based standards to maritime use. Risk studies and a qualification process to develop bunkering procedures. Bunkering procedures for gaseous hydrogen can be developed by organisations such as IACS, SGMF or class societies once the relevant international (ISO/CEN) bunkering standards/guidelines have been published (see gap 9). Bunkering checklists can be developed by IAPH.	L, H, K	Par. 5.3.2 Par. 4.3.4 Par. 4.3.3

Gap No.	Gap description	Recommendations	Gap category	Reference
11	An EU harmonized approach for risk assessment (including criteria) for non-Seveso hydrogen small scale establishments and bunkering activities (e.g. truck-to-ship, ship-to-ship) is lacking.	Develop an EU harmonized approach for risk assessment (including criteria) for non-Seveso small scale hydrogen establishments and bunkering activities. Ideally establish specific EU-wide fixed safety distances for the same type of installation / activity to serve as a simplified guide for full harmonised permitting of hydrogen as fuel related activities (e.g. bunkering). This would enhance the permit procedure in terms of permit process duration, improve permit acceptance probability and would allow operators to select suitable locations more efficiently.	L, H	EMSA Gap 9.1 /6/
12	Indicators for determining common operational safety distances for hydrogen bunkering are currently missing.	The concept of safety zones and the approach to define the limits should be accounted for in bunker procedures and international standards (e.g. ISO).	L, H	EMSA Gap 9.3b /6/
13	Safety requirements for simultaneous hydrogen bunkering and loading / unloading or passenger embarking / disembarking processes are missing.	Perform risk assessments and define a common and clear approach via international guidelines or technical specifications to address simultaneous operations (SIMOPS) in a risk assessment (e.g. QRA).	L, H, K	EMSA Gap 9.2 /6/
On-board storage				
14	Qualification for (swappable&fixed) on-board storage pressure tanks with compressed hydrogen gas is lacking. Rules and requirements for use of swappable containers on board ships do not exist.	Perform qualification of pressure tanks for use in maritime and inland shipping. Safety studies considering hydrogen pressure tanks and requirements for safe solutions. Development of provisions for possible high pressure storage technologies in enclosed areas. Specific attention should be given to requirements for swappable systems (e.g. tube-containers / containers with cylinders) for storage on board (inland) vessels. The latter recommendation is in particular relevant for the update of ES-TRIN because swappable containers is considered as short-term scenario for inland shipping (see Sub-activity report 1.1b).	L, H, K	Par. 5.3.3
15	There is a lack of understanding of failure modes for liquid hydrogen tanks.	Possible storage related failure modes need to be under-stood, and land-based solutions adjusted (if necessary) for safe application in shipping.	K	Par. 5.3.3
Fuel cell system				
16	There is insufficient understanding of the safety aspects concerning release of hydrogen within the fuel cell system.	Perform a review of and update of fuel cell rules and regulations. Risk studies are recommended to improve understanding of possible safety critical scenarios including fire and explosion to recommend controlling measures.	L, H, K	Par. 5.3.4
17	Ventilation requirements for fuel cell rooms are not validated for hydrogen.	Perform relevant and realistic hydrogen dispersion simulations needed to evaluate and/or update ventilation requirements. Hydrogen specific properties must be considered.	L, H, K	Par. 5.3.4
18	Fuel cells open for new arrangement and vessel design solutions challenge existing rules & regulations.	Improve understanding of system design issues and new technology that challenge existing rules & regulations.	L, K	Par. 5.3.4
19	Knowledge basis for requirements for handling of liquid hydrogen in piping to fuel cell system is lacking.	Perform knowledge and safety assessments to identify the needs to adjust LNG requirements for the use of liquid hydrogen.	L, K	Par. 5.3.4

Gap No.	Gap description	Recommendations	Gap category	Reference
Ship life phases				
20	There is a lack of best practices, procedures, codes or similar regarding safe handling of on-board hydrogen and fuel cell installations in all the life phases of a ship. Crew training requirements for use of hydrogen in shipping do not exist.	Develop procedures for commissioning, docking, operation, maintenance and scrapping reflecting the properties of hydrogen. In addition, consider developing safety training. For instance, training might be required for (inland) ship operators who need to disconnect and connect swappable containers (frequently) to the fuel cell inlet piping system who need to be aware of the risks and how to manage those. Guarantee that crew training requirements for hydrogen exist for inland shipping operators.	L, H	Par. 5.3.5 EMSA Gap 10.1 /6/
Hydrogen safety				
21	There is insufficient understanding of hydrogen safety aspects for rules development.	Perform comprehensive safety studies considering hydrogen specific properties, behaviour and conditions needed for the use of hydrogen in shipping. The results should be used as input to development of relevant codes, e.g. IGF Code, ES-TRIN and Class rules.	L, K	Par. 5.3.6
22	There is a lack of understanding of properties and conditions affecting safety of liquid hydrogen in shipping applications.	Perform comprehensive safety studies for liquid hydrogen taking into account the temperature effects on steel, liquid hydrogen evaporation and simulations of hydrogen leak scenarios to determine the hazardous zones.	L, K	Par. 5.3.6

5.2.2 Land-based regulations & standards

5.2.2.1 The Netherlands

This paragraph provides an overview of identified gaps in the external safety regulations and regulations for safety distances to vulnerable objects, applicable in the Netherlands and recommendations to address these gaps. No major gaps have been found in the laws as they are generic and cover the permitting of any installation with hazardous goods, including hydrogen. Most gaps are related to missing technical guidelines that are needed by regulators to verify if the technical and (external) safety requirements are met, thereby resulting in a more efficient permitting process.

The identified gaps & recommendations are provided in the table below.

Table 10: Gaps & recommendations land-based regulations & standards (the Netherlands)

Gap No.	Gap description	Recommendations	Gap category	Reference
Decree on general rules for environmental management of facilities, activities decree / PGS guidelines				
23	A PGS guideline for the safe design and operation of a hydrogen bunker station is missing (see paragraph 3.3.2.2)	Depending on market developments, the Dutch national standardisation body NEN should consider developing PGS 35-2: hydrogen bunker stations. This offers uniformity of regulations that are important for the granting of permits, and the guidance and transparency it provides for the granting of permits for the construction and operation of a hydrogen bunker station. Also consider including requirements for truck-to-ship bunkering operations.	L, K	Par. 3.3.2.2
24	Guidelines for maintenance and repairing hydrogen fuel engines / fuel cell systems on inland vessels are missing in PGS 26.	The PGS program council is currently considering to include hydrogen in PGS 26. PGS 26 is a guideline for safe stalling, maintenance and repairing CNG and LNG road vehicles. Although the guideline is written for road vehicles, the new environmental legislation in 2022 (Bal)	L, K	Par. 3.3.2.2

Gap No.	Gap description	Recommendations	Gap category	Reference
		specifies that PGS 26 is also applicable for the maintenance and repair of fuel engines of maritime & inland vessels. Consider including specific requirements for maintenance and repairing hydrogen fuel engines / fuel cell systems on inland vessels.		
Bevi				
25	Small-scale hydrogen bunker stations (less than 5 ton storage, Brzo lower-tier threshold) & truck-to-ship bunkering is currently not regulated by Bevi / Bkl as they are not defined as categorial establishments / activities.	Consider one of the following: • Include fixed external safety distances in Revi / Bkl • Recommend to authorities to always ask for a QRA and regard these installations as part of Bevi (this is also the practical approach for years for small-scale LNG installations not cov-ered by Bevi) • Develop an EU harmonized approach for risk assessment (including criteria) and definition of external safety distances – see gap no. 11	L, H	Par. 3.3.2.2
QRA calculation guidelines				
26	A specific QRA calculation guideline for hydrogen bunker stations is missing.	It is recommended that the RIVM develops a QRA calculation guideline for hydrogen bunker stations (also include truck-to-ship bunkering) supplying hydrogen as a fuel to (inland) vessels, because the way of calculating the risk of hydrogen releases differs compared to other substances (e.g. related to ignition probability, outflow modelling). Reference is made to a memo from the RIVM on the risk and effect distances of HRS /10/. This will ensure a national harmonized approach towards the calculation of external safety risks. Note: a specific guideline for LNG bunker stations was developed in 2014. A similar guideline could be developed for hydrogen depending on market developments.	L, H	Par. 3.3.2.2
27	The QRA calculation guideline for container terminals is included in the Reference Manual /9/, module C, chapter 5 does not seem to specify failure scenarios for compressed hydrogen tube-containers nor containers with cylinders.	Update the QRA calculation guideline for container terminals to include specific scenarios related to hoisting and storage of tube-containers (or containers with pressurized gas in general). The current assumptions related to gas tank-containers are actually based on liquified gas and do not seem to be applicable for e.g. pressurized hydrogen gas in tube-containers. In addition, the design and strength (e.g. wall thickness of the tube/cylinder) of such containers is very different to a liquefied gas tank-container and therefore the failure scenarios & frequencies may not be appropriate.	L, H	Par. 3.3.2.2

5.2.2.2 Germany

This paragraph provides an overview of identified gaps in the external safety regulations and regulations for safety distances to vulnerable objects, applicable in the German part of the Rhine-Alpine corridor (case study North Rhine-Westphalia) and recommendations to address these gaps.

The German legal framework (see Figure 6 in paragraph 3.3.3) comprises of four levels:

- **Level 1: Laws:** This level does not refer to specific substances (e.g. hydrogen). As such only very general gaps can be identified.

- **Level 2: Regulations:** these usually refer to hazardous substances as hydrogen, but on this level hydrogen is one under many hazardous substances (e.g. in the 12. BImSchV only limit amounts for class assignment are given for hydrogen).
- **Level 3: Technical rules and guidelines** (e.g. TA Luft; TRBS): may be substance specific. Usually they address hydrogen, but usually limited to certain application areas. Gaps may be existing.
- **Level 4** includes official and semi-official standards and recommendations, which have gained a more or less official acceptance; conformance of a permit application may be requested by the authorities, e.g. for KAS-18. As this level is substance specific, gaps with respect to hydrogen are identified.

The subsequent table below contains the gaps identified and recommendations to solve these gaps.

Table 11: Gaps & recommendations land-based regulations & standards (Germany)

Gap No.	Gap description	Recommendations	Gap category	Reference
BImSchG / BauG				
28	BImSchG is missing adequate treatment of hydrogen (e.g. a specific hydrogen related BImSchV)	Clarify if any additions to BImSchG (e.g. a specific hydrogen related BImSchV) in the context of the BauG may be required to address all hazards related to hydrogen)	L	Par. 3.3.3.3
12. BImSchV				
29	12. BImSchV does not provide adequate treatment of hazards due to very low temperature or very high pressure hydrogen	Check if liquid hydrogen needs specific treatment in the 12. BImSchV in terms of potential hazards due to very low temperature or very high pressure hydrogen (GH2 falls under pressurised gases, i.e. it is included)	L	Par. 3.3.3.3
30	Technical details providing TRBS guidance for the specific hazards of hydrogen and hydrogen bunkering installations or bunker stations for vessels are missing	Provide TRBS guidance addressing the specific hazards of hydrogen and hydrogen bunkering installations or stations for vessels.	L, K	Par. 3.3.3.3
BetrSichV				
31	Treatment of the specific hazards of liquid hydrogen in the BetrSichV and in the associated TRBS are missing	Ensure that the specific hazards of liquid hydrogen are addressed appropriately in the BetrSichV and in the associated TRBS set of technical rules	L, K	Par. 3.3.3.3
KAS-18 (“TA Abstand”)				
32	A technical guideline for definition of safety distances (“TA Abstand”) is missing (hazards of hydrogen should be taken into account)	At present, KAS-18 is just a recommendation without regulative validity. A regulation (“TA Abstand”) should be released which addresses the hazard of hydrogen and recommends models suitable for this application.	L, K	Par. 3.3.3.3

5.3 Gaps in detail

5.3.1 IGF Code

The IGF Code entered into force on 1 January 2017. It is separated into two kinds of chapters: fuel specific and fuel independent chapters.

The IGF Code is mandatory for all gases and other low flashpoint fuels. However, for the time being, the fuel specific part only contains detailed requirements for natural gas (LNG or CNG) as fuel. The IGF Code will also need to be developed to cover other fuels like hydrogen which is used in fuel cell application. For gases like hydrogen, the IGF

Code Part A requires the alternative design method in accordance with SOLAS Regulation II-1/55 to be used demonstrating an equivalent level of safety.

A phase 2 development of the IGF Code initiated by IMO and the CCC subcommittee is currently developing technical provisions for fuel cells. Fuel cells will be a new part E. This is aimed to be included in the IGF Code at its first revision, which is due to take place within the 4-year cycle for SOLAS revisions. During the development of these technical provisions it should be considered that the fuel cells power systems differ dependent on the used technology, e.g. PEM or SOFC. The technical provisions under development should be technology independent but cover the safety relevant aspects of a fuel cell application. The IGF Code should be open for new developments within this fast-developing segment of fuel cells.

The main gaps related to the IGF Code are summarised below. The specific gaps related to bunkering are covered in paragraph 5.3.2 and the specific gaps related to the fuel cell system are covered in paragraph 5.3.4.

IGF Code gap 1a: Technical provisions for fuel cells are missing. Use of fuel cells is not regulated.

Finish the development under IGF Code for detailed and prescriptive requirements for fuel cells as power generating equipment in ships.

<u>Legal</u>

Use of fuel cells is not regulated. Continued work agreed under the IGF Code working group.

<u>Knowledge</u>

Detailed safety studies needed for fuel cell room and safety system design.

IGF Code gap 1b: Detailed and prescriptive requirements for storage and use of hydrogen as fuel in ships are missing.

<u>Legal</u>

Use of LFL fuels is regulated by the IGF Code from Jan 2017, but detailed requirements for hydrogen storage and use are lacking. Development is ongoing for detailed provisions for methyl/ethyl alcohols, but not for hydrogen. For hydrogen only the alternative design approach exists.

<u>Knowledge</u>

Detailed safety studies should be undertaken to provide input to the required development.

5.3.2 Bunkering

In general, bunkering interfaces to ship systems (ship-to-ship, truck-to-ship) must be discussed with the port authority, as no uniform approach by different ports & harbours & EU member states exists. Port and local (land-based) authorities may require a QRA as part of their approval.

Gap 7: Bunkering rules for liquid hydrogen do not exist

<u>Legal</u>

Bunkering rules for liquid hydrogen do not exist. Based on this, the ship side of the bunkering process will have to be approved following the alternative design approach as specified in IGF Code and in ES-TRIN. Current rules for bunkering of LNG is based on cryogenic insulation to protect the ship steel from spills and leakages in the bunkering station and double piping when going inside the vessel. This, together with experiences for bunkering of liquid hydrogen onshore would form a knowledge basis for establishing the first requirements for bunkering of liquid hydrogen to a ship. It is uncertain to what degree the solutions developed for LNG will be feasible and applicable for liquid hydrogen. It is possible that N2 filling of voids/double pipes may be required or be necessary. A water curtain on the shipside is required for bunkering of LNG according to IGF, and this is likely to be expected for liquid hydrogen as well.

Harmonisation

There is a need to develop bunkering rules (ship side) for liquid hydrogen.

Knowledge

Ships have more dynamic loads compared to land applications. Ships will require certain ductility (need certain margins) for the materials applied. It appears to be new territory to establish the most appropriate ways to test the ductility for the low temperatures of liquid hydrogen. Applicable land-based industry standards and applications should be reviewed and be used as input. Then a tailored qualification process can be undertaken focusing on the additional challenges for low temperature use on ships. As an example, ship-based applications might require thicker materials. The general approach for approval for use on board ships requires testing for each ship to ensure that the material specification is correct. Use down to -165°C has been validated, but there is very limited experience for the much lower temperatures required for liquid hydrogen storage. Material certification at cryogenic temperatures requires testing of material at relevant design temperature including a margin to verify the materials' properties. For design temperatures equal to liquid hydrogen, testing procedures according to standard certification may be challenging and require further considerations. Gas dispersion and safety analyses will be needed to build knowledge on liquid hydrogen leak behaviour.

Knowledge whether the very low temperatures required for liquid hydrogen bunkering will demand different solutions and materials than LNG (see also harmonization above) is therefore needed. It is uncertain to what degree the very low bunkering temperatures will result in higher susceptibility for unwanted temperature/pressure deviations in the bunkering line. Another issue that call for improved knowledge is the potential vapor dispersion in case of accidental LH2 release.

Gap 10: Bunkering procedures for compressed gaseous hydrogen do not exist

Legal / Harmonization

The land side of the bunkering process is not part of the IGF Code / ES-TRIN. There is some experience with bunkering of gaseous fuels to ship applications and there is also some limited experience with bunkering of small hydrogen gas volumes. In addition, current standards and practices from land-based applications can provide relevant input, and experiences from use of natural gas will be useful, but a need for regulations as well as harmonization for maritime and inland bunkering is anticipated.

There is a need to develop procedures for bunkering of compressed gaseous hydrogen.

Knowledge

Issues related to upscaling of the systems currently available for filling of hydrogen cars and trucks/ buses need to be explored and the technology need to be qualified for larger filling volumes and relevant marine impacts. It must be noted that it is a misconception that maritime bunkering will be similar to automobile/truck dispensing (see paragraph 4.3.4). Further risk studies (including evaluation of gas leaks, gas dispersion, and relevant consequences) and a qualification process to ensure development of applicable requirements are needed to provide input to standardisation work.

5.3.3 On-board storage

Gap 14: Qualification is needed of (swappable & fixed) pressure tanks with compressed hydrogen gas for use in maritime & inland shipping

Legal

The possible allowed locations of pressure tanks are still an open issue. To date there have been limitations regarding such storage in enclosed areas (below deck areas). Different solutions have been seen in the past. As an example, the Alsterwasser in Hamburg was approved with pressurized hydrogen tanks below deck. This approval was based on a previous GL guideline /7/ (formally not rules), which now can only be used on legacy GL classed ships. The guideline did not require a FMEA, however a FMEA is required according to the IGF Code. The design criteria were prescriptive. The current DNV Fuel Cells rules have kept the principles from the first issue of the DNV fuel cell Rules and the prescriptive requirements for ship design, piping fuel storage from the GL guideline. The current DNV fuel cell rules allow for storage in enclosed spaces if certain conditions are satisfied. This will require a case by case assessment. The rules are developed with hydrogen in mind, but do not contain specific provisions for high pressure hydrogen storage technologies for fixed or swappable containerized solutions.

With respect to swappable systems, such as tube-containers or containers with cylinders, there are some concerns:

- The exact solution is unknown (an additional novel item to a novel technology);
- There is an increased risk for leakages as less welded connections are possible and the main tank pipe connections are frequently disconnected;
- In ships, normally the ship components are approved and surveyed during the lifetime as part of the ship. A different quality assurance survey regime needs to be established;
- The safety systems should normally be part of the vessel. It is unclear what does that mean in term of locating the fire detection and extinguishing;
- For compressed hydrogen the tank shall be connected and disconnected to the vent system (a critical safety system that should not be subject to frequent manipulations);
- The container is an enclosed space that increases the risk for explosions in case of a hydrogen leak scenario.

These concerns were discussed with the RH2INE consortium in a workshop (see sub-activity report 1.1b). The conclusion was that all of the above concerns were already addressed during the design of a pilot project and can be overcome. Details about the solutions were not discussed and should be addressed when developing the rules.

Harmonisation

Further qualification activities are needed to qualify pressure tanks for on-board use with compressed hydrogen gas. Existing pressure vessel rules as well as rules for compressed natural gas will apply and provide valuable input. This includes ADR, ADN, the European Transportable Pressure Equipment Directive (1999/36/EC – “TPED”), and the standards given in paragraph 4.2. Pressure tanks approved for use as cargo roads and inland waterways will not automatically be approved for use on ships. There are different standards with different approval conditions that could be used as basis.

Further work is therefore required to develop harmonized requirements for use of compressed hydrogen gas on-board ships. Specific attention should be given to swappable storage solutions (containers).

Knowledge

More documentation providing an improved understanding regarding safety related behaviour of hydrogen is needed. This includes safety studies considering hydrogen leakage and pressure tank requirements to establish the conditions required to consider these sufficiently safe. One example is ventilation requirements. The IGF Code / ES-TRIN requires equivalent safety. This can be challenging to demonstrate. In the process required, it will be important to utilize existing experiences gained from industrial use and use of hydrogen the land-based transport sector (for example for cars and buses).

Considering that hydrogen can behave different from other gases including natural gas, it is important to include H2 properties in the safety assessments. Important and relevant properties include the low ignition energy and wide flammability range. Will it be possible to keep H2 concentrations below the flammable limit in case of a leak, and if not how should the situation be handled? Risk reducing measures will be important to evaluate. There are many possible measures and their efficiency/effect should be evaluated, one example is the possibility to use inert gas. Another whether existing equipment and criteria are sufficient, and whether risk assessments are needed to validate and/or adjust existing criteria.

A range of solution including different materials to contain pressurized hydrogen is available and new materials are under development and coming into the market. For all these, maritime and inland shipping experience is lacking. Similarly as for cars and buses, weight is also an issue for shipping applications, hence making low weight solutions attractive. Hydrogen fuel cell cars are currently available with storage tank pressure of up to 700 bar (e.g. Toyota Mirai and Hyundai ix35 FCEV). For such applications traditional and rather heavy steel tanks will typically be less attractive than light weight composite tanks.

In this context it is important to understand the possible interactions between hydrogen and different materials. Possible challenges that need considered include how the materials endure long term expo- sure from relevant marine conditions (e.g. weather impacts, temperature ranges, stresses, corrosion). Pressure tanks also have to be designed for cycling within defined pressure ranges to ensure durability of interior liners.

Gap 15: There is a lack of understanding of failure modes for liquid hydrogen tanks

Knowledge

For storage of hydrogen in the liquid form, there is uncertainty regarding possible failure modes, for example consequences of losing vacuum insulation of the liquid storage tanks when used in a ship application. Further understanding and knowledge of possible failure modes is to be documented.

Ships have more dynamic loads compared to land applications. Ships will require certain ductility (need certain margins) for the materials applied. It appears to be new territory to establish the most appropriate ways to test the ductility for the low temperatures of liquid hydrogen. Applicable land-based industry standards and applications should be reviewed and be used as input. Then a tailored qualification process can be undertaken focusing on the additional challenges for low temperature use on ships. As an example, ship-based applications might require thicker materials. The general approach for approval for use on board ships requires testing for each ship to ensure that the material specification is correct. Use of temperatures down to -165°C has been validated, but there is very limited experience for the much lower temperatures required for liquid hydrogen storage (-253 °C).

5.3.4 Fuel cell system

Gap 16: There is insufficient understanding of the safety aspects concerning release of hydrogen within the fuel cell system

Legal

Currently, equipment that are not explosion protected may be accepted in a fuel cell (FC) room provided that the ventilation rate is sufficient to avoid gas concentrations in the flammable range in all leakage scenarios. There is uncertainty whether this is the best solution and further evaluation is needed. These evaluations need to consider the relevant safety aspects.

Use of hydrogen fuel cells in shipping may be in a hybrid configuration together with batteries. In this case both the fuel cell rules and the battery rules will apply, possibly with overlaps or interference. The current Classification battery rules might be of relevance also in the context of fuel cell installations. A review of the battery rules in the context of hydrogen and fuel cells will therefore be relevant; to harmonize safety requirements and to gather synergies and learning points.

Knowledge

More knowledge is needed to close the current legal gaps. Further knowledge of hydrogen behaviour and possible safety critical scenarios including fire and explosion is needed to recommend the most efficient risk controlling measures.

Hydrogen ignition and explosion scenarios in the case of a fuel leakage are an area requiring more knowledge. This includes, but is not limited to, issues such as fuel cell compartment interior design, ventilation and flow dynamics inside the fuel cell compartment, double wall piping forced ventilation systems, ignition sources such as static electricity from high pressure gas forced through material cracks etc.

A risk-based approach would be useful in order to develop an understanding of the total risk picture. A risk-based approach can be used to identify possible leak sources/locations and sizes as well as possible causes of ignition. Together with simulations of gas releases, such an approach can help highlight the effects of measures as gas detection, shutdown (ESD), shutdown times, location of possible ignition sources and more.

Simulations of relevant releases of flammable gas in a FC room context can improve knowledge and understanding of the relevant safety aspects. As an example, such simulations can be used to assess the dispersion of flammable gas and the effect of ventilation in the room. This can provide an understanding regarding whether ventilation can lead to maintaining hydrogen concentrations below flammability limits in case of leak from the FC system.

To improve calibration and validation of current simulations tools, larger scale experiments of relevant dispersion/fire/explosion scenarios are needed. In the context of this project, the case considered most relevant is to evaluate the FC room and its relevant ventilation conditions. Similar large-scale experiments have previously been undertaken for LNG at the DNV Spadeadam test site in the UK. There is a need to develop similar knowledge for hydrogen.

Structural strength of walls and decks to withstand explosions may be requested demonstrated, or alternatively; explosion hatches may be required. Calculation models for structural response to hydrogen explosions need validating experiments to improve predicting capabilities. Solutions regarding possible handling of explosion overpressures need to be explored. Such solutions could include pressure release panels, in which case technology for such panel design and in maritime & inland shipping environments are needed.

Gap 17: Ventilation requirements for fuel cell rooms are not validated for hydrogen

Legal

For LNG, the ventilation requirement is said to be 30 air changes per hour for the room. Hydrogen has different properties to LNG related to flammability and how easily hydrogen might ignite. Due to the differences in properties and behaviour between LNG and hydrogen, the most appropriate requirements for safe handling of hydrogen might be different for the same for LNG. The safety related basis for this requirement therefore need further validation.

Knowledge

It appears that the 30 air change per hour criteria is not based on calculations of real scenarios; hence it is not scientifically based. More knowledge is therefore required on how different ventilation conditions (air change per hour and possibly varying ventilation conditions in a fuel cell room) might affect the likelihood of ignition, fire and explosion in case of leakage of a flammable gas.

The properties of hydrogen are in many ways different to natural gas. Hydrogen has a wider range of flammability, it is easier to ignite and it is lighter.

Ventilation is considered a potentially key main barrier towards unsafe situations, but the knowledge regarding the efficiency of ventilation to prevent unwanted hydrogen incidents are lacking.

Due to the properties of hydrogen, efficient detection and possible shutdown by ESD will be important in order to minimize the leak volumes of flammable gas. The safety system needs to be efficient to minimize the risk for ignition/fire/explosions. Efficient ventilation can reduce the concentration of flammable gas, but unless carefully considered, it could also dilute flammable gases to a more ignitable concentration range. Careful risk-based evaluations are therefore critical to obtain an optimal design. Vent panels can be a solution to prevent worst case consequences of explosions.

Many experiments with hydrogen are performed in research projects, however due to the many different properties, it is recommended to perform dedicated experiments in a realistic fuel cell room, and/or perform simulations.

Gap 18: Fuel cells open for new arrangement and vessel design solutions challenge existing rules & regulations

New design issues and system solutions that accompany fuel cells and novel fuels challenge the existing rules and regulations. The below is a list (not exhaustive).

Knowledge / Legal

The modularization offered by fuel cells offer several interesting vessel design aspects, such as improved safe-return-to-port solutions through power autonomous zones. The decentralization of power will also likely minimize the energy content of fuel leakages from any given system and thus helps limiting the consequences of a leakage scenario. However, decentralization of power systems challenges the current IMO / SOLAS regulations which in principle require centralized arrangements of power generation systems.

Some FC suppliers request classification societies to develop system type approval schemes due the modular nature of some FC's. Standards for interfaces and integration would then be an issue, as well as international agreed definition of system interfaces and compartments and zones in relation to fuel cells (what is included in the fuel cell delivery, what is vessel interior). Fuel cell installation guidelines will need to be developed.

Documentation of total efficiency, operational functionality and reliability of combined and hybrid systems are much asked for in the industry, such as different combinations of FC's with waste heat recovery units and batteries, and in combination with incumbent technology. Demonstration project is suggested or similar manner of documentation, such as through modelling & simulation.

Prescriptive requirements for fuel cells which open for different technical solutions without need for separate safety cases is much wanted.

Development of more compact fuel cell systems in cooperation with regulative developments are much wanted, to accelerate and ease the development of fuel cell systems thereby increasing rate of technology uptake in shipping.

Gap 19: Knowledge basis for requirements for handling of liquid hydrogen in piping to fuel cell system is lacking.

Legal / Knowledge

Double walled vacuum insulated pipes are currently being applied for LNG. A similar solution could be feasible for liquid hydrogen, but this would need to be validated. It is uncertain whether the solution ap- plied for LNG will provide sufficient cooling to avoid unwanted evaporation of liquid hydrogen in the pipes. It is anticipated that some liquid hydrogen will evaporate, and the system need to be designed to handle this safely. Alternatives including re-liquefaction or other handling needs should be considered.

5.3.5 Ship life phases

Gap 20: There is a lack of best practices, procedures, codes or similar regarding safe handling of on-board hydrogen and fuel cell installations in all the life phases of a ship.

The phases of a ships life may be divided into:

- New-build/retrofit
- Commissioning and testing
- Operation including maintenance
- Docking
- Scrapping

Legal / Harmonisation

Generally, there is seen a need to establish best practices, procedures, codes or similar regarding safe handling of on-board hydrogen and fuel cell installations in all the phases listed above. Issues include, but are not limited to:

- Gas tanks may need to be emptied during docking;
- Liquefied hydrogen tanks may need to be specially considered regarding pressure build up during docking;
- Requirements for safety and procedures in relation to maintenance on parts of the systems, where gas is still present in other parts of the system;
- Recommended practices/ procedures for handling H2 and other LFL equipment should be developed;

In addition, specially developed safety training may be required. For instance, training might be required for (inland) ship operators who need to disconnect and connect swappable containers (frequently) to the fuel cell inlet piping system. The high risk associated with use of swappable containers on board is during the disconnect and connect of the flexible hose(s) to the fuel system on board.

5.3.6 Hydrogen safety

Gap 21: Insufficient understanding of hydrogen safety aspects for rules development

In the future hydrogen is foreseen to be covered by the rules of classification societies. Currently there is a gap as not all rules include hydrogen specific requirements for which more knowledge is required. The following summarize other knowledge gaps related to hydrogen as fuel.

Knowledge / Legal

Further studies are required to develop safety related understanding of properties and conditions affecting safety of hydrogen in shipping applications. This includes validation of current models used to study hydrogen behaviour and the study assumptions. The results should be used as input to development of relevant codes, e.g. IGF Code, ES-TRIN and Class Rules. The following gives examples of needed activities:

- Relevant leakage scenarios need to be determined, preferably based on experience data and hazard/risk-based assessments. Assessments can include consideration of likelihood of gas detection, valve (ESD) shut-down etc. Input to be considered includes typical volumes of interiors of fuel cells, pipe volumes, ESD valve locations, pipe pressures etc. Experience data and practices from other hydrogen applications should be examined for relevance e.g. data relating to leak frequencies and ignition probabilities;
- Permeability of hydrogen and possible consequences need to be considered in specifications of permitted materials;
- Leak detection, fire and explosion risk including differences between hydrogen and natural gas behaviour (e.g. higher buoyancy, range of flammability);
- Hydrogen leaks in enclosed spaces. Simulation of different ventilation conditions (preferably with validated CFD-codes) to determine how risk for ignition and explosive atmospheres can be minimized. Simulations to determine design scenarios regarding fire and explosion. Improve understanding of hydrogen dispersion and fire behaviour compared to other gases (e.g. effects of high flame temperature and radiation, invisible flame). Use this as input to evaluate design and risk reduction measures. With improved understanding and models, practical guidelines and standards can be obtained. These can cover design of ventilation systems, room and ceiling shapes, explosion release vent panel dynamics and design, room volumes impact on risk, gas detection strategies and design, leak control with ESD and pressure relief philosophy, active and passive fire protection philosophy and design, as well as emergency response and extinguishing strategies;
- There is uncertainty regarding whether hydrogen in double piping should be a recommended or required safety provision for hydrogen in enclosed spaces, or if double piping might add a safety risk by confining hydrogen leaks and may be reducing the possibility for quick dilution and lowering of hydrogen concentration. Due to the risk of ignition even without active ignition sources, it must be considered if only nitrogen filled double piping can be accepted (and not ventilated double piping as used for natural gas);
- Hydrogen leaks outdoors; determine relevant leak and environmental conditions (e.g. wind conditions) and their effects. Simulations to establish requirements for hazardous zones.

CFD models for hydrogen exist and these can be used. However, models are subject to inaccuracies and differences between model and experimental results are therefore often observed.

The modelling can be improved and validated by performing experiments of ventilation, gas dispersion and explosions in replicas of maritime fuel cell rooms.

Previous hydrogen experiments, e.g. from large multinational projects like Hysafe NoE , SUSANA and HySea have been used to test and develop current models. No experiments have been performed for realistic maritime enclosures such as fuel cell or hydrogen storage rooms. Experiments have typically been for small gas volumes and different shapes than expected for a fuel cell room. Leak and ventilation characteristics are expected to be different. It is therefore recommended to perform hydrogen experiments in mock-ups of realistic maritime rooms. Experimental results will improve understanding of dispersion and explosion mechanisms:

- What leak conditions (rates and durations) will result in a gas cloud large enough to threaten integrity of the room in case of a deflagration explosion?
- How much hydrogen can leak if damaging explosion pressures should be avoided?
- How effectively can ventilation be in preventing ignition/fire/explosion?
- What is the optimal room design, e.g. effect of smooth ceiling?
- What are the expected consequences on walls including possible collapse?
- How to design vent release panels?

With calibrated models, more accurate fire and explosion risk assessment of fuel cell rooms can be established.

The Norwegian Maritime Directorate (NMA) has expressed and underlined that more experience for research and testing are needed before use of hydrogen in a commercial ferry. As the safety of the technology is not considered well-defined and mature, NMA have indicated that extensive testing of hydrogen solutions in relevant on-shore simulation laboratories and possibly on test-ships with only a limited safety crew would be required to gain their Flag State approval.

Gap 22: Lack of understanding of properties and conditions affecting safety of liquid hydrogen in shipping applications

<u>Legal / Knowledge</u>

As for hydrogen gas, further studies are required also to develop safety related understanding of properties and conditions affecting safety of liquid hydrogen (LH2) in shipping applications.

The following gives some examples of needed activities:

- Liquid hydrogen is associated with very low temperatures around -253 °C. Temperature effects on steel need to be considered and requirements need to reflect such conditions. Cryogenic hydrogen has a lower temperature than cryogenic natural gas. Such leaks hitting critical structures and their possible cool down and embrittlement effects need to be considered for assessing when cryogenic spray protection is needed and if the requirements need to be adjusted compared to LNG. This will form important input to further Rules and Regulative developments;
- Liquid hydrogen leaks outdoors; determine relevant leak and environmental conditions (e.g. wind conditions) and their effects. Simulations should be considered to establish requirements for hazardous zones;
- Leak detection and how liquid hydrogen will evaporate and behave is expected to be different from LNG (e.g. higher buoyancy, range of flammability) and a hydrogen gas leak.

6 CONCLUSION

In this study the gaps in land-based & water-based regulations and standards for the use and transport of hydrogen on board of-, bunkering hydrogen and onshore systems supplying hydrogen to inland navigational vessels are identified. Recommendations are formulated to enable the development of a regulatory framework for the use of hydrogen for propulsion, bunkering of hydrogen and required infrastructure for the supply of hydrogen to inland navigational vessels in the Rhine-Alpine corridor.

The regulatory gap assessment is carried out for use of hydrogen in maritime and inland shipping. National land-based legislation and standards in the Netherlands and Germany, relevant for shore side of the hydrogen supply chain are also covered. The scope of the study is limited to the use- and supply of compressed gaseous hydrogen & liquid hydrogen. The use of hydrogen carriers (e.g. methanol, ammonia) is considered to be a long-term scenario (10-20 years) for inland shipping /8/ and is therefore not considered in the regulatory analysis.

The study provides an overview of the current legislation & regulations on an International, European, National (Netherlands/Germany) and local level (Ports & Harbours). This is followed by an inventory of relevant existing standards & guidelines and those proposed or in development.

The existing gaps found in regulations, standards & guidelines are identified and described. The gaps are classified under three categories:

Legal Gap (L):

Legal gaps are gaps for the supply and use of hydrogen in inland shipping that severely limit or even block the use of hydrogen as propulsion for ships. These gaps are typically gaps in legislation and regulations.

Harmonization Gap (H):

Harmonization gaps are gaps in the International or EU-wide harmonization of methods, rules, guidelines, provisions and safety aspects for hydrogen. Examples are standards for refuelling points and bunkering procedures.

Knowledge Gap (K):

Specific knowledge gaps are points where more research is needed in the implementation and development of the technology and use of hydrogen to be able to develop regulations.

The gaps are presented and sorted according to their key area of relevance. Therefore, the gaps have been categorized by topic, such as: bunkering, on-board storage, fuel cell system etc. and in some cases also by code/regulation where the gaps exist (e.g. IGF Code, ES-TRIN).

The identified gaps for regulations and standards for the use and transport of hydrogen on board of-, and bunkering hydrogen to maritime and inland navigational vessels are presented in the table below.

Table 12: Identified gaps for water-based regulations & standards

Gap No.	Gap description	Gap category
IGF code: International code of safety for ships using gases or other low flashpoint fuels		
1a	Use of fuel cells is not regulated by IMO. Technical provisions for fuel cells are missing in the IGF Code.	L, K
1b	Detailed and prescriptive requirements for storage (including swappable systems/containers) and use of hydrogen as fuel in ships are missing. Provisions for bunkering gaseous & liquid hydrogen (bunker station shipside etc.) are also missing.	L, K
ES-TRIN: European Standard laying down Technical Requirements for Inland Navigation vessels		
2a	The ES-TRIN provides general provisions for low flashpoint fuels (Ch. 30; Appendix 8) but specific construction requirements regarding hydrogen-fuelled vessels and related fuel cell systems are lacking.	L, K

Gap No.	Gap description	Gap category
2b	Detailed and prescriptive requirements for storage (including swappable systems/containers) and provisions for bunkering gaseous & liquid hydrogen (bunker station shipside etc.) are missing.	L, K
Central Commission for the Rhine (CCNR)		
3	Regulations for the use of hydrogen as a fuel on board inland navigation vessels are lacking. Hydrogen-fuelled vessels are currently not allowed to operate on inland EU waterways. An exemption statement is required that can be requested at national authorities or the CCNR, depending on the operating area. Special requirements of the CCNR are to be observed if an inland vessel will be operating in EU inland waters. RPR contains instructions aimed at conventional fuel bunkering but does not cover the possibility of bunkering hydrogen. Bunkering of hydrogen on inland waterways controlled by CCNR is currently not allowed.	L
Legislation in the Netherlands		
4a	Bunkering of hydrogen on inland waterways in the Netherlands is currently not allowed. Exemptions could be made possible based on special permissions from the competent authority.	L
4b	"Basisnet", a nationwide appointed network for the transportation of dangerous goods, does not consider transportation of hydrogen in bulk. It must be noted that there are no limits for the transport of (mobile) tank-containers on waterways in Basisnet because the associated transport risk is considered to be very low. The probability of a leak in a container is very small that it will not contribute to the external safety risks /8/. This seems to imply that there will be no limits applicable for the transport of swappable hydrogen tube-containers on waterways with container vessels to container terminals.	L, K
Legislation in Germany		
5	Bunkering of hydrogen on inland waterways in Germany is currently not allowed. Exemptions could be made possible based on special permissions from the competent authority.	L
Port & Harbour Regulations		
6a	Specific rules and regulations for hydrogen liquid tankers (including bunker vessels), hydrogen-fueled vessels and hydrogen bunkering activities (truck-to-ship & ship-to-ship) are lacking the port bye-laws of EU Ports & Harbours.	L, K
6b	Audit & Accreditation criteria for hydrogen bunker operators do not exist.	L, K
Bunkering		
7	Rules for bunkering liquid hydrogen do not exist for the shipside of the bunker process.	L, H, K
8	Bunkering procedures & checklists for liquid hydrogen do not exist.	L, H, K
9	International standards for hydrogen refuelling points and bunkering for maritime and inland vessels do not exist.	L, H, K
10	Bunkering procedures & checklists for gaseous hydrogen do not exist.	L, H, K
11	An EU harmonized approach for risk assessment (including criteria) for non-Seveso hydrogen small scale establishments and bunkering activities (e.g. truck-to-ship, ship-to-ship) is lacking.	L, H
12	Indicators for determining common operational safety distances for hydrogen bunkering are currently missing.	L, H
13	Safety requirements for simultaneous hydrogen bunkering and loading / unloading or passenger embarking / disembarking processes are missing.	L, H, K
On-board storage		
14	Qualification for (swappable&fixed) on-board storage pressure tanks with compressed hydrogen gas is lacking. Rules and requirements for use of swappable containers on board ships do not exist.	L, H, K
15	There is a lack of understanding of failure modes for liquid hydrogen tanks.	K
Fuel cell system		
16	There is insufficient understanding of the safety aspects concerning release of hydrogen within the fuel cell system.	L, H, K
17	Ventilation requirements for fuel cell rooms are not validated for hydrogen.	L, H, K
18	Fuel cells open for new arrangement and vessel design solutions challenge existing rules & regulations.	L, K
19	Knowledge basis for requirements for handling of liquid hydrogen in piping to fuel cell system is lacking.	L, K
Ship life phases		
20	There is a lack of best practices, procedures, codes or similar regarding safe handling of on-board hydrogen and fuel cell installations in all the life phases of a ship. Crew training requirements for use of hydrogen in shipping do not exist.	L, H
Hydrogen safety		
21	There is insufficient understanding of hydrogen safety aspects for rules development.	L, K
22	There is a lack of understanding of properties and conditions affecting safety of liquid hydrogen in shipping applications.	L, K

The identified gaps in land-based regulations and standards for establishments/systems supplying hydrogen to vessels in **the Netherlands** are given in the table below.

It must be noted that the Dutch legal framework for regulating land-based establishments & activities will change considerably in 2022. A new Environmental law ("Omgevingswet") is foreseen to come into force on the 1st of January 2022. Existing laws like Wabo & Wm will be replaced by a new environmental law the "Omgevingswet". Brzo & Bevi will cease to exist and be replaced by new decrees: "Besluit activiteiten leefomgeving" (Bal), "Besluit kwaliteit leefomgeving" (Bkl) and "Omgevingsbesluit" (Ob). These new laws and decrees are taken into account in the gap analysis. This means that identified gaps in the existing laws are verified to check whether the same gaps are also present in the new legislation.

Table 13: Identified gaps for land-based regulations & standards in the Netherlands

Gap No.	Gap description	Gap category
PGS guidelines		
23	A PGS guideline for the safe design and operation of a hydrogen bunker station is missing (see paragraph 3.3.2.2)	L, K
24	Guidelines for maintenance and repairing hydrogen fuel engines / fuel cell systems on inland vessels are missing in PGS 26.	L, K
Bevi		
25	Small-scale hydrogen bunker stations (less than 5 ton storage, Brzo lower-tier threshold) & truck-to-ship bunkering is currently not regulated by Bevi / Bkl as they are not defined as categorial establishments / activities.	L, H
QRA calculation guidelines		
26	A specific QRA calculation guideline for hydrogen bunker stations is missing.	L, H
27	The QRA calculation guideline for container terminals is included in the Reference Manual /9/, module C, chapter 5 does not seem to specify failure scenarios for compressed hydrogen tube-containers nor containers with cylinders.	L, H

The identified gaps in land-based regulations and standards for establishments/systems supplying hydrogen to vessels in **Germany** are given in the table below.

Table 14: Identified gaps for land-based regulations & standards in Germany

Gap No.	Gap description	Gap category
BImSchG / BauG		
28	BImSchG is missing adequate treatment of hydrogen (e.g. a specific hydrogen related BImSchV).	L
12. BImSchV		
29	12. BImSchV does not provide adequate treatment of hazards due to very low temperature or very high pressure hydrogen.	L
30	Technical details providing TRBS guidance for the specific hazards of hydrogen and hydrogen bunkering installations or stations for vessels are missing.	L, K
BetrSichV		
31	Treatment of the specific hazards of liquid hydrogen in the BetrSichV and in the associated TRBS are missing.	L, K
KAS-18 ("TA Abstand")		
32	A technical guideline for definition of safety distances ("TA Abstand") is missing (hazards of hydrogen should be taken into account).	L, K

Recommendations are given to solve the gaps (reference is made to paragraph 5.2 in this report). In cases where the gaps are not yet solved, and no concrete actions to deal with the gaps are identified, work has been undertaken to attempt to suggest possible actions to deal with the identified gaps.

Main conclusions

In general, it can be concluded that regulations for the use of hydrogen on board of-, and bunkering of hydrogen to inland navigational vessels are lacking. Currently, hydrogen-fuelled vessels are only allowed to operate on inland waterways based on an exemption given by national authorities or the CCNR. However, ES-TRIN is currently being updated with technical requirements and rules for inland navigational vessels with fuel cell systems.

Sub-study 1a, Sub-activity report 1.1b Hydrogen bunkering scenarios /1/ concluded that the use of swappable containers with compressed gaseous hydrogen is the most feasible scenario for inland shipping in the short-term (upcoming 1-5 years). However, rules and requirements for use of swappable containers with gaseous hydrogen on board ships do not exist. It is recommended that these are also considered in the current update of ES-TRIN to speed up the introduction of hydrogen in inland waterway transport.

Hydrogen bunkering standards, procedures & checklists do currently not exist. The most recent development is that CEN/CENELEC (working group CEN/TC 268/WG 5) considers developing European standards for refuelling points and bunkering of gaseous compressed hydrogen, liquefied hydrogen, methanol and ammonia for both maritime and inland waterways hydrogen-fuelled vessels.

With regards to gap assessment for regulations & standards for the permitting of land-based systems (such as hydrogen bunker stations) in the Netherlands and Germany: no major gaps have been found in the laws as they are generic and cover the permitting of any installation with hazardous goods, including hydrogen. Most gaps are related to missing technical guidelines that are needed by regulators to verify if the technical and (external) safety requirements are met, thereby resulting in a more efficient permitting process.

Finally, there is a general insufficient understanding of hydrogen safety aspects. Comprehensive safety studies are needed to develop regulations, codes and standards.

7 REFERENCES

/1/ DNV, RH2INE Sub-study 1a, Sub-activity 1.1b: “Hydrogen Bunkering Scenarios”, March 2021

/2/ DFC1500 EU MCFC-Fuel cell Power Plant product datasheet. http://www.fuelcellenergy.com/ products-services/products/1-4-mw-dfc1500/

/3/ DNV, Rules for Classification, Part 6, Chapter 2, Section 3 Fuel cell Installations, July 2020

/4/ Korean Register of Shipping, Guidance for Fuel cell Systems on Board of Ships, GC-12-E, July 2014

/5/ BUREAU VERITAS, Guidelines for Fuel cell Systems On-board Commercial Ships, NI 547 DR R00 E, April 2009

/6/ DNV, “Study on the completion of an EU framework on LNG-fuelled ships and its relevant fuel provision infrastructure - LOT 1: Analysis and evaluation of identified gaps and of the remaining aspects for completing an EU-wide framework for marine LNG distribution, bunkering and use”, 2015

/7/ GL Guideline VI-3-11, “Guidelines for the Use of Fuel cell Systems on Board of Ships and Boats”, 2003

/8/ Dutch National Institute for Public Health and the Environment (Rijksinstituut voor Volksgezondheid en Milieu, RIVM), Reference Manual Transport Risk Analysis (Handleiding Risicoanalyse Transport), January 2017

/9/ Dutch National Institute for Public Health and the Environment (Rijksinstituut voor Volksgezondheid en Milieu, RIVM), Reference Manual Bevi Risk Assessment (Handleiding Risicoberekeningen Bevi), version 4.3, 1st of January 2021

/10/ Dutch National Institute for Public Health and the Environment (Rijksinstituut voor Volksgezondheid en Milieu, RIVM), Memo Risk- and effect distances for hydrogen refueling stations for road vehicles, 3rd of October 2016

About DNV

DNV is the independent expert in risk management and assurance, operating in more than 100 countries. Through its broad experience and deep expertise DNV advances safety and sustainable performance, sets industry benchmarks, and inspires and invents solutions.

Whether assessing a new ship design, optimizing the performance of a wind farm, analyzing sensor data from a gas pipeline or certifying a food company's supply chain, DNV enables its customers and their stakeholders to make critical decisions with confidence.

Driven by its purpose, to safeguard life, property, and the environment, DNV helps tackle the challenges and global transformations facing its customers and the world today and is a trusted voice for many of the world's most successful and forward-thinking companies.