D6.2 – Standardization needs and SWOT analysis

Clean Hydrogen Partnership

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Acronyms

Short Acronym	Description
ATENA	Atena scarl – Distretto alta tecnologia ambiente
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CFD	Computational Fluid Dynamics
CWA	CEN Workshop Agreement
DNV	DNV is an international accredited registrar and classification society
EN	European Standard
EU	European Union
FC	Fuel Cell
GHENOVA	Ghenova Ingenieria
GHG	Greenhouse gases
H2	Hydrogen
HAZID	Hazard Identification
IACS	International Association of Classification Societies
IEC	International Electrotechnical Commission
IGF Code	International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels

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IMO	International Maritime Organization
ISO	International Standardization Organization
JTC	Joint Technical Committee
LNG	Liquefied Natural Gas
NFPA	National Fire Protection Association
NG	Natural Gas
PEM	Polymer Electrolyte Membrane (fuel cells)
POLIMI	Politecnico di Milano
PPE	Personal Protective Equipment
RCS	Regulations, Codes and Standards
SC	Sub-committee
SDGs	Sustainable Development Goals
SOLAS	International Convention for the Safety of Life at Sea
TBC	To Be Confirmed
TBE	To be explored
TBs	Technical Bodies
TC	Technical Committee
TS	Technical Specification
UNI	Italian Standardisation body (Ente Italiano di Normazione)
WG	Working Group
WP	Work Package

Executive Summary

The e-SHyIPS project aims to define the new guidelines for an effective introduction of hydrogen in maritime passenger transport sector and to boost its adoption within the global and EU strategies for a clean and sustainable environment, towards the accomplishment of a zero-emission navigation scenario. The goal of e-SHyIPS is to move from the idea to the application, filling the existing gap in normative and technical knowledge concerning all the related aspects on hydrogen in the maritime transport sector. By means of an ecosystem approach, e-SHyIPS proposes theoretical pre-normative research activities on standards, simulation and laboratory experiments, design of an appropriate certification process, spot future standardization activities to enhance the EU standardization and regulatory landscape.

Wthin WP6, the Task 6.2 "Regulatory and standardization need assessment" is dedicated to identify existing gaps, barrier and challenges to improve the existing standardisation landscape and contributibuitng possibly the an update of the IGF Code related to the hydrogen-based fuels passenger ships' chapter. This with the final aim to harmonize the existing international normative landscape and level up the safety culture in general.

By delving into the intricacies of this transition, we seek to offer insights that will inform policymakers, industry stakeholders, and researchers, guiding strategic interventions and collaborative efforts aimed at unlocking the full potential of hydrogen propulsion in passenger shipping.

The results of the activities carried out in the first year of this tasks have been summarized in this public report, particularly relevant to standardization bodies, flags, and regulatory authorities (e.g. IMO).

1. Introduction

1.1 Scope and Objectives

Decarbonisation in shipping is nowadays creating opportunities for the onboard adoption of low and zero carbon fuels. Low-flashpoint innovative fuels, like hydrogen (H2), have a potentially lower environmental footprint, as they have the potential of zero tank-to-wake GHG emissions and, even further, zero well-to-wake impact if they are produced using renewable power sources, through a high-energy demanding electrolysis-based generation. Several ship concept designs with onboard hydrogen fuel consumption (and production, in some designs) have been presented and a few real-life paradigms have been implemented as newbuild projects, like the DNV Classed Norled Hydra vessel (Norled, 2023).

Despite the desirable environmental features of H2, its onboard storage and use as fuel poses safety challenges that require proper management. In 2021, the MarHySafe consortium, comprising 26 leading companies and associations led by DNV, launched the "Handbook for Hydrogen-fueled Vessels" to address the uncertainties surrounding hydrogen as ship fuel and providing the first maritime knowledge base for safe hydrogen operations in shipping (DNV, 2021). Furthermore, the IMO is working on the development of guidelines for H2 systems, including as an example the Interim Guidelines for Fuel Cells, (IMO, 2022). Finally, Classification societies are gradually issuing guidelines for H2 as fuel and the industry is expected to face a growing development of rules and regulations around this fuel.

Yet, still there are no current prescriptive rules and requirements for hydrogen fuel onboard ships by the mandatory IMO codes covering this matter. On January 2017, the IMO adopted the International Code of Safety for Ship Using Gases or other Low-flashpoint Fuels, shortly named as the IGF code, (IMO, 2015), which is primarily covering LNG as fuel, and lacks the necessary updates to cover H2 variants, at liquid (LH2) or compressed gaseous form (CGH2).

The IGF code was developed to mitigate risks related to onboard storage and use of low-flashpoint fuels, by providing goals and functional requirements as the basis for the design, construction, and operation of systems intended to use this type of fuels. The code was developed based on industry best working practices following a goal-based approach, which differentiates its structure and content from other industry standards which are developed on a risk-based manner.

The basic philosophy of the goal-based approach (MSC.1/Circ.1394) is to define goals and functional requirements forming the basis for the design, construction, and operation. This structural difference of the code allows for wider range of applicability of the same code over many designs. The table below presents a comparison of H2 and LNG properties, revealing the associated risks.

Table 1: Properties of hydrogen and LNG: Comparative assessment, (Nerheim et al., 2021)

Property	Unit	H_2	LNG
Molecular weight	g/mol	2.0	16.5–18.9
Density of liquid	kg/m^3	71	450
Density of vapour ISO conditions	kg/Sm^3	0.08	0.7–0.9
Boiling temperature at 1 atm	°C	-253	-163/-161
Liquid phase temperature at 1–10 bar	°C	-253 to -240	-163 to -130
Lower heating value	MJ/kg	120	50
Heat capacity at constant pressure	kJ/kg/K	14.3	2.09
Lower flammability limit in air (LFL)	%	4	5
Upper flammability limit in air (UFL)	%	75	15
Minimum ignition energy	MJ	0.02	0.28
Auto-ignition temperature	°C	560	599
Maximum laminar flame speed in air	m/s	2.933	0.374

In 2021, the European Union has funded a series of research and development projects to support the shipping industry in bridging knowledge gaps.

The e-SHyIPS project, funded by Clean Hydrogen Partnership, is one of these and it is intended to define a pre-standardisation plan for updating the IGF code with requirements related to hydrogen-based fuels for passenger ship, and thus support the H2 uptake in the maritime sector. The project consortium comprises 14 partners, including ship designers, a standardization body, class society, fuel cells manufacturers, research institutes, vessel owners and operators, and universities.

This Deliverable presents the final analysis carried out so far by the consortium over the identification of gaps in the IGF code with relation to hydrogen as fuel, and matches the analysis results with the most updated developments from the internal communities.

Finally, the Deliverable presents the proposal for a new European standardization deliverable.

1.2 Connection with other deliverables

This deliverable represents the consolidation of the results related to the IGF Code gaps analysed in the Deliverable D1.3 "State of the art of safety standardisation framework", and the starting point of the Deliverable D6.4 "International pre-normative strategic plan" which is expected by the end of the project.

1.3 Structure of the document

Passenger ships represent a crucial segment within the maritime domain, serving as vital arteries for commerce, tourism, and global connectivity. However, despite increasing awareness of the environmental challenges posed by traditional fossil fuel-powered vessels, the transition to hydrogen propulsion systems in this sector faces several hurdles. Recognizing the imperative to accelerate this transition, it is essential to identify and address the existing gaps and standardization necessities for the effective implementation of hydrogen technology in passenger ships.

This deliverable aims to provide a comprehensive analysis of the spotted gaps related to the IGF Code, highlighting key challenges, opportunities, and standardization needs.

Furthermore, it will underscore the importance of concerted action to address these gaps and establish robust standardization frameworks that facilitate the safe, efficient, and scalable integration of hydrogen technology into the maritime transportation sector.

To these aims, the deliverable has been developed around 3 main sections:

- Section 2 is dedicated to present the final version of the gap assessment related to the IGF Code
- Section 3 is dedicated to highlitgh the standardization gaps and needs emerged in the project
- Section 4 closes the report, presenting a proposal for a new pre-standardization deliverable (CWA)

2. IGF Code: what's missing for H2 applications

The e-SHyIPS project has created the first detailed mapping of IGF code gaps and necessary studies and updates, towards a better representation of hydrogen fuel nby the code. The results, reported in this chapter, have been presented in various forums and conferences, and are currently under review to be published in a dedicated journal.

2.1 Methodology of the gap assessment carried out in e- SHyIPS

This section describes the methodological steps that were followed in e-SHyIPS, for revealing the IGF code gaps with regards to hydrogen onboard storage and use as fuel.

The gap assessment procedure was performed in a series of dedicated workshops involving all e-SHyIPS partners. The workshops were structured according to the IGF code chapters, and a bottom-up approach was followed to review the code content and assess its relevance to hydrogen. The focus was put primarily on fuel cells, which are proven energy conversion technologies for H2, while internal combustion concepts were not assessed because of immaturity. The risks of hydrogen were accounted for in assessing the gaps and providing recommendations for code updates. The final set of recommendations for IGF code update are not explicitly presented in this work, but rather the basis for further research over the identified gaps is settled.

Conclusions on IGF code updates can be derived through the review of the identified gaps, developed, and organized by IGF code chapter categories.

The adopted gap assessment approach can be summarized in the following steps:

1. Description of the subject for review, i.e., the content of the IGF code.
2. Definition of a basis against which the gaps are identified and comprises the set of requirements for safe onboard storage and use of hydrogen as fuel.
3. Structured review of the subject against the basis and development of proposals to fill the gaps, through dedicated workshops with the participation of all partners of e-SHyIPS. The objective is to ensure that expertise from multiple fields is present during the process and the maximum potential benefit is accomplished.
4. Expert review and consolidation of findings through review of the final gaps, at dedicated workshop.

2.2 The IGF code: a recap

The IGF code contains 19 chapters with mandatory provisions for the arrangement, installation, control and monitoring of machinery, equipment, systems, and processes, using low-flashpoint fuels, focusing on liquefied natural gas (LNG). The code chapters are described in the following Table.

Table 2: IGF Code outline

Parts	**Chapters**
Part A	Generalities, goals, definitions, functional and general requirements
Part A-1: Specific requirements for ships using natural gas as fuel	Chapter 5. Ships design and arrangements Chapter 6. Fuel containment system Chapter 7. Material and general pipe design Chapter 8. Bunkering Chapter 9. Fuel supply to consumers Chapter 10. Power generation including propulsion and other gas consumers. Chapter 11. Fire safety Chapter 12. Explosion prevention Chapter 13. Ventilation Chapter 14. Electrical installation Chapter 15. Control, monitoring and safety systems

Part B-1	Chapter 16 Manufacture, workmanship and testing
Part C-1	Chapter 17. Drills and emergency exercises Chapter 18. Operation
Part D	Chapter 19. Training

2.3 Hydrogen requirements

As defined in step 3, a basis for identification of gaps is necessary, to reveal the needs for updating the code for H2 fuel. This basis is stemming from the H2 -related risks and the types of conditions that can trigger hazards. The following Table presents H2 risks.

Table 3: Hydrogen properties and associated risks

H_2 property	**Risks**
Invisible, odourless, tasteless	Non-traceability, with consequences from contact being: dyspnoea, cryogenic burn (for LH_2) and hypothermia
Low viscosity *High permeability* *Low density – more buoyant*	Easy penetration of structures and accumulation in enclosed spaces, and presence in places which originally are not designated for H_2
Flammable *Low ignition energy* *Explosive* *High flame velocity / blast wave / jet fire / deflagration*	Fires and explosions, with consequences of accidents, asset loss, injuries and/or life loss. Accident consequences can be related to thermal burns from direct flame or radiation / impact from pressure wave that could lead to life loss. Ignition can produce deflagration, subsonic propagating flame. Deflagration can progress towards detonation, depending on the geometry.
Hydrogen embrittlement *Hydrogen attack*	Material defects, mechanical damages, degradation of mechanical properties of metals

The conditions that can trigger hazards are of two types:

- Active: Conditions that allow the development of flammable and/or explosive mixture generation, without these being avoided or traced, e.g., lack of proper insulation, unsuitable materials, etc.
- Passive: Conditions that cause the propagation of events, e.g., lack of protective barriers.

Gaps can also be revealed via the comparative assessment of the code requirements against land-based standards for H2 systems. Among the reviewed standards in the eSHyIPS project, the following ones were deemed very relevant:

- ISO/TR 15916:2015: Examples of extreme and failure events; maintenance, long term planning for asset lifetime; operational requirements; risk assessment principles; exposure of personnel and personal protective equipment; good practices; training; technical documentation; and others.
- ISO 19880-1:2020: Emergency shutdown functionalities, emergency response plans, training, technical documentation, inspection, and maintenance

planning. Bunkering operations. Exposure of personnel, PPE: Protection measures for exposure of staff.

Other standards are presented in the following Table.

Table 4: Overview of Hydrogen related land-based standards, that could offer important input to the revision of the IGF code

Standard	Title	Relevance
ISO 14687:2019	Hydrogen fuel quality -- Product specification	Minimum quality characteristics of hydrogen fuel.
ISO 26142:2010	Hydrogen detection apparatus -- Stationary applications	Performance requirements and test methods of hydrogen detection apparatus that is designed to measure and monitor hydrogen concentrations in stationary applications.
ISO 22734:2019	Hydrogen generators using water electrolysis -- Industrial, commercial, and residential applications	Construction, safety, and performance requirements of modular or factory-matched hydrogen gas generation appliances, herein referred to as hydrogen generators, using electrochemical reactions to electrolyze water to produce hydrogen.
ISO/TS 19883:2017	Safety of pressure swing adsorption systems for hydrogen separation and purification	Safety measures and applicable design features that are used in the design, commissioning, and operation of pressure swing adsorption systems for hydrogen separation and purification in commercial or industrial use.
ISO 16110-1:2007	Hydrogen generators using fuel processing technologies — Part 1: Safety	Applicable to hydrogen systems with a capacity of less than 400 m3/h at 0 °C and 101,325 kPa, herein referred to as hydrogen generators, that convert an input fuel to a hydrogen-rich stream of composition and conditions suitable for the type of device using the hydrogen.
ISO 16110-2:2010	Hydrogen generators using fuel processing technologies — Part 2: Test methods for performance	Test procedures for hydrogen generators (capacity < 400 m3/h at 0 °C and 101,325 kPa) that convert fuel into a hydrogen-rich stream suitable for devices like fuel cell systems or hydrogen storage and delivery systems.
ISO 19880-1:2020	Gaseous hydrogen -- Fueling stations - Part 1: General requirements	Minimum design, installation, commissioning, operation, inspection and maintenance requirements, for the safety, and, where appropriate, for the performance of public and non-public fueling stations that dispense gaseous hydrogen to light duty road vehicles.

2.4 Gap assessment

This chapter describes the IGF code gaps identified after a series of workshops of code reviews, with e-SHyIPS partners' participation. For each gap, different proposals are made that can be categorized by:

a) Proposals for goal update and general requirements to adapt to H2 requirements,
b) Proposals for component suitability for H2 use,
c) Assessments of material suitability,
d) Assessments of special design features for safer H2 designs,

e) Proposals for studies to assess risks (e.g., stemming from dispersion, fire or explosion propagation),
f) Proposals for safety systems, operations, and controls.

2.4.1 Goals and risk-based design

The functional goals in most of the code chapters are generated in accordance with LNG criticalities. H2 as fuel bears additional risks, and higher criticalities compared to LNG. Therefore, the code needs proper readjustment of functional goals at all chapters, as detailed in the following Table.

Table 5: Gaps in goals definition

Gaps	**Proposed actions**
Lack of references to H_2-hazards in the IGF code goals.	Inclusion of goals that relate to H_2 safe design, accounting for the mitigation of H_2 risks.
Can functional goal requirements allow a minimum level of leakages? As per now leakages are not permissible. *There is lack of experience and data on frequency of occurrence of leakages.*	Demonstration of risk-based design approach: Assessment of fume dispersion using CFD simulations for a set of probable leak scenarios. Experience can be addressed by analysing similar events in land-based systems and substituting real case conditions with model results. The mitigation of fire events and ignition control, and the maintenance of structural integrity, need to be added in the functional goals of chapters related to safety systems.
Criticalities of single faults onboard are higher than in land-based systems.	Revision of electrical requirements to account for designs that a single fault would not result into a wider spectrum of failing conditions, not restricted only to the pressure maintenance of the tank but listing all possible potential consequences.
Lack of goals related to good housekeeping and minimum personnel exposure for H_2 operations	Keeping access and evacuation routes clear and keeping weeds and other debris away from hydrogen systems; observation of safe operational requirements, such as working in pairs when operating in a hazardous situation. Minimization of personnel exposure by limiting the number of people exposed, the time that the personnel are exposed.

2.4.2 Arrangements and location

Regarding arrangements and locations, the gaps include elements that affect the definition of chapter goals and general requirements, as well as proposals that affect design, safety systems and operation controls. New studies proposed are dispersion analysis and heat ingress behavior assessment via modelling and simulation, to assess whether the existing code requirements for location and arrangements are of equivalent safety in the case of H2.

Table 6: Gaps related to arrangements and location

Category	Gaps	Proposed actions	IGF chapter
Safety barriers **Hazardous area zones, area classification and distances**	Are safe limits in case of grounding enough for H_2 system intact condition? The current definition of hazardous areas needs extension to include safety zones and barriers around H_2 systems: inherently safer design.	Re-assessment of safe limits in case of grounding collision for all systems that involve H_2, including tank-fuel cell connection. Design of systems and arrangements for control of any range between deflagration conditions is expected, with primary focus on proper venting. Design for detonation is an extreme condition. Assessment of requirements for crew and passenger areas, including safe distances from H_2 systems and safety barriers, proper engine room and storage tank's location. Consideration of principles of inherently safer design as per ISO/TR 15916:2015. Assessment of requirements for separations between compartments - not necessarily a single bulkhead, including safety barriers for tank location below deck. Assessment of the area definition and distances of hazardous zones, as protective measures for handling H_2 risks during bunkering. Prescriptive requirements on zones and distances are given in IEC standard / IEC 60079-10-1: 2020 version. Assessment of levels of isolation from oxidizers, hazardous materials, and other equipment. The current definition of zones in the IGF code needs alignment with the scope of the FC interim guidelines, (IMO, 2022). Assessment of the conditions to maintain gas safe machinery space (get info from ISO/TR 15916:2015, consider gastight external enclosure for fuel cells, properly designed surface on the top to avoid fumes accumulation).	Ch. 5, Ch. 6, Ch. 8, Ch. 9, Ch. 11 Ch. 12
Dispersion of fumes	Consideration of flammable environment development in the arrangement of H_2 system and piping location	Need for dispersion calculations and assess safety barriers needed in the case of open deck storage (gas and liquid). Inclusion of requirement to avoid fuel pipes in cargo/passenger spaces.	Ch. 5, Ch. 6, Ch. 11
Impact of stresses	Can stresses related to environmental conditions propagate through the supports to the tanks and affect tank conditions?	Assessment of the propagation of strengths from tank supports to the tank and potential mechanical or thermodynamic impact. In the case of LH_2, evaluation is needed of the acceleration profile that the fuel containment and handling system will face (as result of a specific ship	Ch. 5, Ch. 6

		design) without leading to leakage, extreme pressure increase.	
Impact of environmental conditions	Are the code requirements sufficiently covering the safe operations under extreme weather conditions?	Assessment of the safe conditions for onboard storage, fuel handling, piping and tank-fuel cell connection under extreme weather conditions and ship motions (winter/snow, summer/extreme heat ingress), including requirements for insulation of double pipes. Inclusion of effect of ship motion to fuel cell performance and unburnt H_2 flow in the system. Assessment of heat ingress in pipes, tanks for various insulations and effect of pressurization.	Ch. 5
Integrity loss	Are the requirements for location of H_2 systems appropriate in terms of integrity maintenance, or should there be additional considerations because of increased criticality compared to LNG?	Assessment of the requirements for fuel containment, handling and piping systems related to ignition and explosion avoidance, via probabilistic analysis of leakages, dispersion, and explosion analyses.	Ch. 5

2.4.3 Power conversion and redundancy

Regarding power conversion systems, the IGF code does not include requirements for the systems that relate to H2 energy conversion, e.g., fuel cells, reformers, etc. The interim guidelines for fuel cells of IMO (IMO, 2022) is the most recent regulatory reference.

In general, the IGF code includes requirements for redundancy of power systems, at cold or hot reserve. Because of the criticalities associated with high explosivity and flammability of H2, the design of redundancy systems requires update in terms of functionality, arrangement, and capacities.

Table 7: Gaps related to power conversion and redundancy

Category	Gaps	Proposed actions	IGF Chapter
Energy converted types and auxiliaries	H_2 energy conversion systems are not considered in Ch. 10	Inclusion of requirements for fuel cells and their auxiliary systems in the IGF code: fuel cells, reformers, catalytic converters, separation membranes, and "getters" to remove unwanted or excess hydrogen, e.g., in the form of an additional chapter of the IGF code.	Ch. 10, Ch. 9
Power and fuel redundanc y	Given the difference in machinery types, are the requirements for power redundancy same as for LNG?	Assessment of hybridization as a preventive measure and development of new concepts for machinery, special for H_2 that include requirements for redundancy of systems in case of blackout and hot/cold reserve.	Ch. 5, Ch. 6, Ch. 10

	What other requirements apply in power redundancy?	Assessment of reliability of different machinery configurations/accounting failures via modelling and simulation. Assessment of redundancy in fuel supply, at the fuel containment system design. Assessment of the minimum required hydrogen capacity to perform operations and ensure safety onboard, considering other redundancy power supply modes (e.g., batteries).	

2.4.4 Fuel containment and quality

In chapter 10, dedicated to power generation components, there is a gap in the consideration of hydrogen fuel quality requirements, subject to the capabilities of the energy converters (fuel cells, H2 engines, etc.). Experience can be taken by land-based standards, i.e. ISO 14687:2020 (Type I, Grade D) and SAE J2719.

Table 8: Gaps related to fuel containment and quality

Category	Gaps	Proposed actions	IGF Chapter
Containment technologies	The IGF code needs to become updated with the types of containment systems and requirements that are relevant to H_2	There is a need for review of the relevance of different tank types to H_2. Information can be extracted from ISO 13985:2006 on "Regulations for liquefied gas fuel containment" that could fit in the IGF code content. Exploit research works on the lifespan of maritime hydrogen containment systems and piping. The code needs to describe a min level of analyses that are required to complete a fuel containment system risk assessment for hydrogen. The DNV MarHySafe handbook provides a good basis for this matter. Further assess extra requirements for the case of portable tanks (CGH_2 or LH_2), compared to permanent tanks (see EN ISO 16924:2018).	Containment technologies

2.4.5 Equipment and components

Regarding equipment and components, most gaps relate to the assessment of existing systems suitability and the inclusion of new design requirements, redefining the goals and functional requirements of systems that relate to bunkering, piping, fuel supply and containment.

Table 9: Gaps related to equipment and components

Category	Gaps	Proposed actions	IGF Chapter
Fuel pumps	Are submerged pumps safe?	Assessment whether a submerged fuel pump can be used in liquefied H_2 tanks.	Ch. 9
Hoses	Gap in over-pressure protection.	Inclusion of protection against overpressure at the design of ship's fuel hoses.	Ch. 8
Electrical equipment	Presence of H_2 close to electrical systems demands stricter specifications compared to the ones described in Ch. 14, i.e. ATEX requirements.	Inclusion of explosion-proof certification and ATEX requirements for electrical components in H_2 systems. Electrical installations specifications should ensure no ignition sources in positions where H_2 is present. A standard that provides requirements for equipment at explosive atmospheres (ATEX) is Directive 2014/34/EU. According to the IGF code, electric installations should be designed such that a single fault will not result in the loss of ability to maintain fuel tank pressures and hull structure temperature within normal operating limits. This requirement is related to liquid fuels, so it is relevant to LH_2. However, for CGH_2, the requirement is not directly relevant, but shut-off valves must be capable to operate, in case of power loss (either independent power source or special valves).	Ch. 11, Ch. 9, Ch. 10, Ch. 14
Manifolds	What is the acceptable leakage level?	Assessment of an acceptable level of leakage rate, in case of no dry-disconnect of bunkering manifold connections. To support this effort, computer-based methods can support: simulation of flowrates during bunkering and dispersion analysis in case of leak at bunkering site.	Ch. 8
Pipelines	Are the dimensional limits applicable to H_2 and why?	Analysis of systems with modelling and simulation to predict system conditions. Then, assessment of the minimum acceptable pipeline diameter and operational pressure to satisfy technological requirements to mass flow rate, as estimated by simulations. Comparative assessment against land-based standards. Assessment of the minimum pipe wall thickness and requirements about fabrication and acceptable joint types (e.g., ISO/TR 15916:2015: welded joints are preferred where leaks cannot be tolerated, EN 13648-1:2008, etc.).	Ch. 7, Ch. 8
Valves	Gaps in valve design and preventive measures against H_2 risks: permeability, explosivity.	Assessment of preventive measures needed in the design of LH_2 and CGH_2 valves (risk-based approach). Requirements for automatic operation, with the capacity to be operated manually in case of emergency. Assessment of requirements for stresses on valves / max limits and Ultimate Design conditions, using land-based experience: ISO 21028-1:2016.	Ch. 7, Ch. 8

2.4.6 Materials and manufacture

H2 systems require suitable material properties and testing methods, to mitigate the risks related to H2 permeability, embrittlement, and H2 attack[1]. The existing material requirement in the IGF code needs to get extended for H2 risks mitigation, describing new materials, manufacture requirements and testing methods. An example on materials testing requirements, e.g., for insulation or joints, is the assessment of fire resistance. An example on manufacture is that of welded joints, which are preferred where leaks cannot be tolerated. Land-based standards could offer input to the IGF code update for this purpose:

- ISO 19880-1:2020 and ISO/TR 15916:2015 for testing, and systems inspection, including safety performance testing, training, technical documentation, inspection, and maintenance planning.
- Ongoing work on materials is made in ISO TC 197, on how materials interact with H2 under different conditions.

To close the gap related to H2 material requirements and testing, it is recommended that an additional chapter is generated including the H2 -specific requirements. In addition, effects over lifetime should be addressed.

2.4.7 Safety systems

Regarding safety systems, there are several gaps in the code, related to H2 criticalities. Safety systems can either prevent the cause or the effect of a hazard. As an example, ventilation can prevent the development of an explosive environment, but cannot prevent a leak. A leak can be prevented with proper material testing.

Table 10: Gaps related to safety systems

Category	Gaps	Proposed actions	IGF chapter
Drainage	Gap in preventing measures for crack avoidance, in case of air condensation during H_2 leakages.	As more buoyant, LH_2 is expected to instantly vaporize and go up in the case of small leaks. However, in the presence of a leak, air may condense, requiring means of cracking avoidance caused by contact of condensed air with surfaces. Prevention measures can be dripping trays of no bituminous material.	Ch. 8
Emergency shut down (ESD)	Gap in the functional requirements of ESD, as means to restrict fire propagation.	Assessment of the avoidance of spurious shutdown (IGF code: 15.2.5) and method to recognize failures in instrumentation over to true fails, e.g., in case of blackout. In this regard, a gap is identified on regarding the resilient design towards internal failures. H_2 safety systems follow a fail-proof design so, they should either fulfil safety requirements or allow safe shutdown. ESD system can be considered as control measure to restrict fire propagation (prescriptive requirement for resilient instrumentation and control design).	Ch. 11, Ch. 10, Ch. 12, Ch. 15

[1] Hydrogen attack is a problem that concerns steels operating at elevated temperatures, above 204°C, in refinery, petrochemical and other chemical facilities and, possibly, high pressure steam boilers.

Explosion prevention	Explosion prevention: A different low flammability limit and ventilation requirement is needed for H_2, compared to LNG.	Assessment of different conditions of ventilation for the diffusion of vapours as preventive control measure to avoid explosion. Update of the H_2 system design philosophy to accept a min level of risk that ensures, in case of a failure, that the effects are contained (e.g., avoid the progress of deflagration to detonation). Assessment of the explosion prevention design to account for design for min risk level and containment of effects, ignition prevention and mitigation of events' propagation. Focus on the properties of the control system. Requirement for a consequence study providing with the relation between risks and mitigation measures (e.g., leaks vs. ventilation). Consequence calculation to be prerequisite. As a paradigm, ISO/TR 15916: 2015 defines requirements for safety systems per hazard and suggests measures/ways to minimise consequences, such that could support the development of procedures for hazards mitigation.	Ch. 12
Fire and gas detection and alarm system	Gap in detector specifications. Gap in the definition of fire detection.	Assessment of the required location and the features of hydrogen detectors and their instrumentation / control system (e.g., intervention time), ref. interim guidelines for FCs regarding the fire detection mechanism, (IMO, 2022). Fire detection should extend to fire and gas detection. CFD simulations can be used to assess the behaviour of a detection system (intervention time) and to provide input to the design of detection systems.	Ch. 11
Fire main	Gap in the fire safety systems goals: distinguish between fire causes.	The goals related to fire safety systems need update to include 2 cases: (a) fighting of a fire not caused by H_2; and (b) fighting of a fire caused in a system where H_2 is leaking. Assessment whether the same preventive and controlling measures can mitigate risks. ISO/TR 15916:2015 provides general remarks on fire safety characteristics, incl. flammability and detonation limits, H_2 properties, dispersion behaviour, flammability, and detonation limits. Therefore, experience can be used for the update of requirements for fire safety in the IGF code.	Ch. 11
Fire propagation avoidance	Gaps in preventive measures to avoid fire propagation	Assessment of requirements for space separation, fire boards and segregation systems, to avoid cross contamination and fire propagation: H_2 fire occurs at higher temperature compared to LNG. Standard flame tests of A-60 materials may not cover temperatures related to H_2 flames. In case of jet flames, A-60 boundaries may not be sufficient. The concentration of flame in certain points may cause these boundaries to lose integrity. Higher capacity boundaries need to be considered. Assessment of the need of supportive measures in case of non-visible flame and the ignition control.	Ch. 11
Fire-extinguishing system	(Un)suitability of conventional fire-fighting systems	Use of suitable/different fire-fighting materials, and attention to material-sensitive requirements: dry chemical powder fire-extinguishing systems, water spray, or other fire extinguishing means need to be assessed according to their suitability for firefighting depending on	Ch. 11

		the level of the phenomenon (deflagration/detonation/etc.).	
Labelling	Update labelling requirements.	Assess requirements for labelling, Warning signs, equipment marking, ISO 19880-1:2020.	Ch. 5
Leakage of gas	Gas leakage GHG potential is irrelevant to H_2	Requirements regarding the GHG potential of methane, e.g., gas leakage treatment, are irrelevant to H_2 .	Ch. 8
	More risks are associated with gas leakage, and therefore more appropriate safety systems are needed.	Assessment of safety measures for risk mitigation related to formation of flammable mixtures, potential of ignition, fire/explosion, effects of external fires/events; focus on means for leak monitoring, and concentration control. Information can be used from land-based standards ISO/TR 15916:2015, EN 13648-1:2008, and ISO 19880-1:2020. Assessment of H_2 dispersion behaviour (ISO TR 15916:2015). Requirements for protection from air condensation because of fuel leakage. Identification of measures to avoid the formation of pockets of liquid in the pipes, e.g., through purging of the pipes.	Ch. 8, Ch. 9, Ch. 15
Pressure relief systems	Gaps in pressure management systems are associated with component suitability.	Different acceptable methods for pressure and temperature maintenance for storage vessels and piping (ISO/TR 15916:2015) insulation, boil-off management systems, relief valve types. Assessment of means of protection against over pressurisation with a pressure-relief system. Assessment of passive or active measures to control acceleration, stemming from the effect of ship motions, and shock vibrations. Assessment of requirements for cryogenic systems: pressure relief mechanisms in vacuum-jacketed tanks and lines (ISO/TR 15916:2015). Mitigation of consequences of over-pressurisation because of external fire or failure of a regulator, which can release high-pressure hydrogen into a part of the system designed for a lower pressure.	Ch. 5, Ch. 8, Ch. 15, Ch. 6, Ch. 7
Safety systems arrangement	Gap in goal definition of systems independency.	Follow-up on requirements for safety functions arrangements and independency (IGF code: 15.2.4), based on criticality. The definition of independency is probably loose, so there is a need to investigate whether these covers: component separation, control/ monitoring/ power systems separation.	Ch. 15
Ventilation	Ventilation requirements differ from LNG: types and positions of detectors and ventilators, LFL, exhaust treatment requirements, etc. Requirement for ventilation in all spaces with H_2 systems.	Enforcement of ventilation requirement for all spaces involving H_2 gas, e.g., fuel storage, preparation, ducts, pipes, etc. Assessment of detection and ventilation requirements with regards to: (a) development of explosive atmosphere, (b) un-burnt fuel accumulation, (c) control system to shut-down fuel supply in case of failure, (d) requirements for fuel cell exhaust treatment (Interim Guidelines for FCs, IMO 2022). Use of ISO/TR 15916:2015 regarding the prevention of hydrogen/oxidizer mixtures from accumulating in confined spaces (under the eaves of roofs, in equipment shacks or cabinets, or within equipment covers or cowlings).	Ch. 10, Ch. 13

		Update requirements about ventilation rates and safety limits, e.g., dilution behaviour, lower flammability limits (LFL), etc. (ISO/TR 15916:2015), for the case of H_2.	
Inerting / purging / Gas freeing / Explosion venting / Venting processes	Gaps in purging and inerting system design: types, materials, process specifications, sensor requirements, separate venting lines, insulation, design for risk propagation control.	Assessment of H_2 purging and inerting systems/materials/process specifications, including the design and the procedural steps (e.g., purging with N_2, and then flashing with H_2 gas or Helium), and definition of the necessary level of pressurisation of pipes to avoid risks of contamination. Definition of requirements about venting insulation and mast dimensions and properties (IEC 62282-2-100:2020 fuel cell modules). Need of separate venting for all gas consumers, in conjunction with the IMO interim guidelines for FCs (IMO, 2022). Explosion venting design to avoid jet-fire development and detonation. Design specifications to avoid deflagration (ignition could produce deflagration, subsonic propagating flame) and especially the progress towards detonation in congested geometries. Design for detonation is an extreme condition, whereas a design for control of any range between deflagration conditions is expected, with primary focus on proper venting. Inclusion of H_2 gas concentration detectors. Hydrogen detectors are typically placed above a probable leak point and where hydrogen may accumulate / highest point of a room, or at the intake of ventilation ducts. ISO 26142:2010 defines the requirements applicable to hydrogen detection apparatus used in stationary applications. ISO/TR 15916:2015 defines requirements on the use of alarms and warning devices (including hydrogen and fire detectors), and area control around a hydrogen system.	Ch. 5, Ch. 8, Ch. 10, Ch.1 2, Ch. 15, Ch. 6, Ch. 7

2.5 Differences and inputs from other relevant recent publications

2.5.1 IMO CCC9 – Amendment to IGF code and Development of safety guidelines for alternative fuels and related technologies

Starting from 2021, the IMO Sub-Committee CCC9 – Carriage of Cargoes and Containers – made significant progress on the development of draft interim guidelines for the safety of ships using hydrogen as fuel, recognizing the pressing need to offer direction to Administrations, shipowners, and the broader industry regarding the safe utilization of hydrogen onboard, and in alignment with IMO's emission targets.

Specifically, the 9th session of the IMO Sub-Committee on Carriage of Cargoes and Containers (CCC 9) was held from 20 to 29 September 2023 with the primary scope of working on interim guidelines for use of ammonia and hydrogen as fuel, that were expected to be finalized at the MSC 109 (2-6 Dec 2024) for entry into force on 1 January 2028.

The proposed amendments pertain to updated non-mandatory criteria applicable to new ships concerning ship design and layout. They outline measures for organizing, setting up, overseeing, and supervising machinery, equipment, and systems reliant on hydrogen as a fuel source, aiming to mitigate risks to the ship, its crew, and the environment.

Thanks to the presence of a member of IMO CCC9 in the e-SHyIPS consortium, a comparison of the approach of gaps identification and a discussion on e-SHyIPS contribution to the present study were raised.

Below it is synthetically highlighted the e-SHyIPS approach, compared to the current approach in CCC9 for the identification of IGF Code gaps.

	IMO CCC9	e-SHyIPS
Gap identification approach	Top-down approach: development of interim guidelines based on CCC8/WP3 and comparing this document with IGF code to identify gaps	Bottom-up approach: discussing with industry with a design-focus perspective to identify knowledge needs. Matching Gaps with ISO standards already in place.
Functional requirement identification approach	Functional requirements are identified with the main goal of addressing hazards. Proprieties of both LH2 and GH2 are taken into account.	
Risk assessment approach	Propose a holistic risk approach for the entire fuel system together with the proposal to provide a list of issues that should be considered in the study. This list should be considered "supporting information" and non-exhaustive.	Propose a qualitative approach based on Preliminary Hazard Analysis on the entire fuel system at early-stage design phase. The results of PHA are instrumental to set quantitative risk analysis and CFD simulations.
Gap identification structure	Mirroring IGF code structure	
IGF code chapter focus	• Ch 2 General – definitions and abbreviations • Ch 3 Goal and Functionl requirement • Ch 4 General requirements – Risk assessment • Ch 5 Ship design and arrangement • Ch 6 Fuel containment system • Ch 7 Material and general pipe design • Ch 8 Bunkering • Ch 9 Fuel Supply to Consumer • Ch 10 Power generation including propulsion and other fuel consumers • Ch 11 Fire Safety	

	• Ch 12 Explosion prevention • Ch 13 Ventilation • Ch 14 Electrical Installations • Ch 15 Control, Monitoring and Safety Systems • Ch 2 General – definitions and abbreviations • Ch 3 Goal and Functionl requirement • Ch 4 General requirements – Risk assessment • Ch 5 Ship design and arrangement • Ch 6 Fuel containment system • Ch 7 Material and general pipe design • Ch 8 Bunkering • Ch 9 Fuel Supply to Consumer • Ch 10 Power generation including propulsion and other fuel consumers • Ch 11 Fire Safety • Ch 12 Explosion prevention • Ch 13 Ventilation • Ch 14 Electrical Installations • Ch 15 Control, Monitoring and Safety Systems Not covering • Ch 16 Survey, manufacture, Workmanship and Testing • Ch 17 Training • Ch 18 Operation	
Vessel typology focus	Cargo	Passenger ships
H2 arrangement on vessel focus	LH2 and GH2 tank + systems on open deck, only. Enclosed spaces studies will be carried out next	LH2 and GH2 tank + systems on open deck, semi-closed and confined spaces

2.5.2 Potential of H2 as a fuel for shipping – an EMSA publication

Recently EMSA produced a publication on hydrogen as marine fuel, developed by ABS, CE Delft and Arcsilea, [EMSA report, 2023]. The objective of the report is to present the impact of hydrogen in important aspects of maritime transport, like technical implementation, sustainability, market availability, suitability and costs. Furthermore, the report describes the existing framework on safety and environmental regulations, standards and guidelines, which are set for hydrogen or other novel marine fuels, by major organizations like SIGTTO, SGMF, SAE, CIMAC, IACS, the EU, and other nations. Finally, the report presents a hydrogen risk assessment for merchant ships, describing key safety related findings and giving recommendations for two indicative ship types: Ro-Pax vessel, and Product carrier.

Regarding the environmental and sustainability footprint of hydrogen, the study concluded tht green hydrogen is seen as one of the fuels that could contribute to the reduction of life-cycle GHG emisisons from shipping. However, challenges like the high associated costs and the lack of port supply infrastructure, as well as the low production capacity of green hydrogen fuel worldwide, hinder the technology uptake. Water use in some production processes is also another barrier to overcome, in order to arrive at a condition of higher green hydrogen production capability.

Regarding the GHG impact of H2 leaks to the atmosphere, the report refers to other studies that indicate the hydrogen global warming potential as an indirect greenhouse gas. The current literature leans towards a net positive impact on climate.

Regarding the technology maturity, the report suggests that the presence of mature energy conversion systems like fuel cells allows for the hydrogen uptake in newbuildings, but the high capital costs of these systems is a barrier. In addition, the report suggests that gas hydrogen is more relevant to the short-sea shipping applications, compared to liquid hydrogen for bigger or more consuming shipping segments. This is aligned with our approach in the definition of eSHyIPs scenarios. Technology variants like liquid organic hydrogen carriers can offer intermediate options to investigate on a per trade basis. In terms of total cost of ownership, the study concludes that the cost gap between 'blue' hydrogen-fuelled and conventionally fuelled ships may almost close by 2050. Carbon cost is an inportant parameter to be accounted for in this calculation. In the case of NH3, the distribution cost is expected to be lower compared to hydrogen.

Regarding safety aspects, the study analysed the well-known risks of flammability, explosivity, risk of detonation/deflagration. The study suggests that the use of well-established methods of risk analysis, like HAZID and FMECA, is essential for the definition of mitigative safeguards that vary per ship type and application. The key needs identified are:

Training

- Training for companies and crew on hydrogen management.

Regulations

- Regulations to close gaps.

Research

- Special dispersion study needs to be conducted and gas detector mapping study to verify proper coverage of detection equipment to detect any hydrogen leak.
- Material selection procedures and proper qualification plans for each material which may come into contact with hydrogen are to be developed.
- Safe operation procedures for whole value chain
- Improvement of gas and fire detection equipment fit to the marine environment

Points to be considered in case-specific analyses

- Elimination of risks from any potential source of arc/spark, static charge etc.
- Provision for venting and purging of each system which contains hydrogen, or if this is not possible, system design to withstand internal deflagration/detonation pressure surges.
- Provision for leak/tightness test after maintenance, connection/disconnection or any other activity requiring opening of system, equipment etc.
- Elimination of potential for air/oxygen migration.
- Minimization of leak related risks for high pressure hydrogen systems, via detailed HAZOP, FMECA study for hydrogen system.

- Safeguards for high pressure hydrogen leak in GH2 systems, to prevent the uncontrolled release of H2 from storage tanks.
- Piping design for 'leak-before-break' concept.
- Minimum hourly air-change rate for ventilation of any space containing hydrogen.
- Risks related to the location of the fuel-treatment room and safeguards, the ventillation in these spaces, and the handling of operations, depend on vessel type.
- Safety analysis for fire and explosion risks from external and internal factors is required, covering extrenal impacts on the fuel piping on the weather deck by dropped objects or other physical damage.
- Double-walled piping with protection is required.
- On the procedural side, emergency handling plans in cosultation with authorities, has to be developed

All above requirements have already been identified and addressed in the eSHyIPS gap assessment.

2.5.3 IMO Interim Guidelines for the safety of ships using Fuel Cell Power Installations

In 2022, the International Maritime Organization's Maritime Safety Committee released the 'interim Guidelines For The Safety Of Ships Using Fuel Cell Power Installations.'

The document aims to establish interim guidelines for ensuring the safety of ships equipped with fuel cell power installations, emphasizing the maritime industry's transition towards cleaner energy sources. The objective of the document is indeed to establish criteria for the arrangement and installation of fuel cell power systems, ensuring an equivalent level of safety and reliability to new and comparable conventional oil-fueled main and auxiliary machinery installations. This applies regardless of the specific fuel cell type and fuel used. The document is structured as follows:

- Functional Requirements: The functional requirements, presented in 18 statements, aim to achieve safety and reliability equivalent to conventional propulsion systems. The document provides a preceding definition of terms specific to the technology.
- Alternative Design Approach: The alternative design approach is outlined in accordance with SOLAS regulation II-1/55.

The subsequent section delves into *Design Principles For Fuel Cell Power Installations*, covering fuel cell spaces, their arrangement, specific access situations, atmospheric space control within fuel cells, ventilation, inertization, material selection, piping arrangement, and exhaust management. A significant focus is dedicated to fire safety, encompassing general provisions and concrete measures for protection, extinguishing, damping, etc.

The document also addresses electrical installation, including hazardous area zone definition and related risk analysis.

A crucial aspect discussed in the document pertains to the *Control, Monitoring, And Safety Systems* strategy. This strategy ensures the monitoring and assurance of the aforementioned safety and functionality measures, incorporating fire detection, gas detection, liquid detection, ventilation, emergency shutdowns, and general safety actions.

The guidelines offer crucial safety recommendations for the design, installation, and operation of fuel cell power systems on ships, with a focus on preventing potential hazards and ensuring compliance with industry standards.

Amendments to the IGF Code and development of guidelines for alternative fuels and related technologies

Experience gained with the Interim guidelines for the safety of ships using fuel cell power installations (MSC.1/Circ.1647)

This document summarizes the experience gained in the use of the MSC.1/Circ.1647 on Interim guidelines for the safety of ships using fuel cell power installations and provides suggestions for improvement.

On the functional requirements it is recommended that well establishesd and documnented technology should be used and in terms of redundancy, no fewer than two fuel cell power systems should be provided onboard.

Additional clarification of terminology and further information on the alternative design approach is given.

In more detail, several additional aspects of Fuel cell modules supplied in metallic enclosures, Fuel cell spaces and arrangements, Fire safety and controls and monitoring are provided as recommendations.

For the Testing of the fuel cell power system it is proposed that fuel cell power systems should be factory tested in accordance with an approved test programme and the risk analysis should also address risks to persons and environment.

As a last point the Sub-Committee is invited to consider the foregoing and take action as appropriate.

2.6 Plan for an e-SHyIPS policy workshop

In order to boost the outreach of the project and achieve the widest audience at policy level, a dedicated 1-day workshop has been planned to be held in next spring 2024. The workshop has two main objectives:

- to present the "work in progress" research activities of e-SHyIPS related to technical and policy aspects;
- to promote knowledge sharing on best practices and use cases related to technical implementation of hydrogen systems on board of passenger ships and to the related regulatory framework.

The major outcome of the workshop will be to produce a significant advancement in the development process of policy guidelines related to an effective introduction of hydrogen in maritime passenger transport sector.

The event, whose details are still work-in-progress, will be held in person (or, possibly in a hybrid format) and, in particular, it will be hosted in Bruxelles, at CEN premises. The target audience shuld be around 50 people. The choice of Bruxells has also been made to facilitate logistics, thus enhancing the potential partecipation of members outside the consortium.

In order to maximize the stakeholders engagement and the involvement of key people both as speakers and audience in the conference, the Consortium agreed to ask for the support of Magellan Circle in the organization of the event. Magellan Circle is a EU funding accelerator and consultant, actively involved in the development of communication and dissemination strategies related to the maritime, port and transport sector. Magellan Circle has indeed a set of useful running tools and channels (i.e. periodic newsletters, social media channels, online platforms) with engaged and already active audience in target for the e-SHyIPS event, which are complementary to those already put in place by ATENA, as responsible for the communication and dissemination of the project. By this means, the networking potential offered by such an event will be maximized.

2.6.1 Involvement of Key Speakers

The Policy Workshop will be mainly devoted to address policy aspects, but it will be also focused on technical issues and perspectives; in this framework, the following organizations outside the Consortium have been targeted to possibly participate as speakers:

- *Policy and standardization perspective*:
    - CEN/CENELEC
    - DG-MOVE Waterborne Department
    - DG CLIMA
    - DG RTD
    - DG COMP
    - INTERNATIONAL CHAMBER OF SHIPPING
    - RINA
    - IMO

- *Industry perspective* (best practices and use cases):
    - Hydrogen Europe
    - ECSA
    - European Sea Port Organization (ESPO)
    - Baltic Ports
    - Med Ports
    - Fincantieri
    - Waterborne Association
    - Sea Europe
    - CLIA

2.6.2 Stakeholders engagement

Leveraging on the strong and wide network of relations and contacts of the e-SHyIPS partners, but also of Magellan Circle, which has a long, well-established experience in the EU consultancy field for maritime, port and transport sector, the following target audience has been identified:

- IMO
- Standardization experts
- Industry Associations
- Institutions and EU MS Ministries
- EU Commission
- Ports
- Terminals
- Transport & Logistics operators
- Shipping
- MTO
- Universities and Research Centers

Selection of key players (i.e. shipping lines, technological providers, port authorities, academia, energy providers) to be invited in taking part to the workshop as audience is instrumental for the success of the event. Therefore, an intensive communication campaign is in order via the e-SHyIPS media channels as well as the Magellan Circle tools.

Also, a dissemination campaign after the event to the enlarged stakeholders community will be put in place, to follow up the event and enhance interactions among invoved parties.

3. Standardization Needs

3.1 CEN/CENELEC Roadmap on H2 standardization

On 1 March 2023, the Director General of CEN and CENELEC, Elena Santiago Cid, received the new Hydrogen Standardisation Roadmap from the hands of Maive Rute, Chief Standardisation Officer of the European Commission.

The Roadmap is a key element in the EU's efforts to facilitate the transition to more sustainable energy and transport systems. It provides a comprehensive overview of the gaps, challenges and standardisation needs of the entire hydrogen supply chain, together with the achievements already made by the industry. It also includes a set of recommendations to optimise and accelerate the standards development process, in line with the new European Standardisation Strategy of 2 February 2022.

The Roadmap has been developed by the European Clean Hydrogen Alliance, set up by the Commission to bring together industry and all other stakeholders to support the large-scale deployment of clean hydrogen technologies by 2030, and CEN and CENELEC are delighted to be working together to realise these goals.

The roadmap, produced by a Working Group, covers standardisation needs for the entire hydrogen value chain (production, distribution, transport, storage and end applications). It considers hydrogen as an energy carrier available in the following forms:

- liquid hydrogen
- hydrogen gas (pure 100% H2 or mixtures of H2 and natural gas H2NG)
- other:
- Liquid Organic Hydrogen Carrier (LOHC)
- Liquid Inorganic Hydrogen Carrier (LIHC)
- ammonia (NH3)
- methanol (CH3OH)

The members of the working group identified and mapped about 400 topics, indicating their relevance (e.g. whether 100% H2 or blending), the current status of the standardisation process and the responsible committees if any. A match was made with the draft work programme of CEN-CENELEC to show which standardisation topics have already been addressed and which have been newly identified. The analysis of the identified topics led to:

- a clustering of topics and timeframes according to standardisation needs
- a definition of priorities
- key actions

3.1.1 Cluster

1. Hydrogen production: The relevant technical committees are already in place and focus on the production of clean hydrogen below defined emission thresholds. Harmonised standards are needed to ensure European technology leadership, as well as standards for power-to-x technologies, gas quality and material compatibility to ensure safety.
2. Infrastructure - Transmission and Distribution (T&D): there is a need to consider the impact of hydrogen on gas infrastructure due to the similarities and differences between methane and hydrogen. There is a need to review the standards of existing gas infrastructures and build new ones to accommodate hydrogen and blends (mixtures of H2 and methane). Infrastructure is already being built with the possibility of using hydrogen in the future, called 'hydrogen-ready'. Research is needed for some aspects, but it is estimated that about 80 per cent of the requirements of existing standards are already applicable to hydrogen.

3. Industrial applications: it is a priority to upgrade existing standards for the use of H2 mixtures (e.g. materials, safety, performance, emissions, leakage, product testing) and 100% H2. Hydrogen gas quality and impurities have a great impact on the combustion process, efficiency and emissions, and these implications must be evaluated and tested in pre-normative studies and with laboratory tests. A joint CEN-CENELEC Sector Fora task force is studying the quality requirements of hydrogen in industrial end uses.
4. Mobility: This category includes road vehicles, heavy duty vehicles (on-road and off-road), trains, ships and aircraft. From a technological point of view, road vehicles and railways are the most advanced, while for heavy vehicles, ships and aircraft the technology still needs to be developed. For all these categories there is a need to develop standards for refuelling and storage. For example, as UNI we are actively involved in the e-SHyIPS project within which we organised the workshop for Hydrogen EXPO. The project aims to bring together stakeholders and experts to gather knowledge on ship design, safety systems, materials and bunkering procedures, with a focus on risk and safety assessment methodologies. The project will define a pre-standardisation plan for hydrogen-powered passenger ships and create a roadmap for increasing the hydrogen economy in the maritime sector.
5. Energy - integration of hydrogen in the energy sector: this is about the adoption and use of hydrogen in power generation and combined heat and power (CHP) and grid flexibility. The Roadmap did not have time to go into this topic in depth, so more work will be needed.
6. Buildings - Residential Application: To fully decarbonise the gas heating sector, a significant increase in the use of green gases, be it biomethane, hydrogen and its blends, is needed. The relevant CEN technical committees are already drafting and updating standards for the use of hydrogen in buildings. The focus is on pure hydrogen and a transition period through blending with natural gas or biomethane. It is a high priority to update existing standards for the design and testing of applications using 100 per cent hydrogen and mixtures of H2, e.g. regarding materials, safety, performance, emissions, leakage, product testing, etc. There is a need to involve more experts in the process and laboratory testing, as well as to involve all standardisation technical committees dealing with products and appliances used in buildings. Finally, it is important to define and guarantee the quality of gas distributed in pipelines and to communicate this to end users.
7. Cross-cutting: covers topics related to the hydrogen value chain: energy carriers, sustainability criteria, safety and metrology. For the development of hydrogen, it is essential to have certification measures that verify compliance with standards, regulatory requirements and sustainability criteria such as environmental footprint and the use of renewable energy for its production. This will differentiate hydrogen and its derivatives from other fuels and gases with higher pollution levels. The adoption of hydrogen will involve different transport modes and technologies. To enable this, standards need to be established to ensure that all technologies are covered and that plants operate reliably. In addition, a new standardised and harmonised methodology is needed to calculate the environmental footprint of hydrogen plants.

3.1.2 Priorities

For hydrogen to be successfully implemented in the market, all systems, processes, equipment and applications must be hydrogen-ready.

Therefore, priorities have to be defined on which to focus in order to coordinate/rationalise standardisation activities and to reconcile them with already existing standards.

It was found that for some parts of the value chain, issues are already well addressed and are well advanced in the standardisation process; their publication could be expected within the next two to three years. For other parts, there are standardisation topics that have been identified but are not yet in progress or have not yet been assigned to the CEN-CENELEC/ISO-IEC Technical Committees or for which the information in the standardisation WG is not yet mature.

In this context, the following three aspects should be treated with high priority:

- Horizontal aspects: topics on which other topics depend. For this category, a table summarising the central topics is presented. (Image below, source CEN/CENELEC H2 Roadmap)
- Topics to be developed: topics for which relevant projects and/or technical committees have NOT been identified. (These include various hydrogen carriers including LOHC - Liquid Organic Hydrogen Carrier or charging stations). For these issues, the right experts and TCs need to be involved in order to start work quickly.
- Pre-normative research topics: topics that need more knowledge prior to standardisation. They form an important bridge between innovations and the first standardisation needs. Fortunately, in many areas these studies are already underway thanks to various research projects (E-shyips is one example).

Horizontal aspects with further details

Horizontal aspects	details
terminology / definitions	collection of relevant topics
sustainability and origin	guarantee of origin (chain of custody)
	emissions / GHG
gas quality aspects	purity
	gas families / test gases
	quality measurement
safety aspects	material compatibility
	potential explosive atmosphere
	leakage
	odorisation
components / equipment	valves

	pipes
	seals
installation	bunkering
	refueling
	storage
energy / hydrogen carrier	liquid hydrogen
	gaseous hydrogen
	other carriers
	LOHC
	LIHC - Liquid Inorganic Hydrogen Carrier & HydroSil
	KBH_4 and other solid H_2 carriers
	metal hydride (e.g. iron pellets)
	ammonia
	methanol
	HHO
metrology	measurement (e.g. quality and volume)
	efficiency
	certification

3.1.3 Key Actions

Beyond the identification of individual standardisation issues, the working group identified complementary needs that are necessary to facilitate the adoption of hydrogen. The most important are the following:

a) a clear regulatory framework that gives a clear direction to the standardisation work;
b) the publication of mandated standards by the European Commission;
c) the engagement of industry in topics 'to be developed' and/or for which no standardisation committees exist or are not yet active; furthermore, a good exchange of information with associations such as the Hydrogen Council, IPHE, IRENA, Hydrogen Europe and others is needed;
d) the need for a general coordination of hydrogen standardisation activities focusing on the technical needs of industry; alignment with European Commission policies and legislation and the implementation capacity of CEN-CENELEC;
e) increased cooperation between European and international standardisation bodies on the basis of existing agreements (Vienna/Frankfurt agreement).

3.2 E-shyips Standardization "SWOT analysis"

The CEN/CENELC Roadmap has highlighted that when it comes to H2 applications to the maritime sector, a lot of work in terms of standardization is expected.

The e-Shyips gap assessment has already identified improvement areas in the IGF code with relation to hydrogen as potential marine fuel.

Among these:

- Proposals for updates in the IGF code functional goals, to include the risks and criticalities related to hydrogen.

- Gaps related to arrangement and location evaluations, including safe distances re-evaluation, acceptable onboard locations and necessary safeguards.
- Gaps about propulsion systems and machinery, to include the options related to hydrogen, with focus on fuel handling systems and energy conversion technologies
- Gaps related to missing safety systems or necessary upgrades to handle hydrogen criticalities.
- Proposals for new chapters related to materials.

A bottom-up approach was followed to review the IGF code content and assess its relevance to hydrogen. The focus was put primarily on fuel cells, which are proven energy conversion technologies for H2, while internal combustion concepts were not assessed because of immaturity. The risks of hydrogen were accounted for in assessing the gaps and providing recommendations for code updates.

As a second step, E-shyips is planning / executing several experiments to gain new knowledge supporting the closure of the gaps identified.

The experiments planned by the project are summarized in the table below:

Title	Experiment: objectives, E-shyips scenario	Type	Ref to IMO doc[2]	e-SHyIPS IGF Code Gap[3]
Virtual towing tank simulation: hydrostatics	Objective: to perform hydrostatic and stability analysis (e.g. useful for bunkering) Scenario: M + L	virtual simulation	Not applicable.	Not applicable. No IGF Code gap has been matched since this experiment intends to ensure that safety reliability of the entire vessel should be at least equivalent to that achieved with new or conventional fuel vessel.
Virtual towing tank simulation: hydrodynamic	Objective: to perform calm-water simulations to verify water resistance and detail operational profiles Scenario: M + L	virtual simulation	Not applicable.	Not applicable. No IGF Code gap has been matched since this experiment intends to ensure that safety reliability of the entire vessel should be at least equivalent to that achieved with new or conventional fuel vessel.
Virtual towing tank simulation: wave effect (and sloshing)	Objective: to perform seakeeping wave simulations including rigid body dynamics of system control points Scenario: M + L	virtual simulation	not present. Reference only to collision and grounding (5.3.3)	Gaps related to arrangements and location (Table 7) - Impact of stresses + Impact of environmental conditions
General arrangement vessel design	Objective: define a baseline for e-SHyIPS experiments Scenario: S + M + L	design - baseline for data analysis and virtual simulation	quality indication for: 3.2, 5.2, 5.13, 6.3 - functional requirements and ship arrangements	Gaps related to arrangements and location (Table 7) - Safety barriers + Hazardous area zones, area classification and distances
H2-based fuel propulsion system basic design	Objective: define a baseline for E-shyips experiments Scenario: S + M + L	design - baseline for data analysis and virtual simulation	quality indication for: 3.2, 5.5 - functional requirements and ship arrangements	Gaps related to arrangements and location (Table 7) + Gaps related to power conversion and redundancy (Table 8)
H2-based fuel propulsion system scenario simulation	Objective: to develop a generic simulation model for the energy conversion plant,	virtual simulation	quality indication and quantity assesemnt for:	Gaps related to power conversion and redundancy (Table 8) + Gaps related to safety systems (Table 11)

[2] Preliminary analysis of the IMO CCC9 – Amendment to IGF code and Development of safety guidelines for alternative fuels and related technologies (cfr section 2.5.1).
[3] Cfr Section: "IGF Code: what's missing for H2 applications".

	capable to provide insight about the energy consumption and safety at realistic operating conditions Scenario: M		3.2.3 - loss of power 6.13 - provision on inerting 7.2 - functional requirement piping design 9.3.13 - Pipe stress	
FMECA risk assessment	Objective: identify hazards related to the potential failure modes of the various parts of a system - the effects these failures may have on the system - how to avoid the failures, and/or mitigate the effects of the failures on the system Scenario: S + M + L	data analysis (HAZID, HAZOP, FMECA)	methodology and tools for: 4.2 risk assessment (at different design stage + holistic approach) quality indication for: 14.4 Hazardous area classification	Gaps related to arrangements and location (Table 7) + Gaps related to safety systems (Table 11) + Gaps in goals definition (Table 6) - Lack of references to H2-hazards in the IGF code goals.
Emergency hydrogen discharge CFD analysis	Objective: evaluate the dynamic of hydrogen emergency release scenarios Scenario: S	virtual simulation	quality indication and quantity assesemnt for: 6.4 - CGH venting system 9.8 - overpressure protection and vent mast	Gaps related to safety systems (Table 11) - Pressure relief systems + venting / venting processes
Simulation of flammable dispersion on-board	Objective: evaluating the effect of forced ventilation (different rating condition and geometries) of possible leak scenario Scenario: S + M	virtual simulation	quality indication and quantity assesemnt for: 3.2.12 - functional goal - explosion prevention 4.3 - limitation of explosion 13.3, 13.5 - ventilation	Gaps related to safety systems (Table 11) - Explosion prevention + Leakage of gas + Gaps related to arrangements and location (Table 7) - Dispertion of fuels + Gaps in goals definition (Table 6) - Can functional goal requirements allow a minimum level of leakages?
Simulation of explosion	Objective: evaluating explosion scenarios originating from the fuel cell room and containment room according to different venting schemes Scenario: S + M	virtual simulation	quality indication for: 3.2.12 - functional goal - explosion prevention 4.3 - limitation of explosion	Gaps related to safety systems (Table 11) - Explosion prevention + Leakage of gas + Explosion venting + Gaps related to arrangements and location (Table 7) - Dispertion of fuels
Safety Systems Definition and Preliminary Design	Objective: define the safety system strategy and design Scenario: S + M + L	design - baseline for data analysis and virtual simulation	quality indication for: 3.2 - functional requirements and arrangements 11.3 - Fire safety and protection 11.4, 11.5 - Fire detection, alarm, extinguishing 15.3 - Control, monitoring and safety systems 15.4 - Gas detection	Gaps related to safety systems (Table 11)
MSC testing of cathode materials	Objective: Analysis of suitable materials for fuel cells. Development of methodology, for example for electrochemically active surface area (ECSA) measurement carried out both with CO-stripping and hydrogen underpotential deposition (HUPD). Scenario: not applicable	lab test	5.5.1. [Hydrogen consumer space] Fuel cells no specific section on FCH, the Draft Guidelines (Annex 2 to CCC 8/WP.3) includes Regulations for internal combustion engines of piston type only (10.3)	Materials and manufacture (Paragraph 3.1.5)

MSC testing of anode materials	Objective: Analysis of suitable materials for fuel cells. Development of methodology, for example electrochemically active surface area (ECSA) measurement carried out both with CO-stripping and hydrogen underpotential deposition (HUPD). Scenario: not applicable	lab test	5.5.1. [Hydrogen consumer space] Fuel cells no specific section on FCH, the Draft Guidelines (Annex 2 to CCC 8/WP.3) includes Regulations for internal combustion engines of piston type only (10.3)	Materials and manufacture (Paragraph 3.1.5)
Inclination tests with full-sized stacks	Objective: testing of different static inclination angles with full-sized stacks Scenario: not applicable	lab test	5.5.1. [Hydrogen consumer space] Fuel cells no specific section on FCH, the Draft Guidelines (Annex 2 to CCC 8/WP.3) includes Regulations for internal combustion engines of piston type only (10.3)	Gaps related to power conversion and redundancy (Table 8) - Energy converted types and auxiliaries + Gaps related to arrangements and location (Table 7) - Impact of environmental conditions
Salt-spray testing of fuel cell stacks	Objective: testing of the effect of salt spray (air filter slip or malfunction) on stack. Scenario: not applicable	lab test	5.5.1. [Hydrogen consumer space] Fuel cells no specific section on FCH, the Draft Guidelines (Annex 2 to CCC 8/WP.3) includes Regulations for internal combustion engines of piston type only (10.3)	Gaps related to power conversion and redundancy (Table 8) - Energy converted types and auxiliaries + Gaps related to arrangements and location (Table 7) - Impact of environmental conditions
Post-mortem analysis of the materials, components and fuel cell system	Objective: detect and evaluate any impurities or impurity-related degradation effects on end of life materials, components and fuel cell system Scenario: not applicable	lab test	quality indication and quantity assesemnt for: 7 - Component Materials (focus on Piping, Metals, plates)	Materials and manufacture (Paragraph 3.1.5)
Fuel delivery and bunkering strategy and design	Objective: evaluate different production/handling strategies and define a baseline for E-shyips experiments Scenario: S + M + L	design - baseline for data analysis and virtual simulation	quality indication for: 8.3 - bunkering station design 8.5 - bunkering system design 9.10 - Fuel bunkering piping systems	Gaps related to equipment and components (Table 10)
Fuel Bunkering Simulation	Objective: simulation of mass transport phenomena, heat transport phenomena, and dispersion and dilution phenomena Scenario: S + M + L	virtual simulation	quality indication and quantity assessment for: 8.4 - bunkering manifold (temperature and pressure) 8.5 - bunkering system design 9.3, 9.4, 9.5 - fuel supply - piping design principles 9.10 - Fuel bunkering piping systems	Gaps related to equipment and components (Table 10)
Risk Assessment	Objective: identify hazards related to the potential	data analysis (HAZID,	methodology and tools for:	Gaps related to arrangements and location (Table 7) + Gaps related to

	failure modes of the various parts of the bunkering system - the effects these failures may have on the system - how to avoid the failures, and/or mitigate the effects of the failures on the system Scenario: S + M + L	HAZOP, FMECA)	4.2 risk assesment (at different design stage + holistic approach) 8.3 - bunkering station risk assesment	safety systems (Table 11) + Gaps in goals definition (Table 6) - Lack of references to H2-hazards in the IGF code goals

4. Proposal for a new CEN Workshop Agreement

A CEN Workshop Agreement (CWA) is a reference document published by the European Committee for Standardization (CEN/CENELEC) and inended to meet an immediate standardization need of the market, when the results have not reached a maturity level high enough to be part of an EN standard[4].

It represents actually a first try-out of the market for a future EN standard.

More in details, a CEN Workshop Agreement (CWA) is a consensus-based document and it serves as a means for stakeholders to establish a common understanding or solution to a particular issue or topic within a relatively short timeframe. CWAs are not full-blown standards but rather provide a basis for further standardization activities or offer guidance in areas where standardization is not yet fully developed.

In the realm of research and innovation projects, CWAs play a crucial role as important exploitable results due to their ability to capture emerging best practices, methodologies, or technologies. These agreements arise indeed from collaborative efforts among industry experts, researchers, policymakers, and other relevant stakeholders, making them valuable resources for guiding future research directions and technological advancements.

One key aspect of CWAs is their agility and adaptability to address rapidly evolving fields or niche areas where traditional standardization processes might be too slow or cumbersome. This agility enables research and innovation projects to benefit from up-to-date insights and recommendations, fostering a dynamic environment conducive to experimentation and creativity.

Moreover, CWAs facilitate knowledge exchange and collaboration across diverse sectors and geographical boundaries, promoting synergy among different stakeholders and enhancing the overall impact of research and innovation initiatives. By providing a common framework or reference point, CWAs help streamline communication, reduce duplication of efforts, and foster interoperability among various systems, products, or services.

In the context of research and innovation projects, CWAs can serve as valuable tools for benchmarking, quality assurance, and technology transfer. They provide a basis for evaluating the effectiveness and reliability of new approaches or solutions, thus contributing to the validation and scalability of innovative ideas. Additionally, CWAs may support the dissemination and adoption of project outcomes by providing clear guidelines or best practices for implementation.

[4] Further information is available in the dedicated CEN/CENELEC webpage: https://boss.cen.eu/developingdeliverables/cwa/pages/

Overall, CWAs represent a flexible and collaborative approach to standardization that is particularly well-suited to the dynamic nature of research and innovation projects. By leveraging the collective expertise and resources of diverse stakeholders, CWAs help accelerate the pace of innovation and facilitate the translation of research findings into tangible benefits for society and the economy.

For all these reasons, based on the gap assessment and the needs emerged in the project, the E-shyips consortium agreed to initiate the process for proposing CEN/CENELEC to publish a new CWA.

The Annex to this deliverable reports the draft CWA project prosal which will be sent to CEN/CENELC shortly.

5. Conslusions

The application of hydrogen as a propulsion source for passenger ships presents a promising avenue for reducing the maritime industry's environmental impact. However, the successful integration of hydrogen technology into passenger ships necessitates a comprehensive approach to standardization.

Standardization is indeed critical to ensuring the safety, efficiency, and interoperability of hydrogen-powered vessels and addressing standardization needs is a foundational step towards realizing the full potential of hydrogen as a clean energy source for passenger ships.

Collaboration among industry stakeholders, including shipbuilders, classification societies, and regulatory bodies, is essential to develop and implement these standards effectively. A unified approach to standardization will not only boost the adoption of hydrogen technology in passenger ships but also contribute to the establishment of a robust, sustainable, and safe hydrogen maritime sector.

6. References

[1] ATEX 114 Directive 2014/34/EU - Equipment and protective systems intended for use in potentially explosive atmospheres.

[2] ATEX 153 Directive 1999/92/EC - Minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres.

[3] DNV MarHySafe, Handbook for Hydrogen-fuelled vessels. 1st Edition, 2021.

[4] e-SHyIPS, https://e-shyips.com/

[5] International maritime organization, Interim guidelines for the safety of ships using fuel cell power installations. MSC.1/Circ.1647, 15 June 2022.

[6] International maritime organization, International Code of Safety for Ship Using Gases or other Low-flashpoint Fuels (IGF code), June 2015.

[7] International maritime organization, Generic guidelines for developing IMO goal-based standards. MSC.1/Circ.1394, 8 July 2019.

[8] ISO/TR 15916:2015. Basic considerations for the safety of hydrogen systems
[9] ISO 19880-1:2020. Gaseous hydrogen, Fuelling stations - Part 1: General requirements
[10] ISO 14687:2019. Hydrogen fuel quality - Product specification
[11] ISO 26142:2010. Hydrogen detection apparatus - Stationary applications
[12] ISO 22734:2019. Hydrogen generators using water electrolysis - Industrial, commercial, and residential applications
[13] ISO/TS 19883:2017. Safety of pressure swing adsorption systems for hydrogen separation and purification
[14] ISO 16110-1:2007. Hydrogen generators using fuel processing technologies - Part 1: Safety
[15] ISO 16110-2:2010. Hydrogen generators using fuel processing technologies - Part 2: Test methods for performance
[16] ISO 19880-1:2020. Gaseous hydrogen - Fuelling stations - Part 1: General requirements
[17] ISO 14687:2020. Hydrogen fuel quality - Product specification
[18] ISO 16924:2018. Natural gas fuelling stations - LNG stations for fuelling vehicles
[19] ISO 13985:2006. Liquid hydrogen - Land vehicle fuel tanks
[20] EN 13648-1:2008. Cryogenic vessels - Safety devices for protection against excessive pressure - Part 1: Safety valves for cryogenic service
[21] ISO/TC 197. Hydrogen technologies
[22] SAE J2719. Hydrogen Fuel Quality for Fuel Cell Vehicles
[23] IEC 62282-2-100:2020. Fuel cell technologies - Part 2-100: Fuel cell modules - Safety
[24] Nerheim A. R., Vilmar Æ., and Finn T. H. "Hydrogen as a maritime fuel - Can experiences with LNG be transferred to hydrogen systems?" Journal of Marine Science and Engineering 9, no. 7: 743. https://doi.org/10.3390/jmse9070743, 2021.
[25] Norled Hydra, https://www.norled.no/en/news/the-mf-hydra-first-in-the-world/ , Accessed 2023.

7. Annexes

[1] CEN Workshop Agreement Project Plan

Draft Project plan for the CEN-CENELEC Workshop on "Pre-normative plan for H2 applications to passenger ships"

Requests to participate in the Workshop and/or comments on the project plan are to be submitted by
<TBC> to <sviluppo.progetti@uni.com>[1]

Recipients of this project plan are kindly requested to name all patent rights known to them to be relevant to the Workshop and to make available all supporting documents.

Milan, <02.02.2024> (Version 1)

[1] Applications for participating in the Workshop and comments on the project plan that are not received by the deadline do not need to be taken into consideration. Once constituted, the Workshop will decide whether or not to consider the comments received in good time.

Contents

1 Status of the project plan

Draft project plan for public commenting (Version 1.0)

This draft project plan is intended to inform the public of a new Workshop. Any interested party can take part in this Workshop and/or comment on this draft project plan. Please send any requests to participate or comments by e-mail to **<sviluppo.progetti@uni.com>**.

All those who have applied for participation or have commented on the project plan by the deadline will be invited to the kick-off meeting of the Workshop on **<date TBC>**.

Approved project plan for CWA development adopted at the kick-off meeting of the Workshop on **<date TBC>** (Version **<No.1>**)

2 Workshop proposer and Workshop participants

2.1 Workshop proposer

The proposer of this CEN Workshop is the E-shyips project funded by Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant agreement n. 101007226 and coordinated by:

Politecnico di Milano, Piazza Leonardo Da Vinci 32, 20133 Milano, Italy

The CEN national member holding the Workshop secretariat is:

UNI - Ente italiano di Normazione

Via Sannio n.2, Milano, Italy (20137)

2.2 Other potential participants

This CWA will be developed in a Workshop (temporary body) that is open to any interested party. The participation of other experts would be helpful and is desired. It is recommended that:

- Academic and research bodies
- Funded European Projects (i.e. Horizon 2020, Horizon Europe)
- Industry and commerce
- Non-governmental organizations (NGO)
- Standards application

take part in the development of this CWA.

2.3 Participants at the kick-off meeting

All relevant E-shyips project partners will be invited to attend the kick-off meeting, the invitation will also be extended to experts from twin projects.

3 Workshop objectives and scope

3.1 Background

The maritime sector contributes significantly to the the environmental impact, with an increased share of greenhouse gas emissions estimated for the next few years. The International Maritime Organization (IMO) has initially set a target to reduce CO2 emissions by at least 50% in 2050. Recently, this strategy has been revised by IMO aiming for an ambitious zero-emissions scenario by the same year, towards the complete decrbonization of the maritime sector. In this context, hydrogen and hydrogen-based fuels are regarded as very promising, and a broad consensun has been reached within the shipping industry to replace conventional propulsion systems of vessels with new hydrogen technologies in the near future. Achieving the aforementioned target, also requires an unprecedent enhancement in innovation for the maritime sector, involving not only the re-design of vessels, but also the implementation of new infrastuctures in ports as well as the development of alternative bunkering approaches, to support the whole value chain related to hydrogen as fuel. Fuel cells and hydrogen techologies have been already demonstrated in few prototypes, at different scales and for different applications. However, to date, an international regulatory framework for the use of hydrogen on-board of ships is absent, this representing a barrier to its adoption at large scale.

In 2021, the IMO has released the Interim Guidelines for Fuel Cells, as a first step towards the development of prescriptive rules for hydrogen systems on-board of ships. Since then, significant progress on the development of guidelines for the safety of ships using hydrogen as fuel have been made, and on 20-29 September 2023 the Sub-Committee on Carriage of Cargoes and Containers (CCC 9) of IMO agreed to finalize and bring the approval of the draft interim guidlines to December 2024. These guidelines will represent a first try-out for the market to underpin the future IGF Code update, which, to date, covers liquefied natural gas (LNG) as a fuel, while it does not consider either liquid (LH2) or compressed gaseous (CGH2) hydrogen. According to the IMO agenda, amendements to the IGF Code will be ready to entry in force not before 2028. In this framework, the urgent need of providing crucial insights related to the use of hydrogen technologies for maritime applications emerges clearly, in order to speed up the process of improvement of the existing standards.

3.2 Scope

The goal of this CWA is to provide a set of design and installation recommendations for the arrangement and installation of propulsion systems, using hydrogen as fuel, on passenger ships, in order to:

- Establish a procedure/recommendations for the inclusion of hydrogen on board passenger ships, from a technical point of view.
- Establish a risk assessment methodology to ensure a high level of safety from the early design phases. Taking care of discriminating based on the presence of passengers on board.

The document will leverage on the results of the experiments carried out within the project to incorporate the new knowledge beneficial to close the IGF code gaps identified.

Ultimately the document is expected to benefit the industry in terms of knowledge sharing.

4 Workshop programme

4.1 General

The CWA will be drawn up in English (language of meetings, minutes, etc.). The CWA will be written in English.

The drafting process is open and all comments will be considered, first by the chair person and secondarily by the participants of the workshop.

In order to minimize travelling, meetings will mostly be done remotely. If a physical meeting is desirable, it will be organized.

The kick-off meeting is planned to take place on <date TBC>.

4.2 Workshop schedule

Table 1: Workshop schedule (preliminary)

CEN Workshop **M1-M12 (December 2023 – Nov 2024)**	**M1** **Jan 2024**	**M2**	**M4**	**M5** **May 2024**	**M10** **Oct 2024**	**M11** **Nov 2024**	**M12** **Dec 2024**
V1 Project Plan (PP)							
submission to CEN							
WS announcement							
Public consultation of PP							

Kick-off							
CWA drafting							
Public commenting (TBC)							
approval							
promotion							

5 Resource planning

The administrative costs of CEN Workshop Secretariat will be covered by resources from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) project E-shyips, identified by Grant Agreement No 101007226.

6 Workshop structure and rules of cooperation

The workshop will be led by a chair or vice-chair, while the project leader will support them in the organization.

The CEN Workshop Chair is responsible for ensuring that the development of the CWA follows the principles and content of the adopted project plan and the requirements of the CEN Guide 29. The CEN Workshop Chair may take decisions on the conduct of the CEN Workshop on the basis of the comments expressed by the participants according to the CWA rules.

The workshop secretariat is responsible for the organization and management of the workshops according to the CEN Guide 29.

CEN Workshop participants draft the CWA and take in consideration the comments after the public commenting phase. CEN Workshop participants are the CWA proposers (the members of E-shyips project), plus other relevant stakeholder, identified by the proposer.

Participation in the Workshop

The Workshop will be constituted during the course of the kick-off meeting. By approving this project plan, the interested parties declare their willingness to participate in the Workshop and will be formally named as Workshop participants, with the associated rights and duties. Participants at the kick-off meeting who do not approve the project plan are not given the status of a Workshop participant and are thus excluded from further decisions made during the kick-off meeting and from any other decisions regarding the Workshop.

As a rule, the request to participate in the Workshop is closed once it is constituted. The current Workshop participants shall decide whether any additional members will be accepted or not.

Any new participant in the Workshop at a later date is decided on by the participants making up the Workshop at that time. It is particularly important to consider these aspects:

- expansion would be conducive to shortening the duration of the Workshop or to avoiding or averting an impending delay in the planned duration of the Workshop;
- the expansion would not result in the Workshop taking longer to complete;
- the new Workshop participant would not address any new or complementary issues beyond the scope defined and approved in the project plan;
- the new Workshop participant would bring complementary expertise into the Workshop in order to incorporate the latest scientific findings and state-of-the-art knowledge;
- the new Workshop participant would actively participate in the drafting of the manuscript by submitting concrete, not abstract, proposals and contributions;
- the new Workshop participant would ensure wider application of the CWA.

All Workshop participants who voted for the publication of the CWA or its draft will be named as authors in the European Foreword, including the organizations which they represent. All Workshop participants who voted against the publication of the CWA, or who have abstained, will not be named in the European Foreword.

6.1 Workshop responsibilities

The Workshop Chair is responsible for content management and any decision-making and voting procedures. The Workshop Chair is supported by the Workshop Vice-Chair and the responsible Workshop secretariat, whereby the Workshop secretariat will always remain neutral regarding the content of the CWA(s). Furthermore, the Workshop secretariat shall ensure that CEN-CENELEC's rules of procedure, rules of presentation, and the principles governing the publication of CWA(s) have been observed. Should a Workshop Chair no longer be able to carry out her/his duties, the Workshop secretariat shall initiate the election of a new Workshop Chair. The list below covers the main tasks of the Workshop Chair. It is not intended to be exhaustive.

- Content related contact point for the Workshop
- Presides at Workshop meetings
- Ensures that the development of the CWA respects the principles and content of the adopted project plan
- Manages the consensus building process, decides when the Workshop participants have reached agreement on the final CWA, on the basis of the comments received
- Ensures due information exchange with the Workshop secretariat
- Represents the Workshop and its results to exterior

The Workshop secretariat, provided by a CEN/CENELEC national member, is responsible for organising and leading the kick-off meeting, in consultation with the Workshop proposer. Further Workshop meetings and/or web conferences shall be organised by the Workshop secretariat in consultation with the Workshop Chair. The list below covers the main tasks of the Workshop secretariat. It is not intended to be exhaustive.

- Administrative and organisational contact point for the Workshop
- Ensures that the development of the CWA respects the principles and content of the adopted project plan and of the requirements of the CEN-CENELEC Guide 29
- Formally registers Workshop participants and maintains record of participating organisations and individuals
- Offers infrastructure and manage documents and their distribution through an electronic platform
- Prepares agenda and distribute information on meetings and meeting minutes as well as follow-up actions of the Workshop
- Initiates and manage CWA approval process upon decision by the Workshop Chair

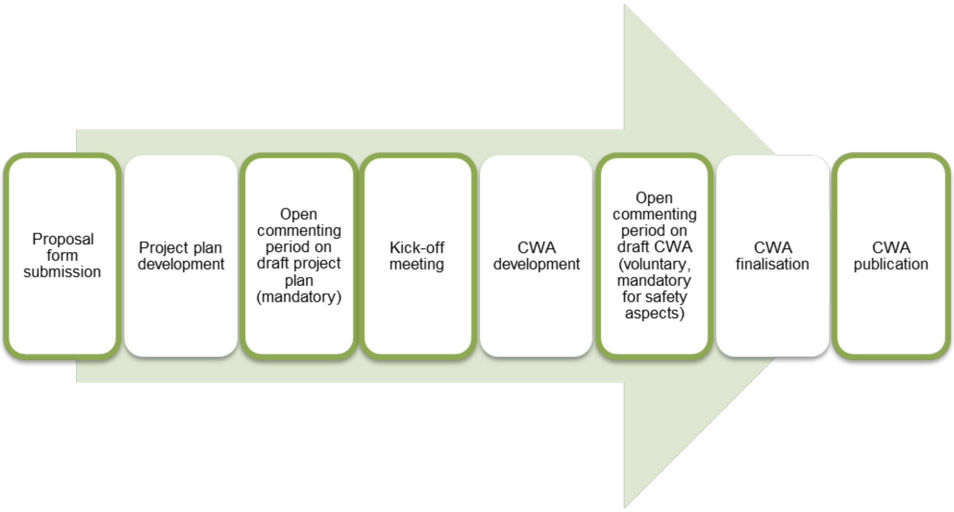
– Interface with CEN-CENELEC Management Centre (CCMC) and Workshop Chair regarding strategic directions, problems arising, and external relationships
– Advises on CEN-CENELEC rules and bring any major problems encountered (if any) in the development of the CWA to the attention of CEN-CENELEC Management Centre (CCMC)
– Administrates the connection with relevant CEN or CENELEC/TCs

6.2 Decision making process

Each Workshop participant is entitled to vote and has one vote. If an organisation sends several experts to the Workshop, that organisation has only one vote, regardless of how many Workshop participants it sends. Transferring voting rights to other Workshop participants is not permitted. During voting procedures, decisions are passed by simple majority; abstentions do not count.

If Workshop participants cannot be present in the meetings when the CWA or its draft is adopted, an alternative means of including them in the voting procedure shall be used.

7 Dissemination and participation strategy



Proposal form submission

The Workshop proposal will be disseminated to the following relevant stakeholders and bodies for consultation:

– standards committee, working group etc.
– publisher of technical rules
– sector forum**Errore. Il segnalibro non è definito.**
– focus group**Errore. Il segnalibro non è definito.**
– coordination group**Errore. Il segnalibro non è definito.**
– others

Open commenting period on draft project plan

The project plan will be disseminated to the following relevant stakeholders and bodies for commenting:

– standards committee, working group etc.
– publisher of technical rules
– sector forum**Errore. Il segnalibro non è definito.**
– focus group**Errore. Il segnalibro non è definito.**
– coordination group**Errore. Il segnalibro non è definito.**
– others

In addition to the CCMC website, the project plan and the date of the kick-off meeting will be advertised on the E-shyips website (https://e-shyips.com/) to raise awareness. Interested parties are requested to contribute either through commenting of the project plan (short term) or through Workshop participation (long term).

Open commenting period on draft CWA

The commenting phase is not compulsory in this case and it can be added. Decision on the submission of the draft CWA to public commenting phase can be agreed at a later stage, during the works of the CEN/WS.

CWA publication

The final CWA will be disseminated to the following relevant stakeholders and bodies:

- standards committee, working group etc.
- publisher of technical rules
- sector forum**Errore. Il segnalibro non è definito.**
- focus group**Errore. Il segnalibro non è definito.**
- coordination group**Errore. Il segnalibro non è definito.**
- others

In addition to the CCMC website, the final CWA will be advertised on:

- sector specific newsletter
- social media, such as
    - Facebook
    - Instagram
    - LinkedIn
    - X
- Research Gate
- EC Newsroom
- others