FLAGSHIPS

Clean waterborne transport in Europe

Deliverable D5.1

Common applicable safety regulations and approaches

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Abstract

Deliverable abstract
This document gives an overview of the regulations and codes applicable to fuel cell and hydrogen (FCH) installations onboard vessels. The emphasis is on sea-going vessels abiding by the regulations by the International Maritime Organization (IMO), but also a section is dedicated to vessels navigating on inland waterways in Europe. Regulatory gaps, necessary to be filled to enable predictable and economic approval of vessels utilizing fuel cells and hydrogen are discussed briefly. As an outcome, it is concluded that though there is a multitude of rules and regulations influencing the utilization of marine FCH technology, nowhere are there yet prescriptive, clear-to-follow rules to their deployment. Furthermore, considering how the regulatory framework (IGF code) under the IMO is currently developed, it is not foreseen that the international rule base would support hydrogen and/or modern, distributed fuel cell installations any time soon (before 2026). The advancement of coherent and mutually acceptable rules for FCH deployment is hindered by several factors, ranging from conflicting interests (hydrogen vs. LNG, low-flashpoint diesel), insufficient technical knowledge (e.g. material compatibility with hydrogen) as well as significant historical burdening of the rule formulation by an extensive period of propulsion systems based on conventional, centralized diesel-engines. A collective and cooperative (industry led or through member state) yielding several significant changes to the rules, would be needed to fully support the fluent deployment of FCH technologies in the marine sectors in a general, global manner. (Most likely, localized, ad-hoc solutions will, therefore, prevail for the foreseeable future.)

Contents

1 Preface

The FLAGSHIPS project raises the readiness of zero-emission waterborne transport to an entirely new level by demonstrating two commercially operated hydrogen fuel-cell vessels.

The demo vessels include a new build in France (Lyon) and a retrofit in Norway (Stavanger). The Lyon demo is a push-boat operating as a utility vessel on one of the most demanding rivers, the Rhône, while the Stavanger demo is a passenger ferry operating as part of the local public transport network. In the project, a total of 1 MW of on-board fuel cell power will be installed and both vessels will run on hydrogen produced on-site with electrolysers powered by renewable electricity. Gaseous hydrogen will be used in the vessels' onboard hydrogen storage.

Both vessels will be approved for safety. The ship owners expect to maintain the ships in normal commercial operation after the 18-month demonstration period of the project and to this end, solid support from local end-users and community has been gathered. The project will reduce the capital cost of marine fuel cell power systems significantly by leveraging know-how from existing onshore and marine system integration activities. European supply chains for H2 fuel and FC system technologies are strengthened by networking through the project.

The project will cooperate over a broad base to complete the required safety assessment and approval for the two vessels, by applying and further developing the existing regulations and codes. Within this objective, this deliverable provides an update of the regulations, codes and standards (RCS) review for marine applications performed within the MARANDA project (H2020-JTI-FCH-2016-1, grant n:o 735717), with a specific emphasis on liquid hydrogen. This review considers international (and specifically the most recent updates from IMO CCC), European (EMSA & SFEM) and Norwegian (NMA) RCS. Leveraging the approach developed within MARANDA, a similar review is conducted for Inland Waterborne Navigation with the support of the Lyon vessel ship owner CFT and the local authority VNF. In both cases, specific attention is paid to bunkering activities as being in between road regulations and waterborne/maritime regulations.

2 Definition and Context

2.1 Definitions

2.1.1 The RCS triptych

Different definitions and interpretations of RCS exist. Below is the one to be considered in this document:

A regulation (R) can either be a rule dealing with details of the procedure, or an order issued by the government and enforced by law. Regulations are generally safety-oriented but they can also be environmental, e.g. MARPOL requirements on GHG emisions and energy efficiency, such as EEDI and SEEMP.

A code (C) is a set of laws or regulations that have been adopted by one or more governmental bodies and is enforceable by law. A code can either be recommendatory or mandatory, if enforced by Conventions Because of the possible threat to the safety of personnel or pollution or damage to the marine environment, codes for shipping include construction standards, navigational rules and standards of crew competence, with an intention to eliminate or reduce the identified threats.

A standard (S) consists of technical definitions and guidelines that function as instructions for designers/manufacturers and operators/users of the equipment in order to standardize products / processes for production efficiency or to provide guidance on the implementation of codes and regulations. Standards are considered voluntary because they are guidelines and not enforceable by law. They can indirectly be enforced by law, if referenced by mandatory codes and regulations.

2.1.2 Transitional documents

Before the final publication of RCS, transitional documents can be used.

Technical Specifications (TS) are used by ISO and IEC, among others, when the subject in question is still under development, or where for any other reason there is a future but not an immediate possibility of an agreement to publish a standard. In this case, it is used for "pre-standardization purposes."

Publicly Available Specifications (PAS) may be an intermediate specification, published prior to the development of a full International Standard. It is a document not fulfilling the requirements for a standard. A PAS remains valid for an initial maximum period of 3 years. The validity may be extended for a single 3-year period, following which it shall be revised to become another type of normative document (such as an International Standard), or shall be withdrawn.

Interim recommendations or “Interim Guidelines” (IG) to a code amendment are used when deemed necessary to provide specific recommendations to the Administrations. They generally lead to acquiring further information until the code amendment is ready to be approved. The IG might be then converted into a mandatory Code / Amendment or remain to be recommendatory as a (permanent) Guideline (Interim just deleted).

2.2 General context

2.2.1 The pivotal role of IMO

Shipping is an international industry, and international environmental, security and safety standards for shipping are developed by the International Maritime Organization (IMO). IMO is a United Nation specialized agency, responsible for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships. Its main role is to create a regulatory framework for the shipping industry that is fair and effective, and most importantly universally adopted and implemented. IMO implements and amends different codes and conventions as per types of ships, goods or cargoes, cargo operation, maritime security, shipbuilding, the safety of the crew, training etc. Without complying with these maritime codes and conventions, merchant ships, shipping companies, operators etc. cannot perform their businesses in the maritime sector.

If IMO codes and conventions structure the shipping industry, their sluggish evolution also brings inertia to the evolution of the industry. As IMO aim is to adopt international treaties which are intended to apply to as many ships as possible, IMO usually tries to act on a consensus basis (having currently 174 Member States) and takes care of achieving consensus throughout the drafting process of new regulations (generally taken care of by dedicated sub-committees) and on the few yearly IMO Committee meetings and conferences when the (amendments to) conventions are adopted.

Without such consensus new rules will not enter into force. For example, the Ballast water convention did not enter into force for 13 years because there were insufficient states ratifying the convention.

There are inevitably a number of years between adoption of a new treaty and its entry into force (after individual ratification by the member states). IMO rules and conventions also need to be transposed into national law in order to be enforceable and this has its own timeline. Taking all this into account, and the necessary technical and legal deliberations that need to take place amongst all stakeholders, and the fact that ship construction has quite a long lead time, this is about as fast as it could go.

It is important to note that IMO only regulates International shipping, and not domestic shipping, although some instruments such as MARPOL which covers oil pollution, sewage and air emissions also cover domestic shipping.

National or regional safety and environmental legislation covers ships operating domestically, and also the bunkering arrangements on land.

Nominally, each country that accedes to an IMO convention should be responsible for application, certification and approval of ships in line with the regulations. However most flag states no longer have the resources to do so and delegate their authority and the responsibility to Recognised Organisations, that is the Classification Societies. However flag states generally retain the responsibility for domestic vessels, and so there are often differences in interpretation and application where something like hydrogen as a fuel is concerned, even if an international standard is agreed.

2.2.2 Growing interest and demonstration projects

The FLAGSHIPS project, although bringing the readiness of hydrogen and fuel cells (FCH) in marine activities to a different level, is not the first of its kind. It is also followed by a good number of followers. Indeed, environmental regulations coming into force at an increased pace have been driving the industry towards the widening of the basket of fuels for onboard use. The previous projects: FellowSHIP (Viking lady) FCShip[1], METHAPU[2], Nemo H2[3], Pa-X-ell[4], ZemShips [5]SchIBZ[6], RiverCell, the Energy Observer, the Race for Water, the Water-go-Round and MARANDA have been pursuing the aim to offer an FCH solution to the environmental compliance need. Similarly, these projects had to assess the suitability of RCS in view of their design requirements and flag authority.

[1] http://www.2020-horizon.com/FCSHIP-Fuel-cell-technology-in-ships-(FCSHIP)(FCSHIP)-s41111.html
[2] http://ec.europa.eu/research/infocentre/article_en.cfm?id=/research/headlines/news/article_08_03_18_en.html&item=Environment&artid=6873
[3] http://www.alewijnse.com/en/maritime/video/nemo-h2-proven-fuel-cell-technology
[4] http://www.e4ships.de/aims-35.html
[5] ZemShips
[6] SchIBZ

FellowSHIP	320 kW MCFC system for auxiliary power of Offshore Supply Vessel	Eidesvik Offshore, Wärtsilä, DNV	2003-2011	MCFC	320 kW	LNG
ZemShip - Alsterwasser	100 kW PEMFC system developed and tested onboard of a small passenger ship in the area of Alster in Hamburg, Germany	Proton Motors, GL, Alster Touristik GmbH, Linde Group etc.	2006-2013	PEM	96 kW	Hydrogen
E4Ships - SchIBZ MS Forester	100 kW containerized SOFC system developed and tested for the auxiliary power supply of comercial ships. Scalable up to 500 kW units.	Thyssen Krupp Marine Systems, DNVGL, Leibniz University Hannover, OWI, Reederei Rörd Braren, Sunfire	Phase 1: 2009-2017 Phase 2: 2017-2022	SOFC	100 kW	Diesel
E4Ships - Pa-X-ell MS MARIELLA	60 kW modularized HT-PEM fuel cell system developed and tested for the decentralized auxiliary power supply onboard passenger vessel MS MARIELLA.	Meyer Werft, DNVGL, Lürssen Werft, etc	Phase 1: 2009-2017 Phase 2: 2017-2022	HTPEM	60 kW (each stack is 30 kW)	Methanol
Nemo H2	Small passenger ship in the canals of Amsterdam	Rederij Lovers etc	2012-present	PEM	60 kW	Hydrogen
RiverCell	250 kW modularized HT-PEM fuel cell system developed and to be tested as a part of a hybrid power supply for river cruice vessles	Meyer Werft, DNVGL, Neptun Werft, Viking Cruises	Phase 1: 2015-2017 Phase 2: 2017-2022	HTPEM	250 kW	Methanol

Figure 1: Notable Maritime FC Projects
Source: DNV GL *https://www.energy.gov/sites/prod/files/2019/10/f68/fcto-h2-at-ports-workshop-2019-vii3-teo.pdf*

Further to these a good number of projects are lining up for (funding and) implementation, implying larger and larger power and energy storage.

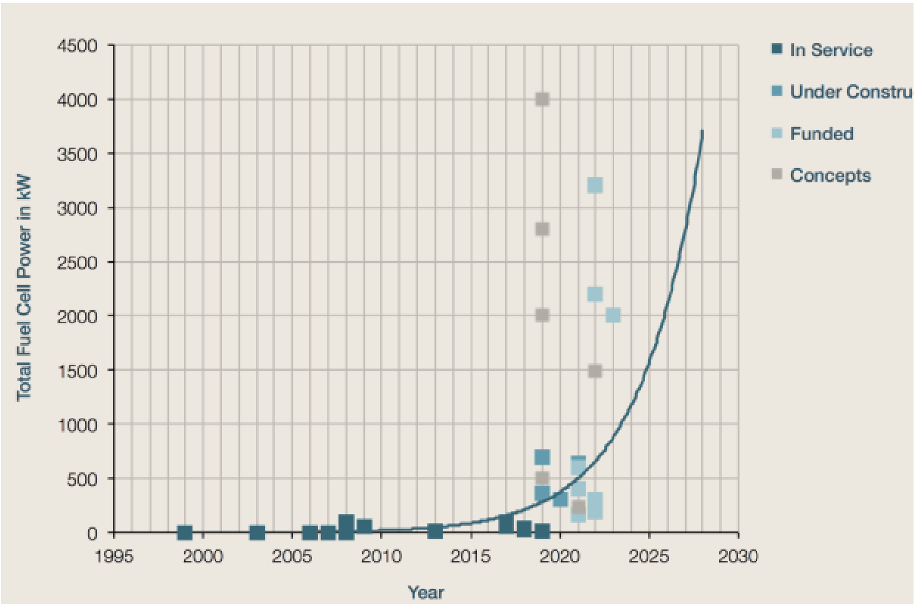

Figure 2: Hydrogen vessels exponential trend curve
Source: ZESTAs http://www.imo.org/en/About/Events/Documents/Alternative%20fuels/2-7b%20-%20ZESTAs%20IMO%2018Oct19%20Final.pdf

In parallel, concept design studies are being performed. Concept risk assessments are being conducted in order to fast track the introduction of HFC to the market, especially as private funding is being made available. We can mention SF-BREEZE[7] and High-Speed Passenger Ferry[8].

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[7] http://energy.sandia.gov/transportation-energy/hydrogen/market-transformation/maritime-fuel-cells/sf-breeze/

[8] https://www.sciencedirect.com/science/article/pii/S0360319919319846 Concept risk assessment of a hydrogen driven high speed passenger ferry - Fredrik G.Aarskog, Olav R.Hansen, Trond Strømgren, Øystein Ulleberg

2.2.3 Significant RCS gaps remain

As identified within MARANDA RCS review in July 2017, numerous gaps exist leaving FCH installations in ships facing a complex regulatory context development. Safety rules for fuel cell installations onboard ships are drawing attention but the necessary regulatory certainty for the practical implementation of this technology is still missing. The large potential benefits of low-flashpoint fuels come with a large set of concerns regarding their use and storage on-board ships. Environmental compliance drives the change but the adoption of lower flashpoints fuels on-board still lacks a relevant regulatory structure. The situation has hardly evolved since 2017.

Yet without prescriptive technical guidance for Administrations for the verification of fuel cells installations using alternative fuels, ship owners still need to go through cumbersome Alternative Design[9] procedures.

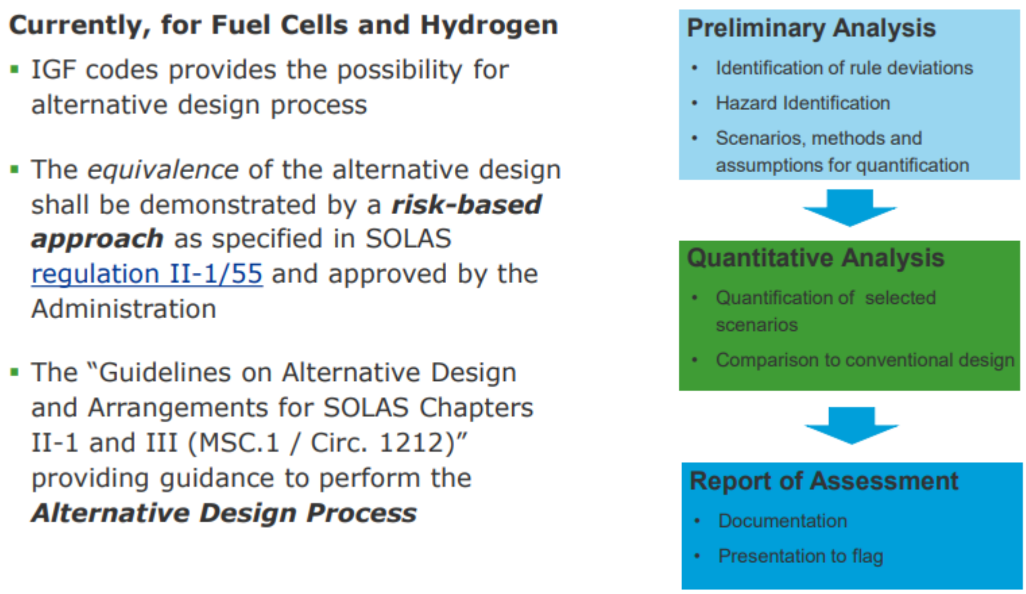

Figure 3: Current status of Alternative Design
Source: DNV GL https://www.jterc.or.jp/koku/koku_semina/pdf/180221_presentation-01.pdf

3 Progress since July 2017

3.1 Progress related to IMO

3.1.1 IGF Code

Reminder

The International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels (IGF Code) is mandatory for all gases and other low flashpoint fuels. However, it only contains detailed requirements for natural gas (LNG or CNG) as fuel. For other gases and low flashpoint fuels, the IGF Code Part A requires in accordance with SOLAS [10]Regulation II-1/55 the alternative design method to be used to demonstrate an equivalent level of safety.

The IGF Code was adopted in 2015. This was the culmination of over 10 years of work by several IMO bodies, including a work item on the development of "provisions for gas-fuelled ships" and of the Interim Guidelines on safety for natural gas-fuelled engine installations in ships (which ended in 2009).

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[9] http://rules.dnvgl.com/docs/pdf/gl/maritimerules2016Jan/gl_v-2-1_e.pdf

[10] The International Convention for the Safety of Life at Sea (SOLAS) defines as an international agreed minimum requirement for the construction, equipment and operation of ships. Flag States must ensure that these minimum requirements are met.

Following its first revision in 2017, it was scheduled that in 2020 fuel cells and other low-flashpoint fuels will also be included in the scope of the Code. For the wider application of low flashpoint fuels, as well as fuel cells and hydrogen, further regulatory and standardization work was needed to close the existing gaps within current regulations, codes and standards. These efforts were led by the Sub-Committee on Carriage of Cargoes and Containers (CCC).

Moreover, guidelines for "bunkering station" "gas control system" and "gas safety system" were expected to be released.

Recent developments

CCC 5 which was held in September 2018 had re-established the Correspondence Group on Development of Technical Provisions for the Safety of Ships using Low-flashpoint Fuels, to continue the work on the draft Interim guidelines on fuel cells and the consideration on low-flashpoint oil fuels. CCC 6 held a year later could not finalize the draft Interim guidelines on fuel cells and agreed to include this work item in the draft terms of reference of the correspondence group.

At this stage, finalization is mainly hampered by a missing consensus on the area classification on fuel cell spaces according to IEC 60079-10. This will have a strong influence on the technical feasibility and commercial viability of fuel cell installations as some members request a strict and inflexible classification of the fuel cell space as a zone 1 hazardous area and others promote a flexible approach based on IEC 60079-10 calculations of the specific installation. Eventually, it remains unclear whether the technical flexibility provided by the IEC standard can be fully utilized in all technical areas (e.g. ventilation, piping), because the impacts have not been understood or accepted by all delegations.

Perspective for hydrogen and fuel cells and the IGF Code

Hydrogen as a stored fuel and fuel cells, in general, follow different regulatory routes at IMO. Hydrogen might not even be under consideration for the next 6 years as shown below, since other alternative fuels are being prioritized by the IMO community to date (e.g. low-flashpoint diesel).

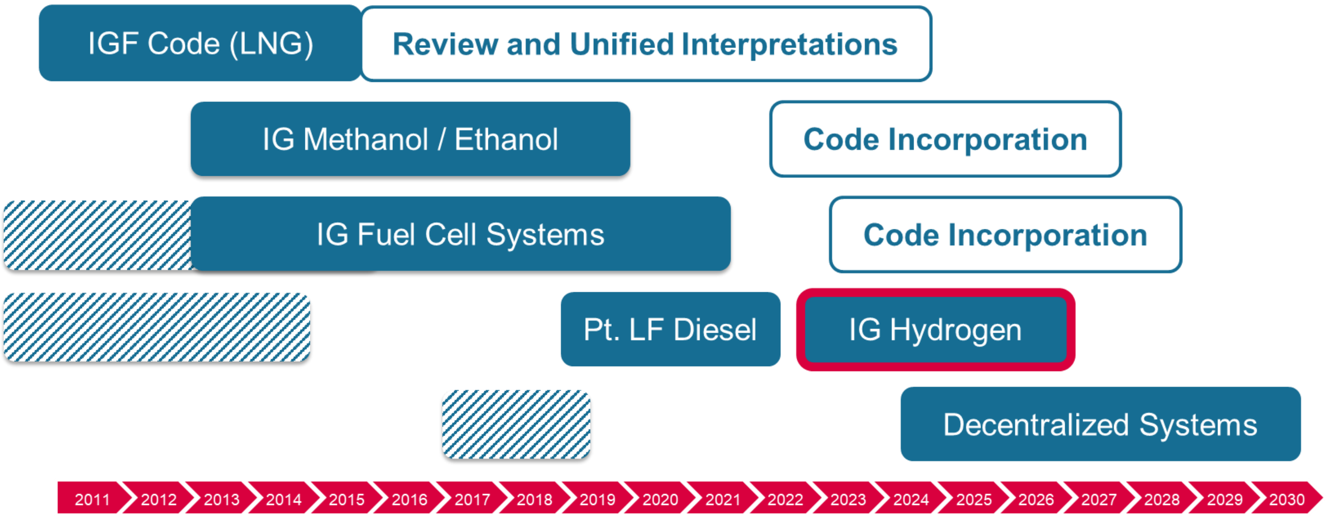

Figure 4: Code development under CESA perspective
Source: Analysis from e4ships - Feb 2020 DR. RALF SÖREN MARQUARDT

Limitations

IGF prescriptions can happen to be unsafe for HFC arrangement given the different behaviour between hydrogen and natural gas;

Typically, there is uncertainty regarding whether hydrogen in double piping should be a recommended or required safety provision for hydrogen in enclosed spaces though it is for LNG. Due to the risk of ignition even without active ignition sources, it must be considered if only nitrogen filled double piping can be accepted.[11]

Flaghisps aims at further highlighting the prescriptive rules from the IGF Code which might lead to unsafe designs if applied without further safety consideratio for HFC designs.

3.1.2 SOLAS

Reminder

International Convention for the Safety of Life at Sea (SOLAS), 1974 specifies minimum standards for the construction, equipment and operation of ships, compatible with their safety.

SOLAS is one of the (if not the) most important IMO Convention providing mandatory regulations based on public international law..

Recent developments

In parallel to the development of fuel provisions, the SOLAS Convention has been seen as needing revision in order to improve the regulatory basis for decentralized energy systems, which could increase ship safety through redundancy and significantly facilitate the application of fuel cell systems. Currently, innovation is hampered by "historic" requirements worded in a centralised language necessitating alternative design approval for distributed power generation. A holistic review of SOLAS could lead to amendments or at least Guidelines providing a level playing field for the approval of decentralized fuel cell installations. Such holistic review would however require decades as the review is generally happening per chapter. Typically work has just started on re-writing Chapter III on lifesaving appliances, after many years of preparatory work to prove that it needs to be rewritten and to work out what needs to be addressed. Amendments to SOLAS follow a 4 year cycle for entry into force, see for example https://www.dnvgl.com/news/solas-2020-updates-159370.

Besides, SOLAS is currently written mostly in a prescriptive form. Recent amendments seek to be more goal based.

The Community of European Shipyards' Associations (CESA), who are part of Sea Europe, has introduced a preliminary review and proposals for a new IMO output (ref. SDC 6/12/1[12] and SSE 6/17/1[13]) with a view to finding co-sponsors for a work programme submission, which has to be supported by IMO member states. The CESA initiative was supported by Romania, Germany and the Islamic Republic of Iran and (informally) welcomed by Denmark and the United Kingdom. However, the supporting member states were currently not in the position to allocate resources for this new output. In addition, the proposal has been rejected by ICS as being unnecessary and potentially dangerous due to the conflation of emergency energy generation and greenhouse gas reduction.

3.1.3 IGC Code

Reminder

The International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code) provides an international standard for the safe transport by sea in bulk of liquefied gases and certain other substances, by prescribing the design and construction standards of ships involved in such transport and the equipment they should carry so as to minimize the risk to the ship, its crew and to the environment, having regard to the nature of the products involved.

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[11] STUDY ON THE USE OF FUEL CELLS IN SHIPPING SAFER, SMARTER, GREENER EMSA European Maritime Safety Agency

[12] https://www.transportstyrelsen.se/contentassets/f97b2171295a43ce904bb58dcc684a3a/6-12-1.pdf

[13] http://www.iacs.org.uk/media/5693/sse-6-17-1-discrepancy-between-chapter-vi-of-the-lsa-code-and-the-testing-provisions-in-resolution-ms-iacs.pdf

Recent developments

Although this code is of no direct relevance to the ships within FLAGSHIPS, the recent progress made around liquid hydrogen -LH2- transportation is a basis of the suggestions formulated in the last chapter.

Paragraph 5 of Preamble of the IGC Code stated that requirements for new products and their conditions of carriage will be circulated as recommendations, on an interim basis, prior to the entry into force of the appropriate amendments.

In November 2016, in response to growing interest in LH2 transportation IMO developed Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk, which was adopted at MSC 97, to take into account the hazards associated with the handling and transport of LH2. As hydrogen must be kept at temperatures below −253°C in order to maintain its liquid state under atmospheric pressure, it presents an even tougher challenge than LNG.

Consequently, ClassNK developed in 2017 its Guidelines for Liquid Hydrogen Carriers which provide safety requirements for the design and construction of LH2 carriers. The guidelines consist of safety requirements applicable to LH2 carriers based on the IMO Interim Recommendations, various international standards as well as additional requirements taking specific hazards arising from the handling of LH2 into consideration.

With this interim recommendations, IMO agrees to acquire information on safe carriage of liquefied hydrogen in bulk prior to amendment to the IGC Code for the inclusion of liquefied hydrogen; and urges Member States and the industry to submit information, observations, comments and recommendations based on the practical experience gained through the application of the Interim Recommendations and submit relevant safety analysis on ships carrying liquefied hydrogen in bulk.

The Interim Recommendations for the carriage of liquefied hydrogen in bulk have been developed based on the results of a comparison study of similar cargoes listed in chapter 19 of the Code, e.g. liquefied natural gas.

This might be an information for the development of IG for hydrogen fueled ships (like the IGC Code was for the IGF Code). It has, however, be noted that cargo transport and fuels have to be treated seperately.

There may also be some consideration of application of the IMDG Code if hydrogen is carried in a non permanent fashion, ie on a vehicle trailer, or ISO Container.

3.2 Standardisation

To date, Hydrogen and Fuel cells are essentially covered by non-maritime regulations codes and standards as summarized below:

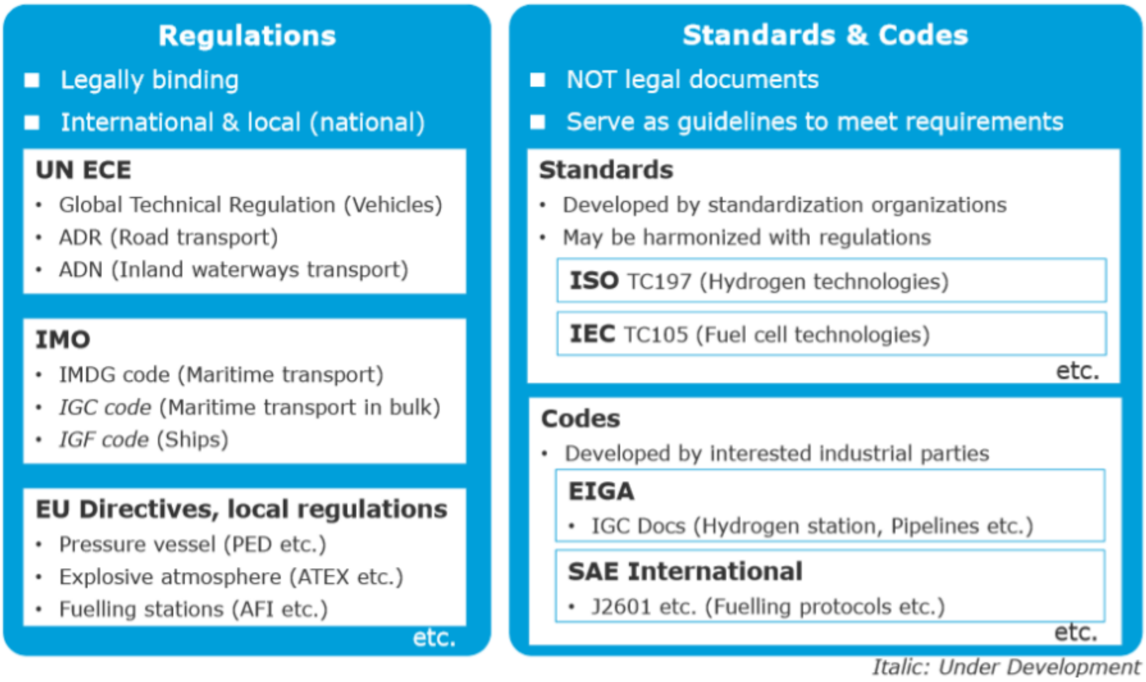

Figure 4: Regulations, Standards & Codes
Source: DNV GL https://www.sintef.no/contentassets/9b9c7b67d0dc4fbf9442143f1c52393c/6-regulations-codes--standards-for-hydrogen-handling-ikuo-hamanaka-dnv-gl.pdf

Recent developments

There is no achievement to be mentioned but acknowledgements and work plans do exist related to:

Liquid Hydrogen for the maritime sector – CEN CENELEC[14] acknowledges the necessity to develop an appropriate PNR roadmap/action plan to address PNR gaps in the maritime sector

It is expected to develop a standardisation roadmap/action plan with relevant actors involved (e.g. IEC TC 105, ISO TC 197, CEN/CLC TCs, EMSA, IMO) also considering regulatory needs.

Liquid hydrogen transport and storage - safety issues -

In addition, there are safety issues related to the storage and transport of LH2 that should be studied. There are knowledge gaps related to spillage of LH2. Dispersion is a poorly understood phenomenon that requires investigation.

Standards are expected to be developed in line with the ones covering liquefied hydrogen-related with transport, ISO 13984:1999 (Land vehicle fuelling system interface) and ISO 13985:2006 (Land vehicle fuel tanks). Liquid hydrogen is also present in the ECE/TRANS/242 International Carriage of Dangerous Goods by Road (ADR).

[14] European Committee for Standardization (CEN), and the European Committee for Electrotechnical Standardization (CENELEC)

Standards development process in Europe

CEN, the European Committee for Standardization, is an association that brings together the National Standardization Bodies of 34 European countries. Together with CENELEC and ETSI, it is responsible for developing and defining voluntary standards at European level.

The CEN-CENELEC Management Centre (CCMC) in Brussels manages and coordinates this system.

The development of a European Standard (EN) is governed by the principles of consensus, openness, transparency, national commitment and technical coherence and follows several steps:

Most standardization work is proposed through the CENELEC Members. Once accepted by the relevant CEN/CENELEC Technical Body, or by the Technical Board, a draft EN is prepared and then released for public comment and vote. If the results of the Enquiry show a 100% approval for the EN then the European Standard will be published.

It generally takes up to 36 months.

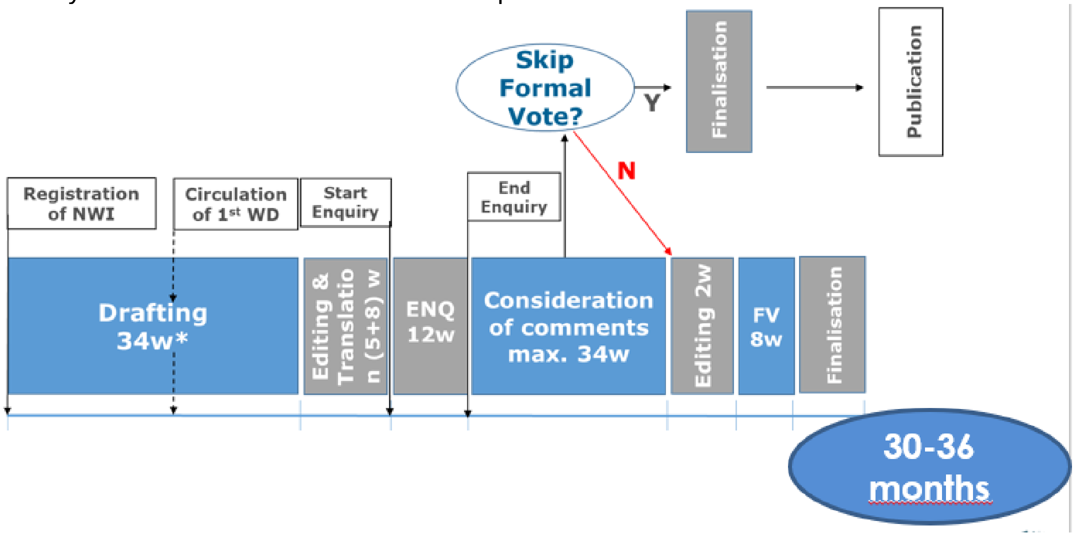

Figure 6: Standard's development process
Source: Dr. Bernard GINDROZ

A Cen Workshop Agreement (CWA) is a fast track to standard. Whilst not delivering a EN it is designed to meet an immediate need and form the basis for future standardization activity. The stakeholder involvement limits itself to those directly interested in the subject. A CWA is developed outside the normal CEN/CENELEC technical body structure.

The proposal of a new CWA leads to the creation of a new Workshop. However, the development of a new CWA might also be proposed within an existing Workshop.

A CWA is valid for 3 years, after which the former Workshop Secretariat shall consult the former Workshop participants and the relevant CEN/CENELEC technical bodies to determine whether the CWA shall be confirmed for another 3 years, revised, transformed into another deliverable, or withdrawn.

3.3 Classification rules

Since 2017, Rules for Classification, which contain procedural and technical requirements related to obtaining and retaining a class certificate, and Surveys have not seen much progress from any of the main class agencies in Europe.

For example, *DNV GL RULES FOR CLASSIFICATION Ships Part 6 Additional class notations Chapter 2 Propulsion, power generation and auxiliary systems*[15] which includes a section on fuel cells was reviewed in January 2017 without additions on the said section. Lloyds had announced rules & test spec for fuel cells for 2019, which apparently should come at a later stage. In between, below there recommended process

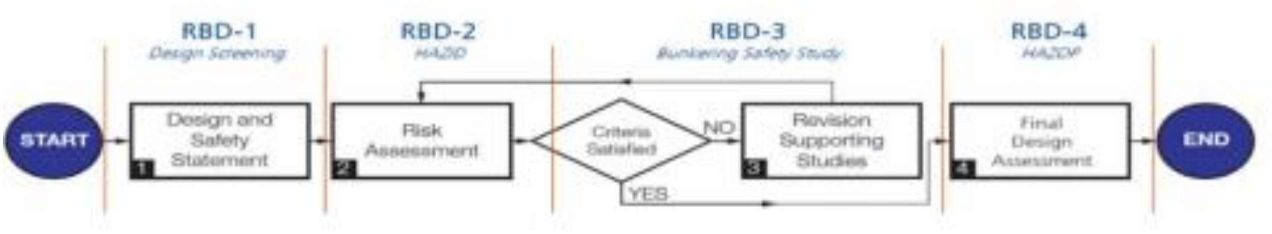

Figure 7: recommended process
Source https://www.hylaw.eu/sites/default/files/2018-12/3.%20FCadenaro_LR_Brussels.pdf

Further to this, below are presented the last applicable rules and surveys.

Table 1: Overview of applicable class rules and key features.

	BV	DNV GL	LR
Own prescriptive rules	Directive published in 2009	Directive published in 2016	-
Alternative authorization procedure	-	-	Risk-based process
Based on MSC.285(86) (LNG interim guidelines)	Yes	Yes	No
Regulated fuels	Natural gas, hydrogen	All fuels with flash-point ≤ 60°C	No; Risk-based process
Class approval mark	No	FC(Power), FC(Safety)	No
Risk analysts required	Yes, No specific method	Yes, FMEA	Yes, No specific method
Complementary material requirements	Yes, Hydrogen (gaseous, liquefied)	Reference to general guidelines of DNV GL	No

Source: MariGreen https://www.dst-org.de/wp-content/uploads/2018/11/Hydrogen-Feasibility-Study-MariGreen.pdf

[15] https://rules.dnvgl.com/docs/pdf/dnvgl/ru-ship/2017-01/DNVGL-RU-SHIP-Pt6Ch2.pdf

As we can also see in the table above, on the requirement of a risk analys for example or the alternative authorization procedure, the method to be used is not unanimous. Such divergence is not supportive of the emergence of a convention at IMO which seeks consensus.

3.4 National level

Overall

We can observe a general lack of hydrogen knowledge by authorities having jurisdiction (AHJ) which continues to impede the development of inherently safe installations.

A Hydrogen Energy Ministerial Meeting was held in Japan on 25 September 2019 to discuss strategies for cooperation toward the development of hydrogen energy. Over 30 countries and organizations attended the meeting, underscoring continued and growing momentum toward the wider production and use of hydrogen in the world. Harmonization of regulations, codes, and standards (RCS) was part of the agenda. The participants agreed to promote the development of international standards for the use of hydrogen as a fuel in maritime applications, such as through the International Maritime Organization (IMO). However, no specific roadmap was introduced.

USA

The experience with the WaterGoRound led the Authorities (U.S. Coast Guard, USCG) to identify a need to establish equivalency to design standards in Title 46, Code of Federal Regulations (CFR) - Shipping

- Design Basis providing framework of standards & requirements
- Vessel specific / case-by-case
- Draw from standards such as IGF Code, ASME, ASTM, IEC & Class Society Rules

Norway

An initiative gathering Norway Maritime Authority (NMA), DNV GL and a dozen of industrial players was launched this year, called Marhysafe (Maritime Hydrogen Safety Joint Development Project) which Phase I focuses on developing a handbook as an important first step to establish code requirements for hydrogen fueled vessels. Marhysafe aims to:

– Remove regulatory and approval barriers

– Develop the knowledge required for safe and reliable onboard hydrogen storage, bunkering and use of hydrogen in shipping

3.5 Private initiatives

Despite several efforts, no initiative was undertaken to promote advancement or harmonization of RCS related to hydrogen and fuel cells in maritime applications.

Worth mentioning, on June 2019, leading ship owners and operators, classification societies, engine and technology builders and suppliers, big data providers, and oil companies signed up to a new Global Industry Alliance (GIA) to support transitioning shipping and its related industries towards a low carbon future. Within the GIA, GloMEEP was founded as a GEF-UNDP-IMO project aimed at supporting the uptake and implementation of energy efficiency measures for shipping, thereby reducing greenhouse gas emissions from shipping.

GloMEEP http://glomeep.imo.org/ is a GEF-UNDP-IMO project aimed at supporting the uptake and implementation of energy efficiency measures for shipping, thereby reducing greenhouse gas emissions from shipping. It supports ten Lead Pilot Countries of the project to implement these measures. Alternative fuels are not addressed by GloMEEP, as only energy efficiency is addressed and not CO_2 intensity.

Worth mentioning also the Oil Companies International Marine Forum OCIMF https://www.ocimf.org/ which leads the global marine industry in the promotion of safe and environmentally responsible transportation of crude oil, oil products, petrochemicals and gas, and to drive the same values in the management of related offshore marine operations.

OCIMF was formed in 1970 in response to the growing public concern about marine pollution, particularly by oil, after the Torrey Canyon incident in 1967. In the early 1970s, a variety of anti-pollution initiatives were starting to emerge nationally, regionally and internationally, but with little coordination. Through OCIMF, the oil industry was able to play a stronger, coordinating role in response to these initiatives, making its professional expertise widely available through cooperation with governments and intergovernmental bodies. OCIMF was granted consultative status at the IMO in 1971 and continues to present oil industry views at IMO meetings. Since then, its role has broadened and now covers safety, health, security and the environment pertaining to tankers, barges, offshore vessels and terminal interfaces.

The current membership of OCIMF comprises well over 100 companies worldwide.

Recently, a newly established Environment Sub-Committee (ESC) met twice in 2019 and agreed to develop an environmental strategy paper for OCIMF, including Greenhouse gas emission reduction. And Alternative fuels specifically. Hydrogen and fuel cells are not yet explicitly on the agenda.

The privately-driven efforts are led by the individual demonstration ships within their approval process (Maranda with DNV GL, WGR with US coast guards, Norled PTRA and Flagships with DNV GL, CFT with BV, Hyseas III with LR,…). However, such endeavors are not coordinated and do not yield any significant general advancement.

4 Under development RCS for FCH use in other applications

All below developments could be leveraged to support the development of RCS in marine use.

Metering system

The issues of metrology and billing have been identified as having high impact and as an urgent to be addressed. There are activities in the field of metrology and billing which are currently funded through EMPIR. The remaining gaps are starting to be covered, but there is still an urgent need to have accurate metering systems for hydrogen billing purposes.

CEN/TC 237

Also, look into EN 1776.
Of importance are the concentrations. Using now <10, 20 and 100% H_2;
There are six relevant EN gas meter standards which are listed below: Recommendation check for revision: EN 1359: 2017 – Gas meters – Diaphragm gas meters
EN 14236: 2018 – Ultrasonic domestic gas meters
EN 12480: 2018 – Gas meters – Rotary displacement gas meters
EN 12261: 2018 – Gas meters – Turbine gas meters
EN 12405-1: 2018 – Gas meters – Conversion devices - Volume conversion
A new standard just about to be launched for Public Enquiry - Gas meter — Thermal–mass flow-meter based gas meter.

Leakage related to safety risks

1. ISO TR 15916; recommended looking into if it could be of use for Europe.
2. Recommendation: check the current safety standards eg explosion risk-related standards on hydrogen and recommended which standards might have a need for an update. Check with CEN/TC 305. Priority: high
3. Recommendation to look into leakage related issues e.g. flame visibility, odorization, general leak surveys, ventilation in confined spaces, diffusion. priority: high

Gas pipework on industrial sites

EN 15001-1+2

Action for revision in TC 234

State of health determination of the on-board hydrogen storage system after an extreme event:

First responders do not have the proper means available to determine the state of health of the onboard hydrogen storage system after the vehicle is involved in an extreme event, such as a crash or a fire. PNR should be performed to help these responders to assess the state of health of the system. The Annual Work Plan of the FCH 2 JU contains a call on the training of first responders, which may potentially contribute towards closing this knowledge gap.

Materials compatibility:

There may be knowledge gaps for specific materials such as polymers or even metallic materials, in particular, stainless steels. Consensus on metrics and methods is also not yet available. Materials selection criteria for H2-compatibility are considered a gap, there is a need for validation of lab experiments with full-scale components testing (source: Research Priority Report on Hydrogen Safety 2016). Also, topics such as Al-based alloys and welding are at the moment under discussion in the frame of the UN-ECE GTR13. Experimental validation of material compatibility is challenging due to the inherently long durations required for testing. Thus, a collective effort - independent of e.g. material or equipment provider participation - would be needed to gather the relevant operational experience and information for regulatory development.

Loses due to permeation (non-metallic material) - in the complete chain,

the (2) non-metallic is more a safety aspect.
Ad 1 CEN/TC 234, CEN/TC 155
Ad2 functional standards need to define the basic requirement with regard to acceptable permeation rates -define what is acceptable. Product standards need to define the testing methods for the related product. Recommendation: all TCs in the chain should look at this and define the action needed. Priority: medium

Condition monitoring, maintenance and repair procedures and related equipment

EN 1594, EN 12007, EN 16348, EN 15399, EN16348 CEN/TC 234, H2 pipelines TBD

Flow behaviour

ISO/TC 30

5 The case of inland navigation

5.1 Existing gaps

The European Standard laying down Technical Requirements for Inland Navigation vessels (ES-TRIN) lays down the uniform technical requirements necessary to ensure the safety of inland navigation vessels. It brings together in a standardised way the requirements previously contained in directive 2006/87/EC and in the Rhine vessel inspection regulations. It contains provisions on inland navigation vessel construction and equipment, special provisions for certain categories of vessels such as passenger and container vessels, provisions on the model of inland navigation vessel certificate as well as instructions on how to apply the technical standard.

ES-TRIN has been established, with great effort, as the centrepiece and baseline for the technical requirements for inland navigation vessels in Europe. Its Section 30 tackles Low Flash Point Fuels, and mainly LNG, is inspired by the IGF Code.

The regulatory gaps for inland navigation are then similar than for the maritime sector as exemplified below.

Table 2: Regulatory Gaps for inland navigation

Gap	Recommendation	Type
Hydrogen as Fuel		
ADN	In the ADN fuel cells are listed under UN 3166 and are exempted from the rules: "The provisions laid down in the ADN do not apply to electric energy storage and production systems (e.g. lithium batteries, electric capacitors, asymmetric capacitors, metal hydride storage systems and fuel cells): - installed in a means of transport, performing a transport operation and destined for its propulsion or for the operation of any of its equipment - contained in an equipment for the operation of this equipment used or intended for use during carriage (e.g. a laptop computer)"	legal
IGF Code	Hydrogen as fuel is not included in the IGF Code	legal
Bunkering		
Harmonized rules for bunkering of low-flash-point fuels	Development of standardized bunkering procedures for both ship and shore. Carried out risk studies and collected practical information	legal, knowledge
Storage on Board		
Storage of gaseous hydrogen	Qualification of pressure tanks for maritime use with compressed hydrogen gas. Safety studies considering hydrogen pressure tanks and requirements for safe solutions. Development of provisions for possible high-pressure storage technologies in enclosed areas.[Tro17]	legal, knowledge
Storage of gaseous hydrogen	Possible storage related failure modes need to be understood, and land based solutions adjusted if necessary for safe application. [Tro17]	legal, knowledge
Fuel Cell System		
Handling	Development of general procedures for safe handling and management of emergence situations	knowledge
Piping System	Standards for the layout and installation of high pressure hydrogen or low temperature hydrogen piping systems and safety systems	legal, knowledge
Ventilation	Development of standards for the ventilation of enclosed spaces with hydrogen applications. Risk studies and the collection of practical experience.	legal, knowledge
Integration in ship	Definition of EX-Zones etc. related to hydrogen, related risk studies	legal, knowledge

Source: MariGreen https://www.dst-org.de/wp-content/uploads/2018/11/Hydrogen-Feasibility-Study-MariGreen.pdf

5.2 The pivotal role of CESNI

However, those gaps could be addressed faster than for sea going vessels, thanks to a designated governance at the EU level, called CESNI, which is

a) legitime to drive RCS at the EU level

b) translates the EU desire to reinforce governance at the European level, particularly in the field of regulations governing inland navigation.

The Comité Européen pour l'Élaboration de Standards dans le Domaine de Navigation Intérieure (CESNI) was created in June 2015, by the Central Commission for the Navigation of the Rhine (CCNR) through the adopt a Resolution creating a European committee for drawing up standards in the field of inland navigation (CESNI). This Resolution promotes the development of uniform, modern, user-friendly requirements and takes into account the CCNR's "Vision 2018" for the sustainable development of inland navigation. According to the resolution[16], consensus is a must and decisions shall also be adopted by unanimity of the votes of those Members present at the meeting, which represents at least 10 times less than IMO member states.

5.3 Elektra project

Berliner Hafen- und Lager-hausgesellschaft mbH (BEHALA) in Germany is constructing what it believes will be the world's first zero-emissions canal pusher boat. The energy supply onboard the inland waterway transport vessel, called Elektra, will be provided solely by hydrogen, fuel cells, and batteries. Construction is scheduled to commence in October 2019 and completion by the shipyard is slated for the fourth quarter of 2020. The ELEKTRA is to be used primarily for freight transport on the Berlin-Hamburg route and for inner-city services in Berlin.

Elektra and the German coalition e4ship conduct an action plan to achieve a delegated act from recommendation to be promulgated by CESNI
The working group has already examined the draft recommendations of the German delegation. The first recommendations of the European Commission are expected in the coming months.

5.4 CESNI Action plan

In order for fuel cell technology to be widely used in inland navigation in the future, there is a need for internationally binding safety requirements. A fuel with a flash point below 55 ° C is used for the operation of fuel cells. These fuels are partly subject to safety requirements different from those applicable to diesel fuels and LNG and which have no not yet defined. In this context, it is essential to lay down in the regulations the minimum technical requirements applicable to the system. CESNI believes, contrary to IMO, that time has come to develop and implement regulations for this technology although CESNI like IMO has not yet incorporated hydrogen as a primary fuel into their work programmes

Given the strong innovation dynamic in the field of fuel cell technology, which is characterized by different fuel cell systems and a multitude of suitable fuels, targeted functional requirements are necessary in order to ensure a certain flexibility for the technical solution. The aim of standardization is seen as focusing on technical standardization, which is expected to only take place once the essential safety requirements have been regulated.

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[16] https://www.cesni.eu/wp-content/uploads/2016/04/Resolution2015-I-3_en.pdf

In order to be able to safely design, build and commission inland waterway vessels fitted with fuel cells, CESNI intends to regulate energy conversion using fuel cell systems as well as storage, distribution and treatment suitable primary fuels (in particular alcohol-based fuels such as methanol or ethanol, but also hydrogen) through:

• Supplement to ES-TRIN, part II, chapter 10, by adding an article 10.22 "Fuel cell systems". From a context perspective, "fuel cell systems" should be between clause 10.10 "Generators, motors and transformers" and clause 10.11 "Batteries, accumulators and their charging devices". However, it should be checked whether article 10.18 "Power electronics" should be completed in this context. In principle, however, it covers conversion systems.

• Verification and, if necessary, addition to ES-TRIN, part II, chapter 30 “Fuels with a flash point below 55 ° C” and extension of annex 8, first by addition of a section II "Alcohol-based fuels". The structure of the section would be based on LNG requirements, but its content would be simpler, since, for example, the storage and distribution of liquids at room temperature require less safety requirements than the treatment of cryogenic liquefied gases. Other risks must however be taken into account, such as toxicity and corrosivity. Annex 8 could be extended later to other primary fuels relevant to fuel cells, for example hydrogen.

6 FLAGSHIPS Gap Analysis and conclusions

6.1 Gap analysis

The major gaps are seen to be:

- Fuel System
    - Machinery space configuration
    - Tank placement
    - Tank & piping requirements
- Gas Detection
    - System certification
- Hazardous Locations
    - Classification of areas
    - Electrical equipment
- Fire Protection
    - fire and explosion risk
    - Installed firefighting systems
    - Fire detection
- Safety aspects concerning the release of hydrogen
    - Desired (venting)
    - Undesired (relevant leakage scenarios, means of leak detection, the permeability of hydrogen)
- Ventilation requirements
    - for fuel cell rooms
    - other spaces
- Bunkering LH2 of CGH2
    - Safety/Hazardous zone
    - Refuelling protocole
- Recommended practices/ procedures for handling H2 equipment
    - Swappable storages
    - Maintenance

In reference, below are listed the gaps from a class perspective.

Table 2: Outlook Rules, Regulations and Guidelines

IGF Code:	
- use of fuel cells - use of other low flashpoint fuels than LNG/CNG - bunkering of gaseous H_2, other low flashpoint fuels and LH_2	Further development of IGF code needed. Detailed safety studies. Use existing standards for non-maritime applications as input.
Bunkering:	
Rules for bunkering of liquid hydrogen	Review of applicable land based standards. Risk studies and a qualification process to develop rules and bunkering procedures.
Gaseous hydrogen	Review of applicable land based standards. Risk studies and a qualification process to develop bunkering procedures.
Low Flashpoint Liquids	Bunkering procedures for LFL's Safety zones for gas vapour from tanks
On-board storage:	
Storage of compressed hydrogen	Qualification of pressure tanks for maritime use with compressed hydrogen gas. Safety studies considering hydrogen pressure tanks and requirements for safe solutions. Development of provisions for possible high pressure storage technologies in enclosed areas.
Storage of liquid hydrogen	Possible storage related failure modes need to be understood, and land based solutions adjusted if necessary for safe application.
Fuel cell System:	
Safe handling of hydrogen releases	Review of and update of fuel cell rules and regulations. Risk studies to improve understanding of possible safety critical scenarios including fire and explosion to recommend risk controlling measures.
Ventilation requirements	The fuel specific properties must be considered. Relevant and realistic hydrogen dispersion simulations needed to evaluate and/or update ventilation requirements.
New arrangement designs	Need for improved understanding of system design issues, new technology challenge existing regulations
Piping to fuel cell system	Knowledge and safety assessments needed to identify needs to adjust LNG requirements for the use of LH.
Reforming of primary fuel	Reformer safety issues should be explored and documented
Ship life phases:	
Best practices/Codes for hydrogen, LFL fuels and fuel cell installations	Procedures should be developed for commissioning, docking, maintenance to reflect the properties of hydrogen and other LFL fuels.
Fuel specific:	
Hydrogen	Comprehensive safety studies considering hydrogen specific properties, behaviour and conditions needed for the use of hydrogen in shipping applications

Source: DNV GL https://www.jterc.or.jp/koku/koku_semina/pdf/180221_presentation-01.pdf

6.2 Conclusions

At CESNI, a solid process is likely to take place allowing progress of RCS covering inland navigations. Having Germany (Elektra) and France (Flagships) directly mobilized on the topic might even help fast track the process at CESNI level.
To be noted that in France, HFC vessels can be authorized through an “arrêté de zone” which is a local exception to the general rule, faster to achieve.

The situation is different for seagoing vessels.
The priority, as seen from Flagships is not so much to establish immediate rules but rather to:

1) To avoid unsafe practices are applied due to missing knowledge or inappropriate use of prescriptions from the IGF code
2) To establish safe principles and approaches for shipowners planning to build HFC based vessels

For this, a possible course of action is currently seen as two-fold:

6.2.1 Action 1: Industry led initiative

The objective of this individual action is to capitalize on the experience acquired from the different demonstration projects (mentioned in 2.2.2) to extract recommendations for safety principles and approaches and share the experience acquired from the AD process.
An option would be to constitute an industry led group (/association) missioned to drive above mentioned objective. Such group could seek in parallel a consultative status at the IMO through an existing NGO with a broader scope in terms of fuel range like the Oil Companies International Marine Forum OCIMF (https://www.ocimf.org/) or through the Global Industry Alliance (GIA). It could also initiate a CWA.

Such group could be structured around the following:
Vision
A global marine industry that drives inherently safe HFC designs and marine operations.

Mission
To lead the global marine industry in the promotion of safe design and operations.
We do this by developing best practices in the design, construction and safe operation of HFC vessels and their interfaces with terminals and considering human factors in everything we do.

Working process
Meetings every 6 months
Sub committees effectively working

Participation
Stakeholders from the current demo projects and those willing to rapidly engage in HFC projects

Connections
Such forum could be a subgroup of existing forums (IPHE, OCIMF,…) or a stand-alone group.

Financing
Members
Hydrogen Europe, FCH JU, DOE,…

6.2.2 Action 2: Seek interim guidelines at IMO related to the IGF code

The objective here shall be to seek direct progress at the IMO level, with the acknowledgement

that the prescriptive IGF Code provisions for LNG/CNG cannot be easily adapted to hydrogen and therefore that resources shall be allocated to help progress provisions for hydrogen and hydrogen based fuel cells. A quick win could be adapt the work on hydrogen properties and consequential safety principles performed for the develoment of IG for LH2 transportation for a H2 fuel IG to be incorporated into the IGF Code later.

Along thes lines, CESA is working on an MSC submission proposing an ”Alternative Fuel Acceleration Plan” aiming at the release of additional IMO ressources, which could be implemented in different form (to be discussed). One element could be the split of the existing LF fuel WG (currently being overloaded) into two WG, one for IGF code review and maintenance activities) and one for IG development for alternative fuels (not just hydrogen).

In this case such subgroup shall be formed under the responsibility of the CCC. Its mandate shall be officialized at CCC7 which is likely to take place in September 2020. It shall aim at the establishment of interim guidelines by 2024 (2 years before the first Zero emission areas are being enforced).
CESA will need the support from other European countries to make it happen.

7 Annexe 1: standards under development by ISO/TC 197

ISO/CD 14687

Hydrogen fuel -- Product specification

ISO/DIS 16111

Transportable gas storage devices -- Hydrogen absorbed in reversible metal hydride

ISO/CD TR 16113

Applications for hydrogen absorbed in reversible metal hydrides not covered in ISO 16111

ISO/DIS 17268

Gaseous hydrogen land vehicle refuelling connection devices

ISO/CD 19880-1

Gaseous hydrogen -- Fuelling stations -- Part 1: General requirements

ISO/DIS 19880-2

Gaseous hydrogen -- Fueling stations -- Part 2: Dispensers

ISO/DIS 19880-3.2

Gaseous hydrogen -- Fueling stations -- Part 3: Valves

ISO/CD 19880-5

Gaseous hydrogen -- Fueling stations -- Part 5: Hoses

ISO/DIS 19880-8

Gaseous hydrogen -- Fueling stations -- Part 8: Fuel quality control

ISO/DIS 19881

Gaseous hydrogen -- Land vehicle fuel containers

ISO/DIS 19882

Gaseous hydrogen -- Thermally activated pressure relief devices for compressed hydrogen vehicle fuel containers

ISO/CD 19884

Gaseous hydrogen - Cylinders and tubes for stationary storage

ISO/AWI 22734

Hydrogen generators using a water electrolysis process

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