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RETROFIT SOLUTIONS TO ACHIEVE 55% GHG REDUCTION BY 2030

Approval in principle for the different options

WP 6 – Electrification and energy management of on-board systems
Task 6.4 – Safety assessment and approval in principle for the power train
D6.5 – Approval in principle for the different options
Partners involved: RINA, LASK, NTUA, CNR, LJMU, ATD
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Acronyms

Acronym	Description
AiP	Approval in Principle
IMO	International Maritime Organization
EU	European Union
GHG	Green House Gasses
HSE	Health, Safety, and Environment
LH_2	Liquified Hydrogen

Executive Summary

The RETROFIT55 project aims to achieve a 55% reduction in greenhouse gas (GHG) emissions by 2030 through innovative retrofit solutions.

In the general context of the innovative technologies of the RETROFIT55 project (PALS, WAPS, Electrification & energy management on board, etc.) already addressed by the relevant Deliverables, this D6.5 is aimed at focusing on the safety assessment and approval in principle of the power train, which is driven by the need to improve energy efficiency and reduce the GHG emissions by introducing alternative fuels to meet the decarbonization targets of the shipping sector.

The first part of the Deliverable presents a brief state of play of the regulatory framework, which is still evolving, with specific reference to the provisions applicable to alternative fuels, including low-flashpoint fuels.

The introduction of alternative low-flashpoint fuels in maritime transport is not yet fully covered by international regulations and standards. This gap poses significant challenges to designers, shipyards, ship operators, classification societies and flag administrations to provide a safety level equivalent to that of conventional fuels. Alternative fuels may introduce additional hazards and risks, both in design and operation (flammability, explosion, toxicity, cryogenic effects, corrosion, material embrittlement, etc.) – which are to be evaluated and mitigated throughout the lifecycle of a ship. New industry standards and guidelines are driven by the need to address the specific risks associated with each type of fuel, in normal and in emergency scenario, when the ship is in port or sailing. This would allow for a homogeneous and easily applicable regulatory framework. Otherwise, operability would be unnecessarily penalized.

The second part of the Deliverable recalls the process to obtain a Class Approval in Principle of new solutions and technologies, which is based on a risk assessment process and safety equivalence, aimed at reviewing and approving innovative concepts / technologies not covered by traditional classification prescriptive rules.

AiP is applicable to ship systems and components using alternative fuels, but the process is valid in general to address detailed engineering plans, safety aspects, and compliance with marinization requirements of land-based technologies. AiP ensures that the innovative design meets all necessary criteria for approval. Only after this meticulous evaluation can the AIP statement be issued, as a crucial step towards bringing the new design to life.

1 Introduction

Maritime transport plays a crucial role in the economy of the European Union and is recognized as one of the most energy-efficient modes of transportation. However, it significantly contributes to the increasing levels of greenhouse gas (GHG) emissions. In 2018, approximately 2.9% of all anthropogenic emissions globally originated from shipping, amounting to 1,076 million tons of CO2. Projections indicate that by 2050, these emissions may significantly increase compared to 2008 levels. This anticipated rise in emissions could jeopardize the goals of the Paris Agreement established in 2015, which aims to avert catastrophic climate change by limiting global warming to well below 2°C and striving to cap it at 1.5°C. At the EU level, maritime transport was responsible for 3 to 4% of total CO2 emissions, exceeding 124 million tons of CO2 in 2021 [1].

Between 2005 and 2018, bunker demand grew by more than 25%, with an average annual growth rate (AAGR) of 1.77% [2]. As shown in Figure 1, energy demand in the maritime sector has historically been driven by global GDP growth, the expansion of international trade, and increased activity in the manufacturing sector.

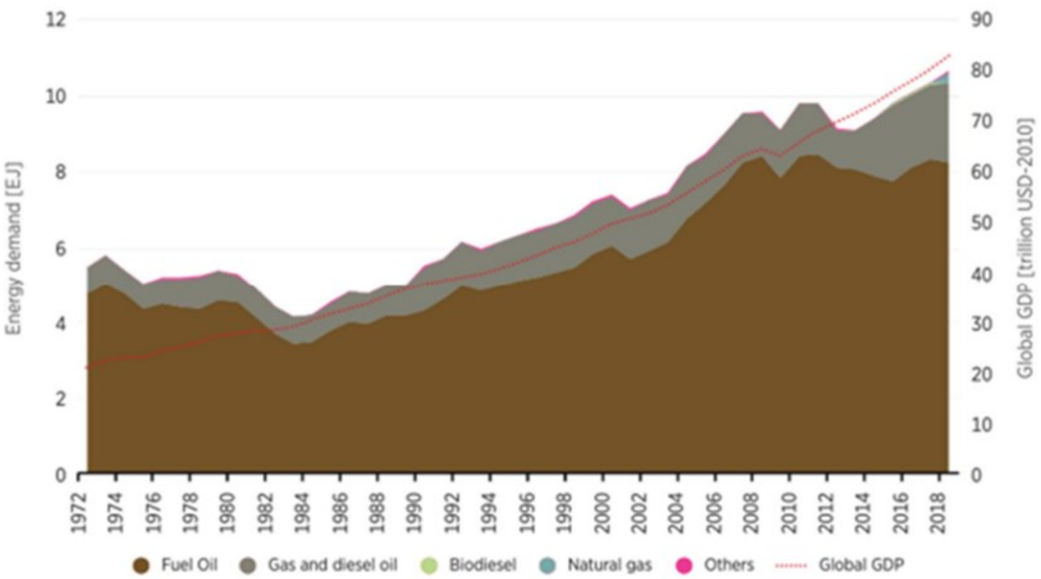


Figure 1: Global shipping energy demand and GDP [1].

The maritime transport sector significantly contributes to GHG emissions, with projections indicating a potential increase by 2050. To address this, the International Maritime Organization (IMO) has set targets for GHG emission reduction, aiming for a 20% reduction by 2030, a 70% reduction by 2040, and net-zero emissions by 2050. The RETROFIT55 project aligns with these goals by integrating efficient technologies with the introduction of alternative low-flashpoint fuels.

The IMO has adopted the International Code of Safety for Ships using Gases or other Low-flashpoint Fuels (IGF Code [3]) to establish regulatory safety criteria and a framework for ships using gases or other low-flashpoint fuels. However, the IGF Code [3] currently includes comprehensive prescriptive standards only for natural gas (methane) in Part A. For other alternative fuels, such as methanol, ammonia, and hydrogen, interim guidelines and alternative design methodologies are being developed, with a view of drafting dedicated mandatory chapters of the IGF Code, but only after having gained experience from early implementation of the interim guidelines on new ships or retrofits

In both IMO and EU regulations there are many implementation aspects that are still unclear or leave room for interpretation, preventing a clear understanding for shipbuilders and operators. It is also crucial to develop and prepare provisions for the training and education of crews and seafarers who will operate on ships powered by alternative fuels. Almost all alternative fuels, to be managed safely, require a much higher level of crew preparation and competence than current fuels

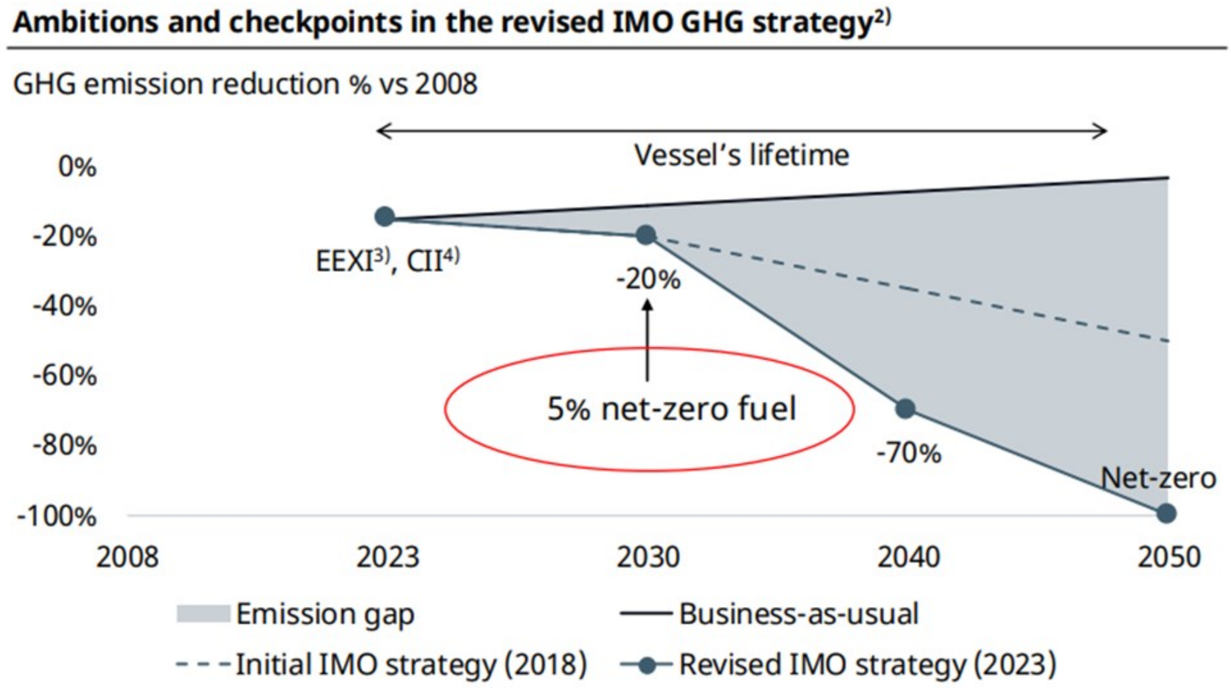
All these aspects need to be considered and agreed as soon as possible to help all stakeholders (shipowners, ship operators, fuel producers, ports, Recognized Organizations, verifiers, and Flag Administrations) understand how to comply with their obligations. In the current scenario, Classification Societies – often acting as Recognized Organizations by the Administration – play a key role in guiding all stakeholders, implementing the non-mandatory interim guidelines, addressing the uncertainties of alternative design methodologies and facilitating the risk assessment, towards the common goal of a safe and efficient integration of alternative fuels on board to meet the emission targets in maritime transport.

To substantially mitigate GHG emissions from international shipping, effective global measures are imperative. In July 2023, the International Maritime Organization (IMO) committed to developing new targets for GHG emission reduction, to be adopted in 2025. The EU's actions to ensure that maritime transport contributes to achieving climate neutrality in Europe by 2050 are crucial in promoting the necessary reductions. The IMO has established a package of mandatory measures to reduce GHG emissions as part of Chapter 4 of Annex VI of the MARPOL Convention, such as the Carbon Intensity Indicator (CII), Energy Efficiency Existing Ship Index (EEXI), and Energy Efficiency Design Index (EEDI), as well as operational measures such as the Ship Energy Efficiency Management Plan (SEEMP) and Energy Efficiency Operational Indicator (EEOI). The revised 2023 IMO strategy (Res. MEPC.377(80)) includes new levels of ambition and enhanced targets to tackle harmful emissions:

- Adopt zero or near-zero GHG emission technologies, fuels and/or energy sources to represent at least 5%, aiming for 10% of energy used by international shipping by 2030
- peak GHG emissions from international shipping as soon as possible and to reach net-zero GHG emissions by or around 2050, with the following checkpoints:
    1. reduce total annual GHG emissions from international shipping by at least 20% aiming for 30% by 2030, compared to 2008; and
    2. reduce total annual GHG emissions from international shipping by at least 70% aiming for 80% by 2040, compared to 2008.

The IMO Marine Environment Protection Committee at its 83rd session (MEPC 83, 7-11 April 2025), inter alia, has:

- further approved and amended revised measures to reduce GHG emissions from ships;
- has reached an agreement on the mid-term GHG reduction measures;
- has approved the draft of amendments to MARPOL Annex VI - including also a new Chapter 5 “Regulations on the IMO net-zero framework” - in view of their adoption by the MEPC extraordinary session in October 2025.



1) Source: Clarksons; total newbuilding and equipment upgrades investment for fleet renewal in 2023-2050; 2) Source: DNV Energy Transition Outlook 2023; well-to-wake GHG emission reduction compared to 2008; 3) Energy Efficiency eXisting ship Index; 4) Carbon Intensity Indicator

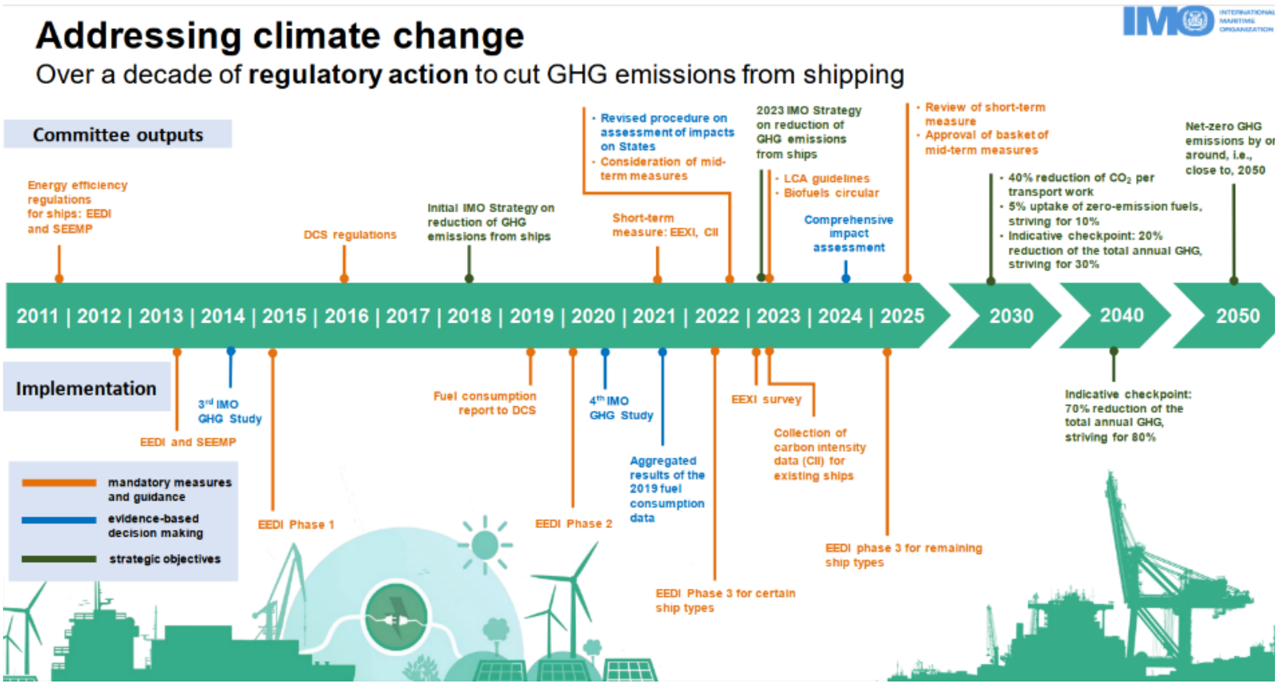


Figure 2: International Maritime Organization Reduction Targets [4].

As part of the European Commission's Fit for 55 legislative package the FuelEU Maritime Regulation (Regulation (EU) 2023/1805) promotes the use of renewable, low-carbon fuels and clean energy technologies for ships to achieve net-zero emissions by 2050.

In extreme synthesis other complementary measures in the FuelEU ecosystem include:

- The Renewable Energy Directive (RED) establishing targets for increased renewable energy use, supporting cooperation between EU countries towards this goal.
- Alternative Fuels Infrastructure Regulation (AFIR) ensuring minimum infrastructure and distribution to support the required uptake of alternative fuel.
- Emissions Trading Scheme (ETS), an instrument for reducing greenhouse gas emissions at the lowest possible economic cost ("carbon pricing").
- The Energy Taxation Directive (ETD) determining minimum taxation rates for fuels, including those used in transport ("energy taxation").

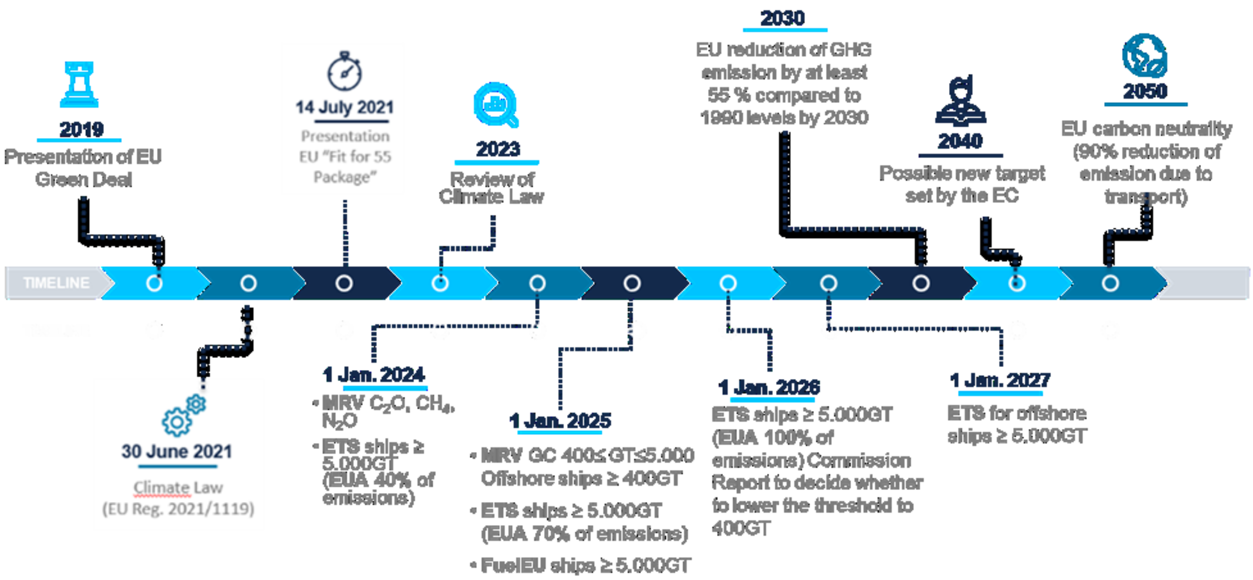


Figure 3: EU Emission reduction targets [5].

While the adoption of more efficient technologies is necessary, they alone will not be sufficient to meet the new standards. It is imperative to integrate these technologies with alternative and renewable fuels. However, there remains a lack of international standards governing the use of low-flashpoint fuels. Therefore, a thorough examination of the various fuels is crucial, along with an in-depth analysis of health, safety, environment (HSE) implications, as basis for risk identification and mitigation.

2 Alternative fuels

2.1 Properties of alternative fuels

To understand and select the most appropriate alternative fuels, it is necessary to examine their specific properties. IMO (MEPC 80) presented a study on the «Readiness and availability of low and zero-carbon emission technologies and fuels in the maritime sector» considering the following fuels:

- Biofuels derived from biomass (algae, waste) such as bio methanol, biomethane, and biodiesel.
- Synthetic fuels or non-biological renewable origin fuels (RFNBO, subset of e-fuels) based on hydrogen produced by electrolysis using renewable or nuclear energy, including carbon-free fuels such as synthetic hydrogen, synthetic ammonia, or direct carbon capture from biogenic sources (synthetic methanol, synthetic methane, synthetic diesel).
- "Blue fuels" based on hydrogen from fossil sources and carbon capture greater than 90%, such as blue hydrogen and blue ammonia.
- Electricity from the grid, produced from fossil and renewable sources, made available as shore power.
- Fossil fuels blended with certified sustainable biofuels with onboard carbon capture greater than 70% (similarly for synthetic fuels).

Beside biofuels and synthetic fuels, the maritime industry is focusing on non-zero carbon fuels such as methanol, ethanol and natural gas in the short/medium period and on zero carbon fuels such as ammonia and hydrogen towards 2050. Each fuel has its own advantages and disadvantages, in terms of cost, availability, environmental impact, and energy efficiency. Understanding these factors is crucial for making informed decisions about the most appropriate “fit-for-purpose” selection(s).

This Deliverable does not pretend to present the latest developments in vessel uptake of alternative fuels, nor to explore, evaluate or solve the extremely complex decision-making process and business scenario to select the most appropriate fuel for a given ship / fleet to meet the emission reduction targets. Some broad considerations will be limited to the most common fuels: hydrogen, methanol, methane and ammonia.

2.1.1 Fuel safety

Healty, safety, and environment

The safe implementation of alternative fuels in maritime vessels requires a thorough evaluation of several factors, such as their flammability, toxicity, and potential environmental impacts. Each type of fuel possesses distinct risks and advantages, thereby necessitating meticulous assessment and modification of safety protocols to guarantee their suitability for maritime applications.

Flammability

Flammability is a critical parameter when considering alternative fuels for shipping. The flammability of a fuel is defined by its Lower Flammable Limit (LFL) and Upper Flammable Limit (UFL)—the range of concentrations within which a fuel mixed with air can ignite. If a fuel concentration is below its LFL, it is too lean to sustain combustion, whereas concentrations above the UFL are too rich to ignite.

Understanding the flammability characteristics of alternative fuels is essential for developing safe storage, handling protocols, and on-board systems. Below is a comparison of the flammability ranges of key alternative fuels.

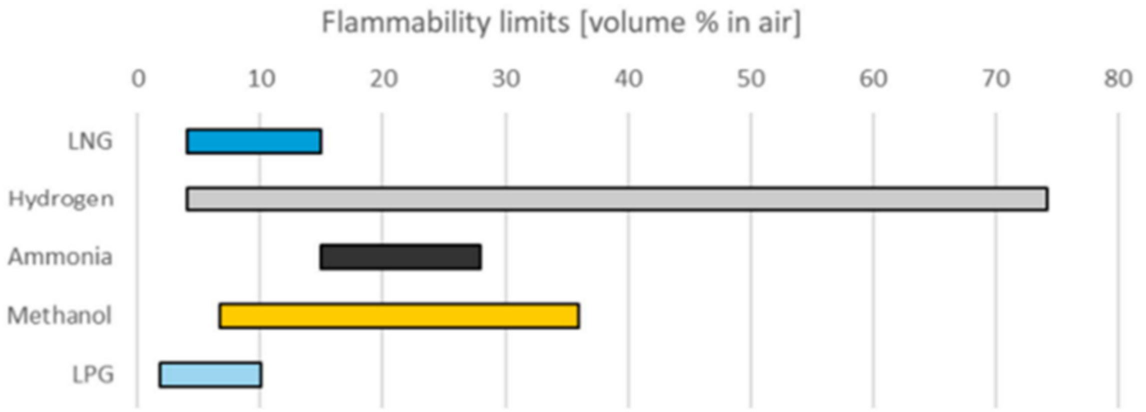


Figure 4: Flammability limits for different fuels [6].

Hydrogen

Hydrogen has an exceptionally broad flammability range (4%–75%), and a low Minimum Ignition Energy (MIE) of 0.017 mJ, significantly lower than that of other fuels, making it highly susceptible to ignition and the most flammable fuel on the list. Furthermore, hydrogen flames are nearly invisible, posing additional risks of undetected fires.

Methanol

Methanol has a flammability range of 6%–36%, with a flash point around 11°C. Similar to hydrogen, its flames are almost invisible, creating challenges for fire detection during onboard incidents. Methanol spills or fires could escalate quickly if not detected early.

Methane

The upper flammability limit and lower flammability limit are 5% and 15% by volume. In open spaces, methane tends to disperse quickly due to its low molecular weight, reducing the likelihood of reaching explosive concentrations. However, if the gas is released in a confined or poorly ventilated area, it can accumulate, and if ignited, cause an explosion.

Ammonia

Ammonia is less flammable than the other alternative fuels, with a range (LFL-UFL) of 15% – 28%. Although the risk of ignition is lower compared to hydrogen or methanol, ammonia can still pose significant safety hazards, particularly if it accumulates in enclosed spaces.

Toxicity and environmental

The toxicity of alternative fuels is another critical consideration, as it directly impacts the health and safety of crew members and the surrounding environment.

Hydrogen

Hydrogen is non-toxic and does not pose a direct health hazard in terms of chemical toxicity. However, it can cause asphyxiation if released in large amounts in confined spaces by displacing oxygen. In the event of a marine spill, hydrogen has minimal environmental impact because it quickly disperses into the atmosphere and is not harmful to marine organisms.

Methanol

Methanol is also highly toxic. Inhalation, ingestion, or skin contact can cause serious harm, including neurological effects and metabolic acidosis. However, methanol is considered less environmentally hazardous in marine spills than fossil fuels because it dissolves readily in water and biodegrades relatively quickly. This property reduces its persistence in the marine ecosystem, making it a somewhat less harmful alternative from an environmental perspective. Methanol is toxic to aquatic organisms at concentrations above 1,000 mg/l, with an LC50 for fish of 15,400 mg/l, significantly higher than the LC50 for HFO (79 mg/l).

Methane

Methane is toxic to humans, but its primary risk lies in undetected leaks within enclosed spaces. Methane is an asphyxiant that displaces oxygen, posing a risk of suffocation. In the marine environment, methane is less impactful because it volatilizes rapidly into the atmosphere, minimizing its long-term ecological effects. However, methane leaks contribute significantly to atmospheric greenhouse gas concentrations, as methane is more potent than CO2 as a greenhouse gas.

Ammonia

Ammonia is among the most toxic of the alternative fuels, it may produce acute toxic effects on humans and animals. Inhalation or direct contact can cause severe chemical burns, respiratory damage, and harm to the skin and eyes. The time-weighted average (TWA) concentration for ammonia is set at 25 ppm, which refers to the average exposure level over an 8-hour workday within a 40-hour workweek. Given the low exposure limits, it is essential to implement strict safety measures to protect workers who handle ammonia. Adequate ventilation, personal protective equipment (PPE) and monitoring systems are essential to minimize the risk of exposure and ensure health and safety. Spills in the marine environment can have catastrophic effects on aquatic ecosystems, disrupting marine flora and fauna by altering the water's pH and introducing highly toxic compounds. The LC50 (Lethal Concentration 50) for ammonia is just 0.068 mg/l, making it highly toxic to marine environments and significantly more hazardous than other fuels in terms of acute ecotoxicity. For example, studies have shown that ammonia exposure can severely damage fish gills and other aquatic organisms, leading to long-term ecological imbalances. The odour threshold of ammonia is in the region of 5 ppm. Thus, the pungent odour act as a warning.

2.1.2 Fuel bunkering

Bunkering refers to the process of replenishing a vessel's fuel supply required for its routine operations. This regulated procedure necessitates adherence to a variety of HSE rules, regulations and standards, at international, national and local level. Handling and bunkering alternative fuels introduce additional HSE risks for the ship and the infrastructure (bunkering at quayside or by barge) leading to additional costs and operational complexity, including the procedures to guarantee the quality and certification of the fuel supplied to vessels.

Safety issues during bunkering

In addition to the already mature procedures for bunkering natural gas regulated by the IGF Code, the IMO interim guidelines adopted / in progress on methyl/ethyl alcohol, LPG, ammonia and hydrogen define goals, functional requirements and some more detailed requirements for safe bunkering. However, several aspects of bunkering, including fire prevention, fuel transfer procedures, handling of cryogenic fuels, spill containment and emergency response will require harmonization and a more detailed definition of standards, possibly derived from other industrial applications. Moreover, personnel involved in bunkering operations should be properly trained and qualified.

Hydrogen

Due to the qualities of hydrogen, particularly the extremely low temperature of liquified hydrogen (LH_2), expertise learned from bunkering arrangements for liquid natural gas (LNG) cannot be directly used. The bunkering procedure will be more challenging than for LNG since no nitrogen can be present inside the pipe systems when liquified hydrogen is supplied, as it will freeze and clog the systems.

Onboard LH_2 bunkering stations will be situated on both sides of the vessel. Bunkering stations would require one bunkering liquid line and perhaps one vapor return line, as well as an inert gas purging facility, accompanying relief/safety valves, safety systems, and a separate control station. The LH_2 is routed by pipework from the bunker station to the fuel storage tanks on board.

When designing hydrogen bunkering infrastructure – either for compressed or liquid hydrogen - equipment, systems, components and factors such as material compatibility / embrittlement / permeability, cryogenic insulation, static grounding and much more need to be considered.

While open bunkering stations are preferred for hydrogen, ventilation may be required for semi-enclosed or enclosed installations. Mechanical ventilation in conjunction with hydrogen presents additional risks, since the ventilation and the emergency venting system itself may generate and propagate fire and explosions. Assessing hazards and doing extra testing may be necessary to validate designs. Finally, the Boil Off Gas (BOG) when H_2 is in liquid state must be managed.

Methanol

Methanol is liquid at atmospheric temperatures and pressures, making bunkering similar to conventional fuel oils. However, its low flashpoint and toxicity necessitate special equipment and procedures. Hoses and couplings must be approved for methanol use and frequently tested in accordance with the most recent version of MSC.1-Circ. 1621 [7].

The bunker station poses clear threats to the ship owing to the probability of methanol liquid and vapor escape. The position of the bunker station is thus an important aspect in determining the amount of risk connected with the ship's bunkering operation. Bunker manifolds are categorized as zone 1 areas within 3 meters of any valves, and section 8 of MSC.1/Circ.1621 [7] specifies the standards for methanol bunkering. Methanol bunker stations should be situated on open decks to allow for enough natural ventilation. Enclosed or semi-enclosed bunker stations should have mechanical ventilation and gas detection systems to ensure equal safety.

The ship's bunkering pipes and materials must fulfil section 7 of MSC.1/Circ.1621 [7] and prevent leaks that endanger passengers, the environment, or the ship itself.

Methane

LNG has been used on ships for many years now, and it has an ever-growing fleet, so the regulations and technologies are quite mature, and the bunkering handling has a dedicated regulation, the IGF Code [3], as well as ISO/TS 18683:2021 [8], and LNG Bunkering Guidelines IACS Recommendation [9].

It is critical that all LNG bunkering activities are carried out with care and attention to prevent leakage of LNG liquid or vapour, and that sources of ignition in the proximity of the bunkering operation are tightly regulated. Therefore, it is vital that each piece in the LNG bunkering chain be precisely planned and has specific safety, operational, and maintenance processes carried out by skilled staff.

Ammonia

Ammonia's toxic and corrosive properties will impact bunkering procedures, particularly when handling anhydrous ammonia as a saturated liquid. It is essential to consider these characteristics due to the associated risks, such as corrosion and potential toxic effects on humans, aquatic life, and the environment. To mitigate these risks, nitrogen gas should be inerted into hoses and pipelines to eliminate moisture and oxygen, thus preventing stress corrosion cracking. Subsequently, the remaining system should be purged with ammonia vapor to remove residual nitrogen. These inerting and purging processes are additional steps not required in Marine Fuel Oil (MFO) bunkering.

Furthermore, unlike conventional liquid marine fuels such as diesel or residual oil, ammonia must be maintained as a saturated liquid through refrigeration or pressure. BOG or flash gas will be produced if the temperature increases or pressure decreases, necessitating effective BOG management on board, which differs from conventional fuels. Additionally, the maximum capacity for utilizing ammonia as fuel is limited to 94% of the total tank capacity, as the maximum filling limit at the supply port is 98% to prevent overpressure, leaving a 4% heel remaining in the tank.

3 IMO: state of the play

The International Maritime Organization is a specialized agency of the United Nations, based in London, whose purpose is to establish intergovernmental regulations concerning the safety of ships maritime trade and safe access to the seas. IMO also sets regulations for marine environment protection, preventing pollution of the air and the water, IMO is continuously encouraging its 176 Member States to develop and update National Action Plans consistent with IMO policies, 50 international conventions and protocols up to date.

3.1 Safety of low-flashpoint fuels

SOLAS has previously restricted the use of fuels having a flashpoint less than 60˚C, except for emergency generators, where the maximum is 43˚C and subject to additional criteria stated in SOLAS II-2 Regulation 4.2.1. The IMO adopted the IGF Code by IMO Resolution MSC.391(95) [3] in June 2015, as applied from SOLAS II-1, Part G, to establish regulatory safety criteria and a framework for ships employing gases or other low-flashpoint fuels, such as methanol, as fuel. The IGF Code [3] outlines aims and functional criteria for low-flashpoint fuels and gases but only includes comprehensive prescriptive standards for natural gas (methane) in Part A1. Low-flashpoint fuels must follow the Alternative Design standards under 2.3 of the IGF Code [3] and establish equivalence as stated in SOLAS II-1/55, which requires engineering assessments based on MSC.1/Circ.1212 [10] and MSC.1/Circ.1455 principles.

3.2 Further development of a safety regulatory framework

It is recalled that the IMO Maritime Safety Committee (MSC 107) had agreed to include in its agenda a continuous output on "Development of a safety regulatory framework to support the reduction of GHG emissions from ships using new technologies and alternative fuels" assigning the Committee as the coordinating organ, in association with other Sub-Committees (CCC, HTW, III, SDC and SSE) and had invited MEPC to be an associated organ. The assigned Group had developed a non-exhaustive and non-restrictive list of fuels and technologies, as set out in annex 1 to document MSC 108/5 – also attached as Attachment 1 for easy reference to this Deliverable - which captured detailed information (technical background, hazards, and risks to ship/shoreside) for each identified fuel and technology.

MSC 108 endorsed the view of the Group regarding the challenges faced by the shipbuilding industry (ship designers, ship builders, fuel suppliers and regulatory bodies) in designing new ships and preparing existing ones to use alternative fuels. MSC 108 also endorsed the view of the Group that when preparing emergency response plans, the Port Community should be informed about the challenges posed by the use of alternative fuels. Moreover, the IMO Secretariat is liaising with ISO on any relevant work undertaken on the issue of potential challenges posed by the use of alternative fuels.

Currently IMO is further developing recommendations to address each of the identified barriers and gaps in IMO instruments that impede the safe use of an alternative fuel or new technology, as listed in the annex 1 (Attachment 1 to this Deliverable) columns titled, "Instruments causing barriers" and "Gaps in the regulations". For instruments causing barriers, the Group has to ensure that each recommendation clearly states which IMO instrument is proposed to be amended and, for gaps in the regulations, ensure that each recommendation clearly states either which IMO instrument is proposed to be amended, or provides the scope, nature and purpose of any new instrument that is recommended for development to fill the gap.

A simplified state of play of IMO regulations and RINA Rules and Guidelines – representative of the provisions of Classification Societies - is presented in Table 1.

Table 1: IMO Codes and Guidelines vs. RINA Rules and Guidelines.

Alternative Fuel	IMO Codes and Guidelines	RINA Rules and Guidelines
LNG	IGF Code	RINA Rules Pt C, Ch 1, App 7 - LNG Fuelled or CNG Fuelled Ships RINA Rules Pt E, Ch 9, Sec 16 - Use of Cargo as Fuel
LPG	Interim Guidelines for the Safety of Ships using LPG Fuels (MSC.1/Circ.1666)	RINA Rules Pt C, Ch 1, App 13 - LPG or NH3 Fuelled Ships
Methanol	IGF Code MSC.391(95) Interim Guidelines for Ships Using Methyl / Ethyl alcohol as Fuel (MSC.1/Circ.1621) [19]	RINA Rules Pt C, Ch 1, App 15 - Methyl/Ethyl Alcohol Fuelled Ships RINA Rules Part F, Chapter 13, Section 39 (Methyl/Ethyl Alcohol Fuelled Ready)
Ammonia	Finalized in Sept.2024 CCC10 and adopted as MSC.1/Circ.1687	RINA Rules Pt C, Ch 1, App 13 - LPG or NH3 Fuelled Ships RINA Rules Pt F, Ch 13, Sec 35 - NH3 Fuelled Ready RINA Rules Pt E, Ch 9, App 1 - NH3 Tank Ready and NH3 Tank
Hydrogen	IGF Code MSC.391(95) IMO MSC.1-Circ.1212 and MSC.1-Circ.1455 for alternative design as required by flag Under development (expected to be finalized at CCC11, Sept. 2025)	RINA Rules Pt C, Ch 1, App 14 - Hydrogen Fuelled Ships RINA Rules Pt F, Ch 13, Sec 38 - H2 Fuelled Ready
Ships transporting liquified hydrogen	Interim Recommendations for Carriage of Liquified Hydrogen in Bulk (Res.MSC.420(97))	GUI26 - Guide for the Storage on board of Ships of Dangerous Substances for use, selling and similar purposes

4 Process to obtain Class Approval in Principle

The role and services of Classification Societies, the scope of classification, the aspects of statutory compliance and certification, as well as the Class certification schemes have already been outlined when addressing the specific technologies developed in the RETROFIT55 Project (e.g. D1.3).

In this Deliverable it is worth recalling the certification scheme which is generally applicable to technologies and solutions developed in R&D projects, i.e. Approval in Principle.

Approval in Principle (AIP) is a framework used by RINA and other classification societies to review and approve innovative and novel concepts not covered by traditional classification prescriptive rules or technology that is not proven (i.e. documented track record for its defined application does not exist), so that a level of safety in line with the current marine industry practice is provided. The AIP concept is often based upon a risk-based approach to classification, that allows for new designs and novel concepts to be validated with safety equivalencies.

The new design is subject to a series of risk assessment techniques, to determine if the concept provides acceptable levels of safety in line with current marine industry practice, requirements and standards.

This systematic process of verification has been used to assess new ship and gas containment designs, such as LNG FPSO project: by employing advanced simulations and modelling techniques, engineers can evaluate the structural integrity and safety features of these innovative designs. This approach ensures that the ships are capable of handling extreme environmental conditions and maintaining optimal performance during operations. Additionally, it helps identify potential areas for improvement and enhances overall efficiency and reliability in gas transportation and storage processes.

AIP is granted after a thorough review of the novel design documentation provided by the manufacturer or shipyard. This process involves examining detailed engineering plans, safety assessments, and compliance with regulatory standards. The review ensures that the innovative design meets all necessary criteria for approval, offering reassurance that the vessel will operate safely and efficiently. Only after this meticulous evaluation can the AIP be issued, signifying a crucial step towards bringing the new design to life.

Taking into consideration the RINA GUI19 – Guide for Approval in Principle of Novel Technologies [12], the AIP process must be based on a systematic approach. Typically, the following items should be included:

- Technology qualification description.
- Operational conditions and limitations.
- Functional requirements.
- A risk assessment must be conducted according to the methods described in the RINA GUI 15 – Guide for Risk Analysis [13] to identify, rank, and control hazards and/or failure modes potentially affecting the novel technology.
- Engineering analyses can be used to demonstrate that the design meets the general requirements for its intended service.
- If parts of systems or scale prototypes are available, measurements and tests may be used as supporting evidence.

Official statement of fitness-for-service can be obtained by the Technology Qualification Process (TQP), in the form of a certificate, class notation, or other equivalent documents (see the section below for more details on TQP). In the event engineering analyses and prototype tests are not available, the feasibility of novel technology may be demonstrated using alternative methods and providing proper justifications.

The typical documentation to be produced during an AIP process consists of, as far as applicable:

- Design criteria of the novel technology
- Applicable rules and regulatory framework
- Detail drawings and schemes
- Technical specifications ensuring fitness-for-service
- Engineering analyses performed during the design procedure
- Reports on risk and safety assessment

Finally, following the evaluation of all the documents reported above, the AIP certificate can be issued, thus confirming that the novel technology meets the general requirements for its intended service.

*Detailed information on the systematic approach underlying the Approval in Principle (AIP) for new technologies, which are not sufficiently covered by established codes and procedures, can be found in the RINA Guidelines GUI19 "Guide for Approval in Principle of Novel Technologies" [12] or equivalent. Additionally, the systematic approach to the qualification of novel technology, ensuring its suitability for its intended service, is detailed in the RINA Guidelines GUI16 "Guide for Technology Qualification Processes" [14] or equivalent. Furthermore, the risk assessment involved in the AIP procedure should be conducted following the methods outlined in the RINA GUI15 "Guide for Risk Analysis" [13] and RINA GUI23 "Guide for Failure Mode and Effect Analysis (FMEA)" [15] or equivalent.

Systems intended for demonstration purposes (such as demo prototypes) must obtain at least an Approval in Principle. Accordingly, the documents specified above should be submitted to a Class Society for review and approval. The Class Society may then verify compliance with relevant rules, regulations, and applicable Standards.

Following the AIP procedure, the evaluation of integrating the new technology onboard the ship occurs.

Novel technologies aren't fully addressed by existing codes and procedures. Thus, they must undergo the Technology Qualification Process (TQP) to ensure they meet all requirements for their intended use.

Novel technology lacks a documented track record for specific applications. Thus, it includes both new technologies in known environments and known technologies in new environments.

Innovative technologies and systems are deemed fit for service when supporting evidence confirms that they meet all the criteria of functionality, safety, reliability, availability, and maintainability outlined in the Technology Qualification (TQ) basis, including specified standards, boundary conditions, and interface requirements.

Qualification involves reviewing the design, engineering analyses, and testing programs in a systematic and documented manner.

Outlined below are the preliminary steps for evaluating the novel technology:

- The technology is divided into subsystems and components using system schematics and P&ID diagrams, with particular attention to manufacturing, installation, and operational processes associated with these subsystems and components.
- The potential novelty of each subsystem and component is assessed.
- The primary challenges and uncertainties related to the novel technology are identified.

The TQP is built upon the following key steps:

- Conducting a risk and safety assessment to identify, rank, and control potential failure modes that could compromise the novel technology's fitness for service.
- Performing engineering analyses to demonstrate compliance with all specific requirements for its intended service as defined by the design of the novel technology.
- Undertaking measurements and tests to provide evidence that the novel technology meets the specified requirements for its intended service.
- Carrying out functionality assessments to ensure that functional requirements, as well as safety, reliability, availability, and maintainability criteria, are satisfied.

Regarding the first step, risk and safety aspects of the novel technology must be evaluated using established techniques to verify compliance with regulations. This involves focusing on potential events that could impact the service readiness of the novel technology, including its interactions with ship systems based on existing proven technologies. The criteria for risk assessment will be further examined in relation to alternative fuels.

Technical outcomes of TQP include:

- Description of the technology and its boundaries.
- Operational conditions and constraints of the novel technology.
- Functional requirements addressed by the novel technology.
- Safety, reliability, availability, and maintainability criteria for the novel technology.

The information provided is used to define specifications for the design, manufacturing, and installation of the novel technology. Similarly, the maintenance schedule follows a lifecycle perspective. A certificate, class notation, or equivalent document is issued as an official statement declaring the technology fit for service based on the TQ basis.

Supporting documentation must include:

- System specifications, drawings, technical reports, design calculations.
- Applicable rules, regulations, and standards.
- Survey requirements for construction, installation, commissioning.
- Operational instructions for normal and emergency situations.
- Maintenance requirements.

Alternative methods for demonstrating feasibility may be employed, provided they are supported by appropriate justification.

Detailed insight into the application of the Technology Qualification Process can be found in the RINA guidelines GUI16 - "Guide for Technology Qualification Processes" [14] and both the IMO MSC/Circ. 1002 "Guidelines for alternative design and arrangements for fire safety" [10] and the IMO MSC.1/Circ.1212 "Guidelines on Alternative Design and Arrangements for SOLAS Ch II-1 and III" [11] shall be taken into account.

4.1 HAZID/HAZOP Analysis

The study of alternative design concepts for the application of alternative fuels involves conducting a HAZID analysis as part of an AIP, in accordance with rules and regulations.

The risk assessment verifies that the proposed design meets safety standards. Detailed guidance on the process is available in RINA GUI15 – Guide for Risk Analysis [13], and further information can be found in IMO MSC/Circ. 1002, Guidelines for Alternative Design and Arrangements for Fire Safety [10], and IMO MSC/Circ. 1212, Guidelines for Alternative Design and Arrangements for SOLAS Chapters II-1 and III [11].

The risk assessment is typically carried out as follows:

- hazards are identified;
- risks are assessed against the defined acceptance criteria and interfaces with other ship systems
- risk control options (RCO) are defined. In detail, strategies of prevention, mitigation, or a possible combination of them are built up in case the risk is to be reduced according to the ALARP principle to settle on acceptable levels;
- the overall study is documented.

Potential hazards to consider in the risk assessment include:

- extreme weather, influencing maximum ship motions, accelerations, inclinations, temperatures;
- mechanical damage, possibly leading to liquid/gas release or progressive ship flooding;
- fire and/or explosion;
- release of flammable or toxic gases;
- release of cryogenic liquids or gases;
- loss of electrical power supply with a negative impact on ship essential service;
- failures related to single or possibly multiple systems on-board;
- any other hazard preliminary identified or listed in IMO or Class Guidelines.

4.1.1 Risk identification

As an example, when evaluating an alternative fuel, consider technical, operational, environmental, and economic risks.

Technical risks

- **Fuel stability:** Alternative fuels vary in chemical composition, risking stability during combustion. For instance, some biodiesels may freeze at low temperatures and deteriorate after few months, while ethanol can absorb water, leading to phase separation.
- **Engine compatibility:** Current engines may require modifications or replacements, increasing technical risks and costs. For example, using hydrogen as fuel might necessitate changes to the engine materials to withstand H2 unique properties.

- **Storage and handling:** Alternative fuels need unique safety measures, like cryogenic storage for LNG or pressurized tanks for hydrogen. These requirements add complexity and potential hazards to onboard storage systems, making it essential to have robust safety protocols.

Any failure in the fuel supply system to the power generation systems on board may result in a black-out and non-availability of steering and propulsion, which may be the root cause of ship collision or grounding with consequent fatalities and total ship loss.

Operational risks

- **Training**: Crew members need specialized familiarization, training and qualification for handling and operating ships with alternative fuels. This includes understanding new bunkering procedures, emergency response strategies, and maintenance of modified power generating sets.
- **Fuel availability**: Consistent global supply is essential to avoid disruptions. The lack of a widespread bunkering network could pose significant operational challenges, especially on long voyages.
- **Bunkering infrastructure**: Investments and upgrades are necessary for adoption. Ports worldwide need to build or retrofit facilities to accommodate alternative fuel bunkering, which involves significant financial and logistical planning.

Operational risks

- **Emissions**: Unexpected by-products or incomplete combustion can harm the environment. Assess emissions from production to usage. For example, methane slip during LNG combustion can undermine its environmental benefits compared to traditional fuels.
- **Spills and contamination**: Accidental spills of LNG and biofuels can damage marine ecosystems. Additionally, the clean-up processes for such spills often differ from conventional oil spill responses and may require specific expertise and equipment.

Economic risks

- **Transition costs**: Significant investment in new technologies, training, infrastructure and maintenance is required. Companies must allocate substantial capital expenditure to overhaul their fleets and port facilities.
- **Fuel prices**: Volatile market prices can affect cost-effectiveness. Fluctuations in alternative fuel markets could lead to unpredictable operating expenses, impacting the overall financial stability of shipping companies.
- **Regulatory compliance**: Adhering to international regulations can add expenses and complexities. Maintaining up-to-date knowledge and implementation of varying regulations across different jurisdictions increases administrative burdens and costs.

By evaluating risks and considering individual cases based on the specific fuel being analysed and the various types of ships to be supplied, stakeholders can better prepare for and mitigate the risks associated with implementing alternative fuels in the maritime industry. The outcome of AIP is an official statement or equivalent document, supported by the necessary documentation. This document is issued after a comprehensive assessment of the provided evidence, including drawings, technical reports, and assessment of all applicable rules and standards. The AIP will confirm that the new technology (e.g. ammonia fuel systems on board) complies with the established requirements for its intended application.

5 Marinization

Marinization ensures that new technology on-board does not compromise operation and safety in the marine environment. The design, installation, and operation must comply with Class Rules (e.g., RINA Rules Part C Ch. 1 Sec. 1) [16], focusing on four main aspects:

- Marine environments are typically salty, wet, and can be very hot. All machinery and systems onboard must be designed to operate under these conditions as shown in Figure 5. This applies to all machinery and systems covered by the Rules unless specified otherwise.

AIR TEMPERATURE	
Location, arrangement	Temperature range (°C)
In enclosed spaces	between 0 and +45 **(2)**
On machinery components, boilers In spaces subject to higher or lower temperatures	According to specific local conditions
On exposed decks	between -25 and +45 **(1)**

WATER TEMPERATURE	
Coolant	Temperature (°C)
Sea water or, if applicable, sea water at charge air coolant inlet	up to +32

(1) Electronic appliances are to be designed for an air temperature up to 55°C (for electronic appliances see also Chapter 2).
(2) Different temperatures may be accepted by the Society in the case of ships intended for restricted service.

Figure 5: Ambient conditions to be considered during design for marinization purposes [16].

- Operation in inclined positions: The vessel's rolling and pitching must not impair the operation and safety of onboard systems. Main and auxiliary machinery essential for propulsion and safety must function when upright and at various heeling angles or trim. Figure 6 details the angles and trim to be considered during design.

Installations, components	Angle of inclination (degrees) **(1)**			
	Athwartship		Fore and aft	
	static	dynamic	static	dynamic
Main and auxiliary machinery	15	22,5	5 **(4)**	7,5
Safety equipment, e.g. emergency power installations, emergency fire pumps and their devices Switch gear, electrical and electronic appliances **(3)** and remote control systems	22,5 **(2)**	22,5 **(2)**	10	10

(1) Athwartship and fore-and-aft inclinations may occur simultaneously.
(2) In ships for the carriage of liquefied gases and of chemicals the emergency power supply must also remain operable with the ship flooded to a final athwartship inclination up to a maximum of 30°.
(3) No undesired switching operations or operational changes are to occur.
(4) Where the length of the ship exceeds 100m, the fore-and-aft static angle of inclination may be taken as 500/L degrees, where L is the length of ship, in metres, as defined in Pt B, Ch 1, Sec 2, [3.1.1].

Figure 6: Values for heeling angles and trim to be considered during design for marinization purposes [16].

The Classification Society may permit deviations from the heeling angles and trim values illustrated in Figure 6, considering the specific type, size, and service conditions of the vessel. For instance, all machinery with a horizontal rotation axis is typically required to be installed onboard by aligning their rotational axis with the ship's length. If this alignment is not feasible due to geometric constraints or assembly limitations, the Manufacturer must be informed to ensure that appropriate operating conditions for thrust bearings are maintained.

- Ship motions can amplify vibrations from machinery at specific frequencies, potentially harming structural resistance. Thus, propulsion and auxiliary machinery must be designed and installed to ensure vibrations during normal operations do not cause undue stress. Figure 7 summarizes restrictions on vibrational modes for electrical equipment onboard in terms of amplitude and accelerations (see Part C Ch. 2 Sec. 2 for details [16]). Contractual agreements between the shipyard and shipowner may include stricter vibration requirements.

Location	Frequency range Hz	Displacement amplitude mm	Acceleration amplitude g
Machinery spaces, command and control stations, accommodation spaces, exposed decks, cargo spaces	from 2,0 to 13,2 from 13,2 to 100	1,0 -	- 0,7
On air compressors, on diesel engines and similar	from 2,0 to 25,0 from 25,0 to 100	1,6 -	- 4,0
Masts	from 2,0 to 13,2 from 13,2 to 50	3,0 -	- 2,1

Figure 7: Values for heeling angles and trim to be considered during design for marinization purposes [16].

- Noise: Ship motion can lead to improper dampening of vibrations, negatively affecting comfort and health. To reduce noise levels, machinery foundations onboard must be properly mounted, and noise-reducing solutions should be considered. The IMO resolution MSC. 337(91) [17] mandates noise level limits for machinery spaces, control rooms, workshops, accommodation, and other areas on ships exceeding 1600 gross tonnage. Additional regulations are in the RINA Rules Pt F, Ch 6, Sec 1 [16]. Contractual agreements between shipyards and shipowners may include stricter noise requirements.

All the requirements reported above assume that the novel technology is installed on commercial vessels. Instead, specific provisions for anti-shock protection of systems providing essential services (i.e., propulsion and safety services) are required for naval vessels.

Further requirements exist for pressure equipment, i.e. novel technologies working with pressure exceeding the ambient one. Specifically, their design, manufacturing and testing are subjected to various sections included within the RINA Rules Part C [16], depending on their pressure and temperature levels, volume and fluid.

Analogously, specific requirements aimed at ensuring expected quality of the power supply equipment are available in the RINA Rules Part C, Ch 2, Sec 2 [13](examples of the frequency and voltage variations allowed for electrical distribution systems are reported in Figure 8 and Figure 9).

Quantity in operation	Variations	
	Continuous	Transient
Voltage	+ 6% - 10%	± 20% (recovery time: 1,5 s)
Frequency	± 5%	± 10% (recovery time: 5 s)

Figure 8: Voltage and frequency variations for AC distribution system.

Quantity in operation	Variations	
	Continuous	Transient
Voltage	+ 6% - 10%	± 20% (recovery time: 1,5 s)
Frequency	± 5%	± 10% (recovery time: 5 s)

Figure 9: Voltage fluctuations allowed for DC distribution system.

6 Integration on-board

The step after AIP is evaluating integration onboard. Classification societies can handle these processes differently, but in the event the certification process of onboard systems (e.g., Approval in Principle of new technologies) and the classification of the vessel are performed by two distinct Class Societies, relationships and procedures are regulated by the "Mutual Agreement on the implementation of Mutual Recognition Provisions of Art 10 of Regulation (EC) No 391/2009" Nevertheless, within the MR framework, further testing aimed at demonstrating safety compliance may be possibly requested by Class Society for equipment which previously obtained Type Approval.

The goal of onboard integration is to ensure new technologies do not interfere with existing ship systems and ship operation. Novel technologies must maintain system availability, maintainability, reliability, and, most importantly, safety.

For novel technologies that provide ship essential services – which are defined by IACS Unified Interpretation (UI) SC134 - the documentation to be submitted to Class Society includes:

- Documentation demonstrating that the equipment and/or its components comply with applicable Rules and safety standards.
- Documentation proving that onboard integration of novel technologies does not negatively influence ship safety.

Redundancy is not required for new technologies that provide non-essential ship services from a certification perspective. However, detailed certification for equipment providing essential services may be sought voluntarily by manufacturers to facilitate commercialization and scaling-up.

Further focusing on ship essential services, the IGF Code, Part A, Paragraph 2.2.40 introduces the concept of "unacceptable loss of power", which means that *"it is not possible to sustain or restore normal operation of the propulsion machinery in the event of one of the essential auxiliaries becoming inoperative, in accordance with SOLAS regulation II-1/26.3"*.

For this reason, equipment providing essential services must have backup (i.e., redundant systems providing the same service), or must be quickly restored in the correct operation in case a fault occurs. Systems providing essential services should be properly arranged onboard.

Furthermore, essential ship services must guarantee minimum comfortable conditions of habitability for the crew and passengers. Definition of the "normal operating and habitable conditions" onboard vessels is available in the SOLAS convention: *"condition under which the ship as a whole, the machinery, services, means and aids ensuring propulsion, ability to steer, safe navigation, fire and flooding safety, internal and external communications and signals, means of escape, and emergency boat winches, as well as the designed comfortable conditions of habitability are in working order and functioning normally"*.

7 Rules for testing and certification of marine materials and equipment

The relevant provisions are part of the RINA Rules for Testing and Certification of Marine Materials and Equipment (NC/C.23).

The materials and equipment to be assessed are defined in the RINA Rules for the Classification of Ships, Part A, Chapter 2, Sec. 1. As a general rule, *“all materials, machinery, boilers, auxiliary installations, equipment, items, etc. (generally referred to as “products”), which are covered by the Class and used or fitted on board ships surveyed by the Society during construction, are to be new and, where intended for essential services (ref. previous sections of this deliverable) as defined in Ch. 1, Sec. 1, tested by the Society”*.

Furthermore, all products which are required by IMO Regulations to be type approved by the Administration are also subject to Class assessment, whenever and to the extent that the Class Society is a Recognized Organization of the ship flag Administration or is acting on their behalf.

In general, the testing and inspection activities shall be carried out at the Manufacturer’s facility. Additionally, testing operations and acceptance tests to be carried out onboard during and/or after installation shall be also considered for products which are assembled onboard or connected to other plants and systems originally present on the vessel.

Products already tested by other Recognized Organizations may be accepted on a case-by-case basis, using the relevant certificates and/or testing reports, provided that no additional test is required by the Rules and that the products refer to the relevant certificates.

For product certification, the acceptability criteria of both testing laboratories and relative testing reports are generally indicated in the Class Rules (e.g., RINA Rules for Testing and Certification of Marine Materials and Equipment, NC/C.23, Ch. 5).

8 Closing remarks

This Deliverable offers guidance on the current regulatory framework for marine equipment, covering concept design, engineering, testing, validation, and integration. It is useful for manufacturers, shipyards, and shipowners.

The transition to alternative fuels in the maritime industry involves both challenges and opportunities. By identifying and mitigating risks, stakeholders can facilitate a shift towards cleaner energy sources. Through collaboration, innovation, and strategic investment, the maritime industry can move towards a greener path.

To successfully navigate this transition, stakeholders must engage in proactive risk management. This includes conducting thorough assessments of potential hazards, implementing robust safety protocols, and continuously monitoring and evaluating the performance of alternative fuel systems. Collaboration between industry leaders, researchers, and policymakers is crucial to share knowledge, drive technological advancements, and develop comprehensive strategies that address both environmental and economic concerns.

The previous sections of this Deliverable have reviewed the Standards, Rules, and Regulations for marine systems. An overview of certifications by Classification Societies – and specifically the Approval in Principle - has been provided as a tool to enhance the project's commercial uptake and foster innovation, creating value for industry stakeholders and regulatory bodies.

Appendix

In the following the Annex 1 from IMO MSC 108 (WP8 – WG report) can be found.

Alternative Fuels / New Technologies	Technical background, hazards, and risks to ship/shoreside (refer to annex 2)	Instruments causing barriers	Gaps in the regulations	IMO organ(s) with associated competence
Liquid Fuels				
Fatty-acid methyl ester (FAME)		It should be noted that there is an inconsistency regarding cargo in MARPOL annex I and annex II, which may prohibit the otherwise safe use as a fuel	• Distinct cold flow properties – need to address correction of temperature during bunkering/fuel transfer. • Cleaning of fuel transferring equipment and storage tanks onboard - maintenance.	[CCC, HTW, III, SSE, SDC]
Hydrothermal liquefaction (HTL) fuel		No input	No input	[CCC, HTW, III, SSE, SDC]
Pyrolysis fuel		No input	No input	[CCC, HTW, III, SSE, SDC]
Methyl/ethyl alcohol fuels		No input	• Toxic requirements for transport as cargo or as a fuel are not consistent between the interim guidelines and the IBC Code. • Lack of standards for system certification of water based and gas based firefighting systems to extinguish alcohol fires.	[CCC, HTW, III, SSE, SDC]
Hydrotreated vegetable oil (HVO)		No input	No input	[CCC, HTW, III, SSE, SDC]
Fischer-Tropsch (FT) diesel		Auto-ignition temperature is below the allowed surface temperature in SOLAS	No input	[CCC, HTW, III, SSE, SDC]
Liquefied & Compressed Gaseous Fuels				
Ammonia		No input	• Development of guidelines • Ammonia as fuel should be considered under the applicability of the IGF Code. • Ammonia fuel definition and specifications (including water contents) should be developed. Cooperation with ISO would help set standards. Note: Interim Guidelines are currently being developed, ref. CCC 10 (2024).	[CCC, HTW, III, SSE, SDC]

Alternative Fuels / New Technologies	Technical background, hazards, and risks to ship/shoreside (refer to annex 2)	Instruments causing barriers	Gaps in the regulations	IMO organ(s) with associated competence
Dimethyl Ether (DME)		The IGC Code identifies DME as a toxic substance and currently prohibits toxic cargo to be used as a fuel	• The IGF Code does not contain prescriptive requirements for dimethyl ether (DME) as fuel. • Interim guidelines have not yet been developed for dimethyl ether (DME) as fuel.	[CCC, HTW, III, SSE, SDC]
Ethane		No input	No input	[CCC, HTW, III, SSE, SDC]
Hydrogen – *(compressed, liquid, metal hydride)*		No input	Development of guidelines (expected to be finalized at CCC 10)	[CCC, HTW, III, SSE, SDC]
Methane/Natural Gas *(compressed/CNG, liquefied/LNG)*		No input	No input	[CCC, HTW, III, SSE, SDC]
Propane/Butane (LPG)		No input	There is a need to continuously update of IGC/IGF Codes	[CCC, HTW, III, SSE, SDC]
Fuel Blends/Mixtures *(e.g. hydrogen - natural gas)*		SOLAS Chapter VI, Reg 5-2 Prohibition of blending of bulk liquid cargoes and production processes during sea voyages.	No guidelines for how to determine risks based on composition of fuel mixtures	[CCC, HTW, III, SSE, SDC]
				[CCC, HTW, III, SSE, SDC]

Alternative Fuels / New Technologies	Technical background, hazards, and risks to ship/shoreside (refer to annex 2)	Instruments causing barriers	Gaps in the regulations	IMO organ(s) with associated competence
New Technology				
Power Conversion Systems				
Fuel Cell Power Installations		Some existing designs of fuel cells power installations may not be up to date in the interim guidelines (i.e. Design and layout of fuel cell spaces	Lack of mandatory requirements for the safety of ships using fuel cell power installations.	[CCC, HTW, III, SSE, SDC]
Fuel Reforming		No guideline or regulations available for fuel reformers if used to provide fuel to an ICE or all other power system, not fuel cells.	Fuel reforming is only described in MSC.1/Circ.1647, however reformers can also be used in systems without fuel cell installations such as for pilot fuel (hydrogen) production in an ammonia engine or LOHC to hydrogen in a ICE.	[CCC, HTW, III, SSE, SDC]
Nuclear Power		• The knowledge in this field is well established and no roadblocks have been identified to a revision of the Code. • The Code is specific to earlier designs of Pressurized Water Reactors (PWRs) and a direct steam cycle propulsion system. In the intervening time, the progress in the	• Resolution A.491(XII) adopted the Code of Safety for Nuclear Merchant Ships as a guide to Administrations on the internationally accepted safety standards for the design, construction, operation, maintenance, inspection, salvage, and disposal of nuclear merchant ships. Since it was adopted in 1981, the nuclear industry has made	[CCC, HTW, III, SSE, SDC]

Alternative Fuels / New Technologies	Technical background, hazards, and risks to ship/shoreside (refer to annex 2)	Instruments causing barriers	Gaps in the regulations	IMO organ(s) with associated competence
		design of Small Modular Reactors (SMRs), the advent of new nuclear technologies and the development of the All-Electric-Ship concept have created the potential for the application of different nuclear technologies to seagoing vessels. These integrated designs are smaller, incorporate inherent passive safety features, and could operate at power for longer periods without refuelling. However, most of those new nuclear technologies are not covered by the existing Code, which also needs to be updated to reflect the current IAEA safety, security, and safeguards standards.	significant progress, and the code urgently needs a revision. • To accommodate new marine-appropriate nuclear energy solutions, the Code must be made technology agnostic and adopt a goal-based approach. The Code must also be brought up to date to reflect the current IAEA nuclear safety, security, and safeguards standards. An expert group convened by WNTI has prepared a complete gap analysis which identifies the sections of the Code that require updates for it to be consistent with the IAEA Standards as they would apply to nuclear-powered merchant ships. A comprehensive entire gap analysis has been provided to the IMO in MSC 108/INF.21.	

Alternative Fuels / New Technologies	Technical background, hazards, and risks to ship/shoreside (refer to annex 2)	Instruments causing barriers	Gaps in the regulations	IMO organ(s) with associated competence
Solar Power		No input	No input	[CCC, HTW, III, SSE, SDC]
Wind Propulsion		For the shipping industry, wind propulsion is not a new technology. To facilitate its wider uptake on commercial vessels some additional safeguards need to be considered, while wind propulsion systems reliability and availability may need to be further improved for the maximum potential benefit to be realized. No major roadblocks to implementation and all substantial barriers have been identified and no issues have been identified that are unsolvable.	• Gap analysis available in document MEPC 81/INF.39 – safety details taken from EMSA Wind propulsion report pages 73 to 109 of the annex. https://www.emsa.europa.eu/publications/reports/item/5078-potential-of-wind-assisted-propulsion-for-shipping.html • The major concerns related to wind propulsion for shipping are related to vessel's stability and manoeuvrability, change in air-draft, operational and navigational obstructions, obstruction in cargo loading/unloading (e.g. for bulk carriers), impact of adverse weather, ice accumulation, fire and lightning protection, noise and vibrations, system and component failures, maintenance. The issues described above may require	[CCC, HTW, III, SSE, SDC] NCSR

Alternative Fuels / New Technologies	Technical background, hazards, and risks to ship/shoreside (refer to annex 2)	Instruments causing barriers	Gaps in the regulations	IMO organ(s) with associated competence
			understanding of the risks as well as for defining the necessary safeguards that will need to be implemented to prevent or mitigate the major hazards. Based on the Hazard Identification (HAZID) studies, preventive and mitigative safeguards as well as recommendations for various ship types are presented, which may help to inform prescriptive requirements and develop inherently safer designs and arrangements. While some safeguards are regulatory requirements, many of these are considered additional safeguards due to the inherent risks of wind propulsion. Overall, the studies did not identify any major risk that cannot be resolved. • Navigational hazards – obstruction to visibility (SOLAS Chapter V), navigation lighting, radar blind spots • Convention on the International Regulations for Preventing collisions at sea, 1972, may be to be aligned to include this new technology.	
Fuel/Energy Storage (storage also addressed within fuel categories)				
Lithium-Ion Batteries		• Continuous technological development makes it difficult to draw up requirements for batteries that may become obsolete in a short period of time. • SOLAS II-1/Reg 41 Main source of electrical power and lighting systems	Batteries in SOLAS can only be considered as main source of power under the alternative design requirements. Fire- fighting requirements.	[CCC, HTW, III, SSE, SDC]
Supercapacitor energy storage technology		No input	The following requirements for supercapacitors are not specified in the SOLAS Convention, FSS Code or other regulations:	[CCC, HTW, III, SSE, SDC]

Alternative Fuels / New Technologies	Technical background, hazards, and risks to ship/shoreside (refer to annex 2)	Instruments causing barriers	Gaps in the regulations	IMO organ(s) with associated competence
			• Requirements for supercapacitor space arrangement (Containment of fire and smoke, fire integrity boundaries standards between supercapacitor space and adjacent spaces, fire extinguishing system arrangements and Ventilation arrangement, Combustible gas detection and alarm system arrangement, if applicable). • Requirements for Capacitor Management System (CMS). • Requirements for supercapacitor chargers/converters. • Requirements for supercapacitor cells/modules. • Requirements for system redundancy (i.e., design criteria for systems to remain operational after a fire casualty • Definition and classification for supercapacitor space (to define as Machinery Spaces of category A or other machinery spaces).	
Other Battery Technologies		No input	No input	[CCC, HTW, III, SSE, SDC]
High-Pressure Composite Cylinders		Lack of maritime guidelines and standards.	• The IGF Code lacks Safety standards for high pressure composite cylinders to be used as fuel storage • MEGC's approved for IMDG / ADR are not sufficiently safe to be used as fuel tanks, unless also designed and approved to meet the safety standards in the IGF Code, (to be developed). • Potential lack of IMDG provisions for the safe transportation of portable fuel	[CCC, HTW, III, SSE, SDC]
Metal Hydrides		No input	Lack of guidelines or standards within the IGF Code	[CCC, HTW, III, SSE, SDC]
Liquid Organic Hydrogen Carrier (LOHC)		No input	Lack of guidelines or standards within the IGF Code	[CCC, HTW, III, SSE, SDC]

Alternative Fuels / New Technologies	Technical background, hazards, and risks to ship/shoreside (refer to annex 2)	Instruments causing barriers	Gaps in the regulations	IMO organ(s) with associated competence
Improved Efficiency				
Wind Assisted Power		No input	• Currently, there are only regulations for static stability and there is no regulation to consider the rotating heeling moment. Need to investigate if the present criteria in the IMO Code on Intact Stability and IMO's second generation of stability criteria and if the damage stability criteria for all ships should be adapted to ships with WAPS. • Need to investigate if the present criteria in the IMO Standards for Ship Manoeuvrability are applicable to ships with WAPS. • Address the need to develop specific guidelines for the navigation safety of ships with WAPS to be used to compensate the larger blind	[CCC, HTW, III, SSE, SDC]
Air Lubrication		No barriers identified	No FSA has been carried out according to our knowledge	N/A
Alternative Fuels / New Technologies	**Technical background, hazards, and risks to ship/shoreside (refer to annex 2)**	**Instruments causing barriers**	**Gaps in the regulations**	**IMO organ(s) with associated competence**
Foils / Hydrodynamic Energy Saving Devices		No input	No input	[CCC, HTW, III, SSE, SDC]
Low-Friction Antifouling Paints		No barriers identified	No gaps identified	N/A
Hull Form Optimization		No barriers identified	No gaps identified	N/A
Optimal Routing		No barriers identified	No gaps identified	N/A
Propeller Optimization and Propulsion Improving Devices		No barriers identified	No gaps identified	N/A
Advanced Waste Heat Recovery		No input	• Circuit media may differ from supplier to supplier. The circuit media would normally circulate in a hermetically enclosed system, avoiding human interfacing and release to the atmosphere. However, it might be prudent to specify hazardous levels allowed for the circuit media or at least identify which existing regulations such media should adhere to. • May require standards for low flash point circuit media if used.	[CCC, HTW, III, SSE, SDC]
				[CCC, HTW, III, SSE, SDC]
Emissions Control & Reduction				

Alternative Fuels / New Technologies	Technical background, hazards, and risks to ship/shoreside (refer to annex 2)	Instruments causing barriers	Gaps in the regulations	IMO organ(s) with associated competence
Ammonia Abatement		No input	No input	[CCC, HTW, III, SSE, SDC]
CO2 Abatement *- onboard carbon capture and storage (OCCS, OCCU)*		Note1: Depending on how the captured carbon is classified, (e.g. waste, cargo or overboard discharge), Note 2: If Co2 is stored in portable containers may conflict with IMDG Code provisions	No regulation in place	[CCC, HTW, III, SSE, SDC]
Methane Abatement		No input	No input	[CCC, HTW, III, SSE, SDC]
N2O Abatement		No input	No input	[CCC, HTW, III, SSE, SDC]
Onshore Power Supply / Cold Ironing		• Lack of Standardization in port infrastructure • Power Supply frequency • Lack of compatibility between ship and shore power systems (e.g., different frequency, voltage, plugging arrangements etc.)	Lack of IMO requirements	[CCC, HTW, III, SSE, SDC]

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