State-of-the-art sustainable energy efficiency technologies roadmap for waterborne transport towards the fit-for-55 guidance compliance

Project 101192661— FLEETfor55

Deliverable D3.1 – Regulatory GAP analysis report

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Acronyms and Abbreviations	Meaning
AFIR	Alternative Fuels Infrastructure Regulation
AiP	Approval in Principle
BESS	Battery Energy Storage Systems
CCC	Carriage of Cargoes and Containers
CCS	Carbon Capture System
CH_4	Methane
CII	Carbon Intensity Index
CO_2	Carbon Dioxide
CDNI	Convention on the Collection, Deposit and Reception of Waste Generated during Navigation on the Rhine and Inland Waterways
CESNI	European Committee for Drawing up Standards in the Field of Inland Navigation
DNSH	Do No Significant Harm
EEA	European Economic Area
EEDI	Energy Efficiency Design Index
EET	Energy Efficient Technology
EEXI	Energy Efficiency Existing Ship Index
EMSA	European Maritime Safety Agency
EN	European Standards
ERS	Electric Road Systems
ES-TRIN	European Standard laying down Technical Requirements for Inland Navigation vessels
ETS	Emissions Trading System
EU	European Union

FAME	Alternative Fuels/ Fatty-acid methyl ester
FMEA	Failure Mode and Effects Analysis
FSA	Formal safety assessment
GBS	Goal Based Standards
GFI	GHG fuel intensity
GHG	Green House Gas
GT	Gross Tonnage
HAZID	Hazard Identification
HAZOP	Hazard Operability Study
HC	Hydrocarbons
IACS	International Association of Classification Societies
IBC	Intermediate Bulk Container
ICE	Internal Combustion Engine
IEC	International Electrotechnical Commission
IGC	International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
IGF	International Code of Safety for Ship Using Gases or Other Low-flashpoint Fuels
IMO	International Maritime Organisation
ISO	International Organization for Standardization
IWT	Inland Waterway Transport
LCA	Life Cycle Assessment
LNG	Liquefied Natural Gas
LOHC	Liquid Organic Hydrogen Carriers
MARPOL	International Convention for the Prevention of Pollution from Ships

MEPC	Marine Environment Protection Committee
MGO	Marine Gas Oil
MRV	Monitoring, Reporting, and Verification
MSC	Maritime Safety Committee
N_2O	Nitrous Oxide
NOx	Nitrogen Dioxide
NRMM	Non-Road Mobile Machinery
OPS	Onshore Power Supply
PEM	Proton Exchange Membrane
P4A	Platina4Action
SDC	Ship Design and Construction
SEEMP	Ship Energy Efficiency Management Plan
SFCS	Sustainable Fuels Certification Scheme/Standard
SOLAS	International Convention for the Safety of Life at Sea
SOFC	Solid Oxide Fuel Cells
SSE	Shore-Side Electricity
TEN-T	Trans-European Transport Network
TFEU	Treaty on the Functioning of the European Union
TSC	Technical Screening Criteria
UC	Use Case
WAPS	Wind-Assisted Propulsion Systems
WP	Work Package
WtW	Well to wake

Table of Contents

Document Info **4**

Table of Contents **9**

List of Figures **11**

List of Tables **11**

Executive Summary **12**

1 Rules and regulations review **13**

1.1 Introduction 13

1.2 IMO regulations 13

1.2.1 IMO short term measures 14

1.2.2 IMO medium term measures 17

1.2.3 IMO regulation for EETs 19

1.3 Regulatory mapping of alternative fuels 21

1.3.1 State of play and work plan for the development and introduction of rules on alternative fuels in the maritime sector 21

1.3.2 State of play and work plan for the development and introduction of rules on alternative fuels in the inland waterway sector 27

1.4 EU regulations for ocean going vessels 28

1.4.1 EU Taxonomy: Context for Climate-Aligned Shipping 29

1.4.2 Extension of the EU Emissions Trading System to Maritime 30

1.4.3 Alternative Fuels Infrastructure Regulation 31

1.4.4 Application of FuelEU Maritime Regulations 32

1.4.5 Zero Emissions at Berth 33

1.5 EU Rules for Inland Navigation 35

1.5.1 Gaseous and particulate pollutant emission limits for non-road mobile machinery (NRMM) 36

1.5.2 EU Taxonomy for sustainable activities in IWT 38

1.5.3 CountEmissionEU 41

1.5.4 NAIADES III and PLATINA4Action 41
1.5.5 CDNI Convention 45
1.5.6 Concluding remarks on EU Rules for inland navigation 45
1.6 Class Rules / Additional Class Notations 46
2 Applicable international standards 54
3 Technical implications of regulatory compliance 63
3.1 Framework for regulatory derogations in the maritime sector 63
3.2 Framework for regulatory derogations in the inland waterway sector 64
3.3 Risk Assessment as part of Alternative Design 65
4 Gaps and technical shortcomings in the regulatory framework 68
5 Conclusions 80
6 Bibliography 82

List of Figures

Figure 1: IMO work plan for the development of new alternative fuels under the IGF code 27

Figure 2: The AFIR within the Fit for 55 package 31

Figure 3: FuelEU Maritime objectives. 33

Figure 4: Example of $EEDI_{INLAND}$ reference curve determined from a data set based on both model-scale measurements converted to full scale, and full-scale measurements. 44

Figure 5: Tiers of the IMO's Goal Based Standards framework 64

Figure 6: Overview on safety evaluation and risk assessments of FLEETfor55 68

List of Tables

Table 1: Regulatory mapping of alternative marine fuels for seagoing vessels (outcome of (MEPC80/INF.17, 2023)) 23

Table 2: State of play on technical requirements for the use of alternative fuels in the inland waterway transport sector and the timeline for future developments. 28

Table 3: Inclusion of maritime emissions in the EU Emissions Trading System 30

Table 4: Summary of measures and regulations in the field of inland waterway transport for the measurement and control of greenhouse gas emissions and air quality. 35

Table 5: Stage V emission limits for engine category IWP, IWA and NRE. 37

Table 6: Class rules/additional notations of the EETs 46

Table 7 Applicable internation standards for EETs 55

Table 8: Overview of Risk Assessment Techniques 66

Table 9: EETs gaps/barriers derived by MSC110/6 69

Executive Summary

D3.1 "*Regulatory GAP analysis report*" presents the state of play of the current and forthcoming regulatory framework (IMO, EU) governing implementation and operation of Energy Efficient Technologies (EETs) on new ships' design and existing fleet retrofit.

D3.1 focuses on EU 'Fit for 55' legislative package, IMO MEPC measures, and regulations applicable to inland navigation.

A review of the regulations is performed and the possible gaps and barriers of the technical shortcomings in marine rules, regulations, guidelines, and industry standards are presented.

D3.1 will be the benchmark for the feasibility assessment of the proposed Use Cases (UCs) and will provide input to the rest of deliverables of WP3 and WP4.

1 Rules and regulations review

1.1 Introduction

The increasing urgency to address climate change has led to stringent regulations aiming to reduce greenhouse gas (GHG) emissions across all sectors. The maritime industry, which is responsible for around 3% of global emissions, is under growing scrutiny to improve its environmental impact, in compliance with the comprehensive strategy of the International Maritime Organization (IMO) and European Union (EU) initiatives implementing combined mandatory technical and operational requirements.

The challenges related to the targets for decarbonizing the maritime sector introduced by IMO and EU led to the creation and development of new fuels, new technologies, and new technical specifications essential to guarantee the safe utilization of these new fuels and technologies aboard ships. The principle of technological neutrality has resulted in a slowdown in the decarbonization process of the sector, due to uncertainty regarding the identification of the most viable solutions for addressing investments by shipping companies. This slowdown, combined with the (temporary) lack of technical regulations, creates additional obstacles to the decarbonization process and green transition in the maritime industry.

Central to these efforts is the evaluation of the efficacy of various emissions reduction and energy improvement technologies compared to effective real-world conditions. This is also the specific scope of FLEETfor55 aimed at advancing the scientific understanding of sustainable maritime practices for short sea, inland waterway and high seas vessels.

For this purpose, the state of play of the current and forthcoming regulatory framework (IMO, EU) governing implementation is presented in the following sections, to be used as basis for the development of all FLEETfor55 activities.

1.2 IMO regulations

The mapping of the IMO regulatory framework will detail:

- Safety regulations (IMO MSC Resolutions / SOLAS)
- Environment regulations (IMO MEPC Resolutions / MARPOL)
- IMO relevant Codes and non-mandatory Guidelines

- Work in progress (IMO MSC and CCC Correspondence Groups) – focus on MSC Correspondence Group on New Technologies & Alternative Fuels
- IMO future Work Plan and deadlines

In line with the ambitious goals set in 2015 by the United Nations Climate Change conference (COP 21) in Paris, the IMO – strongly committed to address GHG emissions from ships since 1990 – adopted in April 2018 the "Initial Strategy on reduction of GHG emissions from ships" (Initial Strategy adopted by Res. MEPC.304(72)) and then revised it in 2023 (2023 IMO Strategy adopted by Res. MEPC.377(80)).

The 2023 IMO Strategy opens a new chapter towards decarbonization of the maritime industry by applying novel technologies, fuels or other energy sources, aiming at representing at least 5% of the energy used by international shipping by 2030, reaching:

- a reduction of the total amount of annual GHG emissions from shipping of at least 20% - striving for 30% - by 2030 compared to 2008;
- a reduction of the total amount of annual GHG emissions from shipping of at least 70% - striving for 80% - by 2040 compared to 2008; and
- net-zero GHG emissions by or around, i.e. close to 2050.

To achieve such goals, the IMO Strategy already listed candidate short, mid and long-term measures with possible timeline specifying that before adoption of any measures the impacts on States should be assessed. The 2023 IMO Strategy clarifies more in detail the mid-term measures to be developed and agreed by 2025, including:

- technical element according to newly adopted guidelines on the life cycle GHG intensity of marine fuels (LCA Guidelines); and
- economic element based on a GHG emissions pricing mechanism.

1.2.1 IMO short term measures

The short-term measures introduce technical and operational requirements which are based on a goal-based approach so not to limit the means of compliance and enable each shipowner to choose the most suitable option(s) for his specific ship and its trade. The measures include:

- the calculation and verification of a new Energy Efficiency Index for existing ships (EEXI);
- a strengthened Ship Energy Efficiency Management Plan (SEEMP); and
- a rating mechanism linked to a new operational Carbon Intensity Indicator (CII).

Bulk carriers, combination carriers, container ships, unconventional propulsion cruise ships, gas carriers, general cargo ships, refrigerated cargo ships, LNG gas carriers, ro-ro cargo ships, vehicle carriers, ro-ro passenger ships, and tankers of 400 GT and above engaged in international voyages have to calculate the attained EEXI. The Attained EEXI is a technical efficiency indicator expressed in gCO_2/ton*nm, corresponding to the following:

$$Attained\ EEXI = \frac{CO_2\ emissions}{\text{transportation work}}$$

where:

- CO_2 emissions are calculated considering the contributions from main engines, auxiliary engines, shaft generators, and any efficiency improvement deriving from the application of innovative technologies for reducing emissions.
- Transportation work is a function of the capacity in fully loaded condition, of the reference speed (calculated at that capacity and at the 75% of the rated installed power, after having deducted any installed shaft generator, if present) and of any corrective factors introduced for specific ship types and designs.

The Attained EEXI should be equal to or lower than the required EEXI, calculated based on a reference line and specific reduction factors for each ship type. Verification of the attained EEXI must be conducted at the first annual, intermediate, or renewal survey of the IAPP Certificate or the initial IEEC Certificate, whichever is first, starting from 1 January 2023.

By 1 January 2023, the ship types mentioned above, and conventional propulsion cruise ships with a gross tonnage of 5,000 GT or more engaged in international voyages, must include in the SEEMP:

- The methodology used to calculate the ship's attained annual operational Carbon Intensity indicator (CII) and reporting this value to the Flag Administration;
- An implementation plan to meet the required annual operational CII for the following three (3) years;
- A self-assessment and improvement procedure.

Confirmation of compliance is be provided by the Flag Administration or its Recognized Organization (RO) before 1 January 2023 and kept on board. The SEEMP will be subject to verification during Company audits.

For ships subject to the new SEEMP requirements:

- Starting from 2023, at the end of each calendar year, the attained annual operational CII is be calculated over a 12-month period and electronically communicated to the Flag Administration /RO by the following March.
- The required annual operational CII is reduced by the same percentage each year for all ship types (5% for 2023; 7% for 2024; 9% for 2025; 11% for 2026, with percentages yet to be decided for 2027-2030).

The Flag Administration/RO is to verify the attained annual operational CII against the required annual operational CII to determine the energy efficiency class A, B, C, D, or E. The required annual operational CII is the midpoint of the range corresponding to the C-rating level. A ship classified as D for three consecutive years or E for any year must develop a corrective action plan to achieve the required annual operational CII. This plan must be included in the SEEMP and submitted to the Flag Administration /RO for verification.

Although the intention of CII is to be a measure of how efficiently a ship transports goods or passenger - being expressed as grams of CO_2 emitted per cargo-carrying capacity and nautical mile - there are practical cases showing distortions in the perception of what an efficient ship is. An example is given by sister ships with a comparable distance travelled resulting in different Attained CII. This is due, for instance, to the fact that the transport work is expressed as travelled distance per “offered capacity” and not as actual carried cargo, resulting in a ship sailing in ballast condition with no cargo having a better rating than a sister ship sailing fully loaded with cargo.

Furthermore, ships with prolonged periods without travelled distance (often for reasons outside the control of the ship’s operator such as time spent at anchor for port unavailability, long stays in port to keep the schedule, lay-up) are strongly penalized by the current formulation which counts all the emissions from main engines and auxiliaries in all the operational conditions instead of those during navigation.

IMO MEPC 83 in April 2025 amended the following CII-related Guidelines:

- G3 Guidelines (Res. MEPC.400(83)) to define CII reduction (Z) for the years 2027 to 2030, which are 13.625% (2027); 16.250% (2028), 18.875% (2029) and 21.500% (2030). The reduction factor for years beyond 2030 will be further considered at a later stage;
- 2024 SEEMP Guidelines (Res. MEPC.401(83)) to include the definition of “hours under way and not under way” in line with FA.5/Circ.42/Rev.3 (i.e. Under way is defined as the period between full ahead on passage (FAOP) and end of sea passage (EOSP) as per the guidelines for setting up a maritime single window) and editorial modifications in the Sample Form (i.e. replacing the term "boilers" by "fired boilers" in sections 4 and 6 and

including a table for reporting of the method for measurement of total fuel consumption in section 6);

Waiting for the finalization of the LCA regulatory framework and the review of the CII, as an interim solution, the Interim Guidance about the use of sustainable biofuels (MEPC.1/Circ.905) was adopted providing a clear interpretation about the calculation of the attained Carbon Intensity Indicator (CII) when a sustainable biofuel is used.

It clarifies that CO_2 emission conversion factor (Cf) of the biofuel can be calculated as the value of the well-to-wake GHG emissions of the fuel according to the certificate (gCO2eq/MJ) multiplied by its lower calorific value (MJ/g), provided that the biofuel:

- is certified by an international certification scheme, meeting its sustainability criteria; and
- has a well-to-wake GHG emissions reduction of at least 65% compared to the well-to-wake emissions of fossil MGO.

A proof of sustainability from a recognized scheme should be provided along with the bunker delivery note to facilitate verification. Biofuels not being certified as sustainable or not fulfilling the “well-to-wake” emission criterion above should be considered like a fossil fuel.

1.2.2 IMO medium term measures

MEPC 83 reached an agreement on the mid-term GHG reduction measures and 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. The new draft measures will be applicable to ships of 5.000 GT and above – excluding ships solely engaged in voyages within waters subject to the sovereignty

or jurisdiction of the flag State; not propelled ships; platforms regardless of their propulsion; and semi-submersible vessels - and require each ship to:

1. From 1 October 2027, have an account with the IMO GHG fuel intensity (GFI) Registry and by 30 June 2028 and by 30 June of each year thereafter, pay an annual administration fee which will be determined by the IMO Secretary-General to cover the administrative cost of the IMO GFI Registry.
2. On or before 1 January 2028, amend the SEEMP to include:

- a description of the methodology that will be used to collect the data to comply with the new requirements; and
- the processes that will be used to report the required data to the ship's Administration.

3. After the end of 2028 and after the end of each calendar year thereafter, calculate its attained annual GFI (GFIattained) over a 12-month period (1 January to 31 December) expressed in grams of CO2eq per unit of energy (gCO2eq/MJ) on a well-to-wake basis (WtW).
4. At the end of each reporting period, determine its GFI compliance balance (expressed in tonne of CO2eq), representing the measurement of the ship's GFI compliance status against the target annual GFI which consists of two tiers:

- base target; and
- direct compliance target.

Both values are calculated considering the average GFI of international shipping in the year 2008 (GFI2008) on a WtW basis (i.e. 93.3 $grCO_2eq/MJ$) and reducing it each year by annual factors (ZT): one for the base target and one for the direct compliance target. So far, ZT are defined for the years 2028-2035 and ZT for the base target for 2040 is set at 65%. By 1 January 2032, the Z-factor (ZT) for the 2036 to 2040 shall be determined.

5. By 31 March of each year starting from 2029 (for the reporting period of 2028), electronically report to its Administration, or any organization duly authorized by it (RO), its GFIattained, target annual GFI (both base target and direct compliance target) and GFI compliance balance. The Administration or its RO shall verify the data by 30 June of each year starting from 2029 (for the reporting period of 2028) and report the verified data to the IMO GFI Registry.
6. Within one month after the ship's verified data has been reported to the IMO GFI Registry or on 31 July at the latest, determine in the IMO GFI Registry its selected GFI compliance approach(es).
7. By 31 August of each year starting from 2029 (for the reporting period of 2028), be provided by the IMO GFI Registry with a ship account statement reflecting the transactions recorded.
8. By 30 September of each year starting from 2029 (for the reporting period of 2028), be provided with a Statement of Compliance issued by the Administration/RO.

In case of use of sustainable fuels, GHG emission factors and sustainability themes or aspects shall be certified by a Sustainable Fuels Certification Scheme/Standard (SFCS) which shall be recognized by the Committee.

- By 1 March 2027, a list of recognized SFCSs will be published and then periodically updated. The recognition of a SFCS shall be subject to renewal every five years and periodic review.

- By 31 March of each year starting from 2029 (for the reporting period of 2028): electronically report to its Administration, or any organization duly authorized by it (RO), its GFIattained, target annual GFI (both base target and direct compliance target) and GFI compliance balance.
- The Administration or its RO shall verify the data by 30 June of each year starting from 2029 (for the reporting period of 2028) and report the verified data to the IMO GFI Registry.
- Within one month after the ship's verified data has been reported to the IMO GFI Registry or on 31 July at the latest, determine in the IMO GFI Registry its selected GFI compliance approach(es).
- By 31 August of each year starting from 2029 (for the reporting period of 2028), be provided by the IMO GFI Registry with a ship account statement reflecting the transactions recorded.
- By 30 September of each year starting from 2029 (for the reporting period of 2028), be provided with a Statement of Compliance issued by the Administration/RO.

In case of use of sustainable fuels, GHG emission factors and sustainability themes or aspects shall be certified by a Sustainable Fuels Certification Scheme/Standard (SFCS) which shall be recognized by the Committee. By 1 March 2027, a list of recognized SFCSs will be published and then periodically updated. The recognition of a SFCS shall be subject to renewal every five years and periodic review. In case of use of zero or near-zero GHG emission technologies, fuels and/or energy sources (ZNZs), the ship may receive rewards from the IMO Net-Zero Fund. ZNZ shall include technologies, fuels and energy sources and be evaluated on a WtW basis. The GFI threshold for ZNZs shall be set at not greater than 19 gCO2eq/MJ for an initial period until 31 December 2034, and from 1 January 2035, the threshold shall be set at not greater than 14 gCO_2eq/MJ. The Committee shall define the reward from the IMO Net-Zero Fund for each ZNZ not later than 1 March 2027 and every 5 years thereafter.

Despite the approval of the draft amendments, the necessary guidelines (e.g. SEEMP Guidelines, GFI Calculation Guidelines; Guidelines for the establishment, the administration and management of the IMO GFI Registry; Guidelines on the definition of ZNZs, of ZNZs rewards and the methodology to determine such rewards; Guidelines on requirements and procedures for recognition of certification schemes/standards and reporting of certification activities) are still to be developed to uniformly and clearly implement such new requirements and a work plan will be agreed in October 2025.

1.2.3 IMO regulation for EETs

Applicable IMO regulations for electrical installations and onshore power supply:

- Some broad references are made to SOLAS Chapter II-1, Part-D Electrical Installations (Reg. 40-45).
- The Interim Guidelines on Safe Operation of Onshore Power Supply Service in Port for Ships Engaged on International Voyages Interim Guidelines (finalized in March 2020, adopted by MSC103) focus on Operation for HV and LV, are applicable to ships engaged in international voyages.
- STCW provisions refer to the training, certification and qualification of seafarers serving on board sea-going ships, defining minimum standards of competence for seafarers (certificate of competency in accordance with reg. III/2 and III/6). Requirements for EV Supply Equipment (EVSE).
- MARPOL Annex VI sets mandatory limits on air emissions and can be considered as the compelling need to adopt “green” solutions but is not specific on the prescriptive requirements for shore side energy supply.
- Interim guidelines on safe operation of onshore power supply (Ops) service in port for ships engaged on international voyages (MSC.1/Circ.1675)

Applicable IMO regulations for Batteries:

- SOLAS reg. II-1/41 Main source of electrical power and lighting systems
- IMO Circ.848 Guidelines for the approval of equivalent fixed gas fire-extinguishing SOLAS 74, for machinery spaces and cargo pump rooms, as amended by
- IMO MSC.1/Circ.1165, as amended by MSC.1/Cric.1269 and MSC.1/Circ.1386 fire-extinguishing systems for machinery spaces and cargo pump rooms

Applicable IMO regulations for Supercapacitors:

- SOLAS Regulation II-2, The supercapacitor space is to be considered an Auxiliary Machinery Space or a Machinery Space other than Category A as defined in SOLAS Regulation II-2 and is subject to the structural fire protection requirements listed herein. The supercapacitor space is to be fitted with a suitable Fixed Fire Extinguishing System

(FFES) recommended by the supercapacitor manufacturer and appropriate to the supercapacitor cell electrolyte chemistry[1].

Applicable IMO regulations for fuel cells and fuel reforming:

- Interim guidelines for the safety of ships using fuel cell power installations (MSC.1/Circ.1647)- to be revised

Applicable IMO regulations for wind propulsion:

- MEPC 81/INF.39 - White paper on wind propulsion (Comoros, France, Solomon Islands and IWSA)

Applicable IMO regulations for carbon capture:

- IMDG Code for the storage and transport of CO2 resulting from onboard carbon capture and storage systems on ships

1.3 Regulatory mapping of alternative fuels

1.3.1 State of play and work plan for the development and introduction of rules on alternative fuels in the maritime sector

The key IMO regulations on alternative fuels are outlined below:

- International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code). This regulation provides an international standard for the safe carriage by sea in bulk of liquefied gases.
- International Code of Safety for Ships Using Gas or Other Low Flash Point Fuels (IGF Code): This code sets general requirements for low flash point fuels, and outlines specific regulations for natural gas. Currently, apart from LNG, there are no mandatory regulations applicable to gas fuelled ships. Nevertheless, work is in progress at IMO to draft interim guidelines on low-flashpoint fuels, and most Classification Societies have already issued class requirements to bridge this regulatory gap.

- [1] chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://ww2.eagle.org/content/dam/eagle/rules-and-guides/current/other/288_supercapacitors_2017/supercapacitors-reqts-e-dec17.pdf

The Maritime Safety Committee, at its 107th session, agreed to include in its biennial agenda, a new output for the development of a safety regulatory framework for the reduction of GHG emissions from ships using new technologies and alternative fuels (under the coordination of the US). The key terms of reference are (MSC108/5, 2024):

- to conduct an assessment for each identified fuel and new technologies (e.g. the state of knowledge of risks and the technical considerations of solutions, hazards and risks, risk control measures) in relation to persons, ships (new built and converted) and applicable operations for these, from e.g. projects applying alternative design and approval process where permitted, and
- to develop a record for safety obstacles and gaps in the current IMO instruments that may impede the use of the alternative fuel or new technology.

This Group developed a summary list of alternative fuels and provided comprehensive references, background and detail to support the assessments under for any of the fuels or technologies being considered. Those references have been compiled and saved on IMO Space for further ongoing consideration. Document (MSC108/5, 2024) offers views and comments on the risks posed by several alternative fuels and new technologies under consideration by the maritime industry. Information in this reference has been used to initially populate "description" and "risks/hazards" fields in the annex for those fuels and technologies that are discussed in the document. Moreover, a coding system has been used for the regulatory mapping, whereby:

- Low (red colour coded): Indicates the absence of related marine standards, regulations and/or interim/final guidelines with required work yet to start.
- Medium (orange colour coded): Indicates the availability of work in progress or approved (waiting for adoption) related marine standards, regulations and/or approved interim/final guidelines.
- High (green colour coded): Indicates the availability of related marine standards, adopted regulations and/or adopted interim/final guidelines.

This IMO Group (participated by RINA) is conducting an assessment for each identified fuel and new technology and developing a record for safety obstacles and gaps. It is evident that these activities will involve several IMO sub-committee and groups, introducing revised criteria to be progressively adopted for regulatory compliance of newbuilds and retrofits. Such activities will be constantly monitored, and RINA.

The regulatory mapping of alternative fuels for seagoing vessels can be found in Table 1.

Table 1: Regulatory mapping of alternative marine fuels for seagoing vessels (outcome of (MEPC80/INF.17, 2023))

FUELS	EXTERNAL STANDARDS	IMO SAFETY- SOLAS	IMO ENVIRONMENT-MARPOL
Methyl Alcohol (Methanol)	Marine standards in progress Marine standards in progress ISO/AWI 6583 "Specification of methanol as a fuel for marine applications" is under development. Currently, IMPCA Methanol reference specification and ASTM D1152 standard are used when specifying methanol quality.	High regulatory readiness level SOLAS Chapter II regulates low-flashpoint fuels (< 60°C) through SOLAS Ch II-1 Part G (low-flashpoint liquid fuel or gas) and IGF Code; alternatively SOLAS Ch II-1 Part F (Alternative design and arrangement) – MSC.1/Circ.1212/Rev.1 and MSC.1/Circ.1455 The IGF Code does not cover methanol as fuel but MSC.1/Circ.1621 Interim guidelines for the safety of ships using methyl/ethyl alcohol as fuel has been developed.	Low regulatory readiness level Methanol is assigned category Y as per the IBC Code, meaning it presents a hazard to either marine resources or human health. MARPOL Annex II requirements do not apply for spill and discharges of methanol as fuel. High regulatory readiness level MARPOL Annex VI regulates emissions of CO2 and NOx
Methane	Marine standards available ISO 23306:2020 "Specification of liquefied natural gas as a fuel for marine applications"	High regulatory readiness level SOLAS Chapter II regulates methane (LNG) as fuel through SOLAS Ch II-1 Part G (low-flashpoint liquid fuel or gas) and the IGF Code.	High regulatory readiness level MARPOL Annex VI regulates emissions of CO2 and NOx Low regulatory readiness level Fugitive emissions of methane are not currently regulated under MARPOL Annex VI.
Ammonia	No marine standards available No marine standards available	Medium regulatory readiness level SOLAS Chapter II regulates low-flashpoint fuels (< 60°C) through SOLAS Ch II-1 Part G (low-flashpoint liquid fuel or gas) and IGF Code; alternatively SOLAS Ch II-1 Part F (Alternative design and arrangement) –	Low regulatory readiness level "Ammonia aqueous" is assigned category Y as per the IBC Code, meaning it presents a hazard to either marine resources or human health. MARPOL Annex II requirements do not apply for spill and discharges of ammonia as fuel. High regulatory readiness level

FUELS	EXTERNAL STANDARDS	IMO SAFETY- SOLAS	IMO ENVIRONMENT-MARPOL
		MSC.1/Circ.1212/Rev.1 and MSC.1/ Circ.1455 IGC Code identifies ammonia as a toxic product and prohibits toxic cargo to be used as a fuel. The IGF Code does not cover ammonia as fuel. Draft interim guidelines for the safety of ships using ammonia as fuel are currently under development.	MARPOL Annex VI regulates emissions of NOx Low regulatory readiness level Other combustion products e.g., N2O are not currently regulated under MARPOL Annex VI.
Hydrogen	No marine standards available ISO 14687:2019 “Hydrogen fuel quality – Product specification”	Medium regulatory readiness level SOLAS Chapter II regulates low-flashpoint fuels (< 60°C) through SOLAS Ch II-1 Part G (low-flashpoint liquid fuel or gas) and IGF Code; alternatively SOLAS Ch II-1 Part F (Alternative design and arrangement) – MSC.1/Circ.1212/Rev.1 and MSC.1/ Circ.1455 The IGF Code does not cover hydrogen as fuel. Resolution MSC.420(97) provides interim recommendations for carriage of liquid hydrogen in bulk. Draft interim guidelines for the safety of ships using hydrogen as fuel are currently under development.	High regulatory readiness level MARPOL Annex VI regulates emissions of NOx
Bio/ synthetic	Marine standards in progress There is work in progress within ISO to include HVO and FAME in the new revision of ISO 8217 “Petroleum products – Fuels (class F) – Specifications of marine fuels” allows up to 7% FAME in distillate marine fuels (DF grade) No marine standards available	High regulatory readiness level SOLAS Chapter II regulates oil fuels with flashpoint > 60°C Medium regulatory readiness level SOLAS Chapter II regulates low-flashpoint fuels (< 60°C) through SOLAS Ch II-1 Part G (low-flashpoint liquid fuel or gas) and IGF Code; alternatively SOLAS Ch II-1 Part F (Alternative design and arrangement) –	High regulatory readiness level MARPOL Annex I regulates spills and discharges MARPOL Annex I definition of “oil” covers petroleum in any form, IMO Working Group on the Evaluation of Safety and Pollution Hazards of Chemicals (ESPH) agreed to recommend that energy rich fuels which are not petroleum-based should be covered by Annex I (i.e.,

FUELS	EXTERNAL STANDARDS	IMO SAFETY- SOLAS	IMO ENVIRONMENT-MARPOL
liquid diesel fuels	EN 14214:2012 "Liquid petroleum products – Fatty acid methyl esters (FAME) for use in diesel engines and heating applications – Requirements and test methods" EN 15940:2016 "Automotive fuels – Paraffinic diesel fuel from synthesis or hydrotreatment – Requirements and test methods" Both EN 14214:2012 and EN 15940:2016 are road transport standards, which have also been used in the marine industry.	MSC.1/Circ.1212/Rev.1 and MSC.1/ Circ.1455 The IGF Code does not cover low-flashpoint fuel oil. Development of draft interim guidelines for the use of oil fuels with a flashpoint between 52°C and 60°C are currently under consideration.	not necessary to require biofuels to be carried only on chemical carriers) Medium regulatory readiness level MARPOL Annex VI regulates emissions of CO2, NOx and PM A Unified Interpretation (MEPC.1/Circ.795/Rev.6) states that a fuel oil blend containing less than or equal to 30% of biofuel or synthetic fuel falls under the definition of marine fuel oil derived from petroleum refining (Regulation 18.3.1) and no further NOx testing is required. In addition, fuel oil blends containing above 30% of biofuel or synthetic fuel can be used when the engine can be operated without changes to its NOx critical components or settings/operating values outside those as given by that engine's approved Technical File.

The International Maritime Organization (IMO) is currently developing technical provisions for the safety of ships using alternative fuels as part of the work programme of the sub-Committee on Carriage of Cargoes and Containers (CCC). Based upon the existing provisions of the IGF code MSC.391(95) - addressing LNG only - IMO has finalised the following guidelines

- MSC.1/Circ.1647 Interim Guidelines for the safety of ships using fuel cell power installations
- MSC.1/Circ.1621 Interim Guidelines for the Safety of Ships Using Methyl/Ethyl Alcohol as Fuel
- MSC. 1/Circ. 1687 Interim guidelines for the safety of ships using ammonia as fuel

All these Interim Guidelines will be revised, starting in 2026, considering the feedback from their early implementation by the maritime industry. All these documents are interim guidelines, goal-based, providing goals, functional requirements and limited detailed

provisions, so that the design and approval process is mostly based upon risk assessment methodologies.

IMO CCC 10 continued its work on the Interim Guidelines for the safety of ships using hydrogen as fuel. The consolidated draft text proposal will be annexed to the Correspondence Group Report at the time this D3.1 is being prepared. The text of the guidelines has been updated considering the feedback and proposals by the members in the four rounds of this correspondence group (180 full pages and almost 100 000 words). Further technical comments and new text proposals should be submitted as commenting papers to CCC 11. According to the work plan the Guidelines on hydrogen should be finalised at CCC 11 in September 2025. RINA has been actively involved in their development, on behalf of the Italian Administration.

It should also be noted that the Interim Guidelines for use of oil fuels with a flashpoint between 52°C and 60°C as fuel did not make any progress but, if time permits, work will continue in 2026.

In parallel, IACS has issued a unified requirement – i.e. common to all classification societies of the Association - IACS UR H1 “Control of Ammonia releases in Ammonia fuelled vessels” adopted in January 2024 and applicable from 1 January 2025, covering the release of ammonia from the onboard systems for bunkering, storing, preparing and using ammonia as fuel. IACS UR H1 establishes that an Ammonia concentration of 300 ppm or more is immediately dangerous, and a concentration of 25 ppm or more is dangerous if the exposure is longer than 8 hours. UR H1 further requires the point at which ammonia is released to the atmosphere, (e.g. outlet of vent mast) to be provided with audible and visual alarms, which are to be activated when the discharged gas has an ammonia concentration of 300 ppm or more, to warn people to promptly leave the area and seek refuge. It is to be noted that IMO will soon reopen discussions on the Interim Guidelines on ammonia, since consideration of the toxicity aspects of ammonia on board require further work.

The work plan for the development of new alternative fuels under the IGF code is presented in Figure 1.

ISWG-AF2 CCC 11	- Further develop/ finalize **interim guidelines for safety of ships using hydrogen as fuel**. - if time permits, further develop/finalize develop **interim guidelines for safety of ships using low flashpoint oil fuels.** - if time permits, consider the revision of the **interim guidelines for safety of ships using methyl/ethyl alcohol as fuel**, with a view to developing mandatory instruments. - if time permits, start discussion regarding the development of **mandatory instruments regarding safety of ships using fuel cells**.	2025
MSC111	- Approve **interim guidelines for safety of ships using hydrogen as fuel**	2026
CCC 12	- further consider the revision of the **interim guidelines for safety of ships using methyl/ethyl alcohol as fuel**, with a view to developing mandatory instruments. - further develop/finalize **interim guidelines for safety of ships using low flashpoint oil fuels.** - if time permits, further consider the development of **mandatory instruments regarding safety of ships using fuel cells**. - further consider amendments to the IGF Code regarding LNG - If time permits, consider the revision of the **interim guidelines on the safety of ships using ammonia as fuel**	2026
CCC 13	- Consider the revision of the **interim guidelines on the safety of ships using ammonia as fuel** - finalize the revision of the **interim guidelines for safety of ships using methyl/ethyl alcohol as fuel**, with a view to developing mandatory instruments. - consider amendments to MSC.1/Circ.1622 based on CCC 10/3/10 and CCC 10/INF.28	2027

Figure 1: IMO work plan for the development of new alternative fuels under the IGF code

1.3.2 State of play and work plan for the development and introduction of rules on alternative fuels in the inland waterway sector

The CESNI temporary working group has outlined the timeline for the integration of new technical requirements for various alternative fuels in the inland waterway sector. Requirements for fuel cells and methanol are already in force under ES-TRIN 2025, while requirements for compressed hydrogen are nearing completion, with full implementation expected in ES-TRIN 2027. Other fuels, such as liquefied hydrogen, compressed natural gas and ammonia, are at an earlier stage, pending pilot project data and draft proposals. Table 2

summarises the current status on technical requirements for the use of alternative fuels in the inland waterway transport sector and the timeline for future developments.

Table 2: State of play on technical requirements for the use of alternative fuels in the inland waterway transport sector and the timeline for future developments.

Energy converter / energy source	Status	ES-TRIN
Fuel cells	Requirements in force	ES-TRIN 2023 Chapter 30, Annex 8, Section 3.1
Methanol	Requirements in force	ES-TRIN 2025 Chapter 30, Annex 8, Sections 2.2 and 3.3
Compressed hydrogen	Pending	Foreseen in ES-TRIN 2027
Liquefied hydrogen	Pending	-
Compressed natural gas	Pending	-
Ammonia	Pending	-

1.4 EU regulations for ocean going vessels

To strengthen its climate ambition, the European Commission enacted the European Climate Law (Regulation (EU) 2021/1119) on 9 July 2021. The law establishes binding targets to cut greenhouse gas emissions by at least 55% compared to 1990 levels by 2030, and to achieve climate neutrality by 2050, with a 90% GHG emissions reduction from the transport sector. Unlike the IMO's Initial Strategy, which uses 2008 as its baseline year, the EU framework is more aggressive and structured differently, making the two targets inherently non-comparable.

To operationalize the 2030 target, the European Commission introduced the Fit for 55 Package - a suite of legislative instruments affecting all sectors, including maritime transport. The most significant legislative proposals – now in-force laws - for the shipping are:

- the review of the current EU Emission Trading System (ETS) to extend it to maritime transport; and
- the new FuelEU Maritime Regulation, aiming to increase the uptake of alternative low-carbon and zero-carbon fuels.

1.4.1 EU Taxonomy: Context for Climate-Aligned Shipping

The EU Taxonomy Regulation (EU 2020/852) establishes a uniform system to identify economic activities that contribute significantly to environmental goals. Shipping activities are classified as either transitional (using best-in-class fossil or alternative technologies) or enabling (infrastructure supporting zero-emission operations). For an activity to be "Taxonomy-aligned," it must:

- Substantially contribute to one environmental objective (e.g. climate mitigation),
- Do No Significant Harm (DNSH) to the others,
- Comply with minimum social safeguards, and
- Meet technical screening criteria (TSC) via delegated acts

Adopted 4 June 2021, in effect from 1 January 2022, the Delegated Regulation (EU) 2021/2139 Climate Delegated Act, sets out the technical screening criteria for activities making a substantial contribution to climate mitigation and adaptation, across nine sectors. More specifically, for the waterborne transport sections 6.7–6.12 address key GHG metrics:

- Sea-going newbuilds: must meet IMO-aligned design efficiency (Energy Efficiency Design Index – EEDI Phase 2/3).
- Operational intensity thresholds:
    - ≤ 76.4 g CO_2e/MJ by 2026,
    - ≤ 61.1 g CO_2e/MJ by 2030
- Inland vessels: Emissions assessed well-to-wake, with a trajectory for gradual reductions to 2050

The Delegated Regulation 2023/2485 amendment published in the Official Journal on 27 June 2023, effective 1 January 2024 (with some inland criteria phased in by 2025), refines and expands TSC with certain permitted additional compliance paths:

1. Zero tailpipe CO_2 or renewable fuels with EEDI at least 20% below the 1 April 2022 baseline, as of 1 January 2026.
2. Vessels equipped for onshore power supply (OPS) at berth.
3. Gas-fuelled vessels must apply best-available technology to minimize methane slip.
4. Alignment required with:

- IMO EEDI Phase 3 (from 1 Jan 2025),
- Energy Efficiency Existing Ship Index (EEXI) (since 1 Jan 2023),
- FuelEU-M GHG intensity limits (Regulation 2023/1805, from 1 Jan 2025)

For inland vessel requirements extend well-to-wake GHG intensity limits, with declining thresholds up to 2050, introducing staged compliance from 2025 onward.

1.4.2 Extension of the EU Emissions Trading System to Maritime

As part of the "Fit for 55" package, the EU 2023/959 directive has extended the Emissions Trading System to cover maritime transport. This inclusion targets ships over 5,000 GT and is being phased in as in the following table.

Table 3: Inclusion of maritime emissions in the EU Emissions Trading System

Year	Target
2025	Shipping companies must surrender allowances for 40% of their emissions reported in 2024
2026	70% of emissions reported in 2025
2027>	100% of reported emissions

The scope includes all emissions from all intra-EU voyages and 50% of voyages into or out of the EU, including CO_2, CH_4, and N_2O emissions by 2026. The directive introduces financial penalties (€100 per excess tonne of CO_2e) and potential port access bans for repeat non-compliance, reinforcing the polluter-pays principle. Payment of penalties does not exempt the Company from surrendering the allowances. If a Company fails to comply with the ETS Directive for two consecutive years, its ships may be denied entry to European ports until the Company fulfils its obligations.

The Directive also provides the following exemptions until 31 December 2030:

- ships with ice class (IA or IA Super or equivalent) may surrender 5% less allowances than the required amount for their reported aggregated verified emissions.
- GHG emissions do not need to be counted in the following cases:
- Voyages made by passenger ships (other than cruise ships) or passenger ro-ro ships to/from European islands with a population of fewer than 200,000 permanent residents;

- voyages made by passenger ships or passenger ro-ro ships as part of a transnational public service contract;
- voyages between a port located in the remote regions of a European Member and a port in the same Member.

The European Maritime Safety Agency (EMSA) supports this implementation through the Monitoring, Reporting, and Verification (MRV) system, utilizing the THETIS-MRV platform to ensure accurate emissions data collection.

1.4.3 Alternative Fuels Infrastructure Regulation

The AFIR, effective since 13 April 2024, aims to ensure the deployment of alternative fuels infrastructure across the EU. The regulation focuses on ensuring minimum infrastructure to support the uptake of alternative fuel vehicles across all transport modes, as well achieving full interoperability of the infrastructure and user accessibility for all transport modes, including maritime.

For maritime transport, AFIR mandates the installation of shore-side electricity supply (SSE) in core and comprehensive TEN-T ports by 2030.

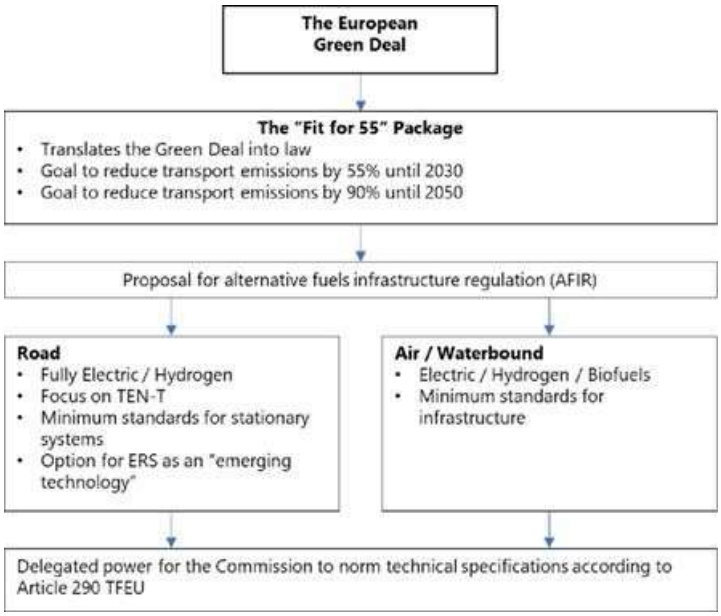

Figure 2: The AFIR within the Fit for 55 package

This legislative measure directly supports the transition to zero-emission berth and underpins the broader deployment of low- and zero-carbon fuels. It also sets the groundwork for upcoming port electrification projects and defines the technical specifications needed to ensure compatibility across ships and port infrastructure.

1.4.4 Application of FuelEU Maritime Regulations

The FuelEU Maritime Regulation EU 2023/1805, effective from 1 January 2025, sets targets to reduce the greenhouse gas intensity of energy used on board ships over 5,000 GT, applying to both EU and non-EU flagged vessels. The regulation covers:

- 100% of the energy used in European/EEA ports and for voyages between European/EEA ports.
- 50% of the energy used for voyages arriving at European/EEA ports from non-European ports or vice versa, and for voyages to and from remote regions of the EU.

The regulation mandates that starting from 2025, an annual average greenhouse gas (GHG) intensity index must be calculated for each ship, which must not exceed a target value that will decrease significantly over the years:

- A 2% reduction in GHG intensity by 2025, gradually increasing to an 80% reduction by 2050, compared to the 2020 baseline.

The calculation of the GHG intensity index requires to divide the total emissions of CO2, CH4, and N2O by the energy used by the ship during the reference year. If the GHG intensity index exceeds the target, the company must pay a penalty proportional to the cost of renewable and low-carbon emission fuels that the ship should have used to comply with the regulation. However, the regulation allows for flexible mechanisms: borrowing or banking ship's compliance surplus between two reference periods and pooling of two or more ships, even from different Companies and different verifiers.

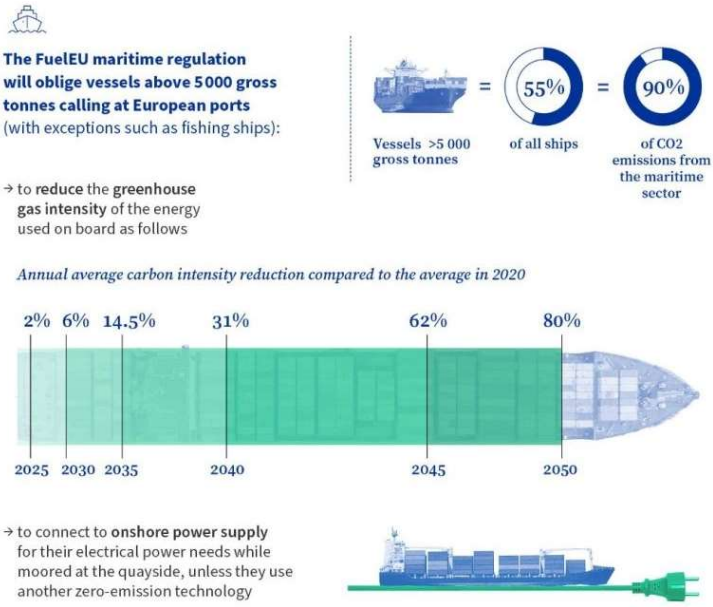

Figure 3: FuelEU Maritime objectives.

The regulation provides compliance flexibility through the pooling of performance across vessels, borrowing and banking across reporting periods, and a technology-neutral approach to fuel selection. Compliance is monitored through the FuelEU database, which records energy usage and GHG intensity data. If this requirement is not met, the company is required to pay a penalty calculated based on the total electrical power demand of the ship at berth and the total number of hours. EU/EEA Member States may exempt:

- Ice-class ships (IA or IA Super or equivalent) until 31 December 2034.
- Voyages and related stay in port of passenger ships (other than cruise ships) between ports of the same EU/EEA State to/from islands with a population of fewer than 200,000 permanent residents, until 31 December 2029.
- Specific routes between ports located in remote regions, until 31 December 2029.
- Voyages and related stay in port performed by passenger ships as part of national or transnational public service obligations/contracts in force at the date of 12 December 2023, until 31 December 2029.

1.4.5 Zero Emissions at Berth

To further reduce emissions, the EU mandates that, from 1 January 2030, container and passenger ships over 5,000 GT must achieve zero emissions while at berth. Compliant ships (i.e., with a GHG intensity index below the target or with paid penalties) must have a FuelEU Document of Compliance on board.

- Starting from 2030, container and passenger ships berthed in EU/EEA ports subject to the "Alternative Fuels Infrastructure Regulation" (Reg. (UE) 2023/1805) must connect to onshore power supply (OPS) systems and use them to meet all energy needs while at berth unless:
- They stay at the quay for less than two hours.
- They use zero-emission technology (definition still subject to working groups).
- They cannot connect due to compatibility/unavailability of connection points.
- They need to carry out maintenance/functional tests.
- There are safety/emergency reasons.

This requirement extends to all EU/EEA ports equipped with such infrastructure by 1 January 2035. OPS integration will become a key operational and technical requirement for affected ships, which will need to ensure compatibility with port-side infrastructure, manage onboard energy demands, and potentially adjust voyage planning to accommodate charging schedules. Enforcement will be supported through administrative penalties tied to non-compliance duration and energy usage levels.

EMSA provides guidance on implementing shore-side electricity, addressing technical and safety challenges to assist port authorities and administrations. EMSA has published several studies and guidelines to support the maritime industry's transition:

- Guidance on the design, installation, and operation of Battery Energy Storage Systems (BESS) on ships, addressing safety and risk reduction measures.
- Comprehensive guidance for port authorities on planning and developing Shore-Side Electricity (SSE) infrastructure, including technical specifications and operational considerations.
- A study evaluating the use of Fuel Cells in shipping, identifying promising technologies and assessing safety aspects.
- Studies mapping regulatory readiness and safety challenges of fuels such as methanol, LNG, ammonia, and hydrogen, helping industry stakeholders identify feasible and compliant fuel transition pathways.
- Strategic recommendations for electrification and hybridization options within vessel systems, with a view to scaling deployment of hybrid propulsion and auxiliary systems.

1.5 EU Rules for Inland Navigation

Table 4 reports a summary of the main current and upcoming measures and regulations affecting inland waterway transport sector that directly or indirectly relate to GHG emissions and air quality.

Table 4: Summary of measures and regulations in the field of inland waterway transport for the measurement and control of greenhouse gas emissions and air quality.

Measures and regulations	Type	Status	Description
EU NRMM (+ ES-TRIN)	EU Regulation	In force	Emission limits for gaseous and particulate pollutants
EU Taxonomy Regulation	EU Regulation	In force	Reports technical screening criteria to define environmentally sustainable activities
CountEmissionsEU	EU Regulation	Proposed	Standardises GHG emissions calculation across transport modes, incl. IWT
PLATINA4Action	EU-Funded Project	Under development	Implementation of the navigation action programme NAIADES III
CDNI Convention	International Treaty	In force	Regulates waste management from inland vessels

References:

1. EU NRMM: Regulation (EU) 2016/1628 of the European Parliament and of the Council of 14 September 2016 (https://eur-lex.europa.eu/eli/reg/2016/1628/oj/eng);
2. ES-TRIN: European Standard laying down Technical Requirements for Inland Navigation vessels (ES-TRIN), EDITION 2025/1 (https://www.cesni.eu/en/standards-and-explanatory-notices/);
3. EU Taxonomy: Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 (https://eur-lex.europa.eu/eli/reg/2020/852/oj/eng), Commission Delegated Regulation (EU) 2021/2139 of 4 June 2021 (https://eur-lex.europa.eu/eli/reg_del/2021/2139/oj/eng), and Commission Delegated Regulation (EU) 2023/2485 of 27 June 2023 (https://eur-lex.europa.eu/eli/reg_del/2023/2485/oj/eng);
4. CountEmissionEU: Proposal COM(2023)441 11.7.2023 2023/0266(COD) (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52023PC0441);

Measures and regulations	Type	Status	Description
5. PLATINA4Action: https://platina4action.iwtprojects.eu/reports/ 6. CDNI Convention: Convention on the collection, deposit and reception of waste generated during navigation on the Rhine and other inland waterways, EDITION 2024 (https://www.cdni-iwt.org/the-cdni-convention/?lang=en)			

Further EU Regulations, such as FuelEU Maritime, EU ETS, and EU MRV, target climate change mitigation in maritime transport, but they rely on GT to define ship scope. Since GT is defined under the IMO convention, which applies only to ships on international sea voyages, inland vessels are not explicitly considered.

In the following a short explanation is given on how the measures and regulations reported in Table 1 are related to inland waterway vessels.

1.5.1 Gaseous and particulate pollutant emission limits for non-road mobile machinery (NRMM)

The Regulation (EU) 2016/1628, together with all its supplements, sets emission limits for gaseous and particulate pollutants from engines installed in non-road mobile machinery (NRMM). This includes engines used for various purposes in the inland navigation sector, such as propulsion and auxiliary systems. The new emissions limits are referred to as “Stage V”.

The European Standard laying down Technical Requirements for Inland Navigation vessels (ES-TRIN, Edition 2025-1), developed by CESNI, integrates these requirements into inland vessels. According to Chapter 9, the provisions apply to all internal combustion engines with a reference power ≥19 kW installed on board. Only engines that comply with Regulation (EU) 2016/1628 may be installed, specifically those falling under the following categories:

- IWP: engines for direct or indirect propulsion exclusively for use in inland waterway vessels, with a reference power ≥ 19 kW. Also includes engines replacing IWA engines, subject to specific compliance conditions;
- IWA: auxiliary engines used exclusively on inland waterway vessels, also with a reference power ≥ 19 kW;
- NRE: engines having a reference power of less than 560 kW used in the place of Stage V engines of categories IWP, IWA;
- engines recognized as equivalent under the same Regulation.

Although ES-TRIN applies to engines with a power greater or equal to 19 kW, engines with a power of less than 19 kW are nonetheless subject to Regulation (EU) 2016/1628.

The compliance of an engine with the emission limits is verified using the reference fuels or fuel combinations specified in Article 25 of Regulation (EU) 2016/1628 and detailed in Annex IX of Regulation (EU) 2017/654. These reference fuels include diesel, petrol, petrol/oil mixtures (for two-stroke spark-ignition engines), natural gas/biomethane, liquefied petroleum gas (LPG), and ethanol.

If the manufacturer has designed the engine to operate on additional fuels and listed them in the application for EU type approval, the engine must also meet the emission limits set out in the Regulation for those fuels. An engine should only be operated on fuels for which it has been type-approved.

Conversely, emission limits for gaseous and particulate pollutants from engines installed on recreational boats sailing on inland waterways are governed by the Directive 2013/53/EU.

Table 5 reports Stage V emission limits for engine category IWP, IWA, and NRE, where CO refers to carbon monoxide, HC to total hydrocarbons, NO_x to oxides of nitrogen (nitric oxide and nitrogen dioxide, expressed as NO_2 equivalent), PM to the mass of any material in the emitted gas, and PN to the number of solid particles emitted. It should be noted that the table presents a simplified overview of the emission limits. Readers are encouraged to consult Annexes I and II of Regulation (EU) 2016/1628 for the complete specifications.

Although it is not subject to limitations, CO_2 emission determined during the EU type-approval process shall be measured and reported for all engine subcategories, as required by Article 43(4) of Regulation (EU) 2016/1628.

As regards sulphur oxides, the limits are regulated at European level by the regulation on the sulphur content of fuels (Directive 2016/802/EU).

Table 5: Stage V emission limits for engine category IWP, IWA and NRE.

Category	Maximum/Rated net power [kW]	CO [g/kWh]	HC [g/kWh]	NO_x [g/kWh]	PM [g/kWh]	PN [#/kWh]
IWP/IWA-1	19 ≤ P < 75	5.00	4.70*		0.30	-
IWP/IWA-2	75 ≤ P < 130	5.00	5.40*		0.14	-
IWP/IWA-3	130 ≤ P < 300	3.50	1.00	2.10	0.10	-
IWP/IWA-4	P ≥ 300	3.50	0.19	1.80	0.015	1 .. 1012
NRE-3	19 ≤ P < 37	5.00	4.70*		0.015	1

Category	Maximum/Rated net power [kW]	CO [g/kWh]	HC [g/kWh]	NO_x [g/kWh]	PM [g/kWh]	PN [#/kWh]
						.. 10^{12}
NRE-4	37 ≤ P < 56	5.00	4.70*		0.015	1 .. 10^{12}
NRE-5	56 ≤ P < 130	5.00	0.19	0.40	0.015	1 .. 10^{12}
NRE-6	130 ≤ P ≤ 560	3.50	0.19	0.40	0.015	1 .. 10^{12}
*HC + NO_x						

1.5.2 EU Taxonomy for sustainable activities in IWT

Regulation (EU) 2020/852, together with its supplement Delegated Regulation (EU) 2021/2139 and its amendment (EU) 2023/2485, collectively known as the EU Taxonomy Regulation, establishes the conditions under which an economic activity qualifies as environmentally sustainable for the purposes of any measure, in particular investments. It defines technical screening criteria to assess whether an activity contributes to climate change mitigation and does not cause significant harm to any of the environmental objectives set out in the regulation, such as climate change adaptation, pollution prevention and control, and others.

Inland waterway vessels and their operations are specifically addressed in Sections 6.7, 6.8 and 6.9 of Annex I of the Delegated Regulation (EU) 2021/2139. This delegated act was subsequently amended by the Regulation (EU) 2023/2485, which apply 1 January 2024, to update and expand the technical screening criteria for these activities. Each section defines the relevant economic activities as follows:

- 6.7 - Inland passenger water transport: Purchase, financing, leasing, rental, and operation of passenger vessels on inland waters, involving vessels that are not suitable for sea transport.
- 6.8 - Inland freight water transport: Purchase, financing, leasing, rental, and operation of freight vessels on inland waters, involving vessels that are not suitable for sea transport.

- 6.9 - Retrofitting of inland water passenger and freight transport: Retrofit and upgrade of vessels for transport of freight or passengers on inland waters, involving vessels that are not suitable for sea transport.

From this specification, not all inland waterway vessels are covered under the EU Taxonomy Regulation. For instance, floating equipment used for construction and dredging operations, as well as patrol and inspection vessels operating on inland waterways, are not explicitly included in the defined economic activities of the delegated act.

To comply with the "Do No Significant Harm" (DNSH) criteria, meaning the activity does not cause significant harm to any of the environmental objectives set out in Article 9 in the EU Taxonomy Regulation, the following points outline some requirements applicable to inland passenger water transport, inland freight water transport, and the retrofitting of inland passenger and freight vessels:

- engines in vessels comply with emission limits set out in Annex II to Regulation (EU) 2016/1628 (including vessels meeting those limits without type-approved solutions such as through after-treatment). This concerns the limit values as defined in the Non-Road Mobile Machinery Directive, the so-called Stage V limits.
- measures are in place to manage and recycle waste at the end-of life, including through decommissioning contractual agreements with recycling service providers, reflection in financial projections or official project documentation. These measures ensure that components and materials are segregated and treated to maximise recycling and reuse in accordance with the waste hierarchy, EU waste regulation principles and applicable regulations, through the reuse and recycling of batteries and electronics and the critical raw materials therein. These measures also include the control and management of hazardous materials.

In addition to the DNSH criteria, specific technical requirements are defined to determine whether an activity contributes substantially to climate change mitigation. These requirements are outlined on the following sub-sections.

1.5.2.1 For Inland passenger water transport

The activity complies with one of the following criteria:

1. the vessels have zero direct (tailpipe) CO_2 emissions;
2. until 31 December 2025, hybrid and dual fuel vessels derive at least 50 % of their energy from zero direct (tailpipe) CO_2 emission fuels or plug-in power for their normal operation;

3. where technologically and economically not feasible to comply with point 2, from 1 January 2026 onwards the yearly average greenhouse gas intensity of the energy used on-board by a ship during a reporting period does not exceed the following limits:

    a. 76.4 g CO_2e/MJ from 1 January 2026 until 31 December 2029;
    b. 61.1 g CO_2e/MJ from 1 January 2030 until 31 December 2034;
    c. 45.8 g CO_2e/MJ from 1 January 2035 until 31 December 2039;
    d. 30.6 g CO_2e/MJ from 1 January 2040 until 31 December 2044;
    e. 15.3 g CO_2e/MJ from 1 January 2045 until 31 December 2049;
    f. 0 g CO_2e/MJ from 1 January 2050.

1.5.2.2 For Inland freight water transport

The activity complies with one or both of the following criteria:

1. the vessels have zero direct (tailpipe) CO_2 emissions;
2. where technologically and economically not feasible to comply with the criterion in point (a), until 31 December 2025, the vessels have direct (tailpipe) emissions of CO_2 per tonne kilometre (g CO_2/t·km), calculated (or estimated in case of new vessels) using the Energy Efficiency Operational Indicator (as set out in MEPC.1/Circ. 684 from IMO), 50 % lower than the average reference value for emissions of CO_2 defined for heavy duty vehicles (vehicle subgroup 5- LH) in accordance with Article 11 of Regulation 2019/1242;
3. where technologically and economically not feasible to comply with point (a), from 1 January 2026 onwards, the yearly average greenhouse gas intensity of the energy used on-board by a ship or a company's fleet during a reporting period does not exceed the following limits:
    a. 76.4 g CO_2e/MJ from 1 January 2026 until 31 December 2029;
    b. 61.1 g CO_2e/MJ from 1 January 2030 until 31 December 2034;
    c. 45.8 g CO_2e/MJ from 1 January 2035 until 31 December 2039;
    d. 30.6 g CO_2e/MJ from 1 January 2040 until 31 December 2044;
    e. 15.3 g CO_2e/MJ from 1 January 2045 until 31 December 2049;
    f. 0 g CO_2e/MJ from 1 January 2050.

Vessels are not dedicated to the transport of fossil fuels.

1.5.2.3 For Retrofitting of inland water passenger and freight transport

The retrofitting activity achieves one or more of the following:

1. reduces fuel consumption of the inland passenger vessel by at least 15 % expressed per unit of energy per complete journey (full passenger cruise), as demonstrated by a comparative calculation for the representative navigation areas (including

representative load profiles and docking) in which the vessel is to operate or by means of the results of model tests or simulations;

2. reduces fuel consumption of the inland freight vessel by at least 15 % expressed per unit of energy per tonne kilometre, as demonstrated by a comparative calculation for the representative navigation areas (including representative load profiles) in which the vessel is to operate or by means of the results of model tests or simulations.

Vessels retrofitted or upgraded are not dedicated to transport of fossil fuels.

1.5.3 CountEmissionEU

CountEmissionsEU is a forthcoming EU Regulation that aims to create a harmonised and transparent methodology for calculating GHG emissions from transport services across all modes, including road, rail, air, maritime, and inland waterway transport. The framework applies to both freight and passenger operations, and also covers emissions associated with hub activities, such as port and terminal operations.

The initiative proposes a single calculation methodology for GHG emissions, a set of default emission values and standards for verifying output data and the use of calculation tools.

While CountEmissionsEU does not mandate where or by whom the methodology must be applied, it sets the rules that any entity must follow if they choose to calculate and disclose GHG emissions for transport services. This ensures that any emissions data presented to shippers, passengers, or e-commerce customers is accurate, consistent, and comparable across service types.

1.5.4 NAIADES III and PLATINA4Action

Inland navigation is an energy-efficient mode of transport with relatively low environmental impact. However, to fully contribute to the EU's climate goals, the sector must undergo a process of modernization and decarbonisation. In this context, the European Commission launched the NAIADES III strategy in 2021.

NAIADES III is the European Union's strategy for inland navigation for the period 2021–2027. It aims to make IWT a cornerstone of sustainable European mobility, focusing on two overarching goals:

1. Shifting more freight to inland waterways, reducing reliance on road transport;
2. Setting the sector on an irreversible path to zero-emissions.

Among its priorities, the NAIADES III strategy outlines several key actions supporting the transition toward a zero-emission inland waterway transport sector. These include:

- A call to promote renewable low-carbon fuels through tax incentives under a revised Energy Taxation Directive, aiming to encourage the shift towards cleaner fuels in inland waterway transport
- The intent of the Commission to develop legislative measures to promote the uptake of zero-emissions vessels.
- Facilitate the development of an EU energy index methodology (similar to the maritime EEDI) through the now completed H2020 Platina III project and its successor, the ongoing Horizon Europe Platina4Action project;
- The EU Taxonomy Climate Delegated Act highlights inland waterways as a key low-carbon transport mode and foresees the creation of technical screening criteria to guide sustainable investment in inland waterway infrastructure.

The European Commission emphasises the need for a harmonised energy index methodology to assess the carbon intensity of inland vessels similar to the maritime EEDI. The link to technical screening criteria is already considered by means of the revised technical screening criteria which are applicable for the period after 2025.

For full details, refer to the original NAIADES III Communication available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0324

Platina4Action (P4A), funded under the Horizon Europe programme, acts as an implementation support platform for NAIADES III. The objectives are:

1. Assess the impact of NAIADES III actions on emission reduction and modal shift and develop policy recommendations to accelerate the transition to zero-emission and digital IWT.
2. Develop and demonstrate a digital twin tool to evaluate the impact of NAIADES III actions and additional policy recommendations.
3. Develop and validate a European labelling system for green IWT vessels on EU waterways to achieve energy and emission reductions.
4. Identify and analyse barriers and opportunities for zero-emission and smart technologies.
5. Develop an RD&I roadmap for technologies and policies.

The status of the labelling system for IWT vessels at the time of writing this document is documented in the P4A Deliverable 3.1 “State of play and requirements for the label for inland

vessels" (December 2024), available at https://platina4action.iwtprojects.eu/reports/, which presents the outcomes of the first two key tasks of the relevant work package. The next phase of P4A will focus on selecting one labelling concept for further refinement, developing an implementation roadmap, and creating baseline data and examples for specific segments. A leading candidate for the labelling methodology is the $EEDI_{INLAND}$, an energy efficiency index for inland vessels developed by DST in 2019 with the support from the German Federal Ministry for Digital and Transport (BMV). It is intended as the inland navigation counterpart to the maritime EEDI.

The initial study on energy efficiency indices for inland vessels, titled *"Evaluating the Energy Requirement of Inland Vessels Using Energy Efficiency Indices"*, is available via CESNI (https://www.cesni.eu/de/studien/). A follow-up study, commissioned by BMV and conducted by DST, includes improvements, full-scale trials to validate the method and propose a cost-effective assessment approach. The findings will soon be made publicly available. The background, methodology, and the latest developments of the framework are outlined below. Readers are encouraged to consult the studies for further details.

. The $EEDI_{INLAND}$ is being developed based on the well-established framework used in maritime shipping, with the goal of promoting energy efficiency in inland vessel design from the outset. It defines performance standards at the design stage, encouraging shipbuilders to integrate features such as optimised hull forms, lightweight structures, energy-efficient engines, and energy-saving technologies. The framework is applicable not only to newbuilds, but also to existing vessels undergoing major conversions or engine renewals, ensuring a fair and consistent approach across the fleet.

Similar to IMO procedures, the Estimated or Attained $EEDI_{INLAND}$ has to be calculated and must fall below the Required EEDI to comply with energy efficiency standards:

$$\text{Estimated/Attained } EEDI_{INLAND} \leq \text{Required } EEDI_{INLAND} = \left(1 - \frac{X}{100}\right) \cdot EEDI_{INLAND} \text{ reference curve}$$

The term "estimated" is used for new vessel designs, while "attained" refers to existing vessels. During the early design phase, the EEDI can be estimated using empirical formulas, numerical simulations, or scale model tests. For existing vessels, full-scale trials allow to determine the input parameters required for calculating the EEDI. Two reduction options for the Required EEDI are currently under consideration: 15% and 25% below the reference curve. For the detailed formulation of each term in the inequality above, please refer to the aforementioned studies.

Figure 4 shows an example of an $EEDI_{INLAND}$ reference curve determined from the data set based on both model-scale measurements, converted to full scale, and full-scale measurements. The curve has been determined in such a way that it includes all data points in the data set.

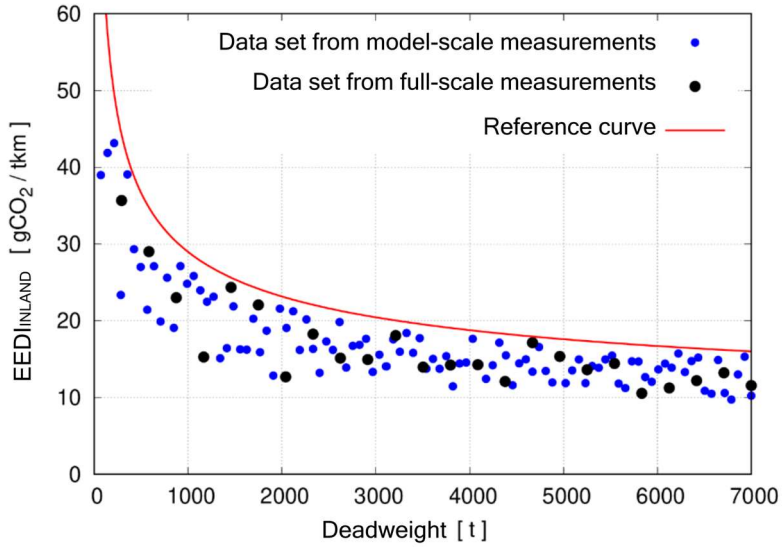

Figure 4: Example of $EEDI_{INLAND}$ reference curve determined from a data set based on both model-scale measurements converted to full scale, and full-scale measurements.

The methodology accounts for both vessel size and the type of cargo transported. Currently, four vessel types are considered: dry cargo and container vessels, tankers, pushed convoys, and passenger ships. It also accommodates different navigation areas. For example, vessels designed for specific conditions, such as day-trip vessels operating on lakes or vessels not certified for Rhine navigation, can still receive an $EEDI_{INLAND}$ assessment tailored to their operational context. Based on the geographical classification of European waterways outlined in the Directive (EU) 2016/1629, the current state includes three navigation zones:

- Zone A I (deep water): water depth > 7.5 m, currents < 2 km/h
- Zone A II (limited depth): water depth 3.5 ÷ 7.5 m, currents 2 ÷ 8 km/h
- Zone A III (channels): water depth ≈ 4 m, including various channel sections (trapezoidal, rectangular, or mixed rectangular/trapezoidal)

As a final step, and to support comparison and benchmarking, the methodology introduces a classification system that assigns vessels to one of seven energy efficiency classes (A to G). This classification is based on the ratio between the Estimated or Attained $EEDI_{INLAND}$ and the Required $EEDI_{INLAND}$, with lower ratios indicating higher efficiency. The classes are defined as follows:

- A: Ratio < 0.30, representing the most efficient vessels;
- B: 0.30 ≤ Ratio < 0.40;
- C: 0.40 ≤ Ratio < 0.50;
- D: 0.50 ≤ Ratio < 0.60;
- E: 0.60 ≤ Ratio < 0.80;

- F: 0.80 ≤ Ratio < 1.00;
- G: Ratio ≥ 1.00, representing the least efficient vessels.

1.5.5 CDNI Convention

The Convention on the collection, deposit and reception of waste generated during navigation on the Rhine and other inland waterways (CDNI) is a multilateral agreement that ensures the environmentally responsible management of waste from inland waterway vessels. Currently, it is in force in six countries: Belgium, France, Germany, Luxembourg, the Netherlands, and Switzerland.

The Convention is structured into three parts:

- Part A governs the collection and disposal of oily and greasy waste (e.g. bilge water, used oil);
- Part B deals with residues and waste arising from the transport of dry or liquid goods and, from 2024, gaseous cargo residues (vapours);
- Part C concerns other waste produced in the course of operating vessels other than the waste in parts A and B (e.g., domestic waste).

To finance waste disposal under Part A, the CDNI applies the “polluter pays” principle through a flat-rate fee:

- A disposal fee of 10€ is charged per 1,000 litres of fuel bunkered and applied uniformly in all States and to all vessels (last updated 2024).
- The fee is collected at the time of fuel purchase and entitles vessels to discharge waste at designated reception facilities without additional cost.
- The ECO card system is used to record fuel transactions and access services across all participating countries.

Although the CDNI does not directly regulate greenhouse gas emissions, the disposal charge under Part A enables contracting parties to monitor fuel consumption, which can serve as an indicator for estimating GHG emissions from the inland navigation sector.

The convention is not intended to apply to recreational craft.

1.5.6 Concluding remarks on EU Rules for inland navigation

With regard to gaseous and particulate pollutants, the engines used in EU inland waterway transport sector are subject to Regulation (EU) 2016/1628, including all its supplements.

According to Article 2(2)(e) of the Regulation, seagoing vessels that require a valid maritime navigation or safety certificate are explicitly excluded from its scope. Instead, air pollutant emissions from seagoing vessels are governed by IMO MARPOL Annex VI. As regards sulphur oxides, the limits are regulated at European level by the regulation on the sulphur content of fuels (Directive 2016/802/EU).

While no specific regulation currently limits GHG emissions from inland vessels, these emissions are indirectly monitored, for example, through the fuel-based fee system of the CDNI Convention. At the same time, in line with the NAIADES III strategy, the EU is progressively introducing instruments, such as the EU Taxonomy, CountEmissionsEU, and the forthcoming labelling system for inland vessels, to guide sustainable investment and support the transition toward a zero-emission inland fleet.

1.6 Class Rules / Additional Class Notations

In this section the class rules and additional class notations for the EETs of the three classification societies that are part of the consortium are reported (Table 6).

Table 6: Class rules/additional notations of the EETs

Energy Efficient Technology	RINA	ABS	DNV
SUSTAINABLE CLIMATE NEUTRAL LOW EMISSION FUELS			
Methanol	Pt C, Ch 1, App 15 – Methyl/Ethyl Alcohol fueled ships	Requirements for Methanol and Ethanol Fueled Vessels, Guide for Gas and Other Low-Flashpoint Fuel Ready Vessels	DNV-RU-SHIP Pt.6 Ch.2 Section 6 LFL fuelled ship installations
Biomethane	Pt C, Ch 1, App 16 - Biofuel	Guide for Gas and Other Low-Flashpoint Fuel Ready Vessels	Not explicitly defined; DNV-RU-SHIP Pt.6 Ch.2 Section LFL fuelled ship installations
Ammonia	Pt C, Ch 1, App 13 – LPG or NH3 fueled ships	Requirements for Ammonia Fueled Vessels, Guide for Gas and Other Low-	DNV-RU-SHIP Pt.6 Ch.2 Section 8 Alternative fuels - Fuel ready

Energy Efficient Technology	RINA	ABS	DNV
		Flashpoint Fuel Ready Vessels	
Biodiesel	Pt C, Ch 1, App 16 - Biofuel	Pt6, Ch 5, Section 1 - Biofuels	DNV-RU-SHIP Pt.6 Ch.2 Section 17 Biofueled ship installations - Biofueled
HVO - Renewable Diesel	Pt C, Ch 1, App 16 – Biofuel	Pt6, Ch 5, Section 1 – Biofuels	DNV-RU-SHIP Pt.6 Ch.2 Section 17 Biofueled ship installations - Biofueled
Hydrogen	Pt C, Ch 1, App 14 - Hydrogen fueled ships	Requirements for Hydrogen Fueled Vessels, Guide for Gas and Other Low-Flashpoint Fuel Ready Vessels	DNV-RU-SHIP Pt.6 Ch.2 Sec.16 Gas fuelled hydrogen
POWER CONVERSION / ELECTRIFICATION / ENERGY DEVICES			
PEM Fuel Cells	Pt C, Ch 2, App 3 - Fuel Cell Powered Ships	Pt 4, Ch 8-9, Guide for Fuel Cells, Guide for Hybrid Electric Power systems, Guide for DC power distribution	DNV-RU-SHIP Pt.6 Ch.2 Section 3 Fuel cell installations - FC
SOFC Fuel Cells	Pt C, Ch 2, App 3 - Fuel Cell Powered Ships	Pt 4, Ch 8-9, Guide for Fuel Cells, Guide for Hybrid Electric Power systems, Guide for DC power distribution	DNV-RU-SHIP Pt.6 Ch.2 Section 3 Fuel cell installations - FC
Other Fuel Cells	Pt C, Ch 2, App 3 - Fuel Cell Powered Ships	Pt 4, Ch 8-9, Guide for Fuel Cells, Guide for Hybrid Electric Power	DNV-RU-SHIP Pt.6 Ch.2 Section 3 Fuel cell installations - FC

Energy Efficient Technology	RINA	ABS	DNV
		systems, Guide for DC power distribution	
Onshore Power Supply	Pt F, Ch 13, Sec 15; Pt F, Ch 7, App 2, Sec 2.2.3 – HVSC Class Notation and OPS System Integration	Pt 4, Ch 8-9, Pt6, Ch 4, Guide for Hybrid Electric Power systems, Guide for DC power distribution	DNV-RU-SHIP Pt.6 Ch.7 Section 5 Electrical shore connections - Shore power
Waste Heat Recovery Systems	Pt F, Ch 7, App 3, Sec 6 – Heat Recovery Systems	Pt 4, Ch 4, Sec 1, - Boilers, Pressure Vessels and Fired Equipment	Not explicitly defined; DNV-RU-SHIP Pt.4 Ch.7: Pressure equipment
Electric Thrusters	Pt C, Ch 1, Sec 12 - Thrusters	Pt 4, Ch 2, Sec 5 - Thrusters	DNV-RU-SHIP Pt.6 Ch.7 Section 7 Redundant- and alternative propulsion DNV-RU-SHIP Pt.6 Ch.3 Navigation, manoeuvring and position keeping
Energy Management Systems	Pt C, Ch 2, App 2, Sec 3.5 - EMS	Pt 4, Ch 9 – Computer Based Systems	DNV-RU-SHIP Pt.6 Ch.2 Section 1 Electrical energy storage
RENEWABLES			
Soft Sails	Not covered in RINA rules – subject to risk-based case-by-case assessment	Requirements for Wind Assisted Propulsion System Installation	DNV-RU-SHIP Pt.6 Ch.7 Section 12 Wind assisted propulsion systems - WAPS
Flettner Rotors	Not covered in RINA rules – subject to risk-based case-by-case assessment	Requirements for Wind Assisted Propulsion System Installation	DNV-RU-SHIP Pt.6 Ch.7 Section 12 Wind assisted propulsion systems - WAPS

Energy Efficient Technology	RINA	ABS	DNV
Rigid Wing Sails	Not covered in RINA rules – subject to risk-based case-by-case assessment	Requirements for Wind Assisted Propulsion System Installation	DNV-RU-SHIP Pt.6 Ch.7 Section 12 Wind assisted propulsion systems - WAPS
Kite Propulsion	Not covered in RINA rules – subject to risk-based case-by-case assessment	Requirements for Wind Assisted Propulsion System Installation, as applicable. Rules For Alternative Arrangements, Novel Concepts and New Technologies-Part 1D	Not explicitly defined; DNV-RU-SHIP Pt.6 Ch.7 Section 12 Wind assisted propulsion systems - WAPS
Suction Wings	Not covered in RINA rules – subject to risk-based case-by-case assessment	Requirements for Wind Assisted Propulsion System Installation, as applicable. Rules For Alternative Arrangements, Novel Concepts and New Technologies-Part 1D	Not explicitly defined; DNV-RU-SHIP Pt.6 Ch.7 Section 12 Wind assisted propulsion systems - WAPS
Turbosails	Not covered in RINA rules – subject to risk-based case-by-case assessment	Requirements for Wind Assisted Propulsion System Installation, as applicable. Rules For Alternative Arrangements, Novel Concepts and New Technologies-Part 1D	Not explicitly defined; DNV-RU-SHIP Pt.6 Ch.7 Section 12 Wind assisted propulsion systems - WAPS
Dynarig Systems	Not covered in RINA rules – subject to risk-	Requirements for Wind Assisted	Not explicitly defined; DNV-RU-SHIP Pt.6

Energy Efficient Technology	RINA	ABS	DNV
	based case-by-case assessment	Propulsion System Installation, as applicable. Rules For Alternative Arrangements, Novel Concepts and New Technologies-Part 1D	Ch.7 Section 12 Wind assisted propulsion systems - WAPS
Photovoltaic Panels	Not covered in RINA rules – subject to risk-based case-by-case assessment	Pt 4, Ch 8-9, Guide for Hybrid Electric Power systems, Guide for DC power distribution	DNV-RU-SHIP Pt.4 Ch 8: Electrical installations
PROPELLER DESIGN			
Shaft Generator Systems	Pt C, Ch 1, Sec 2, [2.2.9]; Pt C, Ch 2, Sec 4 – Sources of electrical power	Pt 4, Ch 8, Sec 3 – Electrical Equipment	DNV-RU-SHIP Pt.4 Ch 8: Electrical installations
Contra-rotating Propellers	Pt F, Ch 2, Sec 3 - Propeller & Shafting	Pt 4, Ch 2, Sec 9, - Contra-Rotating Propellers	DNV-ST-0111 Assessment of station keeping capability of dynamic positioning vessels
Wake Equalizing Ducts	Not covered in RINA rules – subject to risk-based case-by-case assessment	Pt 4, Ch 2 – Propellers, Rules For Alternative Arrangements, Novel Concepts and New Technologies-Part 1D	DNV-RU-SHIP Pt.4 Ch.5 Rotating machinery - driven units DNV-CG-0039 Calculation of marine propellers
ESD Fins	Pt F, Ch 7, App 2, [2.2.17] – Fins on Propeller Boss Cups	Pt 4, Ch 2 - Propellers	DNV-RU-SHIP Pt.4 Ch.5 Rotating machinery - driven units DNV-CG-0039

Energy Efficient Technology	RINA	ABS	DNV
			Calculation of marine propellers
Gate Rudder	Pt C, Ch 1, Sec 11, [6.1.1]; Pt B, Ch 10, Sec 1, [1.1.4] – Special Rudder Types	Pt 4, Ch 2 - Propellers	DNV-RU-SHIP Pt.4 Ch.5 Rotating machinery - driven units DNV-CG-0039 Calculation of marine propellers
Propeller Nozzle	Pt B, Ch 10, Sec 1; Pt C, Ch 1, Sec 8 – Propeller Types	Pt 4, Ch 2 - Propellers	DNV-RU-SHIP Pt.4 Ch.5 Rotating machinery - driven units DNV-CG-0039 Calculation of marine propellers
PBCF	Pt F, Ch 7, App 2, Sec 2.2.17 - PBCF	Pt 4, Ch 2 - Propellers	DNV-RU-SHIP Pt.4 Ch.5 Rotating machinery - driven units DNV-CG-0039 Calculation of marine propellers
Grim Vane Wheel	Not specifically covered – similar intent to PBCF	Pt 4, Ch 2 - Propellers	DNV-RU-SHIP Pt.4 Ch.5 Rotating machinery - driven units DNV-CG-0039 Calculation of marine propellers
Pulling Azimuth Thrusters	Pt C, Ch 1, Sec 12; Pt B, Ch 10, Sec 1; Pt F, Ch	Pt 4, Ch 2 - Propellers	DNV-RU-SHIP Pt.4 Ch.5 Rotating

Energy Efficient Technology	RINA	ABS	DNV
	13, Sec 6 – Azimuth Thruster Systems		machinery - driven units DNV-CG-0039 Calculation of marine propellers
Advanced Propeller Blade Retrofitting	Pt C, Ch 1, Sec 8, [2.3.2] & [2.4]; Pt D, Ch 4, Sec 2 – Blade Retrofitting	Pt 4, Ch 2 - Propellers	DNV-RU-SHIP Pt.4 Ch.5 Rotating machinery - driven units DNV-CG-0039 Calculation of marine propellers
OPERATIONS			
Hull Cleaning - Condition-Based Monitoring	Pt F, Ch 12, Sec 1 & 2 – Condition-Based Maintenance (CBM)	Guide for Smart Functions for Marine Vessels and Offshore Units, Guide for Hull Condition Monitoring System	DNV-RP-0675 Technical ship performance
CPP Pitch Optimization	Pt C, Ch 1, Sec 8; Sec 16, [3.9.6] – Design, Testing, and Monitoring of Controllable Pitch Propellers	ABS - Energy Efficiency Advisory, Rules For Alternative Arrangements, Novel Concepts and New Technologies-Part 1D	Technical and Performance Advisory-DNV
Weather Routing Systems	Not covered in RINA rules – subject to risk-based case-by-case assessment	ABS - Energy Efficiency Advisory, Rules For Alternative Arrangements, Novel Concepts and New Technologies-Part 1D	Technical and Performance Advisory-DNV

Energy Efficient Technology	RINA	ABS	DNV
Slow Steaming	Pt C, Ch 1, App 7, Sec 6.9.4 – Fuel system design must account for slow steaming conditions	ABS - Energy Efficiency Advisory, Rules For Alternative Arrangements, Novel Concepts and New Technologies-Part 1D	Technical and Performance Advisory-DNV
HYDRODYNAMICS			
Hull Form Optimization	Pt B, Ch 3 – Hull Form and Structural Design Requirements	ABS - Energy Efficiency Advisory, Rules For Alternative Arrangements, Novel Concepts and New Technologies-Part 1D	Technical and Performance Advisory-DNV
Air Lubrication Systems	Pt F, Ch 13, Sec 31 – AIR LUB Notation: Design, Integration, and Testing of Air Lubrication Systems	Requirements for Air Lubrication System Installation	DNV-RP-0695 Performance of air lubrication systems
Hull Surface Coatings	Pt E, Ch 4, Sec 3, [11] – Requirements for approved hull coatings and surface protection	Guidance Notes on Maintenance and Repair of Protective Coatings	DNV-CG-0288 Corrosion protection of ships
Bulbous Bow Optimization	Pt B, Ch 9, Sec 1, [2.11] – Structural Design and Reinforcement of Bulbous Bows	ABS - Energy Efficiency Advisory, Rules For Alternative Arrangements, Novel Concepts and New Technologies-Part 1D	Technical and Performance Advisory-DNV
Hull Openings Optimization	Pt B, Ch 4, Sec 3 – Openings in the Hull and Superstructures	Rules For Alternative Arrangements, Novel Concepts and New Technologies-Part 1D	N/A

Energy Efficient Technology	RINA	ABS	DNV
Trim & Draft Optimization	Pt F, Ch 7, App 2, [2.2.7] & [2.2.9] – Fuel Consumption Decision Support System (DSS)	ABS - Energy Efficiency Advisory, Rules For Alternative Arrangements, Novel Concepts and New Technologies-Part 1D	Technical and Performance Advisory-DNV
OPTIMIZED ENGINEERING APPROACH			
Onboard Carbon Capture and Storage (CCS) Systems	Not explicitly covered in RINA rules – closest framework under Pt F, Ch 13, Sec 46 & Sec 26 (EGCS).	Requirements for Onboard Carbon Capture and Storage	DNV-RU-SHIP Pt.6 Ch.7 Section 9 Onboard carbon capture and storage - OCCS and OCCS ready DNV-CG-0667 Carbon capture and storage on board ships
Water-Emulsified Fuel Technology	Pt F, Ch 13, Sec 2.5.2 – Fuel pre-treatment	Rules For Alternative Arrangements, Novel Concepts and New Technologies-Part 1D	Not explicitly defined; DNV-RU-SHIP Pt.6 Ch.2 Section 4 Fuel treatment and conditioning systems - Fuel
Steam/Heat Plant Optimization	Pt C, Ch 1, Sec 10 – Articles 13–16 - Steam Systems	Pt 4, Ch6, Section 6 - Piping Systems for Steam Plants	DNV-RU-SHIP Pt.4 Ch.7: Pressure equipment

2 Applicable international standards

In this section the relevant international standards for the EETs are reported (Table 7).

Table 7 Applicable internation standards for EETs

Energy Efficient Technology	ISO	IEC
SUSTAINABLE CLIMATE NEUTRAL LOW EMISSION FUELS		
Methanol	ISO/6583 "Specification of methanol as a fuel for marine applications" is under development	
Biomethane	ISO 2610 – 2614:23/2615/2620:24: Analysis of biomethane ISO 15403-1: Further specifications on content	EN 16723: Specifications for injection into natural gas networks and for use as automotive fuels
Ammonia	N/A for NH3 as fuel ISO 4276:1978: Method for evaluating residue on evaporation ISO 5771:2008: Requirements for rubber, transfer hoses ISO 7104/ 7105:1985: Methods for determining water content ISO 7103:1982: Sampling of LNH_3 ISO 7106:1985: Methods to determine the oil content ISO/CD 23397 Ships and marine technology — Ammonia fuel systems for ships (under development)	
Biodiesel	ISO 8217: Specifications for bioDiesel blends ISO/TS 17306:2016: Gas chromatography method for determining glycerols in biodiesel	EN 14214: Biodiesel specification - FAME

Energy Efficient Technology	ISO	IEC
HVO - Renewable Diesel	*ASTM D975-21: Biodiesel specification "mono-alkyl esters of long chain fatty acids derived from vegetable oils and animal fats"* 15940: British paraffinic Diesel fuel specification	
Hydrogen	ISO 14687:2019 "Hydrogen fuel quality – Product specification" ISO 15916: Guidance on safety of hydrogen systems ISO19880-1:2020: Standard for H2 fuel station infrastructure ISO 11326:2024 – Test procedures for liquid hydrogen storage tank ISO 14687:2025 –H_2 as fuel, minimum quality requirements	
POWER CONVERSION / ELECTRIFICATION / ENERGY DEVICES		
PEM Fuel Cells	ISO.14687:2019, Hydrogen fuel – Product, specification, Defines purity specifications for hydrogen used in fuel cells, crucial for maritime hydrogen systems (e.g., PEM fuel cells). Applies to: PEMFCs on ships using hydrogen. ISO 16110-1:2007, Hydrogen generators using fuel processing technologies – Part 1: Safety. Safety requirements	

Energy Efficient Technology	ISO	IEC
	for hydrogen generators used in on-board systems. ISO/TR 15916: Basic considerations for the safety of hydrogen system IEC 62282 Series: Fuel cell technologies. 2-100: safety of cell modules, 3-100: safety of stationary cell modules	
SOFC Fuel Cells		
Other Fuel Cells		
Onshore Power Supply	ISO 17117: In conjunction with IEC/IEEE 80005 series, general requirements for electric shore power connection to ships	IEC/IEEE 80005-*1*: High Voltage Shore Connection Systems, -*2*: Low Voltage Shore Connection Systems, -*3* DC Shore Connection Systems, IEC 60092-507: Electrical installations in ships – Part 507: Supplementary requirements for ships with high-voltage shore connection systems
Waste Heat Recovery Systems	ISO 50001: Energy management systems	Indirectly through IEC 61892 – Electrical installations and waste heat recovery requirements
Electric Thrusters	ISO 16361: Requirements for electric and hybrid propulsion systems	IEC 60092: Electrical installation in ships IEC 60034 Rotating electrical machines
Energy Management Systems	ISO 50001: Energy management systems	
RENEWABLES		

Energy Efficient Technology	ISO	IEC
Soft Sails	ISO standards for each special category do not exist. ISO 19030: Measurements of changes in hull and propeller performance ISO 29400:2020 – This standard focuses on offshore wind energy operations and may be used as a guide when installing WAPS. ISO 15016:2025 – Methodologies analysing speed and power trial data and may be used to evaluate the performance of a ship with WAPS installation.	N/A
Flettner Rotors		
Rigid Wing Sails		
Kite Propulsion		
Suction Wings		
Turbosails		
Dynarig Systems		
Photovoltaic Panels	ISO 9060: Standard for accurate measurements using pyranometers and pyrheliometers. ISO 17025: Guidelines for the competence of testing laboratories for PV systems ISO13273-2: Framework for assessing the performance of PV systems	IEC 61701: Salt mist corrosion resistance of PV modules in marine environment. IEC 61724-1: Performance monitoring of PV systems.
PROPELLER DESIGN		

Energy Efficient Technology	ISO	IEC
Shaft Generator Systems	ISO 8528	IEC 60092: Electrical installations in ships
Contra-rotating Propellers	ISO 484/1: Propeller manufacturing tolerances ISO 17467: Cavitation and erosion of propeller ISO 18870: Propeller performance measurement	
Wake Equalizing Ducts	N/A	N/A
ESD Fins	N/A. Indirectly related to: ISO 15016: Model test and full-scale trials to determine speed and power.	N/A
Gate Rudder	N/A. Indirectly related to: ISO 15016: Model test and full-scale trials to determine speed and power. ISO 16327, dedicated to the design of rudder stock and, ISO 19688, which provides guidelines for propulsion and steering gear.	N/A
Propeller Nozzle	N/A. Indirectly related to: ISO 15016: Model test and full-scale trials to determine speed and power. ISO 484 a standard dedicated at propeller manufacture tolerances and, ISO 19688, which provides guidelines for propulsion and steering gear.	N/A
PBCF	N/A. Indirectly related to:	N/A

Energy Efficient Technology	ISO	IEC
	ISO 15016: Model test and full-scale trials to determine speed and power. ISO 484 a standard dedicated at propeller manufacture tolerances and, ISO 19688, which provides guidelines for propulsion and steering gear.	
Grim Vane Wheel	N/A. Indirectly related to: ISO 15016: Model test and full-scale trials to determine speed and power. ISO 19688, which provides guidelines for propulsion and steering gear.	N/A
Pulling Azimuth Thrusters	ISO 15016: Model test and full-scale trials to determine speed and power. ISO 484 a standard dedicated at propeller manufacturing tolerances and, ISO 19688, which provides guidelines for propulsion and steering gear. ISO 3722, 6099, 8849, 10763: Indirectly related standards suitable for actuation components. ISO 16315: The defined principles for electric propulsion for small crafts can	IEC 60092: Standards for design, protection, equipment, control and automations of ship electrical installations IEC 60533: Electromagnetic compatibility, ensuring that the electronics of azimuth thrusters do not interfere with other ship systems and are not susceptible to electromagnetic interference. IEC 61508: Principles for functional safety aspects IEC 61800: Standards for variable frequence drives

Energy Efficient Technology	ISO	IEC
	be extended to Azimuth thrusters.	
OPERATIONS		
Hull Cleaning - Condition-Based Monitoring	ISO 9712:NDT testing qualifications (relevant to condition assessment)	N/A
CPP Pitch Optimization	ISO 18870:Propeller performance	N/A
Weather Routing Systems	N/A	N/A
Slow Steaming	N/A	N/A
HYDRODYNAMICS		
Hull Form Optimization	ISO 9276: Ships and marine technology — Lines plans-Standard for lines preparation ISO 15016: Speed and power performance analysis with trial data	N/A
Air Lubrication Systems	N/A	N/A
Hull Surface Coatings	ISO 2178: Non-magnetic coatings on magnetic substrates — Measurement of coating thickness — Magnetic method (Indirectly linked) ISO 19030: Measurement of changes in hull and propeller performance	
Bulbous Bow Optimization	N/A	N/A
Hull Openings Optimization	ISO 21005: Requirements for ship openings	N/A
Trim & Draft Optimization	N/A	N/A
OPTIMIZED ENGINEERING APPROACH		

Energy Efficient Technology	ISO	IEC
Onboard Carbon Capture and Storage (CCS) Systems	ISO 27919: Performance evaluation guidelines for post-combustion capture ISO 17894: Guidelines relevant for the auxiliary machinery equipped to a CCS. Indirectly related. ISO 27913: This standard is primarily applied for the safety of CO_2 transportation through pipelines. It can be extended to shipboard application, mainly in handling mixture impurities. ISO 27914: This standard provides information on the necessary mixture and its suitability with the geological conditions of the storage site. ISO/TS 27915: Included "good practices" for all CCs equipment on project level and includes a lifecycle assessment to estimate project level emissions. It is intended to be used as the basis for future technological standards.	IEC 60092, 61508, 61533, 61800 IEC 60079: standard for explosive atmospheres, applicable if the capture system or any auxiliary poses explosion risks
Water-Emulsified Fuel Technology	Included in ISO 8217, where marine fuel specifications are given.	N/A
Steam/Heat Plant Optimization	Part of ISO 50001 (Energy management systems)	Indirectly linked to IEC 60092 – Electrical installations in ships

In addition, for the EETs among others the following EMSA reports should be considered:

- EMSA Guidance on the Safety of Battery Energy Storage Systems (BESS) on board ships
- Study on electrical energy storage for ships-Battery systems for maritime applications-technology, sustainability and safety
- Study on the use of fuel cells in shipping
- Potential of wind-assisted propulsion for shipping
- Potential of hydrogen as fuel for shipping
- Potential of ammonia as fuel for shipping
- Safety of ammonia for use in ships
- Mapping safety risks for hydrogen-fuelled ships
- Potential of biofuels for shipping
- Study on the use of ethyl and methyl alcohol as alternative fuels in shipping

3 Technical implications of regulatory compliance

3.1 Framework for regulatory derogations in the maritime sector

In the absence of an established mandatory regulatory framework, for the EETs IMO Goal Based Standards (GBS) approach should be followed. This approach entails the formulation of broad goals, functional requirements to achieve those goals, and verification processes to ensure compliance. This approach allows the definition of proactive regulations aimed at preventing accidents, rather than reacting to accidents. The fundamental philosophy of GBS is closely linked to the risk assessment process, as the preferred path for compliance with safety requirements, typically applied to all alternative designs, novel concepts, and new technologies in general.

It is recalled that the GBS framework consists of five major “tiers” (**Error! Reference source not found.**): Tier I - Goals; Tier II - Functional Requirements; Tier III - Verification of conformity; Tier IV - Regulations and Class requirements; Tier V - Industry standards and practices.

Alternatives, new technologies, and novel concepts may be accepted if designers, shipyards, owners, equipment manufacturers, technology providers, or other stakeholders can

demonstrate compliance with the Tier I Goals and Tier II Functional Requirements, during Tier III Verification of Conformity.

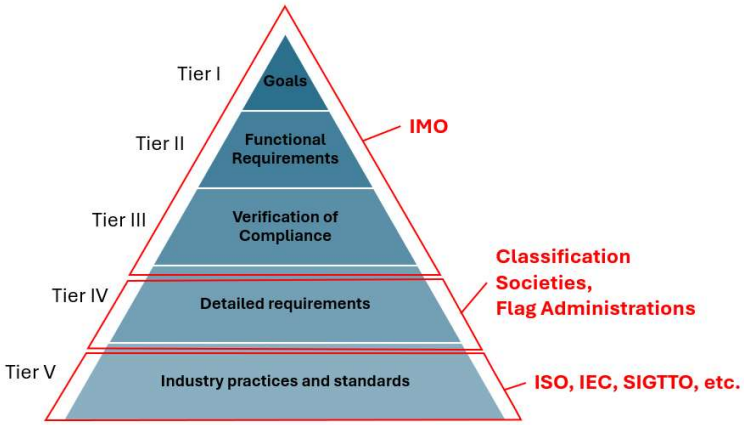

Figure 5: Tiers of the IMO's Goal Based Standards framework

Alternative arrangements, novel concepts, or new technologies (ref. IMO MSC.1/Circ.1212/Rev.1 and Guidelines on Alternative Design and Arrangement for SOLAS Chapters II-1 and III) are today well recognized and widely used by Classification Societies as well as National Flag Administrations. When a goal-based approach is used as the basis for statutory compliance, the Administration must be contacted, either directly or through a Classification Society – acting as Recognized Organization by the Administration - to negotiate an agreement as to the extent to which the Administration is prepared to consider alternatives to such requirements. Detailed procedures are contained in Part 1D, Chapter 2 and IMO MSC.1/Circ.1455 Guidelines for the Approval of Alternatives and Equivalents as Provided for in Various IMO Instruments.

3.2 Framework for regulatory derogations in the inland waterway sector

Any craft (vessel or floating equipment) operating on the Rhine and EU waterways must carry either a Rhine vessel inspection certificate, issued pursuant to Article 22 of the Revised Convention for Rhine Navigation (CCNR), or a Union inland navigation certificate, issued under the Directive (EU) 2016/1629. These certificates are granted by national inspection bodies and attest that crafts meet the technical requirements defined in the CCNR Rhine vessel Inspection regulations (RVIR) or the Directive (EU) 2016/1629, both of which refer to ES-TRIN as the harmonised standard.

Derogations are permitted to support and encourage technological innovation or when full compliance would be technically impractical or economically disproportionate, the so-called hardship clause. These are embedded in both the CCNR and EU legal frameworks (see Article 2.20 of the RVIR or Articles 25 and 26 of the Directive (EU) 2016/1629).

Derogations can be issued on a permanent basis when alternative solutions (materials, installations or items of equipment, or the adoption of arrangements or design aspects other than those included in ES-TRIN) are proven to offer an equivalent level of safety. In contrast, derogations intended for experimental applications, such as trials of new technical solutions, are typically granted for a limited period, in general up to five years, provided that an adequate level of safety is ensured.

The issuance of the derogation can take up to 24 or 36 months, depending on whether the derogation has been requested in accordance with RVIR or EU Directive.

Additional details can be found in the relevant EU and CCNR legal texts, as well as in the CESNI guidance document “Leaflet on Deliberation on Derogations and Equivalences of Technical Requirements of the ES-TRIN for Specific Craft” (March 2019), available at:

https://www.cesni.eu/wp-content/uploads/2019/04/Guide_Sp_craft_en.pdf.

3.3 Risk Assessment as part of Alternative Design

The SOLAS convention allows Administrations to authorize the use of designs and arrangements that differ from mandatory requirements, based upon the “principle of equivalency,” i.e. ensuring that the alternative design has at least the equivalent level of safety - and often availability as well.

This principle is expressed in general terms in SOLAS Regulation I/5 “Equivalents” and it is further detailed in other chapters of the Conventions. MSC.1/Circ.1455 “Guidelines for the approval of alternatives and equivalents as provided for in various IMO instruments”, further details the hazard identification and the whole risk assessment process whose results are subject to verification.

The final approval of alternative design and arrangement is under the responsibility of the flag Administration, but Classification Societies are usually part of the design team addressing the alternative design and play the role of “observers” to assist throughout the process.

In the development of novel environmental and energy technologies for maritime applications, ensuring safety remains a central requirement, particularly in cases where conventional regulations are insufficient or not yet fully established. The most common techniques that may be used for risk analysis purposes are shown in Table 8.

Table 8: Overview of Risk Assessment Techniques

Risk Assessment technique	Risk Identification	Risk Analysis			Evaluation
		Consequences	Likelihood	Risk Level	
Bowtie analysis	A	SA	A	A	A
Change analysis	A	NA	NA	NA	A*
Checklist Analysis	SA	NA	NA	NA	NA
Event Tree Analysis	NA	SA	A	A	A
Explosion Hazard Analysis	NA	A	A	A	A*
Failure Modes and Effects Analysis	SA	SA	NA	NA	NA
Failure Modes and Effects and Criticality Analysis	SA	SA	SA	SA	SA
Fault Tree Analysis	A	NA	SA	A	A
Fire Hazard Analysis	NA	A	A	A	A*
Formal Safety Assessment	A	A	A	A	A
Gas Dispersion Analysis	NA	A	A	A	A*
Hazard Identification Technique (HAZID)	A	A	A*	A*	A*
Hazard and Operability	SA	A	A*	A*	A*

Risk Assessment technique	Risk Identification	Risk Analysis			Evaluation
		Consequences	Likelihood	Risk Level	
Analysis (HAZOP)					
Human Reliability Analysis	SA	SA	SA	SA	A
Layer of Protection Analysis (LOPA)	A	SA	A	A	A*
Probabilistic Risk Assessment	A	A	A	A	A
Reliability Centered Maintenance	A	A	A	A	SA
Safety Integrity Level Assessment	NA	A	A	A	A
What-if Analysis	SA	SA	A	A	A
Table Keys : NA (Not Applicable), A : Applicable, SA : Sometime Applicable, A* : if applicable					

To address this regulatory uncertainty, a structured risk-based approach will be adopted in the project to demonstrate safety equivalence and regulatory compliance as shown in Figure 6. This begins with early-stage hazard identification (HAZID) to systematically uncover potential risks related to system operation, external environments, and human interaction. These insights guide safer conceptual design decisions from the outset. Building upon the initial findings, further evaluations are carried out through Hazard and Operability Studies (HAZOP) and Failure Mode and Effects Analysis (FMEA), which are applied to assess system reliability, identify failure mechanisms, and ensure operability under a range of conditions. In parallel, quantitative assessments are performed to calculate risk levels, enabling the design team to make informed decisions based on measurable safety metrics. The results of these

assessments are not isolated but are continuously integrated into the evolving design process, allowing for early detection of vulnerabilities and refinement of safety measures.

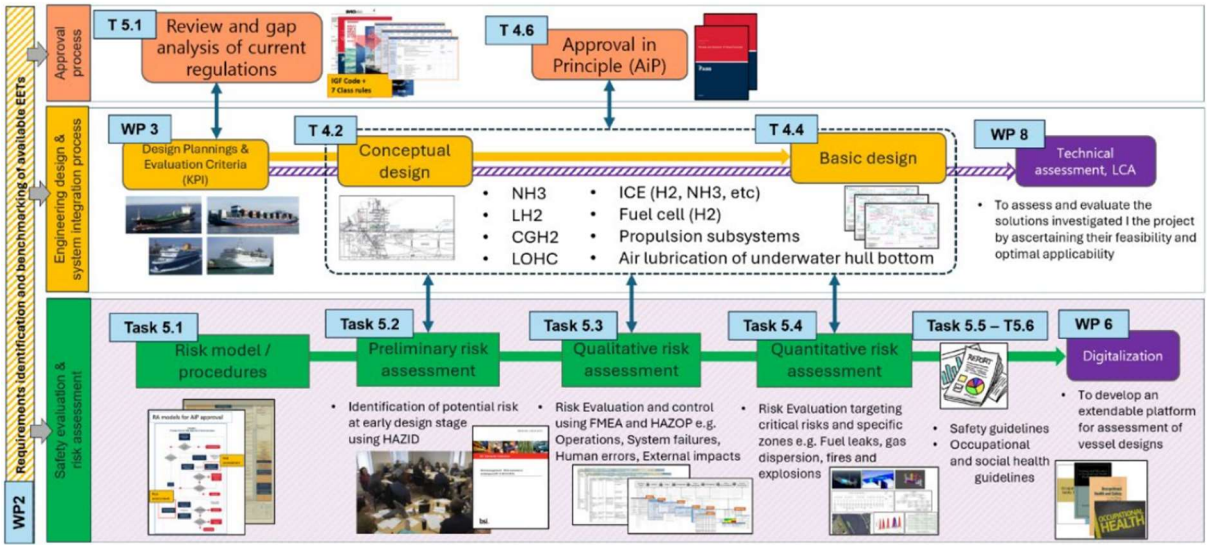

Figure 6: Overview on safety evaluation and risk assessments of FLEETfor55

Ultimately, this comprehensive approach not only enhances the safety and robustness of the technologies under development but also provides a well-substantiated foundation for seeking regulatory acceptance, such as through the Approval in Principle (AiP) process by Classification Societies. By embedding risk evaluation throughout the design lifecycle, the project ensures that even in the absence of fully defined regulations, safety objectives can be confidently met and verified.

4 Gaps and technical shortcomings in the regulatory framework

In this section the gaps and barriers derived from the review of the regulatory framework as they were reported also in the recent MSC110/6 are summarised Table 9.

Table 9: EETs gaps/barriers derived by MSC110/6

EETs	Barrier/Gap	Recommendation
Alternative Fuels/ Fatty-acid methyl ester (FAME)	It should be noted that there is an inconsistency regarding cargo in MARPOL annexes I and II, which may prohibit the otherwise safe use as a fuel.	Investigate the need for, and develop MARPOL amendments as appropriate, to deconflict inconsistencies regarding FAME cargo in MARPOL annexes I and II which may prohibit its otherwise safe use as a fuel. Also consider the need to update the 2019 Guidelines for the Carriage of Blends of Biofuels and MARPOL Annex I Cargoes (MSC-MEPC.2/ Circ.17). Consideration should be given to ISO 8217:2024, "Products from Petroleum, Synthetic and Renewable Sources — Fuels (Class F) — Specifications of Marine Fuels" as a possible reference in carrying out this work. Note: A recent draft MEPC.1 Circular, "Interim Guidance on the Carriage of Blends of Biofuels and MARPOL Annex I Cargoes by Conventional Bunker Ships" was proposed at ESPH 30 (Annex 1 to ESPH 30/WP.1/Rev.1) which would allow conventional bunker ships certified for carriage of oil fuels under MARPOL Annex I to transport blends not more than 30% by volume of biofuel. Approval is pending at this time, but once approved the proposed MEPC.1 Circular would provide partial relief in addressing this issue.
	Distinct cold flow properties – need to address correction of temperature during bunkering/fuel transfer. Cleaning of fuel transferring equipment and storage tanks onboard - maintenance.	Develop guidance on the safe storage and handling of AME as fuel to address: proper maintenance and cleaning of storage tanks and fuel transferring equipment, and the need for temperature correction during bunkering/fuel transfer to account for the distinct cold flow properties of FAME. In this regard, consideration should be given to ISO 8217:2024, "Products from Petroleum, Synthetic and Renewable Sources —

EETs	Barrier/Gap	Recommendation
		Fuels (Class F) — Specifications of Marine Fuels", the 04|2024 CIMAC Guideline "Marine-fuels; A Guideline for Shipowners & Operators", and MEPC.320(74) Section 3.2 - Distillate fuel with FAME content.
Methyl/ethyl alcohol fuels	Toxic requirements for transport as cargo or as a fuel are not consistent between the interim guidelines and the IBC Code.	Investigate, and develop amendments to the IBC Code and the Interim Guidelines for the Safety of Ships Using Methyl/Ethyl Alcohol as Fuel (MSC.1/Circ.1621) as appropriate so that there is consistency in approach regarding requirements on toxicity.
	Lack of standards for system certification of water based and gas-based fire-fighting systems to extinguish alcohol fires.	Within the FSS Code, develop or identify appropriate standards for system certification of water based and gas-based fire-fighting systems to extinguish alcohol fires. In this regard, also consider whether related amendments are needed to the following instruments: .1 Approval Guidelines for Equivalent Fixed Gas Fire-Extinguishing Systems for Machinery Spaces and Cargo Pump Rooms (MSC.848, as amended by MSC.1/Circ.1267), tables 1/2, figures 1, 2, 3; .2 Revised Approval Guidelines for Equivalent Water-Based Fire-Extinguishing Systems for Machinery Spaces and Cargo Pump Rooms (MSC/Circ.1165, as amended by MSC.1/Circ.1237, MSC.1/Circ.1269, and MSC.1/Circ.1386), tables 1/2/3, figures 1/2/3; .3 Approval Guidelines for Fixed Local Application Water-Based Fire-Extinguishing Systems for Machinery Spaces and Cargo Pump Rooms (MSC/Circ.913, as amended by MSC.1/Circ.1387), table 3.2.2.1; .4 revised Guidelines for the Approval of Fixed Aerosol Fire-Extinguishing Systems Equivalent to Fixed Gas Fire-Extinguishing Systems, as referred to in the SOLAS Convention of 1974, for Machinery Spaces (MSC.1/Circular.1270)

EETs	Barrier/Gap	Recommendation
Ammonia	Development of guidelines	Development of guidelines Finalize interim guidelines for the safety of ships using ammonia as fuel Note: Interim Guidelines for ammonia as fuel were completed at CCC 10 and approved at MSC 109 as MSC.1/Circ.1687.
	Ammonia as fuel should be considered under the applicability of the IGF Code.	Consider whether IGF Code applicability can be adjusted in a way to include ammonia as fuel Note: MSC 109 approved draft SOLAS amendments that would extend the application of the IGF Code to ships using gaseous fuels as well as low-flashpoint fuels, with a view to adoption at MSC 110 (MSC 109/22, 6.27 and annex 1). This amendment, once in force, will bring ammonia fuel 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.	Invite ISO to develop a relevant definition and specifications for ammonia as fuel, taking into account its water content among other consideration. Amend the Interim Guidelines for the Safety of Ships Using Ammonia as Fuel (MSC.1/Circ.1687) to include references to the ISO standard once finalized and published.
Hydrogen	Development of guidelines (expected to be finalized at CCC 10)	Finalize interim guidelines for the safety of ships using hydrogen as fuel Note: Interim guidelines for hydrogen as fuel are under development at the CCC Sub-committee and scheduled for finalization at CCC 11, with view to approval at MSC 111 (CCC 10/WP.6, annex 3 – Updated work plan for the development of new alternative fuels under the IGF Code).

EETs	Barrier/Gap	Recommendation
Fuel blends/mixtures	SOLAS reg. VI/5-2 Prohibition of blending of bulk liquid cargoes and production processes during sea voyages.	Consider the need for an interpretation or amendment to SOLAS reg, VI/5-2, "Prohibition of blending of bulk liquid cargoes and production processes during sea voyages" to clarify that it does not apply to the blending or otherwise processing fuel for use onboard.
	No guidelines for how to determine risks based on composition of fuel mixtures	Develop guidance to address the safety risks of fuel mixtures based on their composition. This should take a risk assessment based approach where the properties of each individual component of the mixture would be considered in addition to the risks associated with the mixture itself. A list of most relevant fuel mixtures should be identified first to help narrow the scope to specific mixtures, and help define a potential work output.
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)	Update interim guidelines to better address existing designs of fuel cell power installations (i.e. Design and layout of fuel cell spaces) using comments provided in MSC 110/6, annex 2, as a starting point.
	Lack of mandatory requirements for the safety of ships using fuel cell power installations.	After updating interim guidelines, develop mandatory requirements for the safety of ships using fuel cell power installations. Note: CCC has a work plan item to start discussion on the development of mandatory requirements for the safety of ships using fuel cells at CCC 11 if time permits (CCC 10/16, Annex 2). It is not clear at this time whether these requirements when developed should be included in the IGF Code or in a new Fuel Cell Power Installations Code.

EETs	Barrier/Gap	Recommendation
Fuel reforming	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.	Develop requirements for hydrogen generation onboard ships (i.e. fuel reforming, ammonia cracking or LOHC de-hydrogenation) outside the context of MSC.1/Circ.1647 Interim Guidelines for the Safety of Ships Using Fuel Cell Power installations, to include hydrogen fuel production from any hydrogen-rich fuel, to be used in any power conversion system other than fuel cell power installations.
Wind propulsion and wind assisted power	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 further studies for better 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.	Develop Interim Guidelines for the Safety of Ships Using Wind Propulsion and Wind Assisted Power, considering as a starting point the gaps identified in document MEPC 81/INF.39 - White Paper on Wind Propulsion (Comoros, France, Solomon Islands and IWSA), with a view towards updating the existing IMO instruments and possibly introducing a new Code once industry has gained experience with the Interim Guidelines Note: Wind Propulsion and Wind Assisted Power have been combined under one overarching set of Interim Guidelines
	Navigational hazards – obstruction to visibility (SOLAS chapter V), navigation lighting, radar blind spots	

EETs	Barrier/Gap	Recommendation
	Convention on the International Regulations for preventing collisions at sea, 1972, may need to be aligned to include this new technology.	
	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 spots that are caused.	

EETs	Barrier/Gap	Recommendation
Lithium-Ion Batteries	There is a lack of guidance on the safe design of lithium-ion battery installations on ships, including fire-fighting requirements suited to lithium-ion battery technology. Furthermore, continuous technological development make it difficult to draw up requirements for batteries that may become obsolete in a short period of time.	Develop requirements for the Safety of Ships Using Lithium-ion Battery Installations, to include fire-fighting requirements suited to lithium-ion battery technology. Requirements should be developed that are goal-based, and flexible to adjust to the technology as it evolves. Note: For Interim Guidelines, consider a "technology neutral" approach, e.g. "Interim Guidelines for the Safety of Ships Using Battery Energy Storage Systems" With "same structure as IGF Code" --> High level goal-based generic requirements and separate technology specific set of requirements for e.g. for Lithium-Ion battery technologies, Supercapacitor energy storage technologies, Sodium-Ion battery technologies etc. Also: Consider combining with requirements for supercapacitor energy storage technology under new Interim Guidelines for the Safety of Ships Using Battery Energy Storage Systems.

Supercapacitors	The following requirements for supercapacitors are not specified in the SOLAS Convention, FSS Code or other regulations: • 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 or blackout).	Develop requirements for supercapacitor energy storage systems, to address at a minimum the following safety related aspects: • definition and classification for supercapacitor space (to define as Machinery Spaces of category A or other machinery spaces). • supercapacitor space arrangement (fire and smoke containment, structural fire protection, fire-extinguishing systems, ventilation, combustible gas detection and alarm systems, as applicable). • system redundancy (i.e., design criteria for systems to remain operational after a fire, casualty or blackout). • supercapacitor chargers/converters. • supercapacitor cells/modules. • Capacitor Management System (CMS). Note: Consider combining with requirements for Lithium-ion battery installations under new Interim Guidelines for the Safety of Ships Using Battery Energy Storage Systems.

EETs	Barrier/Gap	Recommendation
	• Definition and classification for supercapacitor space (to define as Machinery Spaces of category A or other machinery spaces).	
Air lubrication	No FSA has been carried out according to our knowledge	Recommend that MSC solicit interested Member States or organizations to conduct an FSA for the use of air lubrication systems on ships, in accordance with MSC-MEPC.2/Circ.12/Rev.2, and provide their results to the Committee for consideration. Results to be evaluated by SDC, with recommendations to MSC. Note: views are split on whether and FSA is even necessary.

EETs	Barrier/Gap	Recommendation
Advanced waste heat recovery	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. May require standards for low flash point circuit media if used.	Develop safety requirements for Advanced Waste Heat Recovery Systems [for Generation of Electricity] that at a minimum address the risks of possible flammability and toxicity hazards due to the circuit media used in the system, taking into account the flashpoint of the circuit media.
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	Consider whether amendments are needed to the IMDG Code for the storage and transport of CO2 resulting from onboard carbon capture and storage systems on ships, taking into consideration the physical characteristics and possible ways that the CO2 may be classified. Develop appropriate IMDG Code amendments if needed. Note: this should be done in the context of developing safety requirements for onboard carbon capture and storage systems on ships – see gap G-34.
	No regulation in place	Develop safety requirements for onboard carbon capture and storage systems on ships.

EETs	Barrier/Gap	Recommendation
Onshore Power Supply / Cold Ironing	Lack of standardization in port infrastructure	Develop requirements for Onshore Power Supply/Cold Ironing that at a minimum address standardization in port infrastructure and of compatibility between ship and shore power systems (e.g., different frequency, voltage, plugging arrangements etc.).
	Power Supply frequency Lack of compatibility between ship and shore power systems (e.g., different frequency, voltage, plugging arrangements etc.) Lack of IMO requirements	The following relevant international standards should be considered for reference in developing new requirements: • IEC/IEEE 80005-1 International Standard – Utility connections in port — Part 1: High voltage shore connection (HVSC) systems — General requirements. • IEC/IEEE 80005-2 International Standard - Utility connections in port -- Part 2: High and low voltage shore connection systems -- Data communication for monitoring and control. • IEC/IEEE 80005-3 Draft International Standard - Utility Connections in Port - Part 3: Low Voltage Shore Connection (LVSC) Systems - General Requirements.

5 Conclusions

Although often overlooked in global maritime regulatory discussions, the inland waterway transport sector is becoming a key part of the European Union's green transition. EU regulatory frameworks such as the NRMM standards, CountEmissionsEU and EU Taxonomy are pushing for better air pollutant emission limits, GHG emissions monitoring, and more sustainable investments. The CDNI Convention, with its fuel consumption monitoring, helps to estimate the greenhouse gas emissions of the sector. The ES-TRIN standard already covers the use on board crafts of fuel cells and methanol and will be extended in 2027 to include other alternative fuels. Strategies and projects such as NAIADES III and Platina4Action (P4A) are working on a labelling system to improve inland vessel design from the outset. The possibility of applying regulatory exemptions for pilot projects shows that the sector is open to experimenting with new technologies. However, the typical 24 to 36-month approval periods by CCNR or the European Commission for the adoption of new technologies can still slow down their practical deployment, highlighting the need for faster regulatory adaptation to match the pace of innovation.

Compared to the maritime sector, which is already subject to binding GHG reduction measures under IMO and EU rules (e.g., FuelEU Maritime, EU ETS, CII), the IWT sector is still in an earlier phase of regulatory development. However, despite being smaller and not yet covered by specific GHG limits, it is accelerating towards a zero-emission fleet, driven by innovation, evolving standards, and EU support.

In the maritime sector, on the other hand, IMO and EU decarbonization measures have been based on different approaches:

- IMO requires ships to comply with mandatory MARPOL Annex VI, or ships will not be allowed to operate
- EU imposes payment for equivalent CO2 emissions and penalties for non-compliance - the principle of "polluter pays“.

The different measures make it challenging to identify the best compliance solutions and these uncertainties limit the investments in new technologies.

- EU measures only affect traffic to/from/within the EU resulting in market distortions and loss of competitiveness.
- In IMO and EU regulations there are implementation aspects still unclear, leaving room for interpretation, preventing a clear understanding for shipbuilders and operators.

- A uniform approach must be agreed at IMO, to avoid each Administration making different decisions, introducing disparities in treatment for ships flying different flags.
- Alternative fuels, to be managed safely, require a much higher level of preparation and competence. It is crucial to develop rules for training and education of crews.
- Technical and/or economic measures are to be matched against the availability of alternative fuels, new technologies and engines at affordable prices.
- Funds collected through economic measures should be used to incentivize innovation, promote R&D projects, and finance infrastructure for alternative fuels. Part of the EC Innovation Fund - funded by the proceeds from EU ETS – will be allocated to support decarbonization of the maritime sector

Finally, regulatory gaps contribute to the uncertainty about EET, which delays their adoption and uptake. Regulatory bodies, i.e. IMO and the EU, provide a wider regulatory framework, with a limited consideration of implementation aspects. This uncertainty limits the early market confidence in alternative EET, indirectly favouring incumbent fossil technologies with a more established regulatory landscape. Prescriptive regulations could potentially tackle this limitation, although their effect on technological development and market dynamics would require further investigation to balance technological neutrality with an acceleration in decarbonisation technologies uptake.

The regulatory and policy mapping performed in Task 3.1 has highlighted the key compliance drivers, technical constraints, and standardization gaps relevant to the deployment of EETs across maritime and inland navigation sectors. This gap analysis serves as a baseline for assessing the technical feasibility and regulatory alignment of the ten (10) distinct Use Cases (UCs) to be defined in Task 3.2. Building on the findings of this task, Task 3.2 will establish a structured framework for each use case, covering both retrofit options for vessel designs and newbuild configurations. Particular attention will be paid to ensure short or mid-term uptake of the EETs, in line with the expectations of the EU “Fit for 55” legislative package. The alignment with policy objectives and identified compliance gaps will directly inform the definition of relevant data inputs, operational profiles, and integration pathways, paving the way for subsequent evaluation in Task 3.3 and the detailed engineering activities in WP4.

6 Bibliography

MEPC80/INF.17. (2023). *Reduction of GHG emissions from ships: Regulatory mapping of alternative marine fuels* . IMO.

MSC108/5. (2024). *Development of a safety regulatory framework to support the reduction of GHG emissions from ships using new technologies and alternative fuels.* IMO.