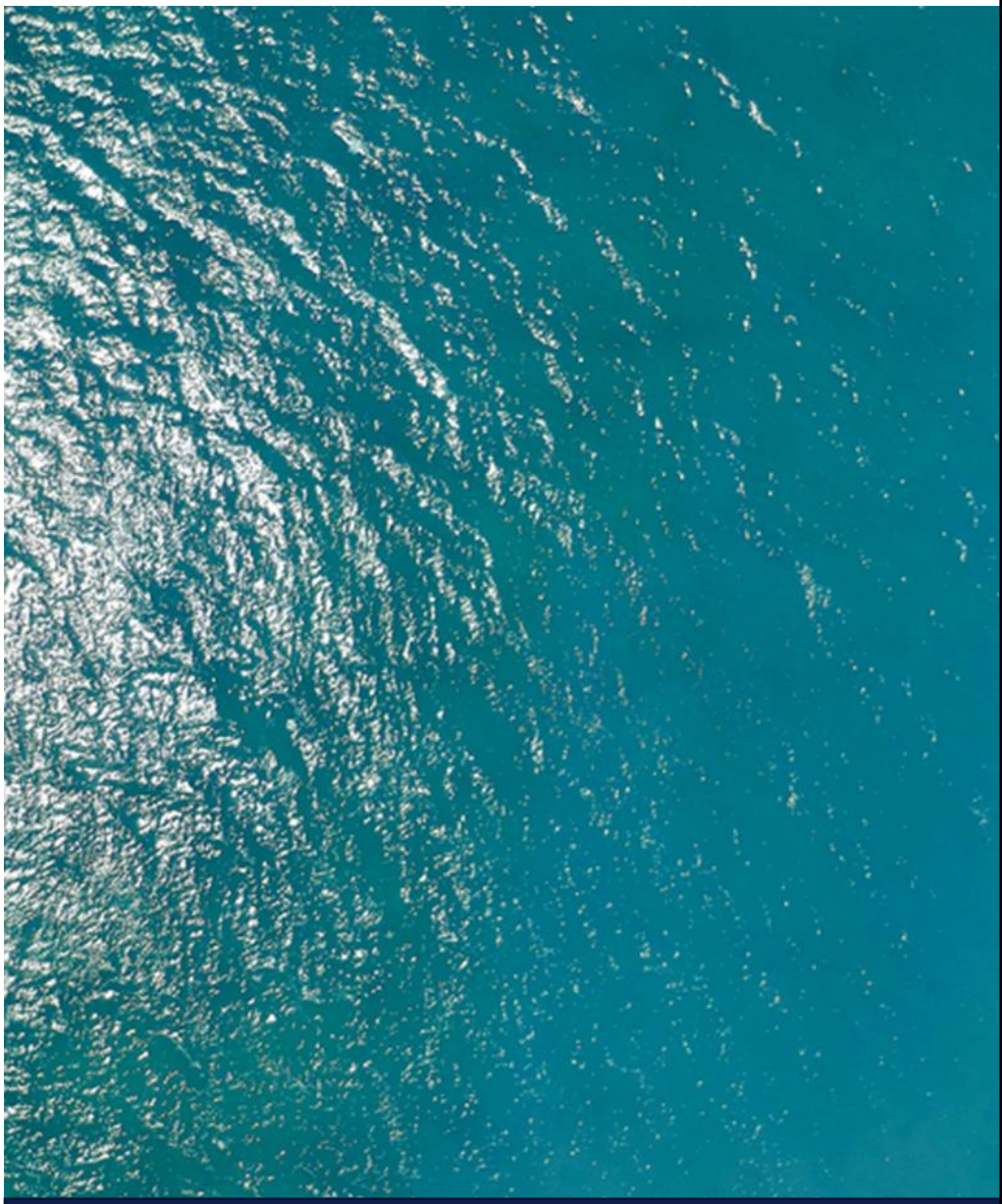
DNV

WHEN TRUST MATTERS

# MAPPING OF SEAFARER COMPETENCE ON LOW/ZERO-EMISSION SHIPS



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# CONTENT



# EXECUTIVE SUMMARY

## KEY TAKEAWAYS

1. More work is needed to codify the exact competence requirements for seafarers using ammonia, methanol and hydrogen as fuels
2. Competence gaps exist between conventional and alternative fuels in terms of the specific characteristics and technical systems of each fuel
3. Future competence requirements should cover each fuel specifically and include tangible STCW competence tables
4. Risk assessments of specific fuel systems should cover seafarer competence needs and requirements
5. Non-technical skills such as decision-making, leadership and situational awareness complement technical skills
6. Maritime institutions and regulatory bodies should consider the framework and requirements for competencies required for future seafarers
7. Other industries using ammonia, methanol and hydrogen should be considered for aligning competence requirements and training
8. The organisational level plays an important role in facilitating competence and safety culture development
9. Seafarers' awareness of safety and risk should be enhanced during the fuel transition
10. Seafarer competence is central to a safe transition and the implementation of alternative fuels

### BACKGROUND

The maritime sector has the ambition to decarbonise and reduce its GHG emissions, which account for approximately 3% of the global total /1/. To achieve this goal, the sector is gradually adopting new alternative fuels that can offer lower or zero carbon emissions compared to conventional marine fuels, such as heavy fuel oil and marine gas oil. However, these new fuels also pose new safety risks and challenges for the shipping industry, as they have different physical and chemical properties than conventional fuels and may require special storage and fuel systems.

### OBJECTIVE

The Zero-Emission Shipping Mission's objective of this report is to map seafarers' skills and competencies required to safely manage and operate vessels utilising ammonia, methanol or hydrogen as a fuel while drawing a comparison to existing competency requirements.
This mapping is achieved by conducting a literature review and comparing findings to current seafarer competencies, especially the IGF code and STCW convention.

### STCW COMPETENCE

Competence requirements for seafarers today are generally split between the support, operational and management roles. The STCW code lists general seafarer requirements in respective competence tables /2/. The IGF code requires seafarers on IGF code vessels to be competent as per STCW Code, Section A-V/3 /3/. This code provides specific information on the basic and advanced competence requirements for seafarers serving on vessels using gases or other low-flashpoint fuels. The relevant provisions in the IGF code as well as STCW Table A-V/3 may be used to define the relevant competency requirements related to the safe use and the management of future alternative fuels such as ammonia, methanol, and hydrogen.

The competence needs, as drawn from the outlined LNG competence requirements, show that seafarers sailing on ammonia, methanol and hydrogen fueled vessels may need the following general competencies:

1. Specific understanding and awareness of the characteristics of the fuel used, along with health and safety risks
2. Technical competence related to new systems:
    a. Storage, supply and transfer
    b. Monitoring and ventilation
    c. Safety and auxiliary systems
    d. Bunkering systems
    e. Tank preparation, inerting, cooling down and gassing up
    f. Contingencies
3. System barriers (i.e. detection of deviations/failures, monitoring and maintaining functionality of barriers)
4. Additional competencies related to operation, maintenance and calibration of new systems
5. Non-technical skills related to the increased, new or altered risks of operating with new alternative fuels

### NON-TECHNICAL SKILLS

The introduction of these novel fuels establishes additional or altered hazards. Competence needs and requirements should therefore not only reflect technical skill, but also non-technical or "soft" skills. Non-technical and technical skills should be approached together for any competencies related to alternative fuels as a high level of non-technical skills benefit technical skills.


| CATEGORY | THE SEAFARER SHOULD BE COMPETENT IN: |
|---|---|
| **GENERAL** | • The applicable rules and regulations of the alternative fuel<br>• The physics, chemistry, properties, and characteristics of the alternative fuel<br>• Monitoring, operation, maintenance, and calibration of relevant (new) systems/equipment<br>• Risk-understanding of additional hazards of the alternative fuel towards personnel, material, and the environment<br>• Ignition source control |
| **STORAGE** | • Procedures for tank storage, maintenance, operation, inspection and understanding<br>• Operation and maintenance procedures of pumps and valves regarding the fuel supply system |
| **MONITORING** | • The monitoring of fuel systems and interpretation of sensors/alarms<br>• Troubleshooting and fault-finding for fuel systems<br>• Gas/leak detection<br>• Enclosed space entering, such as Fuel Preparation Rooms |
| **VENTILATION & LEAKS** | • The use of ventilation and monitoring of pressure in fuel tanks in terms of safety<br>• Inspection and leak-testing of piping<br>• Vapor control<br>• Monitoring and handling of toxic/explosive atmospheres and trapped liquid |
| **AUX. EQUIPMENT** | • Operation and maintenance of inerting, purging, cooling down, vaporising, and drying systems<br>• Operation and maintenance of water curtain system |
| **TRANSFER/BUNKERING/ HANDLING** | • Procedures for transfer and bunkering of the alternative fuel<br>• Emergency procedures for transfer/bunkering |
| **TANK CONDITIONING** | • Procedures and skills for the conditioning of fuel tanks |
| **EMERGENCY** | • Contingency plan implementation<br>• Vessel orientation, positioning in emergencies<br>• Emergency procedures<br>  • Spills & leaks<br>  • Fires & explosion<br>  • Vapor exposure & toxicity<br>• Emergency shutdown<br>• Emergency unloading/transfer<br>• Emergency discharge/release<br>• Emergency separation<br>• Local rules/regulations |
| **NON-TECHNICAL** | • Tanker safety mindset – strong safety culture & sense of ownership<br>• Situational awareness, decision-making, communication, and leadership |

# 1 BACKGROUND AND OBJECTIVE

## BACKGROUND

The maritime sector has the ambition to decarbonise and reduce its GHG emissions, which account for approximately 3% of the global total. To achieve this goal, the sector is gradually adopting new alternative fuels that can offer lower or zero carbon emissions compared to conventional marine fuels, such as heavy fuel oil and marine gas oil /1/. Some of the most promising alternative fuels are ammonia, methanol, and hydrogen, which can be produced from renewable sources. However, these new fuels also pose novel safety risks and challenges for the shipping industry as they have different physical and chemical properties than conventional fuels and may require special storage and fuel systems.

The transition to carbon-neutral fuels will not only require a technological shift but introduce additional competence needs for both seafarers and onshore organisations within the maritime industry. This includes understanding the properties and hazards of these fuels, the best practices for storage, transfer, usage, and the appropriate emergency response procedures in case of accidents or incidents. The transition will require changes in the regulatory framework and training programs for the maritime workforce.

Regardless of the specific fuels and technologies ultimately employed, it is crucial to provide additional competence and training to seafarers. Sufficient competence is essential to guarantee their safety, as well as that of others and the environment. Increased seafarer competency in alternative fuels benefits the safety and operation of vessels using these fuels in the future.

## OBJECTIVE

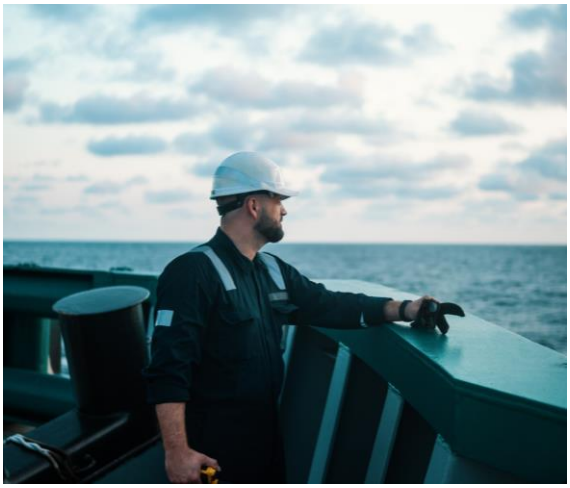
The objective of this report is to map seafarers' skills and competencies required to safely manage and operate vessels utilising ammonia, methanol and hydrogen as a fuel while drawing a comparison to existing competency requirements.

## PROJECT & STAKEHOLDERS

The Zero-Emission Shipping Mission under Mission Innovation is an international public-private partnership with Denmark, Norway and the USA. It is co-lead by them together with the private sector, namely the Global Maritime Forum and Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping.

The aim of the Mission is to accelerate innovation in the shipping sector to make the sector sustainable and fully decarbonised by 2050. This mapping of seafarer competence is part of the project "Safety of Crew in Low/Zero Emission Ships" in collaboration with the Danish Maritime Authority (DMA).

ZERO-EMISSION SHIPPING MISSION



# 2 METHODOLOGY

## APPROACH

This study maps the competencies seafarers may require when operating ships using ammonia, methanol or hydrogen as a fuel. The mapping is achieved by conducting a literature review and comparing findings to current seafarer competencies, especially the IGF code and STCW convention. The focus is on existing identified competency requirements and needs, although future competence needs are briefly covered.

While this mapping may provide an overview of competence needs and requirements regarding alternative fuels, adequate risk assessments of each fuel/system would reveal clear and specific competence needs for that specific fuel/system.

## SCOPE

The scope of this report is limited to competence needs and requirements regarding safety for seafarers on sea-going flagged vessels, as per vessels that fall under the STCW convention.

A distinction is made between *competence needs* and *competence requirements*, whereby requirements are currently compulsory for seafarers through regulation. Needs are necessary, but not compulsory. The competence needs and requirements in this report are limited to ammonia, methanol and hydrogen fuel systems in their existing plausible technology forms, including operation and bunkering. Existing competence requirements that serve as a comparison to the mentioned alternative fuels are limited to LNG as a fuel, as per the IGF code and STCW Table A-V/3.

## PROCESS

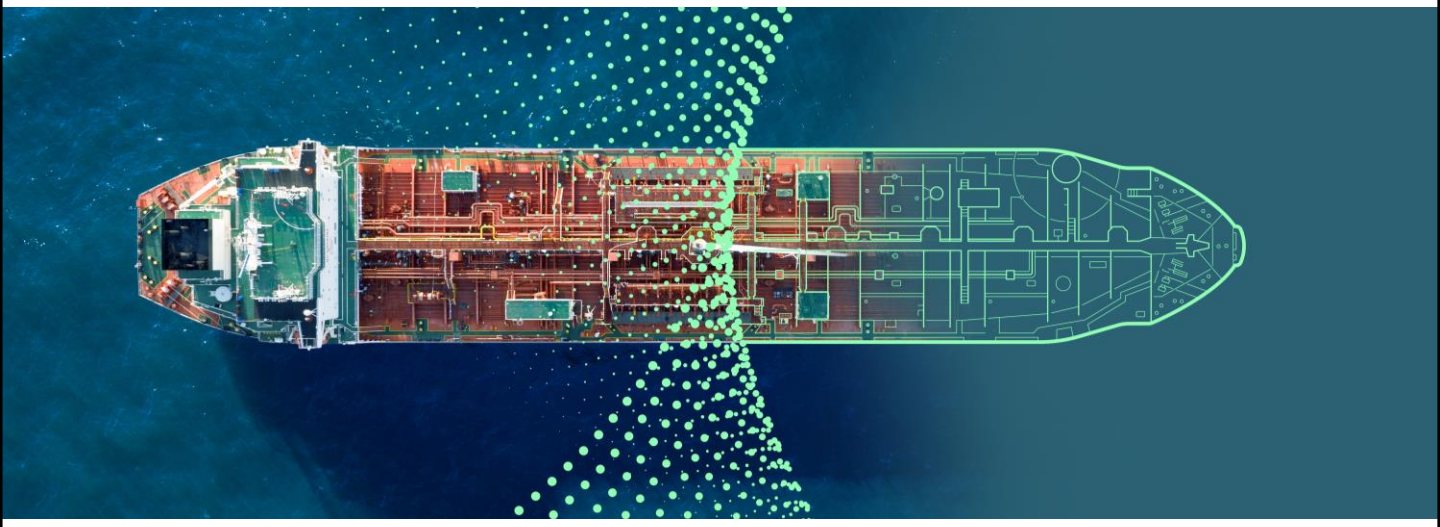
**Literature Review**
- Previous Reports/Studies
- International Regulations
- Class Guidelines/Rules
- Academic Research

**Analysis**
- Map current competence requirements
- Extract competence requirements for:
  - Ammonia
  - Methanol
  - Hydrogen
- Identify other competence needs

**Conclusion**
- Compare and combine competence needs

# 3 CONCEPT DEFINITIONS

| Term | Definition |
|---|---|
| **Alternative Fuels** | Alternative fuels are fuels not commonly used in the maritime sector. They are generally considered to cover low/no-carbon emission fuels. In this study ammonia, methanol and hydrogen are the alternative fuels covered. |
| **Certificate of Competency** | A certificate issued and endorsed for deck officers and engineering officers in accordance with the provisions of the STCW chapters II and III. It entitles the lawful holder thereof to serve in the capacity and perform the functions involved at the level of responsibility specified therein, issued by the respective maritime administrations. |
| **Certificate of Proficiency** | A certificate, other than a certificate of competency issued to a seafarer, stating that the relevant requirements of training, competencies or seagoing service in the Convention have been met, issued by the respective maritime administrations. |
| **Competence** | In a maritime context, 'competence' is a demonstrable attribute including (but not limited to) a person's knowledge, ability/skills to perform specific tasks, decision-making, analytical ability, problem-solving, attitude etc. |
| **IGF code** | International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels |
| **Maritime Education & Training** | Maritime education and training (MET) is an educational system that aims to provide trained and competent seafarers for merchant vessels. MET covers various aspects of maritime operations, such as navigation, engineering, safety, security, and environmental protection. This training is conducted at MET centers that are regulated nationally and under the IMO. |
| **Non-Technical Skill** | Cognitive/social skills, such as situation awareness, leadership, decision-making etc. An example of this could be situation awareness: the perception of environmental elements, understanding their meaning, and anticipating their future status for effective decision-making. |
| **STCW** | The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers. |



# 4 LITERATURE REVIEW

Competence needs and requirements were mapped through a literature review. Competence needs were generally covered by academic literature and previous industry studies/reports, while competence requirements were generally covered by international regulations and class guidelines/rules/standards.

| Report | Year | Author | Summary |
|---|---|---|---|
| **Ammonia as a Marine Fuel Safety Handbook** | 2023 | DNV, GSP, NMA | Practical information handbook, covering use and safety concerns of Ammonia |
| **DNV Maritime Forecast 2050** | 2023 | DNV | General forecast on transition within the maritime industry |
| **Future Fuel for Shipping – State of Play** | 2022 | Nordic Roadmap | Presents Status Quo of the current regulatory and technical basis for alternative fuels in the Nordics |
| **Future Skill and Competence Needs** | 2020 | Skillsea | State of the art on seafarer competence and training towards adoption of alternative fuels |
| **Insights into Seafarer Training and Skills Needed to Support a Decarbonized Shipping Industry** | 2022 | DNV/Maritime Just Transition Task Force | An initial assessment of the impact decarbonization of the international shipping industry will have on crewmembers |
| **Mapping a Maritime Just Transition for Seafarers** | 2022 | Maritime Just Transition Task Force | An initial assessment of the impact decarbonisation of the international shipping industry will have on upskilling of seafarers towards 2050. |
| **MarHySafe - Hydrogen safety handbook** | 2021 | JDP with DNV & NMA | Practical information handbook, covering use and safety concern of Hydrogen |
| **Maritime Safety Trends 2012-2022: Advancing a Culture of Safety in a Changing Industry Landscape** | 2023 | DNV/LLI | Covers general themes on the role of safety during the transition of the maritime industry |
| **Operational Management to Accelerate Safe Maritime Decarbonization** | 2023 | Maritime Technologies Forum | Recommendations and gap identification on the safe adoption of alternative fuels |
| **Recommendations for Design and Operation of Ammonia-Fueled Vessels Based on Multi-disciplinary Risk Analysis** | 2023 | Lloyds Register | Investigating the risks and safeguards to be implemented on ammonia fueled vessels |

| Guideline/Rule/Standard | Class Society | Summary |
|---|---|---|
| **DNV-ST-0026** | DNV | Defines expected competencies of crew on LNG-fueled vessels |
| **DNV-ST-0010** | DNV | Defines expected competencies of crew on LNG carriers |

| Regulation | Body | Summary |
|---|---|---|
| **IGF Code** | IMO | Rules for vessels using low-flashpoint fuels, generally used as a reference for alternative fuels such as Ammonia, Methanol and Hydrogen. |
| **ISM Code** | IMO | International standard for the safe management and operation of ships and for pollution prevention |
| **MSC.1/Circ. 1621** | IMO | Interim Guidelines for the safety of ships using Methyl-Ethyl Alcohol (Methanol) as a Fuel |
| **SN-CWA 17540:2020** | CEN | Specification for bunkering of methanol fueled vessels |
| **SOLAS** | IMO | Sets minimum safety standards for construction of ships |
| **STCW Convention** | IMO | Describes which basic training which shall be completed as well as which training is required for seafarers responsible for designated duties. |
| | IMO | Chapter 5, regulation V/3, states qualification and training requirements for seafarers serving on ships subject to the IGF code |

| Paper | Author | Year | Summary |
|---|---|---|---|
| **A study on the developments of STCW training of seafarers on ships applying in the IGF Code** | Se-Hyun Han & Young-Chan Lee | 2015 | This study reviews the STCW Convention and training courses for seafarers on LNG-fueled ships, which are subject to the IGF Code, and proposes ways to design new courses and improve the STCW Convention. |
| **Competency Standards for Emerging Hydrogen Related Activities** | Richard Skiba | 2020 | This paper covers the possible activities related to hydrogen and the competencies/training workers may need. |
| **Hybrid propulsion and alternative fuels education in the course of decarbonized shipping** | Omer Berkehan Inal et al. | 2021 | The study investigates marine engineering education on alternative fuels and hybrid propulsion for seafarers |

# 5 COMPETENCE MAPPING

## 5.1 GENERAL COMPETENCE REQUIREMENTS

Competence requirements for seafarers fall under IMO's STCW convention, which is implemented through national provisions. The IMO sets the minimum level of competency /2/. Respective maritime administrations may go further than this minimum. The training of seafarers to reach the required level of competency is completed through maritime education & training (MET) at respective MET centres. Their curriculum is certified nationally but complies with the respective STCW regulation as a minimum (or higher). The national maritime administration will issue a Certificate of Proficiency when the training requirements have been met. Competence requirements are generally split between the support, operational and the management level.

The STCW code lists general seafarer requirements in respective competence tables. The below table gives some examples related to general fuel safety regarding the minimum standard of competence of a second engineer on a vessel powered by main propulsion machinery of 3,000kW, as specified by the STCW code Table A-III/2. These STCW tables also specify the competence, underlying knowledge, method for demonstrating competence and criteria for evaluating competence.

These existing competencies may serve as a foundation for additional or altered competencies required with the transition to ammonia, methanol and hydrogen.

## 5.2 COMPETENCE REQUIREMENTS IGF CODE

The IGF code provides mandatory provisions for the arrangement, installation, control and monitoring of machinery, equipment and systems using low-flashpoint fuel. The goal being to minimise the risk to the ship, its crew, and the environment, regarding the specific nature of the fuels involved. The STCW code requires seafarers working onboard ships subject to IGF code to be minimally competent as per the STCW Code, Section A-V/3. This code provides specific information on the basic and advanced competence requirements for seafarers serving on vessels using gases or other low-flashpoint fuels /3/.

STCW Table A-V/3 may be used as a basis to define the relevant competency requirements related to the safe use and management of future alternative fuels such as ammonia, methanol, and hydrogen.

There are currently no IMO regulations specifically covering competence requirements for vessels using ammonia or hydrogen, although there are regulations covering these fuels as cargo.

The IMO refers to the IGF code's competency requirements for methanol as a fuel via the IMO's interim guidelines on methanol. References are made to the competency requirements of LNG, taking the differences of methanol and LNG into account /4/.

While the IGF code focusses on LNG as a fuel, it also covers low-flashpoint fuels, this together with the IMO's alternative design process means that most vessels being designed to use ammonia and hydrogen as a fuel use the IGF code as a basis for equivalency /5/.

**STCW General Competence Requirements Summary – Second Engineer**

- Manage the operation of propulsion plant machinery
- Plan and schedule operations
- Operation, surveillance, performance assessment and maintaining safety of propulsion plant and auxiliary machinery
- Manage fuel, lubrication, and ballast operations
- Manage operation of electrical and electronic control equipment
- Manage troubleshooting, restoration of electrical and electronic control equipment to operating condition
- Manage safe and effective maintenance and repair procedures
- Detect and identify the cause of machinery malfunctions and correct faults
- Ensure safe working practices
- Control trim, stability, and stress
- Monitor and control compliance with legislative requirements and measures to ensure safety of life at sea, security and protection of the marine environment
- Maintain safety and security of the vessel, crew and passengers and the operational condition of lifesaving, fire-fighting and other safety systems
- Develop emergency and damage control plans and handle emergency situations
- Use leadership and managerial skills

## 5.3 DNV TAXONOMY AND LNG COMPETENCE STANDARD

Competencies specified in STCW Table A-V/3 are covered by DNV standard 0026 (DNV-ST-0026) /6/. This standard focuses on specific competencies for LNG as a fuel. These competence requirements are summarised in section 5.4 and are split into categories:

- A – Basic: Basic competence for all officers/crew, regardless of role or function
- B – Deck: Competence requirements for deck officers / operational deck crew
- C – Engine: Competence requirements for engine officers / operational engine crew

Additionally, the DNV standard utilises a taxonomy for defining the type and level of professional behaviour a crewmember is meant to operate at for each competency. These consecutive levels are:

1. Knowledge – to remember or reproduce
2. Understanding – to give meaning to new situations or new material
3. Application – to use information in new and concrete situations to solve problems
4. Integration – to analyse, synthesise and evaluate information

The application of this taxonomy and categories goes beyond the scope of this study but helps understand the foundation of the competencies. Refer to DNV-ST-0026 for details.

The IGF code competencies for LNG as a fuel outlined in section 5.4 are very specific in the competencies required. These could serve as a starting point for developing competencies for operating with alternative fuels.

## 5.4 IGF CODE COMPETENCIES (LNG EXAMPLE)

### COMPETENCE REQUIREMENTS FOR LNG

#### General

General knowledge and understanding of LNG as a fuel, including but not limited to:

- Characteristics of LNG
- Terms such as: rapid phase transition, dew point, bubble point, boil off gas & vapour buoyancy
- Applicable rules and regulations

Risk awareness, health, and safety, including but not limited to:

- Interpret safety data sheet
- Hazards of handling LNG
- Risk of expanding trapped liquid
- Risk of Joule-Thomson effect
- Medical treatment of LNG exposure
- Cryogenic properties of LNG and its effect
- Use of PPEs and safety equipment related to LNG
- Effects of LNG discharge
- Risks of entering nitrogen and cryogenic spaces

#### LNG Storage

LNG Storage Tanks:

- Construction and different types of tanks used with LNG
- Layout and operation of tank system
- Detection of leaks
- Tank pressure holding times
- Hold space atmosphere monitoring
- Tank cooling

Inspection and monitoring of LNG storage:

- Perform inspections
- Remote monitoring
- Operate valves

Bunker transfer:

- Functioning of drip-trays and keeping them water free
- Bunkering procedures (including cool-down procedure)
- Operation of equipment
- Understanding of limitations (movement, loads, pressure etc.)
- Effect of bunkering storage pressure on bunkering (pressurised/atmospheric)

Tank Connection Space:

- Understanding of its functioning and the increased risk of gas leakage
- Safe working procedures

Pressure Control, Temperature Monitoring and Level Gauging:

- Monitoring and Control equipment
- Inspections, tests, checks, maintenance, and calibration
- Interpretation of alarms and readings

## 5.4 IGF CODE COMPETENCIES (LNG EXAMPLE) Cont.

**Gas Supply System**

- Repairs and Exchanging Parts
- Operation/maintenance cryogenic Valves and Pumps
- Operation/maintenance of gas isolation valves (double block / bleed arrangement)

Cool-down procedure and operation/maintenance of pumps:

- High pressure pumps
- In-tank pumps
- Spray pumps

**LNG Monitoring System**

- Control/monitoring system
- Troubleshooting and fault finding
- Vapour control

**Venting and Ventilation**

- Negative and positive pressure use in various areas
- Use of air locks
- Negative pressure in gas dangerous areas
- Monitoring of ventilation equipment and pressure conditions

Double-walled piping:

- Inspection and leak tests
- Assembly/dis-assembly
- Maintenance

Fuel gas venting system:

- Hazardous zones at vent outlets
- Handling of ignited vents
- Safety vent releases
- Explosive atmosphere monitoring
- Trapped liquid procedures

**Compressors**

- Operation and maintenance
- Dissolved gas in lubrication oil understanding

**Safety Systems and Components**

- Operation, maintenance, and calibration of (portable) gas detection system

Emergency Shutdown:

- Operation, consequences, and triggers
- Inspection and maintenance of ESD valves
- Emergency shutdown tests
- Operation/maintenance of safety relief valves, fire detection system and gas detection system
- Operation/maintenance of EX-certified equipment

**Auxiliary Systems**

- Operation/maintenance of inert gas generator
- Operation/maintenance of Nitrogen generator
- Nitrogen injection and purging
- Distribution of Nitrogen
- Operation of air and inert dryers
- Tank conditioning methods: inerting and drying
- Operation, monitoring and adjustment of gas heaters
- Operation of a forcing vaporiser
- Operation of an LNG vaporiser
- Adjust vaporiser settings to protect from freezing
- Operation and maintenance of water curtain
- Air quality control

**Bunkering**

- Bunkering preparations
- Procedures for bunker transfer
- Bunker calculations
- Shore connections

- Emergency procedures:
- Emergency shutdown procedure
- Emergency release
- Emergency breakout operation

**Tank Conditioning**

Procedures for:

- Warming up
- Gas freeing
- Inerting
- Purging
- Cooling down

**Warm Up / Heating**

- Set temperature & flow distribution of glycol intermediate circuit
- Functioning of heating system
- Overpressure protection related to heating system

**Contingencies**

- Contingency plan implementation
- Vessel orientation, positioning
- Emergency procedures
  - LNG spill
  - LNG leak
  - LNG fire
  - Emergency shutdown
  - Emergency unloading/transfer of LNG
  - Emergency discharge/release
  - Emergency separation
- Local rules/regulations

## ONWARDS FROM LNG COMPETENCE

While highly relevant for future competence specifications, LNG requirements needs additional input specific to the alternative fuels:

1. Specific understanding and awareness of the characteristics of the fuel used, along with health and safety risks
2. Technical competence related to new systems:
   a. Storage, supply and transfer
   b. Monitoring and ventilation
   c. Safety and auxiliary systems
   d. Bunkering systems
   e. Tank preparation, inerting, cooling down and gassing up
   f. Contingencies
3. System barriers (i.e. detection of deviations/failures, monitoring and maintaining functionality of barriers)
4. Additional competencies related to operation, maintenance and calibration of new systems
5. Non-technical skills related to the increased, new or altered risks of operating with new alternative fuels

## 5.5 ALTERNATIVE FUEL COMPETENCIES

The advent of alternative fuels such as ammonia, methanol and hydrogen, and a lack of clear competency requirements thereof is a concern for the future adoption of said fuels. The additional hazards that may be introduced with these new fuels could require more competence of seafarers. These fuels can be utilised via internal combustion engine (ICE), with engines either on or soon entering the market. Fuel cells (FC) are also a possibility but remain a novel technology that requires development. The fuel systems feeding the ICEs or FCs would remain similar for either method of utilisation and thus, their required competencies too. This section maps available previously identified competence requirements for ammonia, methanol and hydrogen /1/.

### STATE OF REGULATION

The Nordic Roadmap (No. 1-B/1/2022) provides a thorough overview of the onboard regulations and regulatory frameworks for ships intended to use methane, methanol, hydrogen or ammonia as a fuel /7/. It lists several documents published by the IMO, relevant standards, and best practices, as well as relevant R&D projects and reports. The document also explains the regulatory status per fuel relevant to the IGF code, as described in the below figure.

Currently, the IMO has no guidelines for ammonia and hydrogen as a fuel, but methanol have interim guidelines. There are ongoing processes for interim guidelines for the safety of ships using both ammonia and hydrogen as fuel however, these are not yet formal publications.

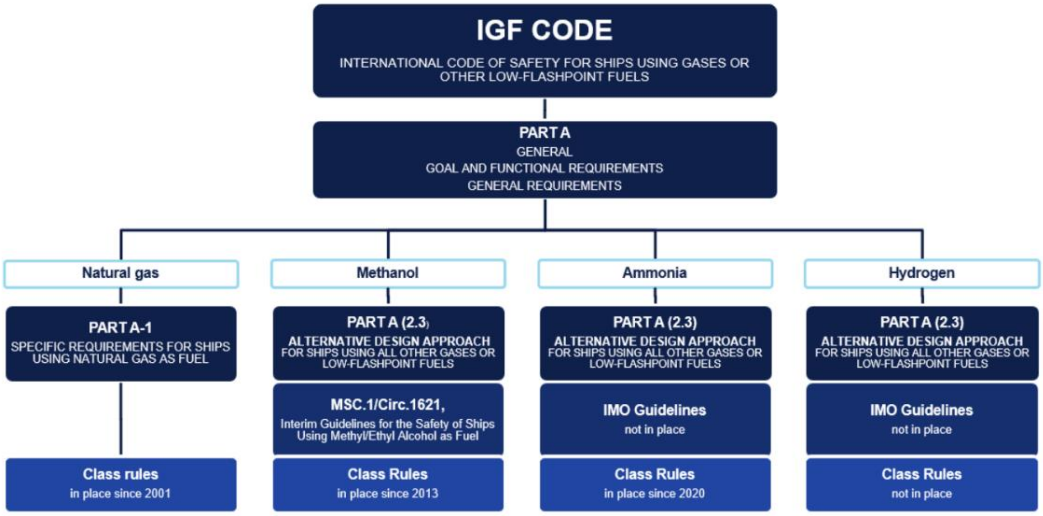
The lack of guidelines makes it difficult to grasp the competence requirements for seafarers for these fuels from a regulatory perspective.

The interim guidelines (MSC.1/Circ.1621) for methanol, state that competence requirements related to methanol as a fuel should refer to the competence requirements within the IGF and STCW Code, Section A-V/3. While considering the specific characteristics of methanol. This approach is likely to be repeated for ammonia and hydrogen, although the IGF code should not be seen as a failsafe solution.

### NON-TECHNICAL COMPETENCIES

Competence needs and requirements should not only reflect technical skill, but also non-technical or “soft” skills. These cover competencies such as situation awareness, risk assessment, control/status of barriers and scenario-based training. Non-technical and technical skills should be approached together for any competencies related to alternative fuels /9/.

Non-technical skills complement the application of technical skills and assist in “out of the box” thinking. Connecting safety risks to technical solutions. Poor non-technical skills are detrimental to the application of technical skills. While strong non-technical skills benefit them. These non-technical skills should be seen as valid competence needs for seafarers operating with ammonia, methanol and hydrogen /9/.



## 5.6 GENERAL CHARACTERISTICS

| AMMONIA | METHANOL | HYDROGEN |
|---|---|---|
| **Description** | | |
| Ammonia is a carbon-free fuel that can be used as fuel in an ICE or FC, and as potential hydrogen storage. It has a high hydrogen density and high energy conversion efficiency. It can be made from renewable energy sources. Its feedstocks, air and water, are abundant and capturing nitrogen from the air is more cost-effective than capturing carbon dioxide. Ammonia is easier and cheaper to transport and store than hydrogen and is generally transported as a liquid /10/. | Methanol is a colourless liquid with high combustibility. It is a popular alternative fuel due to its relative low emissions, compliance with regulations, safe handling, and fuel flexibility. The combustion characteristics of methanol results in lower emissions of sulphur oxides (SOx) and nitrogen oxides (NOx) compared to conventional marine fuels. Furthermore, it can be derived from renewable sources and thereby be classified as a carbon-neutral fuel /11/. | Hydrogen is a carbon-free fuel that can be used as in an ICE or FC. When produced from renewable sources or through electrolysis, hydrogen is a zero-emission fuel. Hydrogen's high energy density makes it a viable option for ships; however, it suffers from low volumetric density, often requiring liquefaction under even lower temperatures than LNG. Hydrogen can also be transported as a pressurised gas or via Liquid Organic Hydrogen Carriers (LOHC). LOHCs are considered out of scope for this study /5/. |
| **Safety** | | |
| • Ammonia is lethally toxic, with exposure to high concentrations leading to severe irritation of the eyes, ears, nose and mouth. With concentrations over 2000 ppm being possibly fatal. Concentrations over 5000 ppm can cause edema, strangulation, asphyxia, and death<br>• Ammonia is less flammable than methanol, hydrogen, and methane with a relatively low flammability range and ignition temperature<br>• Ammonia poses an explosion risk when left to accumulate in enclosed spaces, but this risk is lower than for methanol and hydrogen<br>• Ammonia is generally not cryogenically stored, so the risk of extreme low temperatures is low | • Methanol is toxic and may cause blindness, coma, and death if ingested<br>• As a vapor, methanol is heavier than air and thereby has an increased risk of crew inhalation<br>• At high vapor concentrations methanol can cause asphyxiation<br>• Methanol is extremely flammable and burns with a colourless and smoke free flame at a low temperature, which makes detection difficult<br>• Methanol can generate an explosive atmosphere in air with a temperature higher than 11°C and the risk is especially high when methanol vapour accumulates in enclosed areas | • Hydrogen is a colourless, odourless, and tasteless gas at room temperature/pressure and is thereby difficult to detect<br>• Hydrogen can embrittle components, increasing the likelihood of component failure if the material is not designed for Hydrogen<br>• Liquid hydrogen can cause extreme low temperatures if released, potentially causing liquefaction and solidification of atmospheric oxygen<br>• Hydrogen has low density and high diffusivity, allowing for rapid release on a leak, but can also lead to rapid accumulation of hydrogen in enclosed spaces driven by the leak's momentum<br>• Hydrogen has a high explosion risk as it has a high flammability range, lower ignition energy and high explosion pressure |
| **Competence Regulations & Requirements** | | |
| Ammonia has seen increased interest as a potential alternative fuel, and the maritime industry has experience with Ammonia as a cargo. This fuel type is considered to fall under the IGF code in terms of equivalency, but no specific IMO regulations are available for Ammonia as a fuel. Ammonia systems' high automation and complexity along with the substance's toxicity require special attention. Focus on technical, non-technical, risk-awareness and emergency response specific to Ammonia is essential /12/. | Methanol is seeing a more rapid adoption as an alternative fuel compared to Ammonia and Hydrogen, mainly owing to its relative ease to handle. Regulation covering methanol as a fuel is more mature than that of ammonia and hydrogen. With section 17 & 18 of the IMO's "Interim Guidelines for the Safety of Ships using Methyl/Ethyl Alcohol as Fuel" being the most relevant, along with the IGF code in general and section A-V/3 of the STCW code. Interpretation of section A-V/3 of the STCW code should take the specific characteristics of methanol into account /4/. | Hydrogen, just like ammonia, is considered to fall under the IGF code in terms of equivalency, but no specific IMO regulations are available for hydrogen as a fuel. In addition, the maritime industry has limited experience with hydrogen as cargo /10/. |

# 6 COMPETENCE OVERVIEW

This section will combine the mapped competence requirements of alternative fuels to existing regulations, to produce categorised overarching competence requirements. The IGF code will be relevant for alternative fuels in terms of the same principles, covering segregation, system integrity, double barriers, leakage detection and automatic isolation of system leakages. In addition, other fuel properties like toxicity and flammability/explosiveness will require additional safety barriers, and hence, additional training of seafarers.

To ensure safety at the organisational level, one needs to evaluate and adjust the following aspects: behaviour, processes, competence, learning, goals, and incentives. Moreover, one should use appropriate methods, tools, and indicators to monitor risk, work practices, and safety performance. Organisations should aim to develop a more advanced and proactive safety culture.

The competence requirements covered by the IGF code, which is generally accepted as the nearest equivalent, are summarised, and combined with competence requirements found for the three alternative fuels in the table below. It should be noted that competencies differ depending on one's role on board and the type of fuel. The table below shows the mapped general competencies for seafarers operating with alternative fuels. While these mapped competencies reveal current and possible future needs/requirements, novel fuel systems should consider required seafarer competence in their risk assessments. /2/, /3/, /4/, /9/, /12/, /13/, /14/, /15/.

| CATEGORY | THE SEAFARER SHOULD BE COMPETENT IN |
|---|---|
| **GENERAL** | • The applicable rules and regulations of the alternative fuel<br>• The physics, chemistry, properties, and characteristics of the alternative fuel<br>• Monitoring, operation, maintenance, and calibration of relevant (new) systems/equipment<br>• Risk-understanding of additional hazards of the alternative fuel towards personnel, material, and the environment<br>• Ignition source control |
| **STORAGE** | • Procedures for tank storage, maintenance, operation, inspection and understanding<br>• Operation and maintenance procedures of pumps and valves regarding the fuel supply system |
| **MONITORING** | • The monitoring of fuel systems and interpretation of sensors/alarms<br>• Troubleshooting and fault-finding for fuel systems<br>• Gas/leak detection<br>• Enclosed space entering, such as Fuel Preparation Rooms |
| **VENTILATION & LEAKS** | • The use of ventilation and monitoring of pressure in fuel tanks in terms of safety<br>• Inspection and leak-testing of piping<br>• Vapor control<br>• Monitoring and handling of toxic/explosive atmospheres and trapped liquid |
| **AUX. EQUIPMENT** | • Operation and maintenance of inerting, purging, cooling down, vaporising, and drying systems<br>• Operation and maintenance of water curtain system |
| **TRANSFER/BUNKERING/ HANDLING** | • Procedures for transfer and bunkering of the alternative fuel<br>• Emergency procedures for transfer/bunkering |
| **TANK CONDITIONING** | • Procedures and skills for the conditioning of fuel tanks |
| **EMERGENCY** | • Contingency plan implementation<br>• Vessel orientation, positioning in emergencies<br>• Emergency procedures<br>  • Spills & leaks<br>  • Fires & explosion<br>  • Vapor exposure & toxicity<br>• Emergency shutdown<br>• Emergency unloading/transfer<br>• Emergency discharge/release<br>• Emergency separation<br>• Local rules/regulations |
| **NON-TECHNICAL** | • Tanker safety mindset – strong safety culture & sense of ownership<br>• Situational awareness, decision-making, communication, and leadership |

# 7 FUTURE STEPS & CONCLUSION

**More work needs to be done to codify the exact competence requirements expected of seafarers operating with ammonia, methanol and hydrogen. Mapping competency needs and requirements in general reveals the focus on the technical application of alternative fuels, and a lack of focus on concrete competence and training requirements for seafarers within current regulation. The below section and figure summarises the seafarer competencies needed for a future with alternative fuels.**

### TANGIBLE REQUIREMENTS

Competence gaps between conventional and alternative fuels lie in the specific characteristics and technical systems related to each fuel. Future competence requirements should specifically cover each fuel instead of generally referring to the IGF code, as in the case of methanol, taking into account the specific characteristics and hazards. The aim should be to construct tangible STCW competence tables for ammonia, methanol and hydrogen, as has been done for LNG.

### RISK ASSESSMENT

Risk assessments of specific fuel systems should cover seafarer competence needs and requirements for their safe operation. These risk assessments will be vital for producing tangible competence requirements for each unique system.

### NON-TECHNICAL SKILLS

The focus on future competencies should not only be on technical skills, but also on seafarers' non-technical skills. Skills such as decision-making, leadership and situational awareness complement the application of new technical skills. The STCW mentions leadership, a non-technical skill, but there is more work to be done to assess this part of the future competence needs.

### COMPETENCE TRAINING

The increased competence requirements for seafarers in the future may require increased and more efficient training and competence maintenance methods. Maritime institutions and regulatory bodies should consider the framework and requirements for competencies required for future seafarers, while maritime education and training centres should consider how to best train and maintain competencies.

### OTHER INDUSTRIES

Future efforts should consider industries other than the maritime industry for aligning competence requirements and training for the handling of ammonia, methanol and hydrogen.

### ORGANISATION

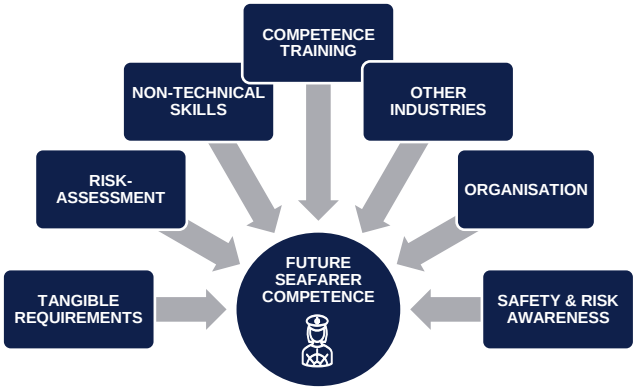
The organisational level plays an important role in facilitating the development of competencies for safety on board. Organisations should develop competence management processes, organisational learning, ways for assessing risk, reporting and map safety status, in order to move towards a mature and proactive safety culture.

### SAFETY & RISK AWARENESS

To ensure the safety of vessels operating on alternative fuels, it is vital to enhance seafarers' awareness of safety and risk during the initial stages of the fuel transition. This way, the crew can act proactively and responsibly on each vessel as an asset to safety.

### CONCLUSION

Seafarer competence is central to a safe transition and the implementation of alternative fuels. While focus seems to be set on the technical functioning of alternative fuel technology the operators of these technologies must not be forgotten. A seafarer should be an asset in the safe functioning of a vessel, and this is realised through training their competencies.



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