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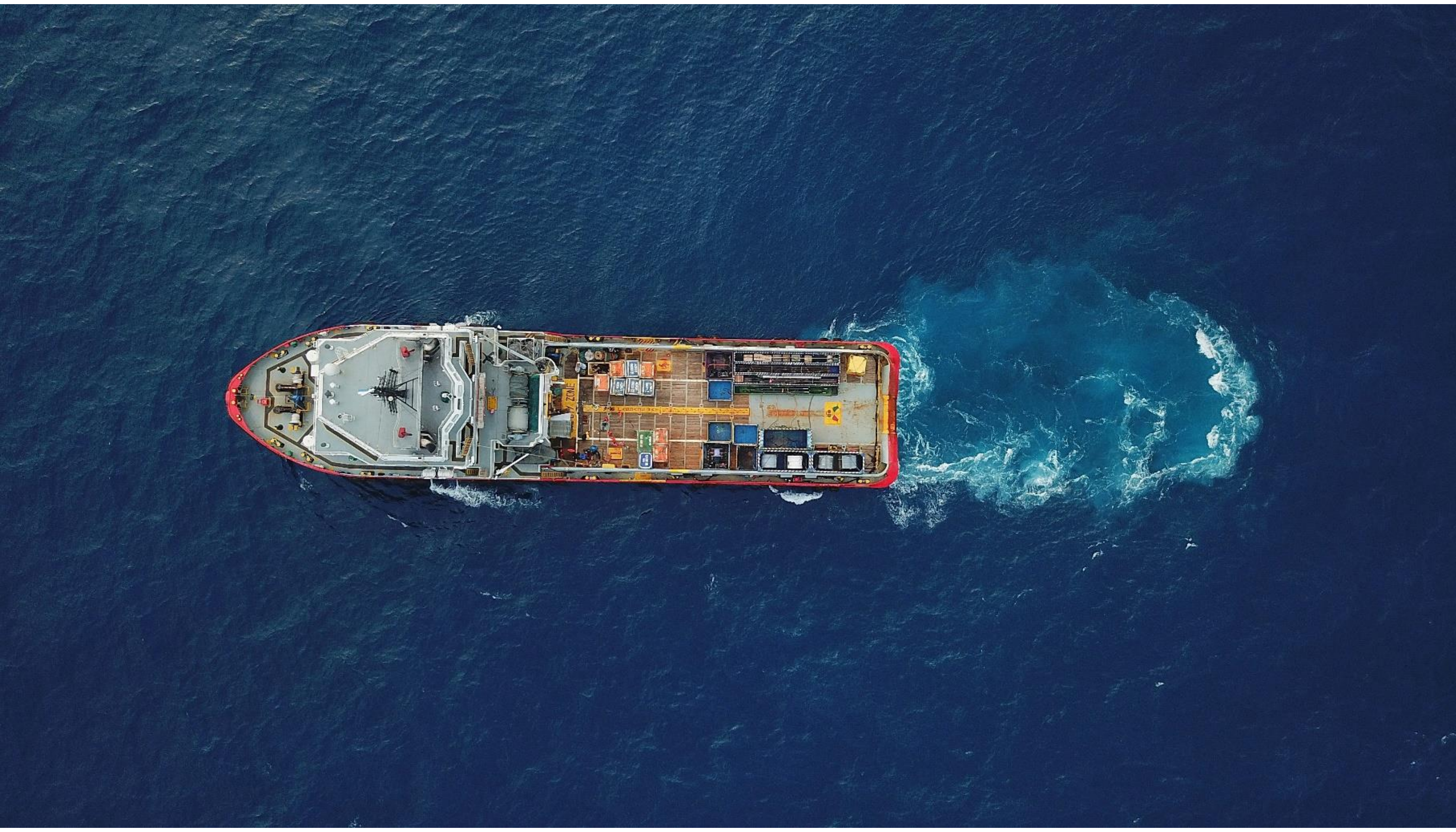

TRAINALTER
Final Report

Study on the identification of specific competences for seafarers on ships using alternative fuels and energy systems

Date: 12/12/2024

EMSA

About this study:

This report was commissioned by the European Maritime Safety Agency (EMSA) under framework contract 2024/EMSA/NEG/10/2023

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List of Abbreviations and Definitions

Terms	Abbreviation
AEGL	Acute Exposure Guideline Levels
AR	Augmented Reality
BESS	Battery energy storage systems
BLEVE	Boiling liquid expanding vapour explosion
BESST	Basic occupational Safety and Security Training
Competence	Knowledge, understanding, skills, attitude and/or behaviour in a defined area of work
CoP	Certificate of proficiency
ESD	Emergency shutdown/Electro-static discharge
ETO	Electro-Technical Officer
EU	The European Union
Ex-certified	Equipment designed for use in hazardous locations
FC	Fuel Cell – such as a Solid Oxide Fuel Cell (SOFC), a Proton Exchange Membrane Fuel Cell (PEMFC) or a High Temperature Proton Exchange Membrane Fuel Cell (HT-PEMFC)
FOGs	Fat, oil, or grease feedstocks
HAZMAT	Hazardous material
HTW	Sub-Committee on Human Element, Training and Watchkeeping of the International Maritime Organization
IACS	International Association of Classification Societies
ICE	Internal Combustion Engine
IGF code	International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels
IMO	The International Maritime Organization
KUPs	*Knowledge* – To remember or to reproduce based on appropriate, previously learned Information. Facts or information acquired by a person through experience or education[2] *Understanding* – To give meaning to new situations and or new material by recollecting and using necessary present information. To give evidence of insight into certain activities. Comprehending the principles, concepts, and procedures relevant to maritime operations. *Proficiency* – To use previously acquired information in new and concrete situations to solve problems that have single or best answers. Ability requiring a combination of knowledge, understanding, and skill to perform.
LEL	Lower explosive limit
LNG	Liquefied natural gas
MGO	Marine gas oil
Onboard functions	Onboard functions as described in the STCW are grouped under seven main categories, each with different levels of responsibility. These functions are further defined at the management, operational and support level.
PPE	Personal protective equipment

[2] STCW code

Terms	Abbreviation
SDS	Safety data sheet
SME	Subject matter expert
SOP	Standard Operating Procedure
STCW	*International Convention on Standards of Training, Certification and Watchkeeping for Seafarers* – sets minimum qualification standards for seafarers
UEL	Upper explosive limit
VR	Virtual Reality
XR	Extended Reality

Executive Summary

The maritime industry is undergoing a technology transition towards decarbonised shipping. To achieve the ambitious goals of reducing emissions from ships, several potential alternative fuels and energy systems have been identified for shipping. One of the main challenges that the technology transition entails is the additional training that seafarers on board ships using alternative fuels and systems need to undergo to ensure the safe and efficient operation and maintenance of these ships. The existing training and competence standards in the STCW Code do not specifically cover all aspects of the new fuels/fuel systems being adopted; these include:

1. Liquid Natural Gas
2. Biofuels
3. Methyl/ethyl alcohols (limited to methanol)
4. Hybrid electrical battery systems
5. Fuel cells
6. Ammonia
7. Hydrogen

This report presents the result of a two-parts study which aimed to:

Part A: Identify and describe specific competences and training areas in terms of knowledge, understanding and proficiency for seafarers to ensure safe operations of ships using alternative fuels and energy systems.

Part B: Identify and justify methods for demonstrating competence and descriptions of training programmes and syllabus for seafarers and instructors.

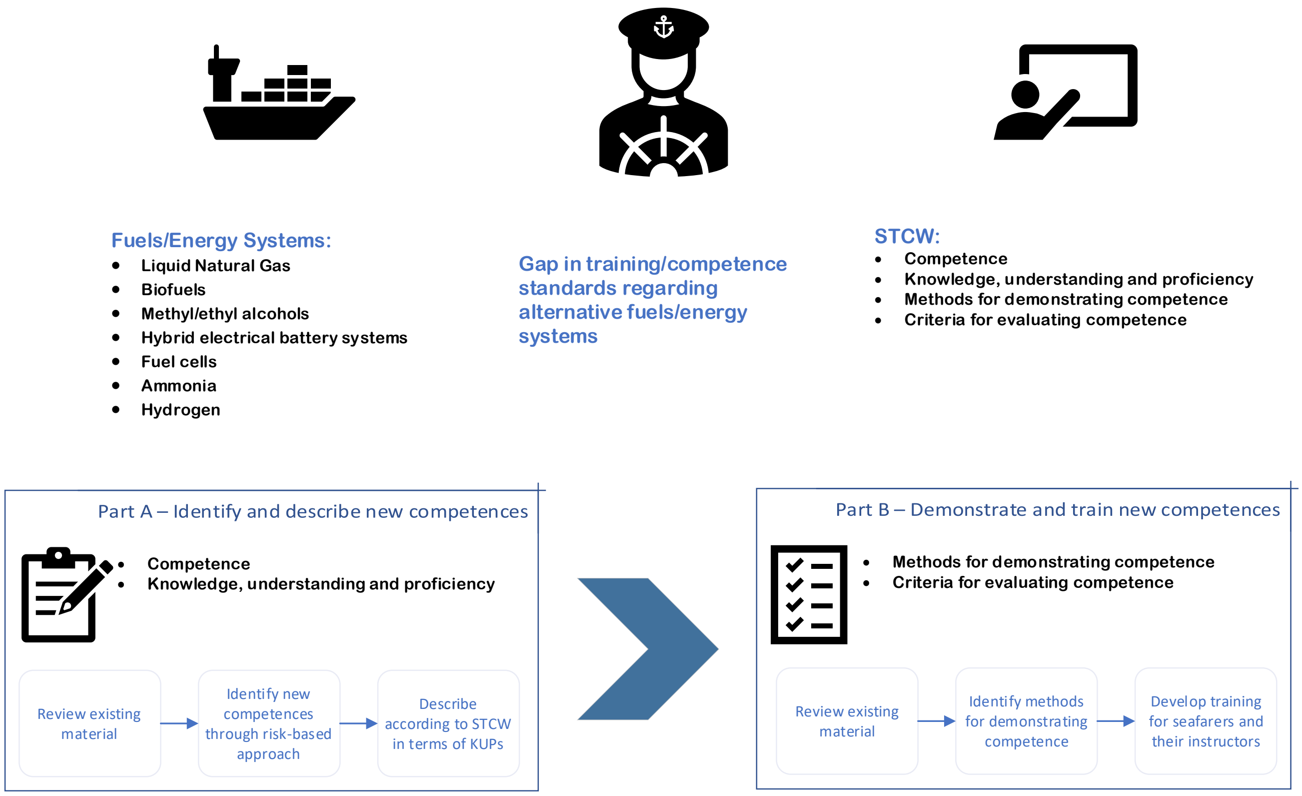

Figure 1-1 Overview of TRAINALTER

Part A – Identifying new competences

Part A is set within the framework of the *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers* which establishes minimum qualification standards for seafarers. The STCW Code outlines minimum required competences for seafarers in a set of competence tables. These contain an overall competence, which is then broken down into knowledge, understanding and proficiency (KUP) elements. These

KUP elements specify what is required of a seafarer within a competence. These competences are then categorised within the function of the seafarer, i.e. their rank (master vs. rating) and task onboard (engineer vs. deck).

Part A aimed to identify and substantiate competences and KUP elements in the style of the STCW Code tables for the fuels/energy systems. This was achieved through a state-of-the-art review and by discussions in a series of workshops with subject matter experts with the goal of producing STCW-style competence tables based on onboard functions and substantiated with KUPs.

Firstly, a state-of-the-art review was conducted to describe the current training of seafarers on the use of alternative fuels and energy systems within the scope, as well as to create an overview of topics for potential competences. These were identified from relevant studies, rules, standards, guidance, and recommendations and, in addition, by interviews with subject matter experts. The state-of-the-art review was considered fundamental for identifying and substantiating competences.

According to the interviewed experts, the current situation as regards training programmes for seafarers on alternative fuel technologies is a classic causality dilemma, where training providers are waiting for regulators to define the training requirements, and regulators are waiting for training providers to specify their plan to indicate an appropriate curriculum. This makes it difficult for shipping companies to justify the investment in training programmes and for training centres to develop programmes and invest in equipment. As a result, the maritime industry is moving slowly, while awaits a STCW update to specify training requirements for emerging alternative fuels.

In addition, the results of the state-of-the-art review show that there is wide range of maturity levels concerning existing training and competence requirements for the different fuels and fuel systems, with, LNG, for example, being quite mature, while hydrogen is less mature. Biofuels offer the least amount of additional competence needs due to their similarity with conventional fuels, although biofuels do exhibit different characteristics in terms of operation. Methyl/Ethyl alcohols are slightly more mature in showcasing their competence needs, as is evident by the existing IMO's interim guidelines for the safety of ships using methyl/ethyl alcohol as fuel, which refer to the IGF Code's competences outlined in the STCW Code. However, these competences must take into account the nature of methyl/ethyl alcohols as fuel, and the focus lies heavily on methanol. In contrast to other fuels, batteries serve as a relatively static and fixed energy source rather than a traditional fuel. Despite the widespread adoption of battery systems in the maritime industry, there remains a scarcity of knowledge and competence related to emergency procedures for handling, while suppliers provide training to crew members on the technical aspects of operation, emphases minimal crew interaction and leave maintenance to specialised teams. As for fuel cells, including SOFCs, PEMFC and HT-PEMFCs, these are approached as being their own system disregarding the surrounding fuel system. References on competence requirements for crew on the fuel cell itself is limited and training seems to be provided by technology suppliers on the technical operation. The general approach is to have the crew interact as little as possible with the fuel cell and leave maintenance to a specialised team. Competence and knowledge considering ammonia as a fuel is very scarce. Although ammonia has been transported as a commodity on board ships for decades, no specific regulation currently exists considering it as fuel, while ammonia fuel systems are still being developed for vessels. The fact that no ship is currently using ammonia for propulsion purposes is a serious problem to identify and define relevant competences, since the reference systems to create competence from are unavailable. The general approach of existing documentation is that they consider toxicity of ammonia and how the substance is carried as a cargo, and not as a fuel onboard. Hydrogen is still developing in the maritime industry, and this is reflected in the available documentation. Competence addressing hydrogen should consider the flammability and explosiveness of hydrogen, as well as the difficulties of its containment.

Moreover, the state-of-the-art review showed that there are currently several training providers offering generic training towards alternative fuel technologies. However, this training is not very specific due to the lack of detailed regulations in the STCW Code on emerging alternative fuel technologies. Training is often targeted to decision-makers in shipping companies and customised for specific projects as short courses, e.g. on ammonia and on methanol. These are designed for shore-based staff that need to stay informed on these fuels. The courses are open to seafarers but are not valid for certification. Furthermore, training on engine technology and onboard systems are provided by manufacturers (e.g. Wärtsilä or MAN) to the shipowners and seafarers of the companies that purchase their engines or fuel cells. Such training is specific on the ship equipment and fuel technology used. From the ship owner's perspective, the challenge of acquiring new vessels powered by alternative fuels lies in the lack of expertise within the main office staff to understand these fuels, which is addressed in different ways but often by hiring superintendents with gas tanker experience.

In addition to all the topics for potential competences identified through the state-of-the-art review, it also allowed for recognising cyber security as an area of potential competence needs. The study provided the description of several potential competence topics. Cyber security considerations and cyber risk management will become even more important as alternative fuel systems develop. It is widely known and proven that cyber security incidents may have physical safety consequences, which is also a reason it is considered both by IMO and other institutions. The relevant study findings were referred on a general basis and cyber risks and potential competence topics were described relevant for all fuels and computer-based systems and not for each fuel or system specifically.

Secondly, a series of workshops, building on the findings stemming from the state-of-the-art review, were held to identify and substantiate competences, in the same vein as the STCW code tables. This was conducted via a risk-based approach, where hazards introduced by the new fuels were linked to potential new competence requirements to mitigate the hazards. In addition, the format of the identified competence description presented in the study includes reference to the seafarer onboard capacities concerned (master, chief engineer, etc.) as well as to the functions involved, those being the same functions used by the STCW Code to structure the standards of competence. The aim of this format is to provide some flexibility if the identified competences were to be assigned and integrated in the STCW Code, either in a table of a standard of competence for a certificate of competence or certificate of proficiency in chapters II or III of the STCW Code for the deck and engine departments, or as part of a proposed standard of competence under chapter V of the Code on special training requirements that might be required for a certificate of proficiency concerning the alternative fuel or energy system.

The results of the workshops allowed new competences to be identified and considered whether obsolete competences or KUPs in the current STCW Code exist. During the study, it was generally found that none of the already existing KUP elements of STCW Code could be considered as wholly obsolete. The reasons for this are twofold. Firstly, most alternative fuels are not yet fully implemented in the maritime industry, and it will take time before obsolete competences can truly be considered. Secondly, when operating on alternative fuels, it still might be required with redundant fuel systems or back-up conventional fuel systems.

Competences, their justification, the associated hazards and risk potential, and related KUP elements were described in detail in tabular form as well as outlined in a competence catalogue for reference.

Per each analysed alternative fuel, a considerable number of competences were identified. As regards biofuels, it should be noted that the term is used for many types of different fuels with different properties. Some biofuels are identical to conventional fuels and can be treated in the same way, while, for instance, bio-methanol is chemically identical to methanol produced via fossil energy. Therefore, because it is expected to pose the same risks and hazards, the relevant competences are detailed under the section dedicated to methanol. Other biofuels exhibit similar characteristics to conventional fuels as well, while some being gaseous under normal conditions, exhibit similarities with LPG fuels, and other share similarities with conventional marine distillates concerning hazardous properties. However, the study highlighted the importance for seafarers to know the specific differences. Long-term experiences using biofuels as fuel in the maritime domain are limited and this uncertainty should also be considered. Depending on the fuel used and the engine operated, there are indications of both increased and decreased maintenance needs. In addition, biofuels have different fuel power production capabilities and different effects on emissions, which can affect voyage planning and officers should be aware of. Moreover, storage, connections and their cleaning, fuel preparation, safe bunkering operations and proper engine monitoring and operation within the regulatory requirements were competences identified for the use of Biofuels.

Concerning methanol, the study was limited to its usage on ships equipped with a propulsion plant based on an internal combustion engine and the surrounding fuel system. The competences identified as necessary to all officers and ratings alike were those addressing general knowledge and understanding of this fuel, as well as the associated risks and hazards, and the proper use of personal protection equipment. In addition, competences needed for deck officers, engineer officers and engine ratings included those relating to bunkering and storage operations, which as safety-critical operations, the ability of the crew to conduct safe bunkering were termed as essential. Moreover, competences on operations and procedures for onboard safety systems, on emergency response and on maintenance and repairs on methanol systems, were described along with its associated risk potential and justification. Competence on tank conditioning and space ventilation operations were also identified, which require thorough knowledge of gas-freeing, inerting, purging operations and the use of the associated technology elements required on board ships using methanol as fuel. These operations are fundamental measures against known hazards.

As regards Battery-powered Hybrid Electrical Systems and Battery Energy Storage Systems, identified competences include, in addition to a general knowledge and understanding of these systems' properties, those relating to measures to reduce battery related risks, mainly addressing the effects of toxic and flammable gas generated by battery systems, as well as relating to personal protection equipment, which all seafarers need to select carefully due to the thermal, explosive and toxic properties of battery fires. Moreover, competences concerning the correct and proper maintenance procedures together with competences concerning battery fire precautions, competences on different firefighting methods, procedures are mitigation measures, were described as required for all capacities on board. Furthermore, competences on battery systems' operation, safety and security, which require a solid electrotechnical competence, and those addressing battery lifetime, chargeability, ventilation of battery spaces, were identified for deck officers, engineer officers and engine ratings.

Relating fuel cells, the identified competences addressed fuel cell power systems based on three different technologies (Solid Oxide Fuel Cell (SOFC), the Proton Exchange Membrane Fuel Cell (PEMFC) and the High Temperature Proton Exchange Membrane Fuel Cell (HT-PEMFC)) delivering electrical and/or thermal energy using LNG, biofuels, methyl/ethyl alcohols, ammonia, and hydrogen. The specific fuel cell competences were limited to the fuel cell itself, while the fuel system surrounding and feeding into the fuel cell was covered by the relevant fuel system. The different fuel cells within the scope of the study have different characteristics and properties, which also impinge on the types of competences required. Identified competences applicable to all fuel cell types include, in addition to the basic functioning of fuels cells, their applied safety concept, potential maintenance and inspection procedures, action to mitigate risks of inherent high temperatures and prevention of fuel contamination. Moreover, competences include those relating to operational limitations, control and monitoring and handling of contingencies and emergency procedures. Except the competence relating to fuel cell basic functioning, the competences were considered needed for deck officer and engineer officers, and, of those, a few also required for engine ratings.

As far as ammonia is concerned, the study identified competences specifically on ships using ammonia as marine fuel in an internal combustion engine and in relation to a surrounding fuel system. The study identified several competences needed for all functions on board, which require a considerable knowledge and understanding of ammonia as fuels, the risks associated with its use, the protection of personnel and regarding hazardous zones with a focus of toxicity and the specific bunkering and containment systems and equipment. In addition, competence in emergency responses, such as leak or spill situations and rescue of people exposed to ammonia, as well as competence in different fire-fighting operations, methods, procedures, and mitigating measures were also found necessary for all functions on board. Moreover, several competences were identified in relation to most engineering functions including those concerning specific safety systems, venting and ventilation operations, bunkering management and operation, monitoring of ammonia fuelled engines, fuel tank internal maintenance, and maintenance of ammonia systems.

As regards hydrogen as fuel, it falls under the IGF code and competence requirements can be drawn from there. Storage and containment of hydrogen has similarities with LNG. The identified competences and KUPs are therefore focused on additional competences surrounding the fuel system and storage considering both compressed and liquid hydrogen. Identified competences, which were described in direct relation to the hazards intrinsic to hydrogen as a fuel, include, in addition to those requiring knowledge of hydrogen properties and health hazards, competences concerning precautions to prevent risk of ignition, explosion and fire, management and execution of bunkering operations, hydrogen fuelled engine operation and monitoring, onboard safety procedures and response to emergencies. These competences were considered relevant to several engineering and deck functions. Moreover, a competence concerning hydrogen specific aspects related to voyage planning was found relevant to the navigation function.

The identified competences could feed into the ongoing process of the revision of the STCW Convention and Code, in particular in the revision of the STCW Code tables of competence and in particular the definition of Knowledge, Understanding and Proficiency (KUP); Methods for demonstrating competence; and Criteria for evaluating competence.

Considering the different circumstances reported in this first part it is expected that the work at the IMO will be considerable, possibly already at the stage of the design of provisional guidelines on training of seafarers on ships using alternative fuels, which has already been considered to fill the training gap before adopting any competence requirements in the STCW Code…". This way of proceeding was used for the training and competence standards for ships subject to the IGF Code; implementing a similar scheme was discussed during HTW 10.

Part B – Demonstrating and training new competences

Part B of the study focused on identifying and defining current and future methods for demonstrating competence in seafarers, learning from other industries, and proposing training programmes for both seafarers and instructors within the STCW framework. This was achieved through interviews with experts of recognised universities, engine manufacturers and production plant operators, reviewing industry best practices, and incorporating new technologies like Extended Reality, Virtual Reality, and Artificial Intelligence. The proposals for training programmes included structured training programmes for both seafarers and their instructors based on IMO Model courses and DNV standards, ensuring comprehensive and up-to-date training methods and frameworks. Various training and competence demonstration methods were analysed and proposed as part of training syllabus.

The study concluded that the methods for demonstrating competence currently defined in STCW are still applicable for alternative fuels and energy systems.

One potential new method was identified, “Approved case studies and projects”, which can be relevant to transfer knowledge from e.g., pilot projects on ammonia and hydrogen as fuel. Providing real-world examples through case studies creates robust practical insight. In addition, e-learning offers flexible and accessible online education, highly applicable to training on alternative fuels. Moreover, VR/AR technologies create immersive and interactive learning experience through various interfaces, such as head mounted displays (HMD), or through computer screens. These virtual environments can simulate real world environments with a high level of fidelity. In contrast to conventional full-mission simulators, VR training offer certain valuable advantages: the instructor and trainees do not need to be in the same room when doing VR training, and applications could include the use of VR technology on board for ship specific training (e.g., standard operating procedures), as well as distributed learning, where the instructor was located in another city than the trainee. However, VR only approximates real-life scenarios and may not fully replicate the practical experience needed for certain competences. Most VR applications designed for one-on-one training limit collaborative training opportunities and can require one instructor per student. In fully immersive VR, users often rely on hand controllers that do not accurately replicate the tactile experience of operating real-life instruments, potentially hindering the development of psychomotor skills. Additionally, VR environments with multiple users in different physical locations are highly dependent on low latency and stable connectivity; poor connectivity can adversely affect training. Therefore, experts recommended that VR should be carefully considered and, if used, it should be always combined with other methods for demonstrating competence.

As a practical example of the above considerations, the proposed methods for demonstrating competence were suggested as part of the proposed course on ammonia as fuel:

Classroom lectures	**Theoretical foundation for seafarers covering ship design, ammonia properties, safety requirements, fuel systems, and storage systems**
Tutorials & group activities	Encourage collaboration and problem-solving through discussions on hazard prevention, safety protocols, and emergency response procedures
Simulator training	Experience real-world scenarios in a controlled environment, such as detecting ammonia leaks, using PPE, practicing SOPs and responding to emergencies.
Practical exercises	Hands-on experience in handling ammonia, including firefighting, gas-measuring instruments, safety equipment use and sensing familiarization with ammonia (i.e., odour).
Onboard training and drills	Training and drills conducted onboard the ship to practice emergency procedures and other operational tasks, such as bunkering or maintenance
Workshops and on-site training	Additional learning at production plants covering the spread of toxic ammonia gas clouds and industry-specific scenarios
Interactive learning	Use of e-learning, extended reality etc. to provide interactive and immersive learning experiences by real-life simulation

The maritime industry can leverage extensive training experiences from the onshore industry, which possesses considerable expertise in the production, storage, and transfer of substances and chemicals. Nevertheless, it is important to emphasise the differences in operational environment for ship and shore industries when considering the transfer of onshore training to maritime. The study conducted an analysis of the training provided for personnel of an ammonia production plant with the objective of obtaining key points that could be used for training of seafarers on ships using ammonia as fuel. In this respect, the study concluded that seafarers should undergo a comprehensive training that maps out the necessary competences for different roles on board aligned to specific tasks/safety critical operations, in order to ensure that personnel only perform duties for which they are qualified in the maritime industry. In addition, developing competence matrices to ensure seafarers are well-versed in theoretical and practical aspects of handling alternative fuels, as well as training focused on standard operating procedures and the practice of pairing less experienced seafarers with certified mentors and emphasizing experience-based learning could be directly to seafarers’ training.

The study also addressed the development of a structured training of seafarers on ships using alternative fuels through an example of training course for ammonia as a fuel. The course syllabus is shown below:

Subject Area		Hours	
		Lecture	Activity
1	**Contribute to the safe operation of a ship subject to ammonia as fuel**	**4**	**-**
1.1.	Design and operational characteristics of ships subject to ammonia as fuel		
1.2.	Basic knowledge of ships subject to ammonia as fuel, their fuel systems and fuel storage systems		
1.3.	Basic knowledge of ammonia and fuel storage systems' operations on board ships subject to ammonia as fuel		
1.4.	Basic knowledge of the physical and chemical properties of ammonia		
1.5.	Knowledge and understanding of safety requirements and safety management on board ships subject to ammonia as fuel		
2	**Take precautions to prevent hazards on a ship subject to ammonia as fuel**	**2**	**-**
2.1.	Basic knowledge of the hazards (toxicity, corrosivity and reactivity) associated with operations on ships subject to ammonia as fuel		
2.2.	Basic knowledge of hazard controls		
2.3.	Understanding of fuel characteristics of ammonia as fuel as found on a Safety Data Sheet (SDS)		
3	**Apply occupational health and safety precautions and measures**	**3**	**1**
3.1.	Awareness of function of gas-measuring instruments and similar equipment		
3.2.	Proper use of specialized safety equipment and protective devices		
3.3.	Basic knowledge of safe working practices and procedures in accordance with legislation and industry guidelines and personal shipboard safety relevant to ships subject to ammonia as fuel		
3.4.	Basic knowledge of first aid related to ammonia		
4	**Carry out firefighting operations on a ship subject to ammonia as fuel**	**1**	**-**
4.1.	Fire organization and action to be taken on ships subject to ammonia as fuel		
4.2.	Special hazards associated with fuel systems and fuel handling on ships subject to ammonia as fuel		
4.3.	Fire-fighting agents and methods used to control and extinguish ammonia fires		
4.4.	Fire-fighting system operations		
5	**Respond to emergencies**	**0.5**	**-**
5.1.	Basic knowledge of emergency procedures, including emergency shutdown		
6	**Take precautions to prevent the leakage of ammonia**	**0.5**	**0**
6.1.	Basic knowledge of measures to be taken in the event of ammonia leakage/spillage/venting		
7	Video demonstration/case study	1	-
8	Self-assessment/debrief	2	-
9	Formal assessment (MCQ/oral exam)	1	-
Total		15	1

Additionally, in consideration of the current shortage of qualified instructors, the report looked also into train-the-trainer courses.

The proposed train-the-trainer course on ammonia as fuel covers the following subject areas:

Subject Area		Hours	
		Lecture	Activity
1	**Contribute to the safe operation of a ship subject to ammonia as fuel**	**4**	**-**
1.1.	Design and operational characteristics of ships subject to ammonia as fuel		

Subject Area		Hours	
		Lecture	Activity
1.2.	Basic knowledge of ships subject to ammonia as fuel, their fuel systems and fuel storage systems		
1.3.	Basic knowledge of ammonia and fuel storage systems' operations on board ships subject to ammonia as fuel		
1.4.	Basic knowledge of the physical and chemical properties of ammonia		
1.5.	Knowledge and understanding of safety requirements and safety management on board ships subject to ammonia as fuel		
2	**Take precautions to prevent hazards on a ship subject to ammonia as fuel**	**2**	**-**
2.1.	Basic knowledge of the hazards (toxicity, corrosivity and reactivity) associated with operations on ships subject to ammonia as fuel		
2.2.	Basic knowledge of hazard controls		
2.3.	Understanding of fuel characteristics of ammonia as fuel as found on a Safety Data Sheet (SDS)		
3	**Apply occupational health and safety precautions and measures**	**3**	**1**
3.1.	Awareness of function of gas-measuring instruments and similar equipment		
3.2.	Proper use of specialized safety equipment and protective devices		
3.3.	Basic knowledge of safe working practices and procedures in accordance with legislation and industry guidelines and personal shipboard safety relevant to ships subject to ammonia as fuel		
3.4.	Basic knowledge of first aid related to ammonia		
4	**Carry out firefighting operations on a ship subject to ammonia as fuel**	**1**	**-**
4.1.	Fire organization and action to be taken on ships subject to ammonia as fuel		
4.2.	Special hazards associated with fuel systems and fuel handling on ships subject to ammonia as fuel		
4.3.	Fire-fighting agents and methods used to control and extinguish ammonia fires		
4.4.	Fire-fighting system operations		
5	**Respond to emergencies**	**0.5**	**-**
5.1.	Basic knowledge of emergency procedures, including emergency shutdown		
6	**Take precautions to prevent the leakage of ammonia**	**0.5**	**0**
6.1.	Basic knowledge of measures to be taken in the event of ammonia leakage/spillage/venting		
7	Video demonstration/case study	1	-
8	Self-assessment/debrief	2	-
9	Formal assessment (MCQ/oral exam)	1	-
Total		15	1

The overall objective of this study was to identify and describe specific competences and training areas in terms of knowledge, understanding, and proficiency for seafarers for selected alternative fuels and energy systems for propulsion and auxiliary power generation, to ensure safe operations of ships. The report identifies the different competences, which could be used at IMO level in support of the ongoing discussions for the revision of the STCW Convention and Code.

The methods to demonstrate competence currently defined in the STCW Code are considered still applicable for alternative fuels and energy systems. Still, one potential new method is identified, "Approved case studies and projects", which can be relevant to transfer knowledge from e.g., pilot projects on ammonia and hydrogen as fuel: real-world examples through case studies create practical insight, e-learning offers flexible and accessible online education and VR/AR technologies create immersive and interactive learning experience.

Although the study can be considered very comprehensive, the results are not aimed at being definitive. They are intended to serve as a basis for the discussions at the IMO on this subject.

1. Introduction

1.1 Background

The maritime industry is undergoing a technology transition towards decarbonised shipping. To achieve the ambitious goals of reducing emissions from ships, several potential alternative fuels have been identified for shipping, such as biofuels, methanol, ammonia, and hydrogen, as well as alternative energy systems, such as fuel cells. These alternative fuels and energy systems offer improved safety and performance in some areas but also pose new challenges for the environmental, technical, and safety performance of ships, depending on their production methods, availability, suitability, and cost. The use of alternative fuels and systems requires a change in ship operations and a revision of the regulatory framework for shipping. The International Maritime Organization (IMO) and the European Union (EU) have adopted and developed several strategies and regulations to promote and regulate the use of alternative fuels in maritime transport, setting minimum safety standards and requirements for ships using these fuels. in maritime transport. Classification societies have also issued rules and guidelines for using alternative fuels and systems, as well as for the approval of alternative designs.

One of the main challenges that the technology transition entails is the additional training that seafarers on vessels with alternative fuels and systems need to undergo, to ensure the safe and efficient operation and maintenance of these vessels. The existing training and competence standards in the Standards of Training, Certification and Watchkeeping (STCW) Convention and Code do not cover all the specific aspects regarding knowledge, understanding and proficiency (KUP) that seafarers on ships using alternative fuels and systems should have. Therefore, a need for interim guidelines and new standards is necessary to address this gap. The provision of such training also poses practical challenges, such as the shortage of experienced seafarers and instructors, and the current scarcity of ships operating on alternative fuels. Seafarers need to be trained in the appropriate competences to be able to safely operate alternative fuelled vessels.

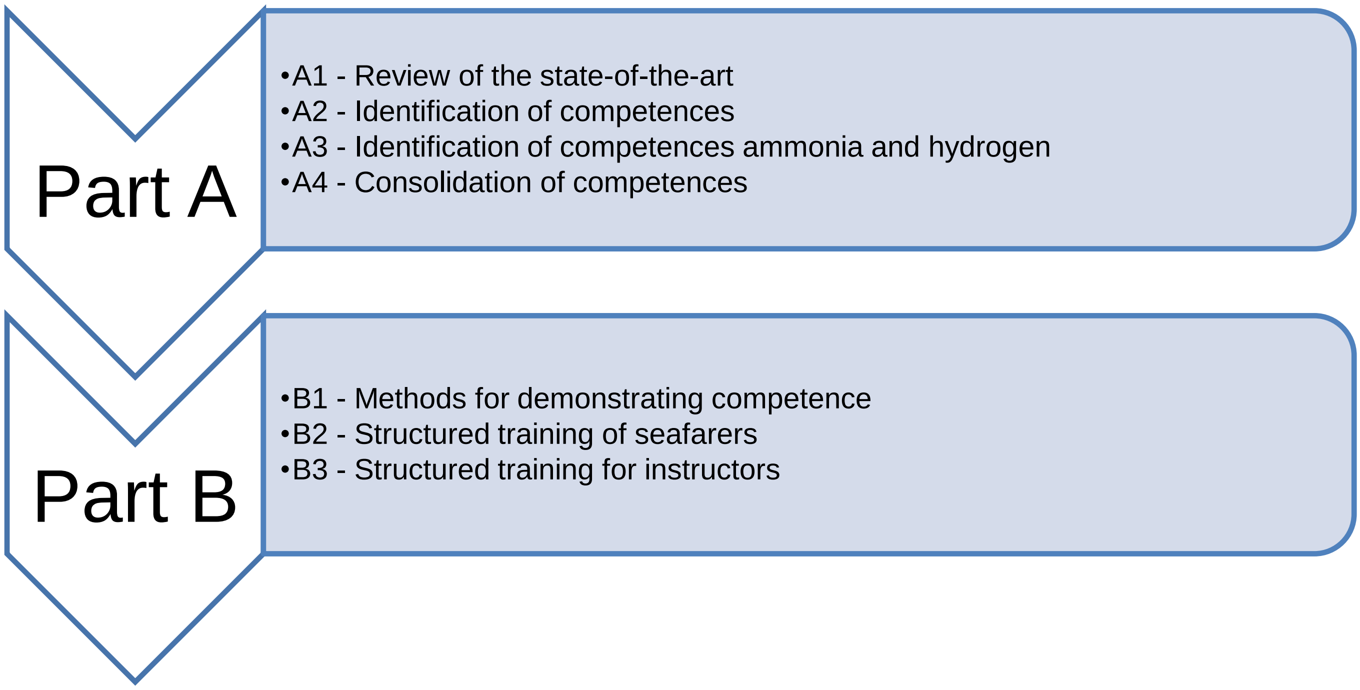

Figure 1-1 Report structure

1.1.1 Scope & Objectives

The overall objective of this study was to identify and describe specific competences and training areas in terms of knowledge, understanding, and proficiency for seafarers. This, is to ensure safe operations of ships using the following alternative fuels and energy systems for propulsion and auxiliary power generation:

- Biofuels used in internal combustion engines, such as: bio-methanol, Fisher Tropsch (FT) diesel, biomethane from digestion of waste and residues, dimethyl ether (DME), fatty acid methyl esters (FAME) from fat, oil, or

grease feedstocks (FOGs) and from vegetable oils, biomethane from gasification, and hydrotreated vegetable oil (HVO) from FOGs.
- Battery-powered hybrid-electric systems, including the safe operation, maintenance and emergency management of ships equipped with Battery Energy Storage Systems (BESS).
- Methyl/ethyl alcohols used in internal combustion engines; this study will limit itself to methanol as this has the most industry interest.
- Ammonia and hydrogen in internal combustion engines.
- Fuel cell power systems based on Solid Oxide Fuel Cell (SOFC), the Proton Exchange Membrane Fuel Cell (PEMFC) and the High-Temperature Proton Exchange Membrane Fuel Cell (HT-PEMFC) for delivery of electrical and/or thermal energy using LNG, biofuels, methyl/ethyl alcohols, ammonia, and hydrogen.

This limits the scope to the following fuels and energy systems combinations, as shown in **Error! Reference source not found.**.

Table 1-1 - Scope concerning energy systems and fuels/energy sources

Energy System	Fuel/Energy source					
	LNG	Biofuel	Methyl/ethyl alcohols	Electricity	Ammonia	Hydrogen
Fuel cell power systems	LNG in FCs	Biofuel in FCs	Methanol in FCs	-	Ammonia in FCs	Hydrogen in FCs
Internal combustion engines	-	Biofuel in ICEs	Methanol in ICEs	-	Ammonia in ICEs	Hydrogen in ICEs
Battery/hybrid-electric	-	-	-	Batteries	-	-

1.1.2 Specific objectives

This study focuses on the following specific objectives:

1. Identification of new competences for seafarers and their description in terms of knowledge, understanding and proficiency (KUP) elements, as well as the description of additional KUPs in competences already existing in the STCW Code, relevant to the safe operation of ships using the following alternative fuels and energy systems.

2. Identification of competence areas and their description in terms of KUP elements relevant to the safe operation of ships using ammonia and hydrogen as fuel in internal combustion engines as far as this is possible, having regard to the available scientific and technical knowledge and experience, as well as to the incomplete technical regulatory framework.

3. Identification of competences and KUP items required for engineer officers and other personnel of the engine department, as specified in the minimum standards of competence specified in the STCW Code, that may need to be updated, upgraded and/or amended, as well as those that can be considered obsolete or not relevant to the safe operation of ships using alternative fuels and energy systems.

4. Identification of methods for demonstrating the identified competences related to alternative fuel and energy systems, to ensure that those competences can be achieved by trainees as efficiently and effectively as possible, with particular attention to in-service experience other than on-board training, and the use of simulators, with the aim of contributing to offsetting the possible effect of the scarcity of positions available on ships using alternative fuels and energy systems as a means to gain experience.

5. Identification of technical areas, processes and/or systems of the alternative fuels' production, storage, transfer and transport industry ashore, which may be relevant to shipping using alternative fuels and energy systems, and specification of relevant knowledge, skills and training topics, with the aim of identifying the potential contribution of that industry to the training and experience gain of seafarers, who will serve on board ships using alternative fuels and energy systems and that may be considered equivalent to in-service training.

6. Description of proposals of structured training of seafarers in the safe operation of ships using alternative fuels and energy systems.

7. Description of proposals of training of instructors' programmes or courses for ships using alternative fuels and energy systems.

These specific objectives were addressed through Part A – Identification of Competences and Part B – Methods for Demonstrating Competence. Part B will build upon the findings of Part A by suggesting training regimes for achieving the identified competences.

Additionally, while not the specific objective of this study, cyber security will be briefly covered in Task A1 as it also demands competences that seafarers should possess. The heightened hazardous nature of most alternative fuels means that the risks associated with a successful cyber-attack are higher.

1.1.3 Tasks

The following tasks aimed to achieve the specific objectives, scope and methods are outlined below, and covered in more detail in their respective sections:

Table 1-2 Part A, outline of Tasks

Task	Objectives	Method
A1 – State of the Art	1. Describe the state-of-the-art concerning current training of seafarers on the use of alternative fuels and energy systems within the scope 2. Create an overview of topics for potential competencies from relevant studies, rules, standards, guidance, and recommendations	Conduct interviews and a literature review on the state-of-the-art for training seafarers. Produce a state-of-the-art register
A2 – Identification of Competences	1. Identifying, justifying, and substantiating new competencies for seafarers in general 2. Identifying, justifying, and substantiating new, updated, upgraded, amended and/or obsolete competencies for engineers	Utilise results from A1 in addition to workshops with subject matter experts (SMEs) to develop a competence catalogue for LNG, biofuel, methyl-ethyl alcohols, hybrid-electric battery systems, and fuel cells
A3 – Competences: Ammonia and Hydrogen	1. Identifying, justifying, and substantiating seafarer competence areas for ammonia and hydrogen including established competence requirements	Utilise results from A1 in addition to workshops with SMEs to develop a competence catalogue, specific to ammonia and hydrogen
B1 – Methods for demonstrating competence	1. Identify and define current and future methods for demonstrating competence, as well as alternative ways of learning due to the scarcity of available positions on ships with alternative fuels and energy systems to gain experience 2. Identify and document how onshore industries treats skill transfer and training for alternative fuels and energy systems in different supply chains, such as production, storage, transfer, and transport. Also, how these industries potentially can contribute to the training and experience gain of seafarers	Utilise results from Part A and conduct interviews of SME both from industry and academia to establish a justified set of methods for demonstrating competence.
B2 - Proposals of structured training of seafarers	1. Provide description of proposals of structured training of seafarers in the safe operation of ships using alternative fuels and energy systems	Utilise the findings from Part A and Task B1, and conduct interviews with SME considering developing a proposal for structured training of seafarers on one specific alternative fuel
B3 – Proposal of structured training for instructors	1. Provide description of proposals of training of instructors' programmes or courses for ships using alternative fuels and energy systems	Utilise the findings from Part A, Task B1, Task B2, and conduct interviews with SME considering developing a proposal for structured training of seafarers on one specific alternative fuel

1.2 Overview of the fuels and energy systems

The fuels and energy systems outlined in Table 1-1 are briefly described in this section.

1.2.1 LNG[3]

Liquified natural gas (LNG) is currently a widely used fuel, consisting of liquified methane held at cryogenic temperatures. Methane is a colourless and nearly odourless gas at atmospheric conditions. When LNG is released into the environment, it forms cold vapours due to the condensation of water vapour from the air. These cold LNG vapours initially sink close to the ground due to being heavier than air. LNG vapour is flammable within specific concentration limits. Ignited LNG fires burn relatively slowly, causing small overpressures in open environments. However, in confined spaces or areas with high obstacle density, higher overpressures may occur. Direct contact with cryogenic LNG can cause freezing injuries, and steel structures may become brittle upon contact.

IMO regulation covering the use of LNG as a fuel was adopted in 2015 and the industry has gained considerable experience in its use since then. Competence requirements for seafarers on vessels using LNG as a fuel have been codified into the STCW Code under the provisions for the training and qualifications of masters, officers, ratings and other personnel on ships subject to the IGF Code. It is widely considered that the competences related to LNG will serve as a foundation for handling some alternative fuels, such as hydrogen and ammonia. This is due to their shared characteristics, including cryogenic storage requirements, handling practices, and associated risks.

1.2.2 Biofuels[4]

The usage of biofuels within the maritime industry is slowly increasing. Biofuels are widely regarded as "drop-in fuels" because they closely resemble their conventional counterparts, requiring minimal modifications for use. The biofuels within the scope of this study are the following:

Bio-methanol: produced via biomass gasification followed by methanol synthesis, is chemically identical to fossil methanol or e-methanol. It can be stored like conventional fuel oil due to its liquid state at normal conditions. However, with a flashpoint of approximately 10°C, methanol is flammable and easily evaporates. It is also toxic to the central nervous system, potentially causing blindness, coma, or death if ingested. Despite these risks, methanol is already used as a marine fuel, and engine technology supporting its use is commercially available.

Fisher Tropsch (FT) diesel: produced by gasification of biomass, followed by the Fischer-Tropsch (FT) synthesis process. FT-diesel has similar properties to conventional diesel. It is considered a drop-in diesel fuel, fully compatible with existing diesel infrastructure and internal combustion engines, fuel storage, and fuel supply systems onboard ships.

Biomethane: chemically identical to methane and thereby covered in the LNG section, 1.2.1.

Dimethyl ether (DME): produced from FOGs, is a gaseous compound at atmospheric pressure and room temperature. During storage and transportation, it is typically liquefied by slightly pressurising the gas. DME is extremely flammable and displays comparable properties to liquid petroleum gas (LPG).

Fatty acid methyl esters (FAME): produced by trans esterifying fats and vegetable oils. These feedstocks can come from various sources, including plants (e.g., soy, corn, rapeseed), animal fats, or waste oils. FAME properties can vary due to the diverse feedstock options. Mainly used in blends, trials in maritime applications show satisfactory results, but FAME biofuels differ from traditional marine distillate fuels in viscosity, calorific value, acidity, and oxidation stability. However, long-term storage pose challenges as FAME can degrade quickly if exposed to high amounts of moisture.

Hydrotreated vegetable oil (HVO): produced through a hydrotreatment process, recognised as a drop-in fuel, showing favourable compatibility with onboard systems. Although the term suggests vegetable oils, HVO can be derived from various sources, including waste animal fats, algae, and cooking oils. It consists of paraffinic

[3] EMSA Guidance on LNG Bunkering
[4] EMSA Study on Safe Bunkering of Biofuels

hydrocarbons and can be blended with other hydrocarbon-only diesels. Compared to conventional diesel, HVO has a similar flashpoint, good cold tolerance, stability, and minimal material compatibility concerns.

Biofuels have comparable competence requirements as conventional fuels due to their similarity, but their operational differences should be covered by new competence requirements.

1.2.3 Methyl/ethyl alcohols

Methyl/ethyl alcohols consist primarily of methanol and ethanol, and both have very similar properties in terms of their use as a fuel. While there are 335 methanol-fuelled vessels in operation or on order, ethanol has a significantly lower uptake, with no reported vessels running purely on ethanol (DNV, 2024). Ethanol does see use as a blend-in fuel, especially in road transport. Due to their similar properties and the significantly larger share of methanol-fuelled vessels, competences identified for methanol will broadly apply to ethanol, although specific differences should be considered. This study will limit itself to methanol when discussing methyl/ethyl alcohols.

Methanol is identical to the earlier described bio-methanol in 1.2.2. Methanol is a colourless liquid with high combustibility. It is a popular alternative fuel due to its relatively low emissions, compliance with regulations, safe handling, and fuel flexibility. Methanol is a toxic substance that can lead to blindness, coma, or death if ingested, and its vapours can cause asphyxiation. It is highly flammable, burns invisibly at low temperatures, and can create explosive atmospheres above 11°C, especially in confined spaces.

The IMO's interim guidelines (MSC.1/Circ.1621), together with the STCW Code, outline some guidance on competence requirements for seafarers handling methyl/ethyl alcohol as fuel.

1.2.4 Battery-powered hybrid electric & BESS[5]

Battery-powered hybrid-electric systems, including Battery Energy Storage Systems (BESS), are seeing increased usage. Batteries onboard largely consist of lithium-ion batteries. Their use is mainly as a form of energy-storage in conjunction with the primary energy system.

Safety concerns related to lithium-ion batteries arise from two main factors. Firstly, the presence of a flammable and unstable electrolyte can lead to ignition and safety events. Secondly, metal electrodes within the battery can burn and release oxygen, resulting in high-temperature fires that are challenging to extinguish. These components contribute to two primary failure modes: cascading thermal runaway and the release of toxic and flammable gases.

Competence-wise, batteries are not explicitly covered by the STCW Code.

1.2.5 Fuel cells[6]

Fuel cells convert the chemical energy of a fuel, usually hydrogen, to electricity through redox reactions and the use of an oxidising agent (usually oxygen). They are produced as modules and placed in racks of multiple modules.

Fuel cells within the scope of this study encompass the following:

Solid Oxide Fuel Cell (SOFC): are high-temperature fuel cells that operate on temperatures between 500-1000°C. These high-temperatures allow for a broader range of fuel types that this FC type can use, in addition to higher efficiency and less sensitivity to fuel contamination. However, the high temperature used can itself be a safety hazard. SOFCs can use hydrogen, ammonia, LNG, methanol, and diesel. Fuels other than hydrogen are reformed within the FC.

Proton Exchange Membrane Fuel Cell (PEMFC): PEMFCs operate by combining hydrogen and oxygen to generate electricity, heat, and water. When using alternative fuel sources other than hydrogen, they must first be converted to hydrogen before being introduced to the PEMFC. The main drawbacks of the PEMFCs are a sensitivity to impurities, a complex water management system and moderate lifetime.

[5] EMSA Study on Electrical Energy Storage for Ships
[6] EMSA Study on the use of Fuel Cells in Shipping

High Temperature Proton Exchange Membrane Fuel Cell (HT-PEMFC): these operate at higher temperatures (200°C than PEMFCs) than PEMFCs. This is achieved by using a mineral acid electrolyte. HT-PEMFCs are thereby less sensitive to contamination and do not require a water management system.

Within this study, competences regarding fuel cells are considered for purely the fuel cell itself and not the surrounding fuel system, as those are covered in other, fuel-specific, sections.

Competences for fuel cells are not explicitly covered by the STCW Code.

1.2.6 Ammonia[7]

Ammonia, which has been widely used for over a century in fertiliser production and as a refrigerant at sea in the past, poses new safety risks when considered as a fuel in the maritime industry.

Ammonia is a colourless, highly toxic gas at atmospheric temperature and pressure. It has a pungent odour and can cause stress corrosion to steel. It is highly corrosive towards other materials, such as rubber, copper, and brass. Ammonia is flammable but has a high ignition threshold, making it considered less hazardous compared to hydrogen. Ammonia is easier to store than hydrogen, being able to be stored as a liquid at -33°C.

Due to its toxicity, high concentrations of ammonia gas can cause burns, blindness, and death. Ammonia as a fuel is not explicitly covered by the STCW Code, although it falls under the International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels (IGF) Code and can draw competence requirements from there. The industry has very little experience with ammonia-fuelled vessels, and ammonia powered main engines are currently still under development.

1.2.7 Hydrogen[8]

Hydrogen presents a promising solution for certain shipping segments, though it poses some safety challenges. The hazards related to hydrogen differ depending on the storage method, but in general it is a colourless, odourless gas that’s hard to detect, can embrittle materials, and its release as a cryogenic liquid can cause severe cold burns. It disperses quickly and can accumulate in enclosed spaces, presenting a high explosion risk due to its flammability and low ignition energy. The danger is amplified in confined areas where hydrogen’s high diffusivity and explosive properties are particularly hazardous. Hydrogen is either stored at extremely low temperatures (-253°C) as liquid hydrogen, or as compressed hydrogen.

Like ammonia, as a fuel it is not explicitly covered by the STCW Code, although it falls under the IGF Code and can draw competence requirements from there. The industry has very little experience with hydrogen-fuelled vessels.

1.2.8 Cyber security

A main driver of decarbonisation is digitalisation and the increased reliance on fully digital and automated systems. As a result of this, seafarers need enhanced digital competence, including cyber security. As digitalisation advances, the cyber risk landscape for ships becomes increasingly complex. Control systems are getting more advanced and complex, and crew must understand how these systems are interconnected and affect each other, as faults can propagate through systems, causing problems which may not be described or encountered before.

The STCW Convention and Code does not specifically address cyber risks. However, the STCW points towards International Safety Management (ISM) Code and International Ship and Port Facility Security Code, seafarers need to have competence on cyber risks. Cyber risk competence in this study will be performed on a general basis for all fuels, as it will be relevant for the operation of a vessel, rather than to a specific system.

[7] Ammonia as a Marine Fuel Safety Handbook
[8] Handbook for Hydrogen-Fuelled Vessels

1.3 Definitions

It is important to note that the STCW Convention and Code does not define some key terms used in its text , and therefore in this study, such as competence, knowledge, understanding and proficiency. These definitions are thereby drawn from DNV-ST-0026[9].

A. *Competence* - Knowledge, understanding, skills, attitude and/or behaviour in a defined area of work.
B. *Knowledge* - To remember or to reproduce based on appropriate, previously learned Information. Facts or information acquired by a person through experience or education.
C. *Understanding* - To give meaning to new situations and or new material by recollecting and using necessary present information. To give evidence of insight into certain activities. Comprehending the principles, concepts, and procedures relevant to maritime operations.
D. *Proficiency* - To use previously acquired information in new and concrete situations to solve problems that have single or best answers. Ability requiring a combination of knowledge, understanding, and skill to perform.

Competence, in this context, is divided into elements of *knowledge, understanding,* and *proficiency* (KUP)*, representing distinct cognitive levels inherent to a specific competence.* These KUP elements collectively define the competence. For example, a seafarer's competence in regulations, rules, and requirements related to methanol may be broken down into the following KUP elements:

- *Knowledge* of the applicable rules, regulations and guidance related to the use of methanol as fuel in the maritime sector
- *Understanding* of methanol-as-fuel regulations
- *Proficiency* in the applicable monitoring and reporting of methanol fuel use

The KUP elements define the level of cognition required. So, a seafarer may not only need to have *knowledge* of applicable rules but should also be *proficient* in reporting.

1.4 Onboard functions

Seafarers onboard perform different functions at different levels. This entails that certain competences are more necessary for certain seafarers than others. For example, a chief engineer will require different competences than a deckhand. The STCW outlines six onboard functions within the management, operational and support levels of responsibility, which are relevant to the use of alternate fuels, namely:

- Navigation - NAV
- Cargo handling and stowage – CHS
- Controlling the operation of the ship and care for persons on board - OPS
- Marine engineering - ME
- Electrical, electronic and control engineering - ELC
- Maintenance and repair – M&R

When identifying competences, these onboard functions were used to categorise them in terms of their role onboard. For example, a competence related to being proficient in conducting maintenance on double-walled piping would be categorised under the maintenance and repair (M&R) onboard function.

1.5 STCW code competence table

Currently, the competences seafarers need to possess to safely operate on board are drawn from STCW competence tables, which form a part of the STCW code. These lay out mandatory minimum standards and special training requirements for different ship types. As an example, section A-V/3 of the STCW code encompasses the *“Mandatory minimum requirements for the training and qualification of masters, officers, ratings and other personnel on ships subject to the IGF Code”.* The tables within this section form the core of the competence requirements for IGF Code vessels. These tables are structured as shown in Table 1-3.

[9] DNV Standard - Competence related to the onboard use of LNG as fuel

Table 1-3 Example of IMO STCW table structure, using Table A-V/3-1 of the STCW code

Column 1 - Competence	Column 2 – Knowledge, understanding and proficiency (KUP)	Column 3 – Methods for demonstrating competence	Column 4 – Criteria for evaluating competence
Outlines an overall competence	Breaks the competence down into KUP elements, which specify specific competences depending on the level of cognition required	Outlines the methods in which the competence can be demonstrated and gained (training/experience)	Defines the point at which it can be determined that the competence has been gained
Example: *Respond to emergencies*	Example: *Basic knowledge of emergency procedures, including emergency shutdown*	Example: *Examination and assessment of evidence obtained from one or more of the following* *1. Approved in-service experience* *2. Approved training ship experience* *3. Approved simulator training* *4. Approved training programme*	Example: *The type and impact of the emergency is promptly identified, and the response actions conform to the emergency procedures and contingency plans*

In the identification of competences in this study, the structure of the STCW competence tables will be followed as closely as possible. Part A covering column 1 and 2, while Part B covers column 3 and 4. However this study's competence tables will also attempt to link competences to the STCW's onboard functions, as shown in 1.4. Additionally, this study attempts to link roles (i.e. engineer officers/ratings) to competences along with onboard functions. These competences can, therefore, be included in the STCW Code chapters II & III (mandatory minimum requirements for master, deck and engine department) or chapter V (special training requirements for personnel on certain types of ships) depending on their relevance.

2. Task A1 – State of the Art

2.1 Description

2.1.1 Objectives

Task A1 had the following objectives:

1. Describe the state-of-the-art concerning current training of seafarers on the use of alternative fuels and energy systems within the scope
2. Create an overview of topics for potential competences from relevant studies, rules, standards, guidance, and recommendations

This task does not investigate the standard basic competences that seafarers require, regardless of the fuel type and energy/system on board. It rather focuses on the competence needs that arise from adopting a specific fuel/energy system.

2.1.2 Approach

The objectives of Task A1 were achieved through the following approach:

1. Prepare an interview guide to map the current state-of-the-art training for seafarers on alternative fuels
2. Identify relevant internal and external interview subjects
3. Interviews with internal and external experts according to an interview guide

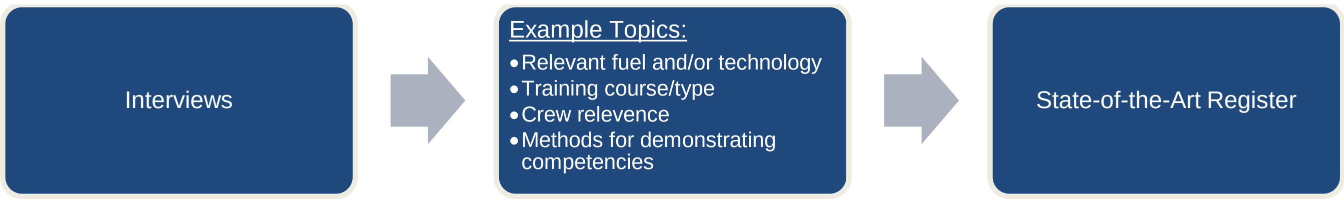

Figure 2-1 - Approach 1 for Task A1

From this approach a state-of-the-art register was developed, containing:

- The relevant fuel/energy system
- The method of current training
- Relevance for crew type (i.e. engineer, deck etc.)
- Methods for demonstrating competence

4. Review of reference sources and material on potential new competences

Figure 2-2 - Approach 2 for Task A1

From this approach, a similar state-of-the-art register as before was developed, containing:

- The relevant fuel/energy system
- Reference to source
- Relevance for crew type (i.e. engineer, deck etc.)
- Potential new competence needs

These state-of-the-art registers could then be used to adjust and specify areas for new competences and training methods in later tasks.

2.2 Results

2.2.1 Results – Interviews

An interview guide to map the current state-of-the-art training for seafarers for alternative fuels was developed for Task A1. The purpose of the interviews was to gather insights from industry experts regarding relevant training programmes, practices and available documentation related to alternative fuels and energy systems for seafarers.

Specifically, the training landscape for this study was explored. Current training programmes, target groups for training, course structures, methods to demonstrate competence and certification methods were explored with internal and external experts.

2.2.1.1 The Causality Dilemma

According to the interviewees, the current situation when it comes to training programmes for seafarers on alternative fuel technologies is a classic causality dilemma[10]: where training providers are waiting for regulators to define the training requirements, and regulators are waiting for training providers to specify their plan to indicate an appropriate curriculum.

The main challenge in providing training for seafarers is the limited number of vessels that are transitioning to alternative fuels and the lack of regulatory framework. This makes it difficult for shipping companies to justify the investment in tailored training programmes and training centres with specialised equipment. As a result, the industry is moving slowly in this area. The maritime industry is awaiting a STCW update to specify training requirements for emerging alternative fuels.

A Baseline Training Framework for Seafarers in Decarbonization is being developed by the IMO and the Maritime Just Transition Task Force to prepare seafarers and officers for the safe operation of ships which will be running on zero and near-zero emission fuels. The framework will be implemented through a programme led by the World Maritime University[11].

Manufacturers of the systems and engines used for alternative fuels were identified by the experts to be crucial in delivering training to seafarers, along with shipboard familiarisation by the shipowners.

2.2.1.2 IGF basic and advanced courses

STCW training for seafarers on ships subject to the IGF code, is the training and on-board experience leading to the issuance of a Certificate of Proficiency (CoP) by the Administration in line with the STCW Convention. This issuance consists of attending basic and advanced courses and obtaining onboard experience as specified in the STCW Convention. When completing this training and completing the onboard experience, the seafarers will be competent to sail on ships running on fuels subject to the IGF Code.

Basic and advanced IGF courses are developed by training institutions with reference to the IMO model course framework and must be approved by a flag state.

2.2.1.3 Generic courses being provided in alternative fuel technologies

There are several training providers offering generic training towards alternative fuel technologies. However, this training is not very specific due to the lack of detailed regulations in the STCW on emerging alternative fuel technologies.

- Lloyds Maritime Academy provides a 14-week Certificate in Alternative Fuels course which offers a close look at a range of new fuel alternatives for onboard crew, but also shoreside managers, operators and traders, but serves as a basic introduction and does not directly assist with obtaining a CoP.
- DNV Maritime Academy offers two awareness courses for alternative fuel technologies:
    - **Ammonia as ship fuel.** Focus on rules and regulations, safety challenges, principles and components of typical ammonia fuel systems and ship type considerations. The course is targeted

[10] Colloquially known as the "chicken or the egg problem"
[11] MPA Singapore - Maritime Energy Training Facility to Deliver Competencies for Maritime Workforce to Handle New Fuels

towards technical personnel within shipping companies, yards, and designers. However, it is also open to seafarers.
- **Methanol as ship fuel**. The course has the same focus and target groups as the above

Training academies focus on providing training for decision-makers in shipping companies and offering customised training for specific projects. These are short courses on e.g. ammonia and methanol that are intended for shore-based staff who are not required to sail but need to stay informed on these fuels. The courses are open to seafarers. As they only provide the attendant with a certificate of attendance, the courses are not valid as a certification, as demanded by the STCW Convention.

2.2.1.4 The role of designers and ship owners

Training for engine technology and onboard systems are often provided by manufacturers like Wärtsilä or MAN to the shipowners and seafarers of the companies that purchase their engines or fuel cells. Ship owners must ensure the training of seafarers in ship-specific equipment and fuel technology by collaborating with designers and manufacturers to develop specific training programs and operation manuals, as well as onboard familiarisation programmes.

From the ship owner's perspective, the challenge of acquiring new vessels powered by alternative fuels lies in the lack of expertise within the office staff to understand these fuels. To address this gap, ship owners need to hire superintendents with gas tanker experience, which can be an additional cost to the shipowner.

2.2.1.5 Interview results table

In the table below, a summary of state-of-the-art training identified from the interviews for each fuel type is listed. These show the identified existing training, its relevance and the method for demonstrating competence it uses.

Table 2-1 Results from interviews

LNG & Biofuels		
Training	**Relevance for Type of Crew**	**Methods for Demonstrating Competence**
IMO model course - Basic Training for service on ships subject to the IGF Code	Seafarers responsible for designated safety duties associated with the care, use or emergency response to the fuel on board ships subject to the IGF Code are to hold the CoP in Basic Training. Every candidate for the CoP in basic training for service on ships subject to the IGF Code is to have completed an approved course. There are no special seagoing service or experience requirements for this level of training[12].	Completed at least 1 month of approved seagoing service that includes a minimum of 3 bunkering operations on board ships subject to the IGF Code, where two of the three bunkering operations may be replaced by approved simulator training on bunkering operations. Personnel holding CoPs in accordance with Regulation V/3 shall, at intervals not exceeding 5 years, undertake appropriate refresher training or be required to provide evidence of having achieved the required standard of competence within the previous 5 years.
IMO model course - Advanced Training for service on ships subject to the IGF Code	Masters, engineer officers and all personnel with immediate responsibility for the care and use of fuels and fuel systems on ships subject to the IGF Code, are to hold the CoP in Advanced Training.	Completed at least 1 month of approved seagoing service that includes a minimum of 3 bunkering operations on board ships subject to the IGF Code, where two of the three bunkering operations may be replaced by approved simulator training on bunkering operations. Personnel holding CoPs in accordance with Regulation V/3 shall, at intervals not exceeding 5 years, undertake appropriate refresher training or be required to provide evidence of having achieved the required standard of competence within the previous 5 years.
Biofuels	No specific training identified. Transitioning from oil to biofuel requires minimal extra training according to industry experts.	-
Methyl/Ethyl Alcohols		
Training	**Relevance for Type of Crew**	**Methods for Demonstrating Competence**
Similar to LNG, but taking into account the Interim Guidelines to ensure competence to handle methanol hazards (MSC 1621)		
Methanol specific course by the Singapore Maritime Academy & Singapore Polytechnic[13]	Focus on maritime personnel responsible for the designated safety duties associated with the care, use, or emergency response to the fuel on board ship. Training course focused on handling methanol as fuel for ships. Covering operational and safety protocols during methanol bunkering, including a practical firefighting component. This course is split into an advanced and basic version.	Certificate of attendance only
DNV's Methanol as a Fuel Course	Course Objective	Certificate of attendance only

[12] Guidance on the training requirements for applicable personnel on ship subject to the IGF code
[13] Basic Training for Handling of Methanol as Fuel for Maritime Personnel

	The course will give the participants an overview about the current developments in the field of methanol as ship fuel. <u>Focus Points</u> ▪ Applicable rules and regulations ▪ Safety challenges and associated risks ▪ Principles and components of typical methanol fuel systems ▪ Ship type considerations <u>Content</u> The maritime industry faces stricter environmental regulations, prompting the need for new fuel solutions. Decision-makers and seafarers can explore methanol fuel systems in a course that addresses safety challenges, regulations, and risk mitigation. The goal is to enhance technical personnel's understanding of methanol as a ship fuel.	
Electricity		
Training	**Relevance for Type of Crew**	**Methods for Demonstrating Competence**
No specific training programs identified. Designer initiated	Courses and operating manuals are being prepared by designers/manufacturers as part of delivering new systems to ships.	-
Shipowner initiated	Shipowners may order generic courses from designers or training academies	
Fuel cells		
Training	**Relevance for Type of Crew**	**Methods for Demonstrating Competence**
No specific training programs identified. Designer initiated	Courses and operating manuals are being prepared by designers/manufacturers as part of delivering new systems to ships.	-
Shipowner initiated	Shipowners may order generic courses from designers or training academies	
Ammonia		
Training	**Relevance for Type of Crew**	**Methods for Demonstrating Competence**
Lloyds Maritime Academy: Certificate in alternative fuels 14-week Certificate in Alternative Fuels course offers a close look at a range of new fuel alternatives – including ammonia.	Masters, ship superintendents, marine engineers, chief officers, chief engineers, captains.	Online. Digital badge
DNV Maritime Academy: Ammonia as ship fuel	<u>Course Objective</u> The course will give the participants an overview about the current developments in the field of Ammonia as ship fuel. <u>Focus Points</u>	Certificate of attendance only

	▪ Applicable rules and regulations ▪ Safety challenges and associated risks ▪ Principles and components of typical ammonia fuel systems ▪ Ship type considerations Content The maritime industry faces stricter environmental regulations, necessitating innovative fuel solutions. Decision-makers and seafarers can explore ammonia fuel systems in a course that addresses safety challenges, regulations, and risk mitigation. The goal is to enhance technical personnel's understanding of using ammonia as ship fuel.	
Hydrogen		
Training	**Relevance for Type of Crew**	**Methods for Demonstrating Competence**
No specific training programs identified. Designer initiated	Courses and operating manuals are being prepared by designers/manufacturers as part of delivering new systems to ships	
Shipowner initiated	Shipowners may order generic courses from designers or training academies	

2.2.2 Results – Review

The results of the identification of topics for potential competence needs within the scope are presented in the various tables below. As expected, more mature fuels and energy systems had more references covering potential competence needs.

2.2.2.1 LNG

LNG can be considered relatively mature when compared to, for example, hydrogen and ammonia. LNG as a fuel is covered by the IGF Code, while the competences related to LNG for seafarers are covered by the STCW Code. Specifically, the STCW Code's Table A-V/3-1. Additional competences covering LNG can go further as required. Table 2-2 shows the competence needs identified from the present literature.

Table 2-2 Identified competences from existing literature for LNG

LNG		
Reference	**Relevance for Type of Crew**	**Topics as Potential Competence Needs**
STCW Code Table A-V/3-1 (IMO, 2015)	The following crew on vessels subject to the IGF code: 1. Masters 2. Officers 3. Ratings	Basic: ▪ Understanding ship design and operational characteristics ▪ Knowledge of fuel systems and storage on IGF Code ships ▪ Awareness of hazard zones, fire safety plans, and monitoring systems ▪ Understanding fuel properties and safety requirements ▪ Assessment through approved experience, training, and programs ▪ Clear and effective communication within the area of responsibility ▪ Adherence to principles and procedures for safe ship operations ▪ Awareness of various hazards (health, environmental, reactivity, etc.) ▪ Knowledge of hazard controls (venting, segregation, etc.) ▪ Understanding fuel characteristics from Safety Data Sheets (SDS) ▪ Proper use of gas-measuring instruments ▪ Utilization of safety equipment (breathing apparatus, protective clothing, etc.) ▪ Adherence to safe working practices and guidelines ▪ Ability to elaborate on risks related to ships subject to the IGF Code ▪ Develop safety plans and instructions ▪ Knowledge of hot work, enclosed spaces, and tank entry procedures ▪ Evaluate evidence from approved in-service experience, training ship experience, simulator training, or training programs ▪ Identify relevant hazards and implement proper control measures ▪ Proper use of flammable and toxic gas-detection devices ▪ Apply occupational health and safety precautions on IGF Code-compliant ships ▪ Breathing apparatus and evacuating equipment ▪ Protective clothing and gear ▪ Resuscitators ▪ Rescue and escape equipment ▪ Adherence to safe working practices, legislative requirements, and industry guidelines ▪ Basic knowledge of first aid, referencing Safety Data Sheets (SDS) for fuels addressed by the IGF Code ▪ Precautions during repair and maintenance work on fuel systems ▪ Electrical safety (reference to IEC 600079-17) and ship/shore safety checklist ▪ Knowledge of firefighting and extinguishing systems for fuels addressed by the IGF Code ▪ Methods and appliances to detect, control, and extinguish fires ▪ Prompt identification of problems and adherence to emergency procedures

LNG		
Reference	**Relevance for Type of Crew**	**Topics as Potential Competence Needs**
		▪ Appropriate evacuation, emergency shutdown, and isolation procedures for fuels addressed by the IGF Code Advanced: ▪ Understanding the chemical structure of different fuels used on board ships subject to the IGF Code. ○ Simple physical laws ○ States of matter (liquid and vapor densities) ○ Boil-off and weathering of cryogenic fuels ○ Compression and expansion of gases ○ Critical pressure and temperature of gases ○ Flashpoint, upper and lower flammable limits, and auto-ignition temperature ○ Saturated vapor pressure and reference temperature ○ Dewpoint and bubble point ○ Hydrate formation ○ Combustion properties (heating values) ○ Methane number and knocking ○ Pollutant characteristics of fuels addressed by the IGF Code ▪ Understanding the properties of single liquids and the nature of solutions ▪ Knowledge of thermodynamic units, basic thermodynamic laws, and diagrams ▪ Awareness of material properties and the effect of low temperatures (including brittle fracture) for liquid cryogenic fuels ▪ Ability to interpret information contained in an SDS about fuels addressed by the IGF Code ▪ Effective use of information resources to identify fuel properties and characteristics, considering safety, environmental protection, and ship operation ▪ Operating principles of marine power plants ▪ Familiarity with ships' auxiliary machinery and relevant marine engineering terms ▪ Assessment through approved in-service experience, training ship experience, simulator training, or approved training programs ▪ Ensuring that plant, auxiliary machinery, and equipment operate within safe limits and technical specifications. ▪ Fuel systems for different propulsion engines ▪ General arrangement and construction ▪ Fuel storage systems (materials and insulation) ▪ Fuel-handling equipment and instrumentation (pumps, pipelines, expansion devices, flame screens, etc.) ▪ Temperature monitoring and tank level gauging systems ▪ Cryogenic fuel tank temperature and pressure maintenance ▪ Fuel system atmosphere control systems (inert gas, nitrogen) ▪ Toxic and flammable gas-detecting systems ▪ Fuel Emergency Shut Down system (ESD) ▪ Understanding fuel system theory and characteristics, including types of fuel system pumps (low pressure, high pressure, vaporizers, heaters, pressure build-up units) ▪ Knowledge of safe procedures for fuel tank operations (inerting, cooling down, initial loading, pressure control, heating, emptying) ▪ Understanding the properties of single liquids and the nature of solutions ▪ Knowledge of thermodynamic units, basic thermodynamic laws, and diagrams ▪ Awareness of material properties and the effect of low temperatures (including brittle fracture) for liquid cryogenic fuels ▪ Ability to interpret information contained in an SDS about fuels addressed by the IGF Code ▪ Effective use of information resources to identify fuel properties and characteristics, considering safety, environmental protection, and ship operation ▪ Operating principles of marine power plants ▪ Familiarity with ships' auxiliary machinery and relevant marine engineering terms

LNG		
Reference	**Relevance for Type of Crew**	**Topics as Potential Competence Needs**

		▪ Assessment through approved in-service experience, training ship experience, simulator training, or approved training programs
		▪ Ensuring that plant, auxiliary machinery, and equipment operate within safe limits and technical specifications.
		▪ Fuel systems for different propulsion engines
		▪ General arrangement and construction
		▪ Fuel storage systems (materials and insulation)
		▪ Fuel-handling equipment and instrumentation (pumps, pipelines, expansion devices, flame screens, etc.)
		▪ Temperature monitoring and tank level gauging systems
		▪ Cryogenic fuel tank temperature and pressure maintenance
		▪ Fuel system atmosphere control systems (inert gas, nitrogen)
		▪ Toxic and flammable gas-detecting systems
		▪ Fuel Emergency Shut Down system (ESD)
		▪ Understanding fuel system theory and characteristics, including types of fuel system pumps (low pressure, high pressure, vaporizers, heaters, pressure build-up units)
		▪ Knowledge of safe procedures for fuel tank operations (inerting, cooling down, initial loading, pressure control, heating, emptying)
		▪ Ability to elaborate on risks related to ships subject to the IGF Code
		▪ Knowledge of safety plans and instructions
		▪ Knowledge of hot work, enclosed spaces, and tank entry procedures
		▪ Identify relevant hazards and implement proper control measures
		▪ Proper use of flammable and toxic gas-detection devices
		▪ Apply occupational health and safety precautions on IGF Code-compliant ship
		▪ Correct use of safety equipment:
		  ○ Breathing apparatus and evacuating equipment
		  ○ Protective clothing and gear
		  ○ Resuscitators
		  ○ Rescue and escape equipment
		  ○ Adherence to safe working practices, legislative requirements, and industry guidelines
		▪ First Aid and Fuel Systems:
		  ○ Basic knowledge of first aid, referencing Safety Data Sheets (SDS) for fuels addressed by the IGF Code
		  ○ Precautions during repair and maintenance work on fuel systems
		  ○ Electrical safety
		▪ Fire Prevention and Control:
		  ○ Knowledge of firefighting and extinguishing systems for fuels addressed by the IGF Code
		  ○ Methods and appliances to detect, control, and extinguish fires
		  ○ Prompt identification of problems and adherence to emergency procedures
		  ○ Evacuation and Shutdown Procedures
		  ○ Appropriate evacuation, emergency shutdown, and isolation procedures for fuels addressed by the IGF Code

DNV-ST-0026 (DNV, 2022)	1. Basic - Basic competence for all officers/crew, regardless of role or function 2. Deck - Competence requirements for deck officers / operational deck crew 3. Engine - Competence requirements for engine officers / operational engine crew	▪ General knowledge and understanding of LNG as a fuel – characteristics, terminology, rules/regulations ▪ Risk awareness, health, and safety – hazards, risks, exposure treatment, cryogenic properties, use of PPEs etc. ▪ LNG storage tanks – types, construction, leak detection, layout/operation, pressure holding times, cooling, monitoring ▪ Inspection and monitoring of LNG storage – valve operation, remote monitoring, inspections ▪ Bunker transfer – drip trays, procedure, operation, limitations, storage pressure ▪ Tank connection space – functioning, gas detection, safe working procedures ▪ Pressure control, temperature monitoring and level gauging – monitoring and control equipment, inspections, tests

LNG		
Reference	**Relevance for Type of Crew**	**Topics as Potential Competence Needs**
		▪ Gas supply system – repairs, operation, maintenance, valves, and pumps ▪ Cool-down procedure and operation/maintenance of pumps – high pressure pumps, in-tank pumps, spray pumps ▪ LNG monitoring system – control/monitoring system, troubleshooting, vapour control ▪ Venting and ventilation – negative and positive pressure use, air locks, monitoring of ventilation and pressure conditions ▪ Double-walled piping – inspection and leak tests, assembly/dis-assembly, maintenance ▪ Fuel gas venting system – hazardous zones, ignited vent, safety vents, explosive atmosphere monitoring, trapped liquid ▪ Compressors – operation and maintenance, dissolved gas in lubrication oil ▪ Gas detection – operation, maintenance, and calibration ▪ Emergency procedures – emergency shutdown, inspection/maintenance of ESD valves, tests, operation/maintenance of EX-certified equipment. fire detection system and gas detection system ▪ Inerting – operation/maintenance of nitrogen generator, nitrogen injection and purging, distribution of nitrogen, ▪ Bunkering – preparations, connections, procedures, emergency procedures ▪ Tank conditioning – warming up, gas freeing, inerting, purging ▪ Heating and cooling – temperature & flow of glycol intermediate circuit, heating system, overpressure protection ▪ 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
Guidance on LNG Bunkering to Port Authorities and Administrations (EMSA, 2017)	All	Drawn from IGF Code, STCW Convention, IMO Model Course (Advanced Training for Liquefied Gas Tanker Cargo Operation) and Directive 2008/106/EC on the minimum level of training seafarers: ▪ Competences as stated in Table A-V/3-1 of the STCW Convention covering the specification of minimum standard of competence in basic training for ships subject to the IGF Code ▪ IGF code basic and advanced model courses

2.2.2.2 Biofuels

Biofuels offer, arguably, the least amount of additional competence needs in comparison to conventional fuel oil, especially when it comes to safety. This is due to their similarity with conventional fuels; however, biofuels do exhibit different characteristics in terms of operation. Table 2-3 provides an overview of identified competences from existing literature.

Table 2-3 Identified competences from existing literature for biofuels

Biofuels		
Reference	**Relevance for Type of Crew**	**Topics as Potential Competence Needs**
Study on the Safe Bunkering with Biofuels (bio-methanol, FT-diesel, DME, HVO and FAME) (EMSA, 2023)	All	Currently no specific competences regarding safety have been identified for biofuels. With the studies that do cover it stating that they are so alike conventional fuels that they can be considered drop in, in most cases.

Biofuels		
Reference	**Relevance for Type of Crew**	**Topics as Potential Competence Needs**
DNV Biofuel study, 2023-0315 (DNV, 2023)	Officers Engineering crew	Identified areas where the differences between biofuels and conventional fuels are significant enough to warrant changes in operation, namely: Main engine: ▪ Engine tuning ▪ Lubrication ▪ Material compatibility ▪ Leakage due to differing viscosity ▪ Power output vs. fuel consumption Fuel supply: ▪ Viscosity control ▪ Temperature control ▪ Clogging ▪ Material compatibility Fuel treatment and preparation: ▪ Tank cleaning ▪ Draining capability ▪ Purification ▪ Filters ▪ Clogging ▪ Material compatibility ▪ Temperature control Fuel specification and documentation: ▪ Tank cleaning ▪ Draining capability ▪ Purification ▪ Filters ▪ Clogging ▪ Material compatibility ▪ Temperature control Fuel bunkering storage and transfer: ▪ Fuel specification and documentation ▪ Stability and storage properties ▪ Fuel temperature ▪ Volumetric energy density ▪ Tank cleaning ▪ Fuel storage for aux systems

2.2.2.3 Methyl/Ethyl alcohols

Methyl/Ethyl alcohols are slightly more mature in showcasing their competence needs, as is evident by existing regulation covering this, namely the IMO's interim guidelines for the safety of ships using methyl/ethyl alcohol as fuel. These refer to the IGF Code's competences outlines in the STCW Code as shown in 2.2.2.1.

However, these competences must take into account the nature of methyl/ethyl alcohols as fuel. The focus lies heavily on methanol as a fuel. This focus is also adopted by this study.

Table 2-4 Identified competences from existing literature for Methyl/Ethyl alcohols

Methyl/Ethyl Alcohols		
Reference	**Relevance for Type of Crew**	**Topics as Potential Competence Needs**
Interim guidelines for the safety of ships using methyl/ethyl alcohol as fuel – MSC.1/Circ.1621 (IMO, 2020)	All	▪ Competences as stated in Table A-V/3-1 of the STCW Convention covering the specification of minimum standard of competence in basic training for ships subject to the IGF Code, but taking into account the nature of methyl/ethyl alcohols as fuel ▪ Taking methanol as an example specific competence need may cover topics such as: ○ Knowledge of the properties of methanol ○ Understanding of the risks and hazard specific to methanol as fuel ○ Proficiency in the prevention and response towards methanol-specific emergencies (including fire, spills, pollution, and vapour intoxication) ○ Proficiency in the operation of methanol firefighting equipment and extinguishing agents ○ Proficiency in the use of methanol specific PPEs, such as a Self-Contained Breathing Apparatus ○ Understanding the environmental impacts and associated risks of methanol spills and gas plumes ○ Understanding and proficiency in the use of methanol fuel systems: handling, storage, and usage
Methanol Bunkering: Technical and Operational Advisory (ABS, 2024)	All	▪ Basic handling of methanol including scenarios for leakage, spillage, and fire. ▪ Fundamentals of methanol, technical safety, operational risks and hazards, fire prevention and firefighting, roles and responsibilities, emergency management and operational procedures. ▪ Ship-specific training ▪ IGF Code training requirements for ships which use gases or other low-flashpoint fuels.
DNV-ST-0687 (unpublished) (DNV, 2024)	1. Basic - Basic competence for all officers/crew, regardless of role or function 2. Deck - Competence requirements for deck officers / operational deck crew 3. Engine - Competence requirements for engine officers / operational engine crew	▪ General knowledge and understanding of Methanol as a fuel – characteristics, terminology, rules/regulations/reporting ▪ Risk awareness, health, and safety – hazards, risks, exposure treatment, toxic/poisoning properties and effect, operational risks, use of PPE. ▪ Voyage planning – Environmental and methanol related regulations, calculation of required amount of methanol, assess stability effects on using primary fuel vs methanol fuel ▪ Methanol storage tanks – types, construction, leak detection, layout/operation, tank connection, monitoring, nitrogen blanketing, tank cleaning ▪ Fuel supply system – Layout and configuration, components, monitoring, operation, maintenance, valves, and pumps ▪ Engine – Starting, diagnostics, fuel switch, shutting down ▪ Safety systems and components – Emergency shutdown, ex-certified equipment, ▪ Bunkering – Preparations, bunker transfer arrangement, bunker transfer, procedure, operation, limitations, shore connections and emergency release ▪ Contingencies – Emergency plans, methanol leaks and spills, fire, emergency unloading / discharge ▪ Maintenance – Materials, spare parts, performing maintenance ▪ Monitoring – Pressure control, temperature monitoring, level gauging systems and overfill protection equipment ▪ Tank conditioning – Gas freeing, inerting, purging ▪ Ventilation – Positive vs negative pressure, adjusting, maintenance ▪ Auxiliary systems and equipment – in-tank fuel pumps, inert gas generator, deluge system ▪ NOx emission reduction system – Operation and maintenance
Methanol as a marine fuel v 1.0 (SGMF, 2024)	Introduces methanol as a fuel	▪ General information: Properties, uses, availability, regulations and environmental aspects ▪ Safety aspects: Cryogenic, exclusivity, safety systems and management, emergency response ▪ Fuel systems: Storage, power generation concepts (ICE, fuel cell)

Methyl/Ethyl Alcohols		
Reference	**Relevance for Type of Crew**	**Topics as Potential Competence Needs**
		▪ Bunkering

2.2.2.4 Battery-powered hybrid electric & BESS

In contrast to other fuels examined in this report, batteries serve as a relatively static and fixed energy source rather than a traditional fuel. Despite their widespread adoption in the maritime industry, there remains a scarcity of knowledge and competence related to emergency procedures for handling battery systems. Typically, technology suppliers provide training to crew members on the technical aspects of battery system operation, emphasising minimal crew interaction and specialised maintenance teams.

Table 2-5 Identified competences from existing literature for battery-powered hybrid electric & BESS systems

Battery-powered hybrid electric & BESS		
Reference	**Relevance for Type of Crew**	**Topics as Potential Competence Needs**
Guidelines on requirements for training in chemical energy storage (maritime battery systems) on board Norwegian ships (NMA, 2021)	Persons who will operate maritime battery systems used on board ships or perform inspection or maintenance of such systems	▪ Be familiar with battery chemistry and the different types of battery cells ▪ Be familiar with a frequency converter ▪ Be familiar with important technical concepts for the battery system ▪ Be able to account for the dangers of the battery system from a safety point of view ▪ Be able to account for the dangers related to different hazards (temperature, poisoning and ignition) ▪ Be able to account for the auxiliary system ▪ Be able to account for the important and critical alarms related to the battery system, both with regard to possible causes and consequences of the alarms ▪ Be able to account for the handling of hazards and incidents that could occur in maritime battery systems ▪ Be able to assess the risks associated with the battery system, both individually and in cooperation with others
EMSA Guidance on the Safety of Battery Energy Storage Systems (BESS) on board ships (EMSA, 2023)	Electro-technical officers	▪ Provides functional requirements based on goals and hazards for different aspects and modules of BESS, such as cells modules and packs, uninterruptible power supply (UPS), converters and inverter-chargers, BMS, energy management system, spaces for battery system, fire safety, fire extinguishment, ventilation / HVAC, electrical arrangements ▪ Testing overview: Relevant standards, procedures and requirements, protocols, different types of tests and documentation ▪ Operations procedures: General knowledge, normal operational procedure, emergency operational procedures, maintenance ▪ Normal operational procedures: PPE procedures, operating modes, battery (e-)logbook, shore-side charging ▪ Emergency operational procedures: Procedures, drills and exercises, detection arrangements, fire-fighting, medical scenarios, reporting ▪ Maintenance: lock out/tag out (LOTO) procedure ▪ Training: Type of certification, number of people on board with correct training ▪ Risk assessment: Hazards, preventive measures, risks, recommendations In Annex B, the guidance for Officer's qualification is described, pre-requisites to STCW ETO Certification ▪ Types of long duration batteries ▪ Different battery chemistry characteristics ▪ Safety hazards to consider ▪ Components in a Battery Energy Storage System (BESS)

Battery-powered hybrid electric & BESS		
Reference	**Relevance for Type of Crew**	**Topics as Potential Competence Needs**
		▪ Different battery system functions on-board ▪ Battery system use cases on board ships ▪ AC/DC coupled systems ▪ End of life options for batteries ▪ Battery chemistry: Characteristics, charge rates, chemistries, and potential failure mechanisms ▪ Lithium- ion BESS: Principles, BESS safety ▪ Notions on other batteries technologies: Redux, Plating, organic and other ▪ Desing considerations: Common characteristics. Projected life, performance, Li-ion batteries, ▪ Safety: Battery scorecards, relevant BESS standards, fire protection and ventilation systems, relevant safety standards ▪ Major components in a BESS: Batteries, fire suppression, inverters, Step-up Transformers, Secondary containment, Controllers, Housings, Battery management system, Energy management systems, Substation, Other systems (HVAC, BMTS.) ▪ Operation and maintenance ▪ System resiliency: Redundancy, backup power / UPS ▪ AC/DC coupled systems: DC systems, DC coupled to generation, DC coupled to DC loads, High voltage DC principles, design, operations and maintenance ▪ Operational risks ▪ Inspections and maintenance: Service agreements, O&M agreement challenges ▪ Decommissioning: recycling (the process, li-ion decommissioning, planning for disposal), Environmental considerations (recyclability, regulatory framework, decommissioning)
Shore-Side Electricity: Guidance to Port Authorities and Administrations (Part 1 – Equipment and Technology)	Relevant for engineers and electricians	▪ Shore-side electricity (SSE) overview: block diagrams and architecture, options, opportunities and challenges: ▪ SSE general infrastructure and equipment: power source characteristics and quality, Power factor concept, cable types, protection systems, substations, switchboards, circuit breakers, transformers, inverters/rectifiers, frequency converters, energy storage systems (ESS), ship-shore connection equipment including cable management system
Shore-Side Electricity: Guidance to Port Authorities and Administrations (Part 2 – Planning, Operations and Safety) (EMSA, 2022)	Relevant for officers on board. Mostly for electrical officers and engine officers, to get understanding of shore-side electricity, but also deck officer, as it provides regulations and operational procedures	▪ SSE concepts: Onshore Power Supply (OPS), Shore-side battery Charging (SBC), SBC Battery Swapping (SBC-BS), Shore-side Power Banks (SPB), port generators ▪ Regulatory framework: IMO (SOLAS, MARPOL, Onshore Power Supply (OPS) Guidelines, STCW), relevant EU directives, standards (ISO, IEC/IEEE) ▪ Responsibilities: Stakeholders in SSE operation, port roles and responsibilities in SSE ▪ SSE operation: operation concepts, preparation for operation, charging methods, ▪ Safety: Hazards and failure modes, risk assessments, protection systems, checklists
Study on electrical energy storage for ships (EMSA, 2020)	General information, relevant for all crew. Some information only relevant for decision makers and ship officers.	▪ General knowledge: battery technology, concepts, terms (C-rate, charge, discharge, State of Charge (SOC), energy content ▪ Battery technologies, advantages, and disadvantages: Lithium-ion, lead-acid, high temperature sodium, super capacitors, flow batteries, future technologies (solid-state, zinc-ion, calcium-ion, potassium-ion, magnesium, fluoride-ion, rechargeable metal-air, rechargeable metal-sulphur, dual-ion ▪ Ship types and different battery topologies: Ferries, cargo vessels ▪ Utilization: Spinning reserve, peak shaving, optimise load, immediate power, backup power ▪ System topologies: Battery hybrid propulsion, all-electric propulsion ▪ Standards, regulations, and guidelines: IMO and flag state requirements, relevant codes and standards, classification rules ▪ Battery safety: safety aspects of lithium-ion batteries (thermal runaway and propagation, electrolyte off gas), battery technology considerations (Battery Management system (BMS), cell and chemistry considerations, module design)

Battery-powered hybrid electric & BESS		
Reference	**Relevance for Type of Crew**	**Topics as Potential Competence Needs**
		▪ Operational safety risks of lithium-ion batteries: overcharge, over-discharge, overcurrent, overheating, excessive cold, external short circuit, mechanical damage, external fire, internal defect ▪ Risk assessment: HAZID, hazards, preventive measures, risks, recommendations

2.2.2.5 Fuel cells

Fuel cells, including SOFCs, PEMFC and HT-PEMFCs are approached in the sense of being their own system. References to competence requirements for crew specifically related to the operation of fuel cells are limited. Training is typically provided by technology suppliers, focusing on the technical operation of the fuel cell. The prevailing approach is to minimise crew interaction with the fuel cell, delegating maintenance tasks to specialised teams.

Table 2-6 Identified competences from existing literature for fuel cell power systems

Fuel cell power systems		
Reference	**Relevance for Type of Crew**	**Topics as Potential Competence Needs**
Study on the use of fuel cells in shipping (EMSA, 2017)	Basic - Basic competence for all officers/crew, regardless of role or function Deck - Competence requirements for deck officers / operational deck crew Engine - Competence requirements for engine officers / operational engine crew	▪ Basic functioning of a FC in converting fuel to hydrogen for consumption ▪ High temperatures of SOFCs and HT-PEMFCs ▪ Fuel contamination
DNV-RU-SHIP Pt.6 Ch.2 (DNV, 2023)	All	▪ Hazardous spaces ▪ Exhaust air/gas ▪ Ventilation ▪ Safety systems and actions

2.2.2.6 Ammonia

Although ammonia has been transported on board ships for decades, competence and knowledge related to its use as a fuel remain scarce. There is no concrete regulation in place considering it as a fuel, and at the time of writing this report systems are still being developed for vessels to run on ammonia. However, as no ships are currently using ammonia for propulsion purposes, this creates a gap considering the unavailability of reference systems to create competences from, hence, there are a few documents considering competence. The general impression of the documentation available is that they consider the toxicity of ammonia and how the substance is carried as a cargo, but not as a fuel onboard.

Table 2-7 Identified competences from existing literature for ammonia

Ammonia		
Reference	**Relevance for Type of Crew**	**Topics as Potential Competence Needs**
Ammonia as a marine fuel – Safety handbook, Rev.2 (DNV/GSP/NMA, 2023)	General knowledge, relevant for all crew.	Intended as practical guidance on safety aspects of the ship design in development of ammonia fuelled ships for ship owners, yards, and designers. Ammonia as a fuel contains the following topics for consideration: ▪ Properties of ammonia: toxicity, anhydrous characteristics, temperatures, corrosive properties ▪ Comparison with natural gas: regulatory frameworks, properties of the substances ▪ Toxicity: health effect, exposure guidance in concentration and time, environmental effects, toxicity towards aquatic/marine life ▪ Regulatory framework: current regulations (SOLAS, IGF, IGC and Class rules), development of international regulations, current status of competency and training ▪ Safety implications of differences between ammonia and natural gas: safety barriers, application of IGF code ▪ General design implications for ammonia fuelled ships: principle of onboard ammonia fuelled installation, ship design (machinery space, tank connection space, fuel preparation room, safe haven), fuel system, bunkering system, fuel supply to consumers, fire safety, explosion protection, toxic exposure protection, ventilation, control, monitoring and safety systems ▪ Operation: Guidance on what a ship-specific fuel handling manual should contain ▪ Personnel protection: emergency escape breathing equipment, hazardous zones, relevant first-aid
Potential of ammonia as a fuel in shipping (ABS/CE Delft/Arcsilea/EMSA, 2023)	General knowledge. Relevant for decision makers, such as captain, chief engineer and officer roles onboard.	The report presents various aspects of ammonia as a fuel in shipping, everything from general information from aspects around the production to the economics, greenhouse gas impact and safety regulation. The report provides a thorough description of the regulatory aspects of ammonia as a fuel, as well as a thorough overview over best-practice approach provided by industry member associations/organisations. Topics as potential competence needs: ▪ ISO standards relevant for ammonia for the industrial or land-based sectors: Material, sampling, measuring, technology, and specification for bunkering and dry-disconnect/connect ▪ IMO: SOLAS, IGC, IGF, STCW, ISM, MARPOL ▪ IGC: Material selection requirements, tank types and materials ▪ IGF Code: Risk assessment ▪ STCW: Requirements ▪ ISM: Requirements ▪ MARPOL: Environmental aspects, NOx, SOx ▪ Industry associations/organisations: Overview over industry best-practice approaches, requirements, class society ▪ Governmental bodies approaches: overview over requirements and region-specific regulations ▪ Risk assessment: HAZID, hazards, preventive measures, risks, recommendations
Ammonia as a marine fuel Version 2.0 (SGMF, 2024)	Introduces ammonia as a fuel	▪ General information: Properties, uses, availability, regulations and environmental aspects ▪ Safety aspects: Cryogenic, exclusivity, safety systems and management, emergency response ▪ Fuel systems: Storage, power generation concepts (ICE, fuel cell) ▪ Bunkering
DNV-RP-0699: Competence related to the onboard use of ammonia as fuel	1. Basic - Basic competence for all officers/crew, regardless of role or function 2. Deck - Competence requirements for deck officers / operational deck crew 3. Engine - Competence requirements for engine officers / operational engine crew	▪ General knowledge and understanding ▪ The ammonia bunkering- and fuel containment system ▪ The fuel supply system ▪ Venting and ventilation ▪ Technical safety barriers ▪ Auxiliary systems ▪ Bunkering

Ammonia		
Reference	**Relevance for Type of Crew**	**Topics as Potential Competence Needs**
		▪ Tank conditioning ▪ Maintenance ▪ Emergencies and contingencies

2.2.2.7 Hydrogen

Hydrogen is still developing in the maritime industry, and this is also reflected in the available documentation. Competence considering hydrogen should take into account the flammability and explosiveness of hydrogen. The substance is extremely versatile and not easy to contain considering the diffusion properties of hydrogen.

Table 2-8 Identified competences from existing literature for hydrogen

Hydrogen		
Reference	**Relevance for Type of Crew**	**Topics as Potential Competence Needs**
Handbook for hydrogen-fuelled (DNV & partners, 2021)	General information, relevant for all crew. Some information only relevant for decision makers and ship officers. The document is more relevant for the design phase of a vessel, rather than the operational phase.	▪ General information of hydrogen as a fuel: safety related properties, comparison to methane ▪ General hydrogen system configurations, systems and related equipment: fuel cell technology, compressed hydrogen system, liquid hydrogen system ▪ Regulatory frameworks: IMO, SOLAS, IGF Code, international hydrogen standards (ISO/TC, IEC), American Society of Mechanical Engineers (ASME), Compressed Gas Association (CGA), European Directives, National Fire Protection Association, Class rules ▪ Types of hydrogen storage onboard and relevant requirements: Compressed hydrogen storage, steel and composite hydrogen tanks, liquid hydrogen storage, safety distances and hazardous zones ▪ Bunkering aspects: Regulations and general safety considerations, inputs to procedures ▪ Engineering aspects of hydrogen systems: Relevant standards and rules for piping, materials, welding, and components ▪ Safety aspects: Risk assessment (HAZID, Qualitative Risk Assessment, Explosion Risk Analysis), accident experience transfer ▪ Risk mitigation and control measures: safe design, detection and alarms, ignition control, isolation and shutdown, vents and pressure-relief systems / masts, ventilation, leak control, fire control and fire protection
Potential of Hydrogen as a fuel for shipping (ABS/CE Delft/Arcsilea/EMSA, 2023)	General information	▪ General information considering hydrogen: Properties and production technologies (electrolysis, direct solar hydrogen production, biomass fermentation, thermochemical biomass conversion), sustainability aspects, availability (European vs world-wide) ▪ Principle layouts of onboard fuel systems: Internal combustion engine, thermos-Catalytic Decomposition (TCD) process, fuel cell, and relevant cost considerations ▪ Safety and environmental regulations, standards and guidelines: ISO, IMO (IGC, IGF, STCW, ISM, MARPOL), industry associations, IEC, Society of Automotive Engineers International (SAE), International Council of Combustion Engines (CIMAC) ▪ Safety considerations for hydrogen as a fuel: General properties, hazards, combustion and ignition properties, risk assessment methodologies, example of ship specific risk assessment (HAZID and risk register of RO-RO ferry and product carrier cases)

Hydrogen		
Reference	Relevance for Type of Crew	Topics as Potential Competence Needs
Hydrogen as a marine fuel Version 1.0 (SGMF, 2023)	Introduces hydrogen as a fuel.	▪ General information: Properties, uses, availability, regulations and environmental aspects ▪ Safety aspects: Cryogenic, exclusivity, safety systems and management, emergency response ▪ Fuel systems: Storage, power generation concepts (ICE, fuel cell) ▪ Bunkering

2.2.2.8 Cyber security

Decarbonisation of the maritime fleet introduces more hazardous materials, increasing the risk of severe consequences in the event of system malfunctions. Crew members must understand and manage factors such as toxicity and explosiveness. This requirement extends to competencies related to digital control systems. A cyber incident in a conventional diesel-electric system may be relatively manageable compared to the dynamic and hazardous properties of substances like ammonia or hydrogen.

Cyber security is now effective as both an ISM requirement, as well as an IACS (International Association of Classification Societies) requirement, meaning that both yards, vendors, designers, shipowner, and crew must understand the aspects around cyber security and technical integrity.

Table 2-9 Identified competences from existing literature for cyber security

Cyber Security		
Reference	Relevance for Type of Crew	Topics as Potential Competence Needs
Guidelines on maritime cyber risk management (MSC-FAL.1/Circ.3) (IMO, 2017)	General information, relevant for all crew. Some information only relevant for decision makers and ship officers.	▪ Understand that rapidly changing technology and threats may make it difficult to address cyber risks only through technical standards ▪ Competence on the diversity of the maritime industry, acknowledging that not two organizations are the same and that cyber risks may affect different organisations, systems, ships and crew differently ▪ Understanding of potential vulnerable systems, including but not limited to: ○ Bridge systems, cargo handling and management systems, propulsion and machinery management and power control systems, access control systems, passenger servicing and management systems, passenger facing public networks, administrative and crew welfare systems, and communication systems. ▪ Describe terminology as information technology and operational technology, and the difference between ▪ Understand that cyber risks may be posed by malicious threat actors causing malicious actions OR unintended consequence of benign actions (e.g., not understanding consequences of actions such as uncritical use of USB-sticks) ▪ Cyber vulnerabilities, threats, and risks ▪ Cyber risk management (framework) and mitigating actions ▪ Cyber risk awareness culture ▪ Understand what activities affect the functional elements identify, protect, detect, respond and recover ▪ CIA-triad and its impact on maritime operations (confidentiality, integrity and availability) ▪ Other best practice maritime cyber security documentation

Cyber Security		
Reference	**Relevance for Type of Crew**	**Topics as Potential Competence Needs**
Maritime cyber risk management in safety management systems (Resolution MSC428(98)), (IMO, 2017)	Relevant for decision makers, such as captain, chief engineer and officer roles onboard.	▪ General competence on cyber risk threats and vulnerabilities, and potential consequences of not addressing such risks ▪ Understand how cyber is to be addressed in the ISM code and the respective safety management systems, and how it affects document of compliance
Cyber resilience of ships (IACS UR E26) (IACS, 2017)	Relevant for decision makers, such as captain, chief engineer and officer roles onboard.	▪ Minimum technical requirements and documentation required for design regarding cyber resilience of ships and rationale for such, considering the functional element goals; identify, protect, detect, respond and recover ▪ Cyber resilience operational procedures, periodic training and drills ▪ Cyber resilience surveys
Cyber resilience of on-board systems and equipment (IACS UR E27), (IACS, 2023)	Relevant for decision makers, such as captain, chief engineer and officer roles onboard.	▪ Minimum technical requirements and documentation required for design regarding cyber resilience of ships onboard systems and equipment ▪ Cyber asset inventory ▪ Topology diagrams ▪ Security capabilities ▪ Cyber incident response and recovery plans
Cyber security resilience management for ships and mobile offshore units in operation (DNV-RP-0496) (DNV, 2021)	Relevant for decision makers, such as captain, chief engineer and officer roles onboard.	▪ Advanced cyber risk management and determination of risks ▪ Causes, barriers, and consequences ▪ Cyber risk mitigation

Cybersecurity considerations and risk management are becoming increasingly critical as alternative fuel systems evolve. It is well-established that cybersecurity incidents can have physical safety implications, which is why they are addressed by the IMO and other governing institutions. The findings presented in Table 2-9 approach cybersecurity on a general level, applicable to all fuels and computer-based systems, rather than addressing risks specific to each fuel. Cybersecurity is recognised as a key competence for future alternative fuel supply systems; however, it will not be further explored in this study.

2.2.3 Task A1 conclusion

The goal of Task A1 was to:

Describe the state-of-the-art concerning current training of seafarers on the use of alternative fuels and energy systems for:

I. Liquid Natural Gas
II. Biofuels
III. Methyl/ethyl alcohols (limited to Methanol)
IV. Hybrid electrical battery systems
V. Fuel cells
VI. Ammonia
VII. Hydrogen

And create an overview of topics for potential competences from relevant studies, rules, standards, guidance, and recommendations.

The results show that there is wide range of levels of maturity when it comes to existing training and competence requirements for the different fuels and fuel systems. With LNG for example, being quite mature, while hydrogen is less mature.

Additionally, seafarer competence in cyber security is relevant to some degree to all the fuels/fuel systems and while not specifically covered further in this study remains an important theme throughout.

The results presented in A1 will serve as a foundation for identifying new competences and their respective KUPs. This will be completed in Task A2 and A3. With the competences summarised in a catalogue.

3. Task A2 – Competences

3.1 Description

Task A2 focussed on the further identification and substantiation of seafarer competences using the results from Task A1 and subsequent workshops.

3.1.1 Objectives

Task A2 had the following objectives:

1. Identifying, justifying, and substantiating new competences for seafarers in general
2. Identifying, justifying, and substantiating new, updated, upgraded, amended and/or obsolete competences for engineers

3.1.2 Approach

Task A2 was approached systematically, using the results from A1. The functions outlined in 1.4 were then used, together with KUPs, and discussed in a series of workshops with experts. These workshops had the goal of producing STCW-style competence tables based on onboard functions and substantiated with KUPs.

New/amended competences were primarily developed through a risk/hazard-based approach, where the primary goal of the competence would be to mitigate a risk/hazard originating from the use of alternative fuels/systems.

Figure 3-1 Task A2 approach

Identified and expanded competences could then be consolidated into a Competence Catalogue, 0. The identified competences were coupled to onboard functions, as defined by the STCW Convention, and are as follows:

- Navigation - NAV
- Cargo handling and stowage – CHS
- Controlling the operation of the ship and care for persons on board - OPS
- Marine engineering - ME
- Electrical, electronic and control engineering - ELC
- Maintenance and repair – M&R

The workshops had a structure as shown in Figure 3-2. This was systematically done per fuel/energy system within the scope of this study.

The competences were determined based on expert opinions during the workshops. However, it's important to recognise that these findings are constrained by the knowledge available at the time of the workshops. Consequently, the results should be viewed, not as an exhaustive solution, but rather as an initial groundwork for future development.

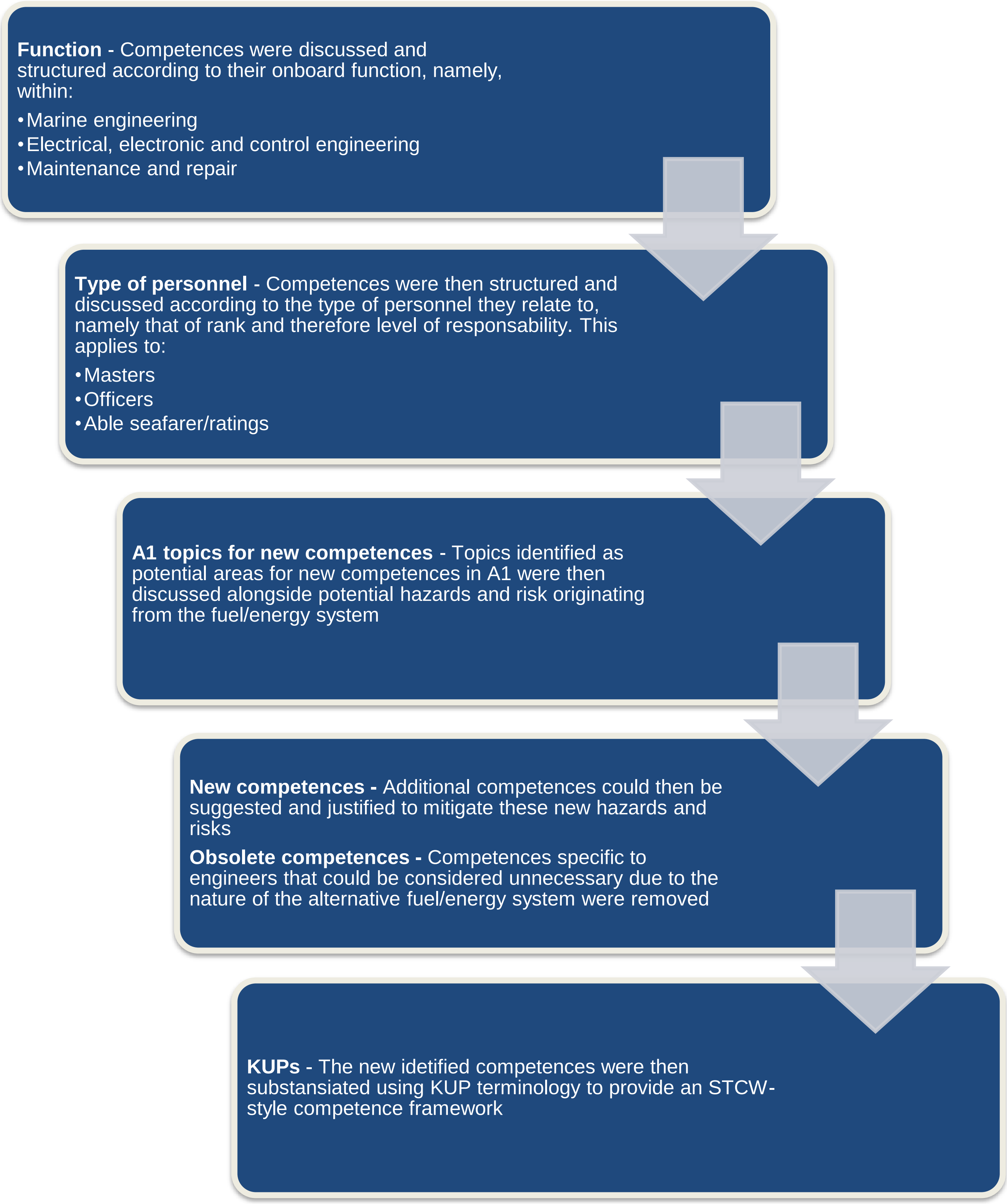

Figure 3-2 Workshop approach

3.2 Main results – Identification of Competences

The results of the workshops, identified new/amended/obsolete competences, are presented in the following sections. Each sub-section highlights a table with the identified new competences, as well as justification and KUP elements.

During the study, it was generally found that none of the already existing KUP elements of STCW could be considered as wholly obsolete. The reasons for this are twofold. Firstly, most alternative fuels are not yet fully implemented in the maritime industry, and it will take time before obsolete competences can truly be considered. Secondly, when operating on alternative fuels, it still might be required with redundant fuel systems or back-up conventional fuel systems. For instance, the requirements of emergency generators will still be effective, hence, knowledge of conventional fuel systems will still apply.

3.2.1 LNG

Liquefied Natural Gas (LNG) is natural gas that has been cooled to a liquid state at about -162°C (-260°F) for ease and safety of non-pressurized storage or transport. In its liquid form, LNG occupies about 1/600th the volume of natural gas in its gaseous state, making it highly efficient for transportation over long distances where pipelines are not feasible. LNG is primarily composed of methane, with small amounts of other hydrocarbons, and is used as a cleaner-burning alternative to other fossil fuels, contributing to reduced greenhouse gas emissions. It should be noted that LNG competence requirements are well codified in the STCW Convention and Code and in the IGF Code, Table 3-1 draws heavily on this and provides a solid foundation and comparison for the other fuels/energy systems. The results for LNG are based on the DNV competence guideline, DNV-ST-0026[14] (DNV, 2022).

Table 3-1 LNG competences

LNG						
Function	**Personnel**	**A1 topic**	**Hazards and risk potential**	**Competence**	**Justify**	**KUP Elements**
All	All	Understanding fuel properties and safety requirements	Hazards intrinsic to LNG as a fuel for personnel, among which: ■ Cryogenic burns ■ Asphyxiation ■ Highly flammable (fire and explosion) ■ Rapid phase transition ■ BLEVE	**Competence in the general knowledge and understanding of LNG, regarding LNG's properties and health hazards**	General knowledge and understanding of LNG are needed for crew to understand the inherent risks associated with LNG	Knowledge of the applicable rules and regulations related to the use of LNG in the maritime sector Understanding of ■ what LNG is ■ how LNG differs from other marine fuels ■ the relationship between pressure and temperature ■ the flashpoint, lower explosive limit, upper explosive limit, and auto-ignition temperature of LNG ■ what happens when opening a valve used to contain LNG ■ the term "rapid phase transition" ■ the terms "dew point" and "bubble point" in relation to nitrogen and how this affects LNG ■ the terms "boil-off gas" and "vapour buoyancy"
All	All	Principles and procedures for safe ship operations	■ Risk of exposure to LNG (asphyxia, low temperatures) ■ Expanding trapped liquid ■ Danger of ignition and explosion of LNG	**Competence in taking precautions and measures to reduce LNG-related risks**	Crew should understand the risks associated with LNG, its effect on health and safety and be able to take precautions	Understanding of ■ the hazards associated with handling LNG (e.g. asphyxia, low temperatures) ■ the risk of expanding trapped liquid/BLEVE ■ the hazardous areas/Ex-zones on board in relation to LNG and operational limitations in those areas ■ the term 'cryogenic' and the risks it presents for humans ■ how the cryogenic properties of LNG affect standard steel components upon contact

[14] Competence related to the onboard use of LNG as fuel

LNG						
Function	**Personnel**	**A1 topic**	**Hazards and risk potential**	**Competence**	**Justify**	**KUP Elements**
						■ the behaviour of LNG when discharged (into water/on ground) ■ the environmental impact of an operational release of LNG as compared to a release of a similar quantity of CO_2 ■ the risks of entering spaces containing nitrogen systems ■ risks of entering spaces with high-pressure cryogenic pumps Proficiency in ■ Interpreting the material safety data sheet for LNG ■ basic first aid in case of injuries / physical problems due to LNG exposure ■ the use of appropriate personal protective aids when working with LNG ■ the use of available rescue and escape equipment
OPS ME ELC M&R	Deck and Engineering officers	Tank conditioning	Improper conditioning of LNG tanks leading to incorrect gas freeing, inerting or purging and potential hazards	**Competence in taking precautions to prevent risk of ignition, explosion**	Crew should be able prepare LNG storage tanks and ensure they are safe and ready to receive LNG	Warming up / heating Understanding of ■ the resources, infrastructure and local conditions required for warming up (i.e. the water glycol intermediate circuit) ■ the link of the heating system with the engine cooling system ■ overpressure protection in relation to the heating system Proficiency in ■ calculating the approximate duration of warming up ■ setting temperature control points and flow distribution of the water glycol intermediate circuit ■ performing warming up procedure, always keeping the tank atmosphere in a non-explosive range Gas freeing of tanks Understanding of ■ principles and physics involved in the changing of tank atmospheres, including resources, infrastructure and local conditions required for gas-freeing ■ likely behaviour of vapour pressure during gas freeing Proficiency in ■ calculating the approximate duration of gas freeing ■ performing gas freeing, always keeping the tank atmosphere in a non-explosive range
OPS ME ELC	Engineering officers	Inerting	Improper inerting of equipment, pipes/lines and tanks leading to residual oxygen or other reactive gases are present, which can create an explosive atmosphere	**Competence in the inerting an LNG fuel system**	Proper inerting is needed to prevent unexpected residue from being present in tanks or lines	Inerting Understanding of ■ the principle of inerting ■ possible problems related to inerting and causes, such as condensate formation ■ dangers associated with incorrect inerting procedure Proficiency in ■ planning for inerting tanks, pipelines and equipment ■ determining when the inerting operation is completed based on parameters ■ determining oxygen content ■ determining dew point ■ performing a controlled change in tank atmosphere through inerting Inert gas generator Understanding of ■ the principles of operation of an inert gas generator, (e.g. a nitrogen generator)

LNG						
Function	**Personnel**	**A1 topic**	**Hazards and risk potential**	**Competence**	**Justify**	**KUP Elements**
						■ the maximum allowable percentage of oxygen in the mix ■ how the inert gas/nitrogen injection and purging arrangement works ■ when the inert gas generator should be operational and what the nitrogen outlet requirements are Proficiency in ■ operating an inert gas generator to supply dry air of appropriate quality ■ operating the nitrogen generator ■ performing maintenance on the nitrogen generator ■ operating the air compressor used for nitrogen generation and distribution ■ performing maintenance on the air compressor used for nitrogen generation and distribution ■ operating the booster compressor ■ performing maintenance on the booster compressor ■ taking appropriate action in case of nitrogen quality problems <u>Air and inert gas dryers</u> Understanding of ■ the purpose and operating principles of air and inert gas dryers ■ the 'drying' method and its importance ■ the 'inerting' method and its importance Proficiency in ■ operating the air and inert gas dryer ■ performing maintenance on the air and inert gas dryer
OPS ME CHS	Engineering officers	Purging	Improper purging of equipment, pipes, and tanks	**Competence in the purging of an LNG fuel system**	Proper purging is needed to prevent unexpected residue from being present in tanks or lines	Understanding of the principles of air purging Proficiency in ■ line up and procedures to purge tanks and pipelines ■ perform air purging ■ perform nitrogen purging ■ determine when nitrogen purging operation is completed, based on parameters
OPS ME CHS	Deck and Engineering officers	Storage	Incorrect storage of LNG: ■ Storage method ■ Bunker tanks ■ Tank connection space ■ Bunker transfer arrangements	**Competence in methods of storing LNG, its transfer arrangements and tank connection space**	Proper storage of LNG onboard is essential for its safe operation. Officers should be aware of the different aspects of storing LNG	<u>Storage method</u> Understanding of the storage temperature of LNG <u>Bunker tanks</u> Understanding of ■ the different tanks used for LNG containment (e.g. membrane, independent types) ■ the layout and operation of the tank system ■ the indicators of leaks in the insulation system ■ pressure holding times of the bunker tanks/system ■ the importance of monitoring hold space atmosphere ■ the methods of cooling down tanks Proficiency in ■ performing inspections of the bunker support system ■ performing inspections of the insulation system <u>Tank connection space</u> Knowledge of the increased risk of gas leakage in the tank connection space Understanding of ■ the function of the tank connection space

LNG						
Function	Personnel	A1 topic	Hazards and risk potential	Competence	Justify	KUP Elements
						■ the safe working procedure for working in the tank connection space <u>Bunker transfer arrangement</u> Knowledge of ■ the maximum loads/limitations of the loading arrangement (vessel side) ■ the movement limitations of the bunker transfer arrangement Understanding of ■ the importance of drip trays being kept free of (rain)water before commencing bunkering (if applicable) ■ the loading arrangement for bunkering LNG ■ the difference between high-pressure and low-pressure gas supply systems (pressurised/atmospheric) Proficiency in ■ estimating the required free space and trajectory for the loading arrangement ■ verifying that fendering does not interfere with the bunker transfer arrangement ■ preparing the line-up for bunker transfer ■ operating the manifold and the strainers ■ running the cool down procedure (if applicable) ■ adjusting valves in a correct manner during the cool down procedure ■ interpreting bunkering transfer diagrams
All	All	Bunkering	Improper execution of the safe bunkering of LNG	**Competence to plan, execute and monitor the safe bunkering of LNG**	As a safety-critical operation, the ability of a crew to conduct the safe bunkering of LNG is essential	Knowledge of safety and emergency procedures for operation of LNG-specific machinery, fuel- and control systems <u>Bunkering preparations</u> Knowledge of ■ the acceptable pump rates during the bunker transfer ■ the determining factors for using the vapour return system (if applicable) Understanding of ■ the tasks and responsibilities of both crew and bunkering personnel during preparation and bunkering operation ■ the need for using insulation flanges as opposed to bonding wires ■ the importance of earthing/grounding ■ measures taken on board to ensure proper grounding and static discharge during operations/bunkering Proficiency in ■ determining the condition of the bunker tanks (e.g. safe range of temperature and pressure for bunker tanks) ■ agreeing pre-bunkering formalities and operational alignment between ship and bunker operator in line with port regulations (pre-bunkering/compatibility checklist, communication lines ■ agreeing on emergency actions in combination with shore in case of emergencies ■ determining the vapour handling capacities of bunker provider and own vessel ■ determining the pressure levels of the nitrogen batteries to ensure adequate supply for the bunkering operation ■ determining the tank sequence for bunkering ■ determining the need for inerting and purging of the filling lines prior to the bunker transfer <u>Bunker transfer</u>

LNG						
Function	**Personnel**	**A1 topic**	**Hazards and risk potential**	**Competence**	**Justify**	**KUP Elements**
						Knowledge of the occurrence of 'flash gas' and what it is Understanding of ■ the physical properties of bunkers ■ the process sequences for bunkering operations Proficiency in ■ interpreting signals from the bunker control system ■ demonstrate correct and clear communication during bunkering process Quantity and quality of LNG bunkering Understanding of ■ the difficulty of calculating the quantity and quality of LNG bunkers ■ the procedure for bunker quantity and quality calculations as defined by the company Proficiency in verifying bunker quantity received
OPS ME ELC M&R	Deck and engineering officers	Gas supply system	Improper operation of the LNG supply system: ■ Cryogenic valves and pumps ■ Gas isolation valves ■ High-pressure pumps ■ In tank pumps ■ Spray pumps ■ Level gauging system	**Competence in the proper operation and functioning of an LNG fuel system**	Improper operation of LNG supply and monitoring system may cause unwanted events for the ship and pose safety challenges for the crew	Cryogenic valves and pumps understanding of ■ the design and construction of cryogenic valves ■ operation of cryogenic pumps in high-pressure gas supply systems Gas isolation valves Knowledge of how to recognise high differential pressure (high-pressure control valve) Proficiency in ■ performing routine tests on gas isolation valves/double block and bleed arrangement ■ interpreting test results of gas isolation valves/double block and bleed arrangement engine High-pressure pumps Proficiency in ■ operating a high-pressure reciprocating plunger fuel injection pump ■ monitoring pump readings ■ performing the cooling down procedure ■ performing maintenance on a high-pressure pump In tank pumps Understanding of ■ the setup and operation of the in-tank pumps ■ the critical importance of maintaining gas tight cable penetration Proficiency in ■ starting up the in-tank pumps ■ interpreting readings related to the operation of in-tank pumps Spray pumps Understanding of the purpose of spray pumps Proficiency in operating the spray pumps Level gauging systems Understanding of ■ the equipment used for overfill protection

LNG						
Function	**Personnel**	**A1 topic**	**Hazards and risk potential**	**Competence**	**Justify**	**KUP Elements**
						■ principle and method of operation of various types of level gauging systems ■ the likely problems of the various level gauging systems Proficiency in ■ interpreting readings from level gauging equipment ■ performing inspections, tests and routine calibration on level gauging equipment and overfill protection equipment <u>Vapour control</u> Understanding of ■ the methods for handling vapours from cooling down ■ limitations for venting off vapours ■ the return of the vapours during gas freeing and warming up Proficiency in ■ performing a manual emergency vapour release
OPS ME ELC M&R	Engineering	Ventilation	Insufficient venting and ventilation	**Competence in venting and ventilation of an LNG fuel system**	Improper operation of, or insufficient, venting and ventilation may cause in build-up of flammable and explosive gas	Understanding of: ■ the critical importance of a functioning ventilation system to ensure provision of LNG to the engine ■ the importance and the function of air locks ■ the use of positive and negative pressure at various places in the system ■ the importance of relative negative pressure in the gas dangerous areas ■ why vent outlets should be regarded as potential hazardous zones ■ actions in case of ignited vents Proficiency in performing checks related to positive pressure and negative pressure conditions and equipment <u>Double-walled piping</u> Understanding of ■ the importance and purpose of double-walled piping ■ how to handle double-walled piping during disassembling and reassembling Proficiency in ■ performing inspection and leak tests on double-walled piping ■ performing maintenance on double-walled piping
OPS ME ELC M&R	Engineering	LNG monitoring system	Improper monitoring of LNG temperature and pressure leading to knock-on hazards	**Competence to appropriately monitor the LNG fuel systems**	The proper monitoring of LNG fuel systems is needed to detect potential hazards/issues early	<u>Control and alarm board</u> Proficiency in ■ interpreting readings from the process control system ■ performing fault-finding related to the control and alarm board ■ performing troubleshooting related to the control and alarm board <u>Pressure control</u> Understanding of ■ the equipment used for measuring pressure ■ the terms operating pressure, pressure alarm high (PAH) and pressure alarm low (PAL) ■ how to control pressure <u>Temperature Monitoring</u> Understanding of ■ the equipment used for temperature monitoring

LNG						
Function	**Personnel**	**A1 topic**	**Hazards and risk potential**	**Competence**	**Justify**	**KUP Elements**
						■ how to control temperature Proficiency in ■ interpreting readings from temperature monitoring equipment ■ performing inspections, tests and routine calibration of temperature monitoring equipment ■ how to perform basic maintenance on relevant sensors
OPS ME ELC M&R	Engineering	Repair and maintenance work	Improper maintenance of LNG fuel system	**Competence in the maintenance on LNG systems**	Improper maintenance may cause malfunction of LNG related systems	Repairs and exchanging parts Understanding of ■ the importance of using stainless steel in piping and equipment ■ why improvised solutions using non-standard parts are dangerous Proficiency in verifying if the vessel has proper equipment on board to repair stainless steel piping
NAV OPS ME ELC M&R	Deck and engineering officers	Emergency procedures	Hazards intrinsic to LNG as a fuel for personnel, among which: ■ Cryogenic burns ■ Asphyxiation ■ Highly flammable (fire and explosion) ■ Rapid phase transition ■ BLEVE	**Competence on LNG specific safety systems**	Being able to monitor ship operation and LNG systems properly is important for the general safety of the crew and the vessel	Gas detection systems Understanding of ■ the gas detection system on board ■ the operation of the interlocks as part of the gas detection and gas control system Proficiency in ■ maintaining an adequate inventory of spare parts to ensure continuity of the gas detection system ■ calibrating the gas detection system ■ performing maintenance on the gas detection system Fire detection system Understanding of the components of the fire detection system Portable gas detection equipment Understanding of the purpose and principles of operation of different portable gas detection instruments Proficiency in ■ calibrating and use portable gas detection equipment (oxygen, methane) ■ calibrating and use a dew point meter Ex-certified equipment Understanding of ■ locations where Ex-proof lighting and equipment is required ■ the specific maintenance requirements for Ex-proof fans Proficiency in ■ Performing the inspection, maintenance and repair of Ex-certified equipment (certified people only) ■ interpreting a wiring diagram of an Ex-certified instrument ■ connecting a motor in Ex-mode ■ replacing Ex-barriers in I/O modules ■ maintaining inventory of Ex-certified spare parts, based on the criticality in relation to LNG-related components Safety relief valves Understanding of the working principle of a safety relief valve

LNG						
Function	Personnel	A1 topic	Hazards and risk potential	Competence	Justify	KUP Elements
						Proficiency in ■ performing inspections and tests on safety relief valves (qualified people only) ■ performing maintenance on safety relief valves (qualified people only) ■ performing the emergency closing procedure of safety relief valves Emergency shutdown system Understanding of ■ the consequences of activating an ESD call button ■ the operation and triggers of the emergency shutdown system ■ the emergency shutdown sequence ■ the difference between the safety system principles ‘emergency shutdown’ and ‘inherently safe’ Proficiency in ■ performing emergency shutdown tests ■ performing inspection and maintenance on ESD-valves
All	All	Contingencies	Emergencies and contingency, among which: ■ Gas leakage ■ LNG spills ■ Fire an explosion	**Advanced knowledge on emergencies and contingencies on LNG**	LNG behaves differently than conventional fuels and therefore needs different considerations in case of emergencies	Proficiency in ■ acting in accordance with applicable contingency plan in case of an emergency ■ determine most suitable vessel position / orientation in case of LNG emergency LNG fire Understanding of ■ the potential danger of trying to extinguish a fire prior to stopping a leak ■ how to recognise the heat intensity of burning LNG ■ the extinguishing agents to be used on LNG Proficiency in demonstrating the proper way to control an LNG fire (flash, jet, and pool fire) Gas leak Understanding of the indications of a gas leak Proficiency in ■ taking appropriate action in case of a detected gas leak ■ the various methods to locate a gas leak LNG spill Understanding of ■ the danger of cloud formation when LNG comes into contact with outside air and hot surfaces ■ the actions required to mitigate spill Proficiency in ■ the proper way to handle an LNG-spill ■ directing a gas cloud using the effect of water spray Shore connections / emergency release of connections to shore Understanding of ■ the potential risk in connection with emergency release couplings, immediately after release ■ the type and construction of shore connection arms (if applicable) ■ the importance of emergency release or dry break couplings ■ the use of flexible hoses

LNG						
Function	**Personnel**	**A1 topic**	**Hazards and risk potential**	**Competence**	**Justify**	**KUP Elements**
						■ the emergency shutdown procedure between ship and shore ■ the emergency breakout operation of shore connection Proficiency in ■ interpreting mooring requirements for a loading point ■ mooring the vessel anticipating emergency release ■ in outweighing the consequences of igniting LNG or LNG release <u>Emergency shutdown</u> Proficiency in performing an emergency shutdown <u>Emergency unloading/ transfer of LNG</u> Understanding of the possibilities for emergency unloading or transfer of LNG Proficiency in performing the procedure for transferring LNG to another vessel in case of an emergency <u>Emergency separation</u> Understanding of: ■ criteria/situations which would trigger emergency separation during LNG bunkering ■ the steps involved in emergency separation during bunkering Proficiency in finding the local port requirements on emergency separation during LNG bunkering

3.2.2 Biofuels

Biofuels used in internal combustion engines within this study include:

- Bio-methanol
- Fisher Tropsch (FT) diesel
- Biomethane
- Dimethyl ether (DME)
- Fatty acid methyl esters (FAME)
- Hydrotreated vegetable oil (HVO)

It should be noted that biofuel is the term used for many kinds of different fuels with different properties. Some biofuels are identical to conventional fuels and can be treated in the same way. For instance, bio-methanol is chemically identical to methanol produced via fossil energy (fossil methanol) or via electricity (e-methanol) and is therefore expected to pose the same risks and hazards. Hence, identified competences for bio-methanol are listed in the section for methyl/ethyl alcohol in 3.2.3. Other biofuels exhibit similar characteristics to conventional fuels as well. Bio-DME, being gaseous under normal conditions, exhibits similarities with LPG fuels, while bio-FT-diesel, HVO, and to a certain extent FAME share similarities with conventional marine distillates concerning hazardous properties15. However, it is important for crew to know the specific differences. Long-term experiences using biofuels as fuel in the maritime domain are limited and this uncertainty should be considered. Ongoing studies, such as Project LOTUS[16] (Long-term impact of continuous use of biofuels on vessel operations) are researching this. There are indications of both increased and decreased maintenance needs, depending on the fuel and used and the engine tuned and operated. Table 3-2 provides the identified competences for biofuels.

Table 3-2 Biofuel competences

Biofuels						
Function	**Personnel**	**A1 topic**	**Hazards and risk potential**	**New recommended competence**	**Justify**	**KUP Elements**
All	All	General properties	Hazards related to biofuel as a fuel: ▪ Biofuel compatibility, safe handling, and toxicity ▪ Corrosive properties of biofuel ▪ Flammability of biofuel	**Competence in general knowledge and understanding of biofuels, regarding common biofuel properties and health hazards**	General knowledge and understanding of the selected type of biofuel are needed for crew to understand the inherent risks associated with it. Crew should be aware of the application of proper personal protective aids when handling the biofuel	Knowledge of: ▪ the different types of biofuels and their blends ▪ the applicable rules and regulations related to the use of the biofuel type in the maritime sector Understanding of ▪ the quality of the biofuel in use ▪ the biofuel's reactivity with sealings and other material ▪ the environmental impact of an operational release of biofuel as compared to a release of a similar quantity of MGO ▪ the hazard associated with handling the biofuel type ▪ the potential for biofuel to degrade at varying speeds Proficiency in ▪ interpreting the material safety data sheet for the biofuel type ▪ demonstrating the use of appropriate personal protective aids when working with a type of biofuel ▪ demonstrating the use of available rescue and escape equipment

[15] EMSA Study on Safe Bunkering of Biofuels
[16] Project LOTUS

Biofuels						
Function	**Personnel**	**A1 topic**	**Hazards and risk potential**	**New recommended competence**	**Justify**	**KUP Elements**
NAV OPS ME	Deck and engineering officers	Voyage planning	Insufficient awareness of the effects of the biofuel type on voyage planning	**Competence in the biofuel-specific aspects related to voyage planning**	Biofuels have different fuel power production capabilities and different effects on emissions, which can affect voyage planning which officers should be aware of	Understanding of ■ the engine's effectiveness per biofuel type ■ the biofuel's effect on emissions (NOx), which might deviate from the IMO-approved values. For example, FAME-based fuels tend to increase the NOx-emissions while HVO gives similar emissions as MGO ■ the effect of the biofuel density on the vessel range (assessed together with the net calorific value) Proficiency in estimating the net calorific value for the biofuel in use, i.e. the amount of energy available in a certain mass of fuel (MJ/kg)
CHS OPS ME ELC M&R	Deck and engineering officers Engineering ratings	Storage	Incorrect biofuel storage: ■ Storage method ■ Tank connections ■ Tanks and piping ■ Tank cleaning	**Competence in the methods of biofuel storage, their connections and cleaning**	Proper storage of methanol onboard is essential for its safe operation. Officers should be aware of the different aspects of how the voyage can affect the biofuel, for example how the biofuel can become degraded by factors such as contamination, oxidation, or microbial growth	<u>Bunker tanks</u> Understanding of ■ the layout and operation of the onboard biofuel system ■ the limited storage time of some biofuels and that the biofuel shall be avoided for auxiliary machinery/equipment not frequently used Proficiency in performing inspections of the methanol storage system <u>Storage characteristics</u> Knowledge of ■ how hydrocarbons can degrade ■ signs of degradation of the biofuel (e.g. waxing/gelling) ■ the biofuel's draining capability (can lead to poor mixability) Understanding of ■ stability/shelf life of the biofuel type ■ the terms rancidity/microbial growth ■ how to store the biofuel type, and how the following terms affect the type of biofuel: temperature (both low and high), motions, humidity, water content, tank condition. ■ how the above-mentioned factors affect the storage time of the biofuel ■ the importance of a clean tank ■ the layout and operation of the tank system <u>Tanks and piping</u> Understanding of ■ the biofuel's compatibility with sealings and other rubber-based components ■ the effect of biofuels on metallic materials (in the case of an acidic biofuel or their potential to develop acidity with time, and hence cause corrosion). ■ the biofuel's viscosity and how differences in surface tension properties can cause leaks (some biofuels and blends thereof may have lower surface tension compared to conventional fuel, hence increasing the likelihood of leakage in flanges, etc.) Proficiency in ■ cleaning tanks that have or will store biofuel ■ verifying the compatibility of sealing materials and metals to the biofuel ■ monitoring and tuning the fuel temperature ■ monitoring and tuning the viscosity ■ determining the longevity of materials exposed to the biofuel type
NAV OPS ME	Deck and engineering officers	Handling	Incorrect handling of biofuel according to regulations	**Competence with the regulation, rules and**	Officers onboard should be able to handle the	Knowledge of ■ the applicable rules, regulations and guidance related to the use of the biofuel type as fuel in the maritime sector

Biofuels						
Function	**Personnel**	**A1 topic**	**Hazards and risk potential**	**New recommended competence**	**Justify**	**KUP Elements**
				requirements related to biofuel	biofuel according to the appropriate regulations.	■ regulation regarding blending in port/onboard Understanding of ■ biofuel-as-fuel regulations ■ the compatibility of the biofuel in use ■ the lack of industry experience regarding long-term use of biofuels Proficiency in the applicable monitoring and reporting of biofuel use (MARPOL compliance with emissions regulations)
OPS ME M&R	Deck and engineering officers Engineering ratings	Engine operation	Improper operation and maintenance of an engine using biofuel	**Competence in the proper operation, functioning and monitoring of an engine using biofuel**	Awareness of the effect of the biofuel type on the engine (including lubrication)	Knowledge of ■ the lubricity of the biofuel in use. Different fuels might have different lubricity that can affect both fuel pumps and injectors (Increase wear and tear if poor lubricity) ■ the viscosity of the biofuel type in use ■ the density of the biofuel ■ the effect of density on the volumetric injection ■ how the biofuel may benefit from an alternative nozzle design ■ potential clogging of filters due to biofuels dissolving residuals and clogging filters Understanding of ■ for engines without common rail, how the difference in density of the biofuel into the fuel injection can add more or less fuel in terms of mass, in addition to calorific value ■ how to control of viscosity of fuels for use in engines ■ the importance of fuelling at the correct temperature ■ biofuel and lube oil compatibility Proficiency in ■ monitoring of fuel filters ■ filtering the biofuel ■ monitoring and tuning viscosity control of the biofuel ■ matching the lube oil with the biofuel properties ■ selecting the correct nozzle design depending on the biofuel in use
OPS ME	Deck and engineering officers Engineering ratings	Fuel preparation	Improper biofuel preparation, for example improper handling of fuel density leading to improper tuning of the fuel separator potentially causing excessive sludge production	**Competence in fuel preparation**	The different biofuels require different methods of preparation before use, which crew should be aware of	Understanding of ■ the differences in fuel separation due to differences in fuel density ■ how to purify the fuel (to adjust the density)
CHS OPS ME	Deck and engineering officers Engineering ratings	Bunkering	Improper execution of the safe bunkering of biofuel	**Competence to plan, execute and monitor the safe bunkering of biofuel**	As a safety-critical operation, the ability of a crew to conduct the safe bunkering of the biofuel is essential	Understating of ■ how the density of the biofuel can cause poor miscibility ■ importance of clean tanks Proficiency in ■ use of PPE ■ calculating the volumetric energy density

3.2.3 Methyl/ethyl alcohols

Methyl/ethyl alcohols was limited to methanol as a fuel, specifically its usage in an ICE and the surrounding fuel system. The results are presented in Table 3-3. The results for methanol are based on the unpublished competence guideline, DNV-ST-0687[17] (DNV, 2024).

Table 3-3 Methanol competences

Methyl/Ethyl Alcohols - Methanol						
Function	**Personnel**	**A1 topic**	**Hazards and risk potential**	**New recommended competence**	**Justify**	**KUP Elements**
All	All	General knowledge and understanding of Methanol as a fuel Risk awareness, health, and safety	Hazards intrinsic to methanol as a fuel for personnel, among which: ▪ Methanol poisoning ▪ Corrosive properties of methanol ▪ Flammability of methanol ▪ Methanol toxicity	**Competence in general knowledge and understanding of methanol. Regarding methanol's properties and health hazards.**	General knowledge and understanding of methanol are needed for crew to understand the inherent risks associated with methanol	Knowledge of ▪ the flashpoint, lower explosive limit (LEL), upper explosive limit (UEL) and autoignition temperature of methanol ▪ the potentially fatal level of methanol if ingested or inhaled ▪ exposure limits of methanol ▪ the fact that methanol exposure symptoms may only appear 72 hours after the fact Understanding of ▪ methanol and its properties ▪ the material safety data sheet (MSDS) of methanol ▪ the consequences and behaviour of methanol being discharged into water, air and on deck (in vapour and liquid form) ▪ methanol's corrosive & toxic properties ▪ methanol poisoning, how it may occur, its effects and symptoms ▪ the interaction of methanol with water and how it may cause corrosion and remain flammable ▪ the potential for methanol as a pollutant
			▪ Risk of entering an area where methanol may have leaked ▪ Methanol vapour accumulation in enclosed spaces ▪ Danger of ignition and explosion of methanol	**Competence in taking precautions and measures to reduce methanol related risks**	Crew should understand the risks associated with methanol systems and be able to take precautions	Understanding of ▪ the risks of entering spaces where methanol may be present ▪ the risks of working on machinery that contains methanol ▪ the necessity of gas detection and proper ventilation for spaces containing methanol ▪ the restricted areas/Ex zones related to methanol ▪ the main safety features for methanol specific systems
			Exposure of personnel to methanol	**Competence in personal protection equipment for methanol**	Crew should be aware of the application of proper personal protective equipment when it comes to methanol	Understanding of ▪ the protective equipment to be used when present in spaces containing methanol ▪ the protective equipment to be used when working on machinery/lines that may contain methanol ▪ when to use Self-contained Breathing Apparatus and chemical suits when the likelihood of being exposed to methanol is high ▪ the actions to be executed during a methanol leak alarm regarding personal protection ▪ the use cases, importance, and operation of portable gas detection instruments ▪ specific first aid procedures for methanol, such as avoiding contamination Proficiency in the use of methanol specific personal protective equipment

[17]Competence related to the use of methanol as fuel (not published)

Methyl/Ethyl Alcohols - Methanol						
Function	**Personnel**	**A1 topic**	**Hazards and risk potential**	**New recommended competence**	**Justify**	**KUP Elements**
NAV CHS OPS ME ELC M&R	Deck and engineering officers	Voyage planning	Incorrect handling of methanol according to regulations and voyage needs	**Competence with the regulation, rules and requirements related to methanol and related voyage planning**	Officers onboard should be able to handle methanol according to the appropriate regulations, in addition to proper reporting	Knowledge of the applicable rules, regulations and guidance related to the use of methanol as fuel in the maritime sector Understanding of ▪ methanol-as-fuel regulations ▪ the accurate reading of methanol fuel levels Proficiency in ▪ the application of methanol related regulations pertaining to each individual voyage ▪ the applicable monitoring and reporting of methanol fuel use ▪ the type of permissions needed for certain voyages/port calls when using/bunkering methanol ▪ mapping methanol bunkering possibilities ▪ estimating required methanol fuel and consumption for a voyage ▪ calculating the stability of the vessel as methanol is consumed
CHS OPS ME ELC M&R	Deck and engineering officers Engineering ratings	Methanol storage	Incorrect methanol storage: ▪ Storage method ▪ Nitrogen blanketing ▪ Tank connections ▪ Tanks/piping ▪ Tank cleaning	**Competence in the methods of methanol storage, their connections and cleaning**	Proper storage of methanol onboard is essential for its safe operation. Officers should be aware of the different aspects of methanol storage, while ratings should be able to ensure their proper operation	<u>Bunker Tanks</u> Understanding of ▪ the different types of tanks used for storing methanol ▪ the advantages/disadvantages and key aspects of the various tanks used for methanol storage ▪ the layout and operation of the onboard methanol fuel system ▪ the importance of monitoring hold space atmosphere ▪ the use of auto-shut off valves Proficiency in performing inspections of the methanol storage system <u>Nitrogen blanketing</u> Knowledge of the appropriate nitrogen blanketing method Understanding the usage of nitrogen blanketing in the fuel tanks <u>Tank connections</u> Knowledge of ▪ the vulnerability of tank connections ▪ the appropriate procedure for working on/near tank connections <u>Tanks and piping</u> Understanding of ▪ the effect of methanol on materials and need for special coating ▪ the material choice for components exposed to methanol ▪ the double-barrier concept ▪ the double-piping requirements for methanol, their location, functioning, and assembly ▪ how to handle contaminated water used for methanol tank cleaning Proficiency in ▪ the methods of protecting materials from the effects of methanol ▪ determining the longevity of materials exposed to methanol ▪ in leak-testing, inspecting, and performing maintenance on double-walled piping ▪ in cleaning methanol fuel tanks

Methyl/Ethyl Alcohols - Methanol						
Function	**Personnel**	**A1 topic**	**Hazards and risk potential**	**New recommended competence**	**Justify**	**KUP Elements**
CHS OPS ME ELC M&R	Deck and engineering officers Engineering ratings	Fuel supply system	Improper operation/monitoring of the methanol fuel system: ■ Methanol pumproom ■ Methanol temperature control ■ Sealing oil system ■ Fuel booster injection system ■ Fuel valve train ■ Fuel monitoring system	**Competence on the proper operation, functioning and monitoring of a methanol fuel system**	Proper operation of the methanol fuel system is needed for the safe and effective operation of a methanol fuelled vessel. Officers should be aware of the different aspects of a methanol fuel system, while ratings should be able to ensure their proper operation	Understanding of ■ the fuel system's layout, arrangement, and safety features. From tank to engine. ■ the importance of keeping the fuel system separate from all other piping systems ■ equipment used for monitoring pressure and temperature ■ pressure and temperature readings ■ how to perform inspection, tests, and calibration of monitoring equipment ■ how to control temperature and pressure ■ how to perform basic maintenance on relevant sensors <u>Pumproom</u> Knowledge of the methanol tank supply pressure Understanding of ■ the functioning and importance of the methanol pumproom ■ the limitations and challenges that come with having an isolated pumproom ■ the entry procedure for the methanol pumproom ■ the importance of purging methanol components or lines before performing work on them ■ the operation and importance of the pumproom's bilge system <u>Methanol temperature control</u> Knowledge of the preferred temperature for storing and delivering methanol Understanding of how the temperature of methanol can be controlled Proficiency in the cooling/heating of methanol depending on the operation, conditions, and tank location <u>Sealing oil system</u> Understanding of ■ the purpose of the sealing oil system for methanol ■ the operation and layout of the sealing oil system ■ how to detect and troubleshoot a malfunctioning sealing oil system <u>Fuel booster injection system</u> Knowledge of the required methanol injection pressure Understanding of the operation and layout of the fuel booster injection system Proficiency in ■ the testing of the fuel booster injection system ■ the monitoring of the performance of the fuel booster injection system ■ performing maintenance on the fuel booster injection system <u>Fuel valve train</u> Understanding of ■ the operation and layout of the fuel valve train ■ the configuration and importance of a "double block and bleed configuration" ■ how to purge the fuel valve train with nitrogen

Methyl/Ethyl Alcohols - Methanol						
Function	**Personnel**	**A1 topic**	**Hazards and risk potential**	**New recommended competence**	**Justify**	**KUP Elements**
						Proficiency in the testing and monitoring of the fuel valve train <u>Fuel monitoring system</u> Understanding of ■ the readings from the fuel control system ■ vapour return and venting regarding methanol Proficiency in the troubleshooting of the fuel system
CHS OPS ME ELC M&R	Deck and engineering officers Engineering ratings	Methanol engine	Improper operation and maintenance of a methanol fuelled engine	**Competence in the proper operation, functioning and monitoring of a methanol fuelled engine**	Proper operation of a methanol fuelled engine is needed for the safe and effective operation of a methanol fuelled vessel. Officers should be aware of the different aspects of methanol engines, while ratings should be able to ensure their proper operation	Understanding of ■ the start-up and shut-down of a methanol fuelled engine ■ the principles of a methanol fuelled engine ■ the importance of ventilation regarding operating a methanol fuelled engine ■ the operational limitations of a methanol fuelled engine ■ the prerequisites for operating a methanol fuelled engine, including use of pilot fuel if needed ■ alarms related to a methanol fuelled engine ■ the thresholds for using methanol as a fuel in an engine ■ the process for draining, purging and removal of methanol from an engine Proficiency in the start-up and shut-down of a methanol fuelled engine
CHS OPS ME ELC M&R	Engineering officers and ratings	Safety system	Improper execution of safety systems and procedures	**Competence in the proper operation and procedures for onboard safety systems**	In case of an emergency on board engineering officers and ratings should be able to execute emergency procedures. They should also be aware of Ex zones/equipment.	Understanding of ■ the gas and fire detection systems on board ■ the locations of the gas and fire detection systems ■ the onboard automated safety functions ■ the emergency shutdown procedure and its consequences related to the methanol fuel system Proficiency in ■ performing and emergency shutdown of the methanol fuel system ■ performing maintenance and inspections on safety system components related to the methanol fuel system ■ the calibration of gas and fire detection systems ■ the maintenance of gas and fire detection systems <u>Ex-certified equipment</u> Understanding of Ex-certified equipment, their location and importance Proficiency in ■ performing maintenance and inspections on Ex-certified equipment ■ operating Ex-certified machinery
CHS OPS ME ELC	Deck and engineering officers	Methanol bunkering	Improper execution of the safe bunkering of methanol	**Competence to plan, execute and monitor the safe bunkering of methanol**	As a safety-critical operation, the ability of a crew to conduct the safe bunkering of methanol is essential	Knowledge of safety and emergency procedures for operation of methanol specific machinery, fuel- and control systems Understanding of ■ the different methods for methanol bunkering ■ the different tasks and responsibilities for personnel involved ■ the process for transferring methanol ■ the procedure for emergency separation ■ port state regulation specific to methanol ■ required quality of methanol Proficiency in

Methyl/Ethyl Alcohols - Methanol						
Function	**Personnel**	**A1 topic**	**Hazards and risk potential**	**New recommended competence**	**Justify**	**KUP Elements**
						■ bunkering procedures, emergency procedures, bunkering interfaces ■ conducting bunkering risk assessment ■ preparing for bunkering: ○ executing bunkering checklist ○ vessel alignment, loading arrangement ○ tank/system readiness ○ pump-rates and tank sequence ○ vapour return ○ grounding and static discharge ○ inerting and purging of lines ■ conducting bunker transfer: ○ operation of bunkering manifold ○ understanding of measuring devices ○ operation of pumping system ○ communication across all parties during bunkering ○ bunkering sequences ○ testing methanol quality
CHS OPS ME ELC	All	Contingencies	Improper handling of emergencies (fire, release/leak, explosion etc.) related to methanol	**Competence to respond to emergencies related to methanol**	The proper handling of methanol related emergencies is essential to mitigating their consequences	Knowledge of ■ the safe areas onboard for evacuation if methanol is released ■ the appropriate extinguishing agents and techniques for fighting a methanol fire Understanding of ■ the signs of a methanol leak ■ the appropriate PPE needed for different emergencies ■ the specific properties of burning methanol, especially its difficulty to be seen ■ the risk of boiling liquid expanding vapour explosion if methanol tanks are exposed to fire ■ the procedures for emergency discharge of methanol overboard and its consequences Proficiency in ■ applying the relevant contingency plans for emergencies ■ the appropriate response for handling a methanol leak ■ venting of methanol vapour
M&R	Deck and engineering officers Engineering ratings	Maintenance	Improper execution of maintenance and repair on methanol systems, leading to potential hazards and exposure of crew to methanol	**Competence in performing maintenance and repairs on methanol systems**	Proper maintenance and repair for methanol systems improves robustness and proper procedures for crew to perform maintenance prevents accidental exposure of crew to methanol when opening methanol systems	Understanding of ■ the required parts and equipment necessary for performing maintenance or repairs on methanol systems ■ the specific equipment and procedures necessary to perform maintenance or repairs on double-walled piping ■ the effect/requirements of methanol on different materials relevant to a methanol fuel system (coatings, seals, lubrication etc.) and associated replacement material requirements Proficiency in ■ performing maintenance and repair on methanol related systems within the expectations/limitations of the manufacturer
CHS OPS ME ELC	Deck and engineering officers	Tank conditioning	Improper conditioning of methanol tanks leading to incorrect gas freeing, inerting or purging and potential hazards	**Competence to condition methanol tanks**	Proper conditioning of methanol fuel tanks is needed to prevent unexpected methanol residue to be present in	Gas-freeing Understanding of ■ the effects of changing tank atmospheres ■ the requirements for gas-freeing

Methyl/Ethyl Alcohols - Methanol						
Function	**Personnel**	**A1 topic**	**Hazards and risk potential**	**New recommended competence**	**Justify**	**KUP Elements**
					tanks or incomplete purging/inerting	Proficiency in ■ determining the duration for gas-freeing ■ executing a gas-freeing operation for a methanol tank Inerting Understanding of ■ the purpose of inerting ■ the issues that may occur when inerting ■ risks associated with improper inerting Proficiency in ■ developing an inerting plan ■ determining that inerting has been completed ■ determining oxygen-content Purging Understanding of the principles of purging Proficiency in ■ purging procedures ■ performing nitrogen purging ■ determining that purging has been completed
CHS OPS ME ELC M&R	Deck and engineering officers	Ventilation	Improper operation of ventilation systems leading to incorrect pressures and ventilation in methanol spaces	**Competence in operating ventilation systems related to methanol spaces**	Proper ventilation is needed to prevent accumulation of methanol in spaces, in the possible event of a leak	Understanding of ■ the importance of air locks ■ the use of ventilation pressures to avoid accumulation of methanol vapour ■ the workings of PV-valves ■ hazardous zones related to vent outlets Proficiency in performing maintenance and inspections where relevant
CHS OPS ME ELC M&R	Deck and engineering officers	Auxiliary/inerting systems	Improper operation and maintenance of auxiliary systems (such as the inert gas system) could lead to hazards, such as incomplete purging	**Competence in the operation and maintenance of auxiliary systems related to the methanol fuel system**	Auxiliary systems for the methanol fuel system, such as the inert gas system, are important for the proper functioning of the methanol fuel system and crew should be able to operate and maintain them	Knowledge of the maximum allowable amount of oxygen in gas mixtures Understanding of ■ the role of an inert gas generator ■ the operation of the inert gas generator ■ how nitrogen injection and purging works ■ how a nitrogen plant functions ■ the risks of entering inerted spaces ■ the purpose of the methanol tank deluge system ■ risks associated with operating with inert gas Proficiency in ■ the operation of the inert gas generator ■ the operation of the nitrogen plant ■ in the operation ■ performing maintenance on the nitrogen plant ■ performing appropriate action in case of nitrogen quality issues ■ performing inspection and maintenance of the deluge system

3.2.4 Battery-powered hybrid electric & BESS

The competences related to the safe operation, maintenance and emergency management of ships equipped with Battery Energy Storage Systems, including battery powered hybrid electric systems are consolidated in Table 3-4.

Table 3-4 Battery-powered hybrid electric & BESS competences

Battery-powered hybrid electric & BESS						
Function	**Personnel**	**A1 topic**	**Hazards and risk potential**	**New recommended competence**	**Justify**	**KUP Elements**
All	All	Battery properties	Hazards intrinsic to batteries for personnel, among which: ▪ High voltage ▪ Thermal properties ▪ Explosive properties	**General competence in the knowledge and understanding of batteries, such as properties, hazards, and risks** **Competence in taking precautions and measures to reduce battery related risks**	Ventilation (heat vs explosion risk): Increased ventilation, oxygen increases, which results in heat generation (fire) Closed ventilation, oxygen is limited, gas is generated, results in explosive atmosphere	Knowledge of the different relevant battery types and their respective characteristics and properties Understanding of ▪ hazardous/Ex-zones and areas ▪ that batteries are inherently explosive in nature, and cannot be made Ex-proof ▪ the importance of ventilation and heat vs explosion risk Proficiency in monitoring, control, and safety systems relevant for battery systems (e.g., battery management system, gas detection systems)
				Competence in personal protection equipment for battery systems	Due to the thermal, explosive, and toxic properties battery fires may have, PPEs must be selected carefully	Proficiency in choosing and using PPE for maintenance
				Competence in considering implications of incorrect or improper maintenance **Competence in determining what aspects of maintenance should be left to service personnel**	The crew must understand what maintenance activities the crew should not perform. Batteries are vulnerable to improper and incorrect maintenance.	Understanding of ▪ not bypassing safety protocols ▪ not handling damaged batteries ▪ that crew should know what should be left to specialist service personnel and what can be done by crew self

All	All	Battery fire precautions	Production of explosive gasses due to battery fire	**Competence in battery fire precautions and the installed safety barriers to mitigate risks**	Ignited battery systems are extremely dangerous, both in terms of gas accumulating toxic and explosive properties.	Knowledge of
						▪ a typical fire safety plan
						▪ de-energizing the electric circuit when gas is detected
						▪ the root causes of battery failures
						    ○ low ambient pressure
						    ○ overheating
						    ○ vibration
						    ○ shock
						    ○ external short circuit
						    ○ impact
						    ○ overcharge
						    ○ forced discharge
						
						Understanding of gas detection in battery systems (toxic and explosive)

Battery-powered hybrid electric & BESS						
Function	**Personnel**	**A1 topic**	**Hazards and risk potential**	**New recommended competence**	**Justify**	**KUP Elements**
						Proficiency in calibrating and maintaining gas detection systems
All	All	Battery fire	Battery fire ■ Short circuit ■ Thermal runaway ■ Explosive gasses ■ Toxic gasses	**Competence of different firefighting methods, procedures, mitigating measures and consequences related to battery systems** **Competence and understanding of toxic and explosive gasses related to battery systems**	Different fire-fighting techniques can have different consequences on the battery and risk the further escalation of the emergency. Battery fires accumulate both toxic and explosive gasses.	Knowledge of ■ the characteristics and behaviour of heat development/thermal runaway ■ the characteristics and behaviour of toxic gasses emitted by ignited batteries, for example: ○ Hydrogen Fluoride ○ Hydrogen Cyanide ○ Carbon monoxide ○ Nitrogen Dioxide ○ Hydrogen Chloride ○ Benzene ○ Toluene ■ characteristics and behaviour of explosive gasses Understanding of ■ the consequences of a thermal runaway and the difficulties in handling such events ■ toxic contamination of PPE used in fire-fighting battery fires ■ how venting and ventilation affects the fire-fighting process and what fire-fighting measure to choose ■ risk of short circuit in battery systems when using water as a fire-fighting medium Proficiency in ■ fire-fighting techniques of fire in battery systems. Salt water may cause short circuit in battery systems. NOVEC 1230 may cause toxic gas when exposed to high temperatures ■ choosing and using PPE for fire-fighting, e.g., HAZMAT ■ the disposal/cleaning of contaminated PPE
				Competence in the effects and first aid of toxic gasses	Toxic gasses may accumulate during battery fires, which may affect the patient and the first-responder (e.g., contaminated clothing).	Understanding the dangers to own safety when rescuing others from toxic emergencies
ME M&R ELC OPS	Deck and engineering officers Engineering ratings	Battery operation	High voltage systems Equipment failure	**Competence on operating battery systems and safety/security mechanisms.** **Electrotechnical competence**	Proper operation of battery systems and a solid electrotechnical foundation is needed to ensure the proper functioning of battery systems	Understanding of ■ the need for general battery competence when working on a battery powered ship and the need for special high-voltage electrical competence when required to work on or with the battery systems ■ nominal charge levels and speed for battery ■ special battery behaviour when in operation (e.g., shut-down in case of end of life or increased temperature) ■ total harmonic distortion and its effect on the battery ■ battery systems, such as build up, strings, modules and properties such as current, voltage. ■ common mode voltage, its causes and effects ■ the fact that batteries cannot be de-energised. It is not possible to emergency-discharge, as it is with for example liquid or gaseous fuels. Energy in contained in a battery system is therefore always a fire hazard. Knowledge of varying battery temperatures and at what temperature the battery system initiates an automatic shutdown

Battery-powered hybrid electric & BESS						
Function	**Personnel**	**A1 topic**	**Hazards and risk potential**	**New recommended competence**	**Justify**	**KUP Elements**
						Proficiency in ■ conducting correct maintenance on the battery system ■ inspection of the battery systems, including mechanical damage and corrosion ■ the functioning of a battery control system ■ monitoring the current and state of charge ■ monitoring the temperatures in battery cells and battery rooms ■ connecting and disconnecting batteries and battery strings from the electrical net ■ the modes of charging
			Battery lifetime / degradation	**Competence in what affects battery lifetime Internal short-circuit as battery ages and the chargeability of a battery with age**	Risks to battery increases as battery is ageing, and improper battery operations may affect the process further	Understanding of ■ the expected lifespan and when to change the batteries ■ the effect of increased heat production in the battery as the battery ages ■ the limitations of quick charging and implications on the lifetime of the battery ■ the effects of depleting the battery to zero and consequences it might have (on both the battery and operations)
			Venting and ventilation	**Competence in operating ventilation systems related to battery spaces**	Venting and ventilation are important due to the thermal, explosive, and toxic properties of battery systems	Understanding of ■ the importance of venting and the ventilation system, i.e., cooling effect and off gas handling. ■ the integrated off gas duct function, location, and property (i.e., Ex-zone) ■ how the heat exchanger relates to the ventilation systems
			Operational limitations of battery and incorrect / improper operation or maintenance	**Competence on the usage of battery as a form of energy storage**	Potential lack of range, poor voyage planning, lack of charging infrastructure	Understanding of ■ the range of the battery ■ the operational limits of using battery as a form of energy storage, as well as alternative propulsion or emergency generator, if applicable. ■ the infrastructure needed to charge battery ■ battery overcharge, causes and effects

3.2.5 Fuel cells

Table 3-5 covers the scope: *Fuel cell power systems based on Solid Oxide Fuel Cell (SOFC), the Proton Exchange Membrane Fuel Cell (PEMFC) and the High Temperature Proton Exchange Membrane Fuel Cell (HT-PEMFC) for delivery of electrical and/or thermal energy using LNG, bio-fuels, methyl/ethyl alcohols, ammonia, and hydrogen.* Fuel cells within this scope are limited to the fuel cell itself. While the fuel system surrounding and feeding into the fuel cell is covered by the relevant fuel system sections. The different fuel cells within the scope of this section have different characteristics and properties. These also effect the types of competences required.

Table 3-5 Fuel cell competences

Fuel cells						
Function	**Personnel**	**A1 topic**	**Hazards and risk potential**	**New recommended competence**	**Justify**	**KUP Elements**
All	All	-	Explosion risk inherent to a FC due to presence of oxygen, fuel and ignition source	**Competence in the basic functioning of a FC and the applied safety concept**	All crewmembers should be aware of the basic functioning of a FC and safety concept attached to it in order to be able to respond to potential safety issues	Knowledge of ■ the FC's specific safety concept and safety barriers ■ of the role of the explosion resistant container within the FC ■ the role of ventilation or inertisation as a safety barrier in the FC space ■ the importance of retaining a double-barrier Understanding of ■ the basic functioning of a FC ■ the inherent explosion/fire risk of a FC, especially if an internal fuel leak within the FC occurs ■ the differences between a SOFC, a PEMFC and a HT-PEMFC ■ the safety features required of a FC as per guidelines ■ the handling of high temperatures associated with a SOFC
CHS OPS ME ELC M&R	Deck and engineering officers Engineering ratings	-	Improper maintenance conducted due to the complexity and sensitivity of FCs	**Competence in potential maintenance and inspection procedures on FCs**	Due to the complexity and sensitivity of FCs, manufacturers generally limit the work that can be done on FCs by the crew. Specialised maintenance crews can be used	Understanding of the limitations set by the manufacturer on conducting work on a FC Proficiency in ■ the replacement of fuel filters for the FC ■ the authorised maintenance and inspection procedures
CHS OPS ME ELC M&R	Deck and engineering officers Engineering ratings	-	A SOFC can reach high temperatures and act as an ignition source if not sufficiently cooled externally	**Competence in risk awareness inherent to the high temperatures of a SOFC**	Due to the high-temperatures inherent to a SOFC, a SOFC can reach high temperatures and act as ignition source	Understanding of ■ the importance of sufficient external cooling of a SOFC ■ the fact that an SOFC can be a burn hazard ■ the fact that an SOFC can be an ignition source ■ the effects of potential high temperature exhaust Proficiency in limiting the spread of high temperatures from the SOFC upon cooling system failure
CHS OPS ME ELC M&R	Deck and engineering officers Engineering ratings	-	Contamination of fuel leading to damage to the FC membrane catalyser. This can block the membrane and damage the FC	**Competence in preventing fuel contamination for the FC**	FCs are susceptible to fuel contamination. Fuel quality should therefore be of high quality and purity to avoid potential damage to the FC. High-temperature FCs are generally less vulnerable	Knowledge of the fuel standards for FCs Understanding of ■ how to avoid fuel contamination ■ the effects of fuel contamination ■ the vulnerability of fuel contamination regarding different FC types ■ the possibility for fuel contamination when welding/working on fuel lines, which introduces the possibility of contaminants entering the fuel lines ■ the fuel monitoring system and when a system shutdown is triggered ■ the importance of de-sulphuring LNG fuel
NAV CHS OPS ME ELC	Deck and engineering officers Engineering ratings	-	Delayed FC load responsiveness can lead to operational limitations	**Competence in the operational limitations inherent to FCs**	FCs generally respond slow to load variations, which is why they are generally paired with battery systems, this load unresponsiveness introduces operational limitations	Understanding of ■ the operational limitations inherent to the different FCs ■ the startup/shutdown time delays for FCs, especially an SOFC ■ the consequences of certain actions on the FC service life (e.g. emergency shutdown) ■ the role of battery systems in conjunction with FCs ■ the load responsiveness and limits of FCs

Fuel cells						
Function	**Personnel**	**A1 topic**	**Hazards and risk potential**	**New recommended competence**	**Justify**	**KUP Elements**
CHS OPS ME ELC	Engineering officers Engineering ratings	-	Potential failures within the FC going undetected	**Competence in the control and monitoring of the FC**	FCs should be closely monitored and shut down upon the discovery of failures	Knowledge of the type of FC failures that trigger a shutdown of the FC/fuel system Understanding of the readings and alarms from the FC and the importance of detecting internal FC failures Proficiency in the troubleshooting of the FC
CHS OPS ME ELC	Deck and engineering officers Engineering ratings	-	High temperature in SOFC auto-cracking fuel to hydrogen, potentially causing ignition Fuel leakage in FC Damage to SOFC by rapid cooling due to loss of fuel supply Unburnt hydrogen in exhaust	**Competence in handling of contingencies related to FC-related emergencies**	Crew should be aware of potential hazardous scenarios that may occur and be able to handle relevant emergencies	Knowledge of ■ the appropriate emergency procedures ■ when an ESD is triggered Understanding of ■ potential hazardous scenarios related to FC ■ the risks specific to a SOFC to cracking fuel to hydrogen within the FC ■ when crew action is needed ■ the consequences to an SOFC when it is cut off from fuel Proficiency in procedures for limiting fuel leakage inside and outside FC
CHS OPS ME ELC M&R	Deck and engineering officers Engineering ratings	-	Misinterpretation of the functioning of the FC safety system leading to a hazardous event	**Competence in the proper operation and procedures for onboard safety systems**	Crew need to be aware of FC safety systems to prevent and mitigate failures	Understanding of ■ the safety principles for a FC: ○ Segregation ○ Double-barrier ○ Ventilation/inertisation ○ Leakage detection ○ ESD ■ the layout of the system regarding redundancy
CHS OPS ME ELC	Deck and engineering officers	-	Improper operation of FC leading to reduced operational lifespan of the FC	**Competence in safeguarding the operational lifespan of the FC**	Many actions/failures can reduce the operational lifespan of a FC. Crew should be aware of these so they can be avoided/mitigated	Understanding of the different actions to a FC that can reduce its operational lifespan: ○ Improper temperature handling ○ Contaminated fuel ○ Load instability

4. Task A3 – Ammonia & Hydrogen Competences

4.1 Description

Task A3 focussed on the further identification and substantiation of seafarer competencies using the results from Task A1 and workshops. This Task differed from Task A2 as it focusses on the use of ammonia and hydrogen in ICEs.

4.1.1 Objectives

Task A3 had the following objective:

1. Identifying, justifying, and substantiating seafarer competence areas for ammonia and hydrogen including established competence requirements

4.1.2 Approach

Task A3 was approached systematically, using the results from A1. The functions outlined in 1.4 were then used, together with KUPs, and discussed in a series of workshops with experts. These workshops had the goal of producing STCW-style competence tables based on onboard functions and substantiated with KUPs.

New/amended competences were primarily developed through a risk/hazard-based approach, where the primary goal of the competence would be to mitigate a risk/hazard originating from the use of alternative fuels/systems.

Identified and expanded competences could then be consolidated into a Competence Catalogue.

4.2 Main results – Identification of new competences related to Ammonia and Hydrogen

The results of the workshops, identified new/amended competences, are presented in the following sections.

4.2.1 Ammonia

The identified ammonia competences covered its role as a marine fuel, specifically, its usage in an ICE and the surrounding fuel system. The results shown in Table 4-1 covered aspects around state-of-the-art fuel supply systems using ammonia as a fuel. The results for ammonia are based on the unpublished competence guideline, DNV-RP-0699[18] (DNV, 2024).

[18]Competence related to the onboard use of ammonia as fuel (not published)

Table 4-1 Ammonia competences

Ammonia			
Function	**Hazards and Risk Potential**	**New Competence**	**KUP Elements**
All	General hazards intrinsic to ammonia as a fuel, among which: ■ Ammonia poisoning ■ Corrosive properties of ammonia ■ Flammability of ammonia ■ Ammonia toxicity ■ Anhydrous ammonia ■ Cold storage temperature of ammonia	**Competence in the general knowledge and understanding of ammonia as a fuel**	Knowledge of ■ rules and regulations regarding ammonia ■ flashpoint, lower explosive limit (LEL), upper explosive limit (UEL) and autoignition temperature of ammonia ■ of the potentially safe/fatal level of ammonia if exposure, ingested or inhaled Understanding of ■ ammonia and its properties ■ the consequences and behaviour of ammonia being discharged into water, air and on deck (in vapour and liquid form) ■ ammonia's corrosive properties ■ ammonia's toxic and poisoning properties, how it may occur, its effects and symptoms ■ relevant properties of ammonia mixtures, such as exhaust from dual fuel engines or ammonia induced lube oil Proficiency in interpreting the safety data sheet (SDS) for ammonia
	Health, safety, and environment: ■ Risk awareness and proactive barrier competence ■ Risk of entering an area where ammonia may have leaked ■ Ammonia vapour accumulation (in enclosed spaces)	**Competence in understanding the risks associated with ammonia systems and be able to take precautions and act in a proactive manner to avoid unwanted events** **Competence in personnel protection for ammonia, regarding hazardous zones and with a focus on toxicity**	Knowledge of the behaviour of ammonia when discharged into water and into air Understanding of ■ Acute Exposure Guideline Levels (AEGL) for ammonia ■ Permissible Exposure Limit (PEL) ■ of the risks of entering spaces where methanol may be present ■ the risks of working on equipment and machinery that contains ammonia ■ gas detection and proper ventilation for spaces containing ammonia systems ■ the ship specific Gas Dispersion Analysis (GDA) and potential situations which may occur ■ the use of a Self-contained Breathing Apparatus and chemical suits when the likelihood of being exposed to ammonia is present Proficiency in ■ reporting if any personnel is exposed by ammonia ■ basic first aid ■ the familiarisation process of safety related ship specific aspects ■ the ammonia specific procedures and policies ■ using personal protective equipment, including personal rescue and escape equipment ■ calibrating and using personal gas detection systems ■ recognising and acting according to specific alarms related to ammonia ■ locating and recognising dangers related to hazardous zones and potential toxic areas on board, such as tank connections paces, fuel preparation room, ventilation outlets, vent mast, bunkering station, and engine rooms ■ escape routes, including trunks
	Hazards intrinsic to the ammonia bunkering and fuel containment and supply system	**Competence in operating ammonia specific bunkering and fuel containment systems and equipment, such as various systems and working principles of ammonia (dual) fuel supply system:** ■ **Combustion engines (liquid vs gas)** ■ **Fuel cells (solid oxide fuel cells, proton-exchange membrane fuel cells** ■ **Boilers/gas turbines**	Knowledge of the limitations of the bunkering arrangement Understanding of ■ the different tank types for storage of ammonia ■ the design principle and requirement for piping in ammonia fuel supply systems ■ methods for containing ammonia, atmospheric tanks vs pressure tanks ■ different bunkering arrangements for ammonia, with or without vapour return - ■ system specific protective equipment, such as pressure and temperature monitoring ■ risks considered associated with the condensation of gaseous ammonia

Ammonia			
Function	**Hazards and Risk Potential**	**New Competence**	**KUP Elements**
			■ how ammonia is affected by temperature considering condensation, including water content and dew point Proficiency in ■ interpreting and using readings from instruments and control systems ■ performing inspections on fuel tank support and insulation ■ removing condensation/water from ammonia, e.g., using drain pot
OPS	Responsive actions to emergency situations considering hazards intrinsic to ammonia as a fuel for personnel, among which: ■ Ammonia poisoning ■ Corrosive properties of ammonia ■ Flammability of ammonia ■ Ammonia toxicity / anhydrous ammonia ■ Cold storage temperature of ammonia	**Competence in ammonia specific safety systems**	Understanding of ■ the different means of ammonia leak detection, such as gas -, liquid-, temperature -, and pressure detection ■ the Emergency Shutdown (ESD) system and cause and effect diagram ■ different safety related barriers, such as relief valves, spray shielding, drip trays, certified electrical equipment (EX-rated), double-walled piping, water safety systems and Ammonia Release Mitigating System (ARMS) Proficiency in ■ calibrating, maintaining and operating gas leak detection systems ■ the troubleshooting/fault-finding of ammonia specific safety systems ■ performing ESD tests ■ ensuring the operability of water safety systems in all ambient conditions, e.g., in freezing conditions ■ operating and explaining the working principles of the different ARMS solutions
OPS ME	Ammonia gaseous leakage and specific: ■ Hazardous zones ■ Tank connection space ■ Fuel preparation room	**Competence in of ammonia specific hazardous zones relative to the fuel supply system.** **Competence in the principles and importance of venting and ventilation**	Understanding of ■ the risks associated with tank connection spaces and fuel preparation rooms ■ the purpose, function and typical equipment related to such zones / rooms ■ the difference between venting and ventilation ■ the importance of functioning ventilation system to ensure safe operation of the ammonia fuel system ■ catastrophic ventilation and ship specific air changes Proficiency in ■ the safe working procedures related to such zones/rooms ■ monitoring and operating ventilation systems, vent piping, and discharge system for toxic atmosphere ■ verifying proper functionality and performing the calibration of instrumentation in pressure monitoring system to ensure correct positive pressure and negative pressure conditions ■ the entry procedures for entering hazardous zones
ME	Containment of ammonia during bunkering operations: ■ Leakage ■ Spills	**Competence in bunkering ammonia**	Understanding of ■ preparing a fuel tank for safe ammonia filling (e.g. appropriate temperature and pressure) ■ the ammonia bunkering transfer ■ correct and clear communication procedures relevant for ammonia bunkering ■ the importance of cooling down liquid and vapour lines before bunkering ■ the potential necessity of additional PPE when conducting bunkering operations ■ the potential risks associated with connection and disconnection, as well as emergency release and dry breakaway couplings Proficiency in ■ inerting and purging bunkering lines ■ handling vapour capacities ■ checking the composition of bunkering arrangement, e.g., amount of water and oxygen, validated quality of purging operation (both pre- and post-bunkering)

Ammonia			
Function	**Hazards and Risk Potential**	**New Competence**	**KUP Elements**
			■ safe connecting and disconnecting of ammonia bunker transfer lines
ME M&R ELEC	Operational hazards of ammonia as a fuel	**Competence in the proper operation, functioning and monitoring of various ammonia fuelled machinery**	Understanding of the principal configuration, working principle and main components of a (dual) fuel ammonia fuel supply system, from the containment system to the respective consumers. Proficiency in ■ operation of the ammonia fuel supply system, and connected equipment, such as heating systems / vaporisers, pumps. gas isolation valves, boil off gas systems, exhaust systems, bilge and drainage systems, and systems to prevent condensation of gaseous ammonia ■ troubleshooting related to the control and alarm board of the ammonia fuel supply system
ME M&R ELEC OPS	Containment of ammonia: ■ Maintenance of ammonia related systems	**Competence in preparing an ammonia fuel tank for internal maintenance**	Understanding of the potential for unpumpable liquids and remains to be present in ammonia tanks when emptying Proficiency in ■ the procedures for emptying an ammonia tank completely (warming up, gas freeing) ■ always keeping the tank atmosphere at a non-explosive and non-toxic range
M&R	Various systems and working principles of ammonia (dual) fuel supply system: ■ Combustion engines (liquid vs gas) ■ Fuel cells (solid oxide fuel cells, proton-exchange membrane fuel cells) ■ Boilers / gas turbines	**Competence in maintenance on ammonia systems**	Understanding of ■ warming up of fuel tank, aeration and gas freeing before maintenance ■ that some equipment and systems might require special training. Awareness of what maintenance not to perform ■ the need for using compatible materials in piping and equipment ■ the potential dangers for residuals of ammonia in systems directly or indirectly coupled to the ammonia fuel supply system ■ the potential residuals/traces/containment of ammonia on PPE after completing maintenance Proficiency in ■ analysing the dangers of maintenance on two systems simultaneously ■ analysing the process of the maintenance operation in order to assess and determine if the operation should be paused or aborted ■ analysing and assessing the status and degradation of system on equipment, e.g., corrosion, corrosion under insulation, vibration / stress / fatigue. ■ performing maintenance on ammonia related systems and equipment, as well as safety related systems and equipment ■ exercising post-maintenance caution, such as importance of safe distance to hazardous zones when starting up systems
ALL	Containment of ammonia in relation to emergencies and contingencies: ■ Liquid leaks ■ Gaseous leaks ■ Emergency unloading / transfer of ammonia ■ Emergency discharge ■ Emergency separation	**Competence in communication, alarm management, responses to an ammonia leak or spill situation, and rescue of people exposed to ammonia**	Understanding of ■ the different credible critical scenarios which can occur by using relevant risk assessments ■ that ammonia may be close to the sea surface in case of an abandon ship situation ■ the restrictions in visibility in case of an ammonia leak, as it may result in a dense cloud ■ the dangers of ammonia leaks, liquid and gaseous ■ the chemical reaction when ammonia is combined with water ■ the different emergency stop methods and effects ■ proper communication procedures related to the ammonia hazards during an emergency ■ what can cause an ESD scenario Proficiency in ■ determining safe locations onboard, e.g., safe haven ■ showing the location and demonstrating the function of a safe haven ■ determining most suitable vessel position/orientation considering environmental conditions and nearby infrastructure in case of an ammonia release or spill

Ammonia			
Function	**Hazards and Risk Potential**	**New Competence**	**KUP Elements**
			▪ communicating with other stakeholders (voice radio and alarms) ▪ emergency stop and shutdown ▪ demonstrating methods in locate gas leaks ▪ interpreting the functionality and effects of activating ESD system ▪ describing the effects on the ammonia fuel supply system in case of a blackout ▪ alerting nearby stakeholders (e.g., port, ships, offshore installations) in case of an ammonia leak ▪ methods for emergency discharge of ammonia ▪ methods for emergency separation during ammonia bunkering
ALL	Ammonia fire	**Competence in the different firefighting methods, procedures, mitigating measures and consequences for ammonia** **Competence in handling toxic and explosive ammonia gasses**	Understanding of ▪ the flammable properties of ammonia ▪ the role of the Ammonia Release Mitigation System (ARMS) and double walled pipes as safety measures to tackle toxicity hazards Proficiency in demonstrating methods for extinguishing an ammonia fire

4.2.2 Hydrogen

As a fuel hydrogen falls under the IGF code and competence requirements can be drawn from there. Storage and containment of hydrogen has similarities with LNG. The identified competencies and KUPs are therefore focused on additional competencies surrounding the fuel system and storage considering both compressed and liquid hydrogen

Table 4-2 Hydrogen competences

Hydrogen			
Function	**Hazards and Risk Potential**	**New Competence**	**KUP Elements**
All	General hazards intrinsic to Hydrogen as a fuel to personnel, among which: ▪ Hydrogen's ability to diffuse through materials ▪ Corrosive properties of hydrogen ▪ Hydrogen's extreme low temperature ▪ Hydrogen's large flammability range ▪ Low ignition threshold ▪ Low boiling point for cryogenic hydrogen ▪ Cold storage temperature of hydrogen ▪ Risk of asphyxiation ▪ Exposure of crew to cryogenic (liquid) hydrogen ▪ Extreme subzero temperatures	**Competence in knowledge and understanding of hydrogen properties and health hazards**	Knowledge of ▪ the relevant rules and regulations for hydrogen ▪ hydrogen's extreme conditions – i.e. temperature, pressure, diffusion, flammability, ▪ flashpoint, lower explosive limit (LEL), upper explosive limit (UEL) and autoignition temperature of hydrogen ▪ the extreme risks of injuries when in contact with subzero gases ▪ hydrogen's rapid diffusion and its potential consequences Understanding of ▪ hydrogen and its properties ▪ the material data sheet (MSDS) of hydrogen ▪ the difference between compressed and liquid (cryogenic) Hydrogen ▪ hydrogen's sensitivity to oxygen ▪ the high flammability of hydrogen ▪ sensitivity of hydrogen to self-ignite (350-700 bar) ▪ the requirements behind EX-zones related to hydrogen ▪ that oxygen can condense from air with liquid and expose risk (Cryo PPEs -240C) ▪ hydrogen can displace oxygen in the air and potentially causing asphyxiation

Hydrogen			
Function	**Hazards and Risk Potential**	**New Competence**	**KUP Elements**
			■ what not to do when working with hydrogen as fuel ■ the risks of entering an area where hydrogen may have leaked Proficiency in ■ safe use/application PPE for hydrogen-related risks ■ correctly applying breathing apparatus as part of PPE ■ the ability to quickly respond to gas detection alarms ■ working in enclosed spaces ■ executing a proactive mindset about risk awareness for hydrogen
CHS OPS ME ELC	Hazards intrinsic to the Hydrogen bunkering, fuel containment, and supply system Including fire and explosion hazards • Flammability both compressed and liquid • Ignition sources • Explosion risk	**Competence in taking precautions to prevent risk of ignition, explosion, and hydrogen fire** **Competence to plan, execute and monitor the safe bunkering of hydrogen**	Knowledge of ■ the risks involved with breaking containment of hydrogen (nitrogen can't be used for inerting because it will condense) ■ how composite materials used in compressed hydrogen tanks are affected when exposed to fire and mechanical damage ■ that a high-pressure leakage can self-ignite ■ the fact the compressed hydrogen tanks are vulnerable (impact, fire, UV) due to being made from composites ■ density of hydrogen can change extremely depending on temperature Understanding of ■ the differences and properties of compressed and liquid hydrogen ■ preventing ingress of air/nitrogen into the hydrogen system ■ procedures and risks for hydrogen bunkering operations ■ the danger of using nitrogen as an inert gas with liquid hydrogen regarding its condensation ■ how the leak detection system for hydrogen works, including its limitations ■ how static electricity builds up and how to avoid this when working in Ex areas ■ limiting air mixing with hydrogen ■ the importance of adequate ventilation in areas where hydrogen is being processed or stored ■ the importance of vacuum insultation for liquid hydrogen ■ the temperature hazards and that air solidifies at extreme cold temperatures related to liquid hydrogen ■ importance of overpressure in the hydrogen system ■ the consequences of loss of vacuum in type C tanks ■ importance that you lose the most important safety barrier when inerting/vacuum is compromised ■ importance of material type for the different hydrogen storage tanks ■ the consequences of leakage ■ the risks of breaking containment ■ the effects of contamination inside liquid hydrogen piping (of condensed air and nitrogen) ■ the risks of connecting and disconnecting swappable modular hydrogen storage containers ■ not using nitrogen with liquid hydrogen in double walled piping due to nitrogen potentially leaking into the liquid hydrogen piping ■ that liquid hydrogen condenses air around tanks when leaking ■ that liquid hydrogen contamination inside piping can end up in fuel tanks when bunkering liquid hydrogen potentially leading to an explosive atmosphere if temperatures inside the tank increase ■ the differences behind "emptied, purged and gas-free" Proficiency in

Hydrogen			
Function	**Hazards and Risk Potential**	**New Competence**	**KUP Elements**
			■ the ability to recognise (hear) high pressure hydrogen leaks which are invisible ■ filling limits, loading limits and the difference regarding these between liquid and compressed hydrogen ■ awareness concerning the higher level of risk regarding ignition of hydrogen ■ applying grounding and bonding to prevent static electricity as a potential ignition source ■ the ability to communicate risks and safety procedures for hydrogen fire ■ the safe evacuation from hydrogen fire/ leakage ■ the steps to execute a change of swappable modular hydrogen storage container ■ applying helium to inert liquid hydrogen
NAV	Insufficient awareness of the effects of hydrogen as a fuel on voyage planning	**Competence in the hydrogen specific aspects related to voyage planning**	Proficiency in ■ the application of hydrogen related regulations pertaining to each individual voyage ■ the type of permissions needed for certain voyages/port calls when using/bunkering hydrogen ■ mapping hydrogen bunkering possibilities ■ estimating required hydrogen fuel and consumption for a voyage ■ calculating the stability of the vessel as hydrogen is consumed
CHS OPS ME ELC M&R	Improper operation and maintenance of the hydrogen fuel system, auxiliary systems, and engine	**Competence in the proper operation, functioning and monitoring of a hydrogen fuelled engine**	Knowledge of ■ hydrogen's ability to diffuse through materials ■ the risks involved in high pressure storage systems ■ hydrogen properties (colourless, odourless, invisible flame, etc). ■ risk of hydrogen to self-ignite ■ hydrogen specific EX-machinery ■ potential hydrogen explosion scenarios ■ of the general dangers and explosion risk for hydrogen fuelled vessels. Understanding of ■ the functioning of the hydrogen fuel system, connections of the system and leak prevention/inspection ■ importance of maintenance requirements to prevent leaks ■ the ease of hydrogen to leak ■ how accumulation of hydrogen happens ■ importance of material type for the different hydrogen storage tanks ■ the efficiency of ventilation systems ■ risk of hydrogen presence in the exhaust ■ the consequences of hydrogen ingress to the engine crankcase Proficiency in ■ Ex-certified equipment for hydrogen
CHS OPS ME ELC M&R	Improper execution of process safety systems and procedures	**Competence in the proper operation and procedures for onboard safety systems**	Knowledge of ■ the basic hydrogen process monitoring & control system ■ the fact that the density of hydrogen changes extremely fast ■ the properties of hydrogen at different temperatures ■ consequences of hydrogen release being exposed to oxygen Understanding of ■ the challenges of detecting hydrogen ■ the effects of ESD and when it is activated, including limited redundancy upon ESD ■ how level/pressure and temperature transmitters work on hydrogen fuel system / engine ■ determining the ratio of fullness in hydrogen vessels ■ the consequences of loss of vacuum pressure ■ the consequences of loss of inert gas pressure

Hydrogen			
Function	**Hazards and Risk Potential**	**New Competence**	**KUP Elements**
			■ how the leak detection system works Proficiency in ■ the ability to effectively shut off the fuel supply upon failure
CHS OPS ME ELC M&R	Improper handling of emergencies (fire, leakage, explosion, related to hydrogen)	**Competence to respond to emergencies related to hydrogen**	Knowledge of ■ the properties of hydrogen fires and the principle of “invisible fires/micro flame” ■ the effects of hydrogen leakage and that a high-pressure leak can self-ignite ■ important shutdown valves for the fuel supply system, and how to operate these in case of an emergency Understanding of ■ how the emergency shutdown system is designed and the different levels of shutdown to isolate from ignition sources ■ the principles behind first and secondary barrier for leakage point ■ how a blackout will impact the safety system and the concept of “fail safe” ■ the difference between principles of conventional firefighting and firefighting both compressed/liquid hydrogen ■ the purpose of ventilation for hydrogen and the principle of dilution ■ of the risk of accumulation of hydrogen at the vent mast Proficiency in ■ the ability to shut down the fuel supply in case of fire or leakage ■ using various types of leak detection systems/methods ■ carrying out emergency response according to the emergency response plan

4.3 Part A Conclusion

Part A aimed to identify and substantiate competences and KUP elements in the style of the STCW Code tables for the fuels/energy systems, this was achieved via the following approach:

A1: Firstly, a state-of-the-art review was conducted to get a sense of the current state of seafarer competence requirements and training for the relevant fuels/fuel systems. By using existing literature, standards, and guidelines, in addition to interviews with experts.

A2: Secondly, a series of workshops, building on the findings from A1, were held to identify and substantiate competences, in the same vein as the STCW Code tables. This was conducted via a risk-based approach, where hazards introduced by the new fuels were linked to potential new competence requirements to mitigate the hazards. All mentioned fuels/energy systems were included here, except for hydrogen and ammonia.

A3: Lastly, a similar approach was taken for hydrogen and ammonia as in A2, but with a more generalised focus on the identified competences due to lack of industry experience with the aforementioned fuels.

Part A has identified the competence needs for the fuels and energy systems covered, namely: Liquid Natural Gas, Biofuels, Methyl/ethyl alcohols (limited to Methanol), Hybrid electrical battery systems, Fuel cells, Ammonia and Hydrogen. These competences are catalogued in Appendix A.

As shown in section 1.5 the first two columns of the STCW table cover the competence and their KUP elements. This was the focus of Part A.

Part A		Part B	
Column 1 - Competence	**Column 2 – Knowledge, understanding and proficiency (KUP)**	**Column 3 – Methods for demonstrating competence**	**Column 4 – Criteria for evaluating competence**

Figure 4-1 STCW table columns

Part B will focus on columns 3 and 4 covering how these competences are demonstrated and evaluated. Namely how to train seafarers in the identified competences.

Part B aims to identify methods for demonstrating competence and propose methods for training in addition to ways of training the future trainers.

5. Task B1 – Methods for demonstrating competence

5.1 Description

Task B1 identifies methods for demonstrating competence, identify alternative ways of learning, and identify how onshore industries treat skill transfer and training for alternative fuels and energy systems, by conducting interviews of Subject Matter Experts (SME). The findings and results from task A1 to A3 which focused on the identification and substantiation of new seafarer competences regarding alternative fuels and energy systems serves as valuable inputs towards Task B1.

5.1.1 Objectives

Task B1 had the following objectives:

1. Identify and define current and future methods for demonstrating competence, as well as alternative ways of learning due to the scarcity of available positions on ships with alternative fuels and energy systems to gain experience
2. Identify and document how onshore industries treats skill transfer and training for alternative fuels and energy systems in different supply chains, such as production, storage, transfer, and transport. Also, how these industries potentially can contribute to the training and experience gain of seafarers.

5.1.2 Approach

The objectives of Task B1 were achieved through the following approach:

1. Review of the current methods for demonstrating competence in the STCW Code
2. Preparation of interview guides to identify what methods for demonstrating competence are applicable and useful for alternative fuels and energy systems, as well as alternative ways of learning
3. Preparation of interview guide to identify how onshore industries treat skill transfer and training for alternative fuels
4. Interviews with internal and external experts according to interview guide
5. Gathered information to be analysed and create register of methods for demonstrating competence (section 5.2.2), new technology and alternative ways of learning (section 6.2.2) and contribution of training of seafarers from other industries (section 5.2.3)

Figure 5-1 Approach for Task B1

To provide a solid contextual foundation for the interviews, current methods for demonstrating competence as described in the STCW Code, with a special focus on the IGF Code, were reviewed. The interview guides were designed to gather feedback from industry experts on the methods suitable for demonstrating specific competence, as described in Section 5. A total of six interviews with nine interviewees were conducted to discuss the most effective methods for demonstrating competence in new alternative fuels and energy systems.

Considering the identification and documenting on how onshore industries treats skill transfer and training, a separate interview guide was developed. This guide focused on what activities and goals are important for safety of the workers. Two subject matter experts from one organisation that produces ammonia were selected for interview, as ammonia production also needs to consider hydrogen in the process.

5.2 Main results

The overall conclusions related to demonstrating competence are:

- The methods to demonstrate competence currently defined in the STCW Code are still applicable for alternative fuels and energy systems. One potential new method is identified, "Approved case studies and projects", which can be relevant to transfer knowledge from e.g., pilot projects on ammonia and hydrogen as fuel.
- Real-world examples through case studies creates practical insight
- E-learning offers flexible and accessible online education
- VR/AR technologies create immersive and interactive learning experience

5.2.1 Methods to demonstrate competence

The STCW competence tables outlines the mandatory minimum standards and special training requirements for various ship types and onboard positions. Considering Table 1-3 Example of IMO STCW table structure, using Table A-V/3-1 of the STCW code in Part A of this study, Section 1-5 concentrated on Column 1 "Competence" and Column 2 "Knowledge, Understanding, and Proficiency (KUP) elements KUP elements". This section shifts the focus to Column 3 "Methods for demonstrating competence" within each competence area for the alternative fuel technology which is identified in Section 5.

Table 5-1 describes the reviewed methods for demonstrating competence, as well as a description of each, which is used as basis for the register of methods for demonstrating competence in Table 5-3. Seafarer competence can be demonstrated through written or oral *exams* (to test theoretical knowledge), practical *demonstrations* of skills, or formal *assessments* by qualified assessors, using any of the methods outlined in Table 5-1.

Table 5-1 Identified current and new methods for demonstrating competence

Method of demonstrating competence	Description
Approved in-service experience	**Approved in-service experience** refers to a period of service on board a ship that is recognised by the relevant maritime administration or authority, during which a seafarer actively engages in duties and gains practical experience related to their certification and competence. This experience is part of a structured training programme and includes on-the-job training and assessment of competence, with documented records confirming the seafarer's performance and learning. The method leverages the practical experience and knowledge gained by seafarers during their service on board ships, ensuring that the competence is based on real-world scenarios and hands-on experience.
Approved training ship experience	**Approved training ship experience** refers to the documented and successful completion of an approved training programme that involves formal training and assessment on board a training ship. This experience is part of a structured program designed to provide seafarers with practical shipboard training, which is recognised by the relevant maritime authority as meeting the requirements for certification under the STCW Convention. The method leverages the practical experience and knowledge gained by seafarers during their service on board ships, ensuring that the competence is based on real-world scenarios and hands-on experience.
Approved simulator training	**Approved simulator training** refers to the use of simulators that meet the standards set by the STCW Convention and are approved by the relevant maritime authority, for the purpose of providing mandatory simulator-based training or for demonstrating competence. This training method is particularly used for skills that are difficult to practice in real life due to safety, cost, or logistical reasons. Simulator training provides a safe and controlled environment where seafarers can demonstrate their competence in taking precautions and reducing risks. It is possible to rehearse on different scenarios related to the competence area and to inject malfunctions (faults) into the training.
Approved laboratory equipment training	**Approved laboratory equipment training** refers to the documented and successful completion of training and assessments from an approved training course or facility, where the training involves the use of laboratory equipment that meets the standards set by the STCW Convention and is approved by the relevant maritime authority. Using replicated equipment from actual fuel technologies gives a hands-on experience to train on contingency scenarios.
Approved training programme	**Approved training programme** refers to a comprehensive educational and practical training course that meets the standards set forth by the STCW and is sanctioned by the relevant maritime administration. Such programs typically include a combination of theoretical instruction, practical workshop skill training, and seagoing service, and are documented to verify successful completion. Approved training programme provides structured and standardised education, ensuring that all participants receive the necessary level of knowledge and competence on the fuels.

Method of demonstrating competence	Description
Approved distance learning and e-Learning	**Approved distance learning and e-Learning** refer to a documented and successful completion of an approved distance/e-learning programme. It refers to a mode of delivering education and training to seafarers that is conducted remotely using digital platforms and has been reviewed and sanctioned by the relevant maritime administration. These programmes are approved by the maritime authority to ensure that they are suitable for the selected objectives and training tasks, and that they meet the competence level for the subject covered. Alternative ways of learning, such as virtual reality technologies, are covered by this method for demonstrating competence. VR would be a safe alternative to train on emergencies, if models are customized to fit the different scenarios. Distance learning offers flexibility and accessibility, allowing learners access to showcase their competence from remote workplaces.
Onboard training and drills	**Onboard training and drills** refer to a structured and supervised programme conducted on board a ship, designed to provide seafarers with hands-on experience and practical skills relevant to their duties. Onboard training and drills provide a hands-on way of demonstrating real-life scenarios, related to general knowledge, health hazards and use of PPE. It allows seafarers to apply theoretical knowledge in a real-world setting, under the guidance of qualified personnel. Regularly scheduled exercises that simulate emergency situations ensures seafarers can practice and verify the proficiency of the crew in emergency procedures, ensuring a high level of preparedness. This method for demonstrating competence includes: • **Onboard training**: Practical instruction and exercises that allow seafarers to apply theoretical knowledge in a real-world setting, under the guidance of qualified personnel. This training is often documented in a training record book and is part of the seafarer's continuous professional development. • **Drills**: Regularly scheduled exercises that simulate emergency situations, such as fire, abandon ship, or man overboard scenarios. Drills are conducted to practice and verify the proficiency of the crew in emergency procedures, ensuring a high level of preparedness and compliance with the International Safety Management (ISM) Code.
Approved case studies and projects	**Approved case studies and projects** is the only identified method for demonstrating competence, which also is found useful for alternative fuels, but not described in the STCW Convention and Code. The method can provide a practical and comprehensive way for seafarers to engage with real-world scenarios and challenges associated with alternative fuels like ammonia and hydrogen. Case studies and projects can be designed to simulate the complexities and risks involved in the use of these fuels, offering a safe environment for seafarers to apply their knowledge and skills. Approved case studies and projects based on alternative fuels encourages critical thinking and problem-solving by applying theoretical knowledge to real-world situations, demonstrating the learner's ability to handle complex tasks.

Note, that not one method is a catch all for demonstrating competence, but rather a combination of different methods may be the most effective. While the STCW Convention and Code outlines the minimum requirements for demonstrating competence, maritime education and training institutions should not be restricted to a single method. Instead, they should have the flexibility to choose the most suitable method based on industry feedback. The intent of these applicable methods is to identify the most effective approach for each specific competence.

In addition to the identified methods for demonstrating competence, the maritime industry needs to search for alternative learning methods for seafarers. When reviewing methods for demonstrating competence, Virtual Reality (VR) was found to be a prominent alternative way of learning, which falls under the category of “Approved distance learning and e-Learning”. Conventional simulator training is still highly relevant. However, simulations related to maintenance, bunkering, faults, emergencies and maritime operations are found to be relevant for the new types of fuel. At present the industry may not have dedicated simulator training for ammonia, hydrogen, or methanol, but a range of new simulator variations which may be applicable for such, are being developed.

VR is a technology which allows users to be immersed in an interactable virtual environment. This can be achieved through various interfaces, such as head mounted displays (HMD), or through computer screens. These virtual environments can simulate real world environments with a high level of fidelity, allowing for enhanced levels of immersion and interaction. In contrast to conventional full-mission simulators, the instructor and trainees do not need to be in the same room when doing VR training. Applications could include the use of VR technology on board for ship specific training (e.g., standard operating procedures), as well as distributed learning, where the instructor was located in another city than the trainee.

There are of course some limitations with VR. It only approximates real-life scenarios and may not fully replicate the practical experience needed for certain competences. Most VR applications are designed for one-on-one training, which limits collaborative training opportunities and can be resource-intensive, requiring one instructor per student. In fully immersive VR, users often rely on clunky hand controllers, which do not accurately replicate the tactile experience of operating real-life instruments, potentially hindering the development of psychomotor skills. Additionally, VR environments with multiple users in different physical locations are highly dependent on low latency and stable connectivity; poor connectivity can adversely affect training.

Training generally aims to achieve competency outcomes, which are best attained through practical experience on board. However, this is not always feasible or practical, especially when regarding the limited availability or maturity of alternative fuelled vessels. A sufficient level of competency is currently, typically, achieved through a combination of:

1. Theoretical learning - lectures, videos, reading materials
2. Simulator training - application of knowledge and realistic practice
3. Practical experience at sea - onboard familiarisation

VR serves as a technological solution to achieve both theoretical and simulator training, depending on its application. The added realism and practicality, relatively low cost, safe and controllable environment, and ease of implementation all underline this. However, it is still a simulation of real-life experiences and cannot fully replace the need for additional practical experience. More practical examples of the use of VR are described in Section 6.2.2 - New technologies for training.

5.2.2 Register of methods for demonstrating competence

This section presents the findings considering methods for demonstrating competence, integrated into a register. The register describes which methods for demonstrating competence may be suitable for each competence, as described in the competence column in the tables provided in Section 5.

In Section 5, each fuel and energy system is listed individually. Since there are competences which can be applicable to several fuels, the register first presents the methods for demonstrating competence which are applicable to more fuel types than one. Then, if there is a specific competence which is relevant for one fuel only (e.g., competence considering the toxicity of ammonia), the specific methods for demonstrating competence will be described.

The results are summarized in Table 5-2 Register of methods for demonstrating competence. The register does not follow a prioritized order of methods for demonstrating competence, however, it includes a justification for the proposed methods of demonstrating competence, as well as the relevance for type of crew.

Table 5-2 Register of methods for demonstrating competence

METHODS FOR DEMONSTRATING COMPETENCE RELEVANT FOR SEVERAL FUELS			
Fuel tech	**Competence area**	**Applicable Methods for demonstrating competence**	**Relevance for type of crew**
LNG BIO MET BAT AMM HYD	Competence in the general knowledge and understanding of the fuel, as well as properties and health hazards	• Approved training program • Approved distance learning and e-Learning • Onboard training and drills • Approved case studies and projects	All crew
LNG BIO MET BAT AMM HYD	Competence in risk reducing measures related to the specific fuel. This includes measures to prevent exposure, spills, ignition, fire and explosion	• Approved in-service experience • Approved simulator training • Approved training programme	All crew
LNG BIO MET BAT AMM HYD	Competence in the proper operation and procedures on fuel/technology specific safety systems	• Approved in-service experience • Approved training ship experience • Approved simulator training. • Approved training programme • Onboard training and drills	All crew

METHODS FOR DEMONSTRATING COMPETENCE RELEVANT FOR SEVERAL FUELS			
Fuel tech	**Competence area**	**Applicable Methods for demonstrating competence**	**Relevance for type of crew**
LNG BIO MET BAT AMM HYD	Advanced knowledge on emergencies and contingencies related to the fuel system/technology	• Approved in-service experience • Approved training ship experience • Approved simulator training • Approved laboratory equipment training • Approved training programme • Approved distance learning/e-learning • Onboard training and drills	Officers (For ratings-only written test)
LNG BIO MET BAT AMM HYD	Competence in the maintenance and repairs on fuel specific systems. Understand what types of maintenance that should be left to specialist service personnel	• Approved in-service experience • Approved training ship experience • Approved simulator training. • Approved laboratory equipment training • Approved distance learning/e-learning • Approved training programme	All crew
LNG BIO MET AMM HYD	Competence in methods of storage, transfer arrangements, cleaning and tank connection space.	• Approved training programme	Officers
LNG BIO MET AMM HYD	Competence in the proper operation, functioning and monitoring of the fuel system	• Approved in-service experience • Approved simulator training • Approved training programme	Officers
LNG BIO MET AMM HYD	Competence to plan, execute and monitor the safe bunkering of the fuel, taking the fuel specific precautions and systems into consideration.	• Approved in-service experience • Approved training ship experience • Approved simulator training. • Approved training programme • Onboard training and drilling	Officers
LNG BAT MET AMM HYD	Competence in the principles and operation of ventilation systems and hazardous zones.	• Approved in-service experience • Approved simulator training • Approved training programme	Officers
HYD BIO AMM	Competence in the fuel specific aspects related to voyage planning	• Approved in-service experience • Approved simulator training • Approved training programme	Officers
BIO MET	Competence with the regulation, rules and requirements related to biofuel	• Approved training programme	Officers

LNG			
Fuel tech.	**Competence area**	**Applicable Methods for demonstrating competence**	**Relevance for type of crew**
LNG	Competence in the inerting an LNG fuel system	• Approved in-service experience • Approved simulator training. • Approved training programme	Officers
LNG	Competence in the purging of an LNG fuel system	• Approved training program • Approved in-service experience • Approved simulator training. • Approved training programme	Officers

BIOFUELS			
Fuel tech.	**Competence area**	**Applicable Methods for demonstrating competence**	**Relevance for type of crew**
BIO	Competence in fuel preparation	• Approved in-service experience • Approved simulator training. • Approved training course • Onboard training and drills	Officers

BATTERY-POWERED HYBRID-ELECTRIC SYSTEMS			
Fuel tech.	**Competence area**	**Applicable Methods for demonstrating competence**	**Relevance for type of crew**
BAT	Competence of different firefighting methods, procedures, mitigating measures and consequences related to battery systems	• Approved in-service experience • Approved training programme • Onboard training and drills • Approved laboratory equipment training	Officers
BAT	Competence and understanding of toxic and explosive gasses related to battery systems	• Approved in-service experience • Approved training programme • Onboard training and drills • Approved laboratory equipment training	Officers
BAT	Competence in the effects of toxic gases and appropriate first aid	• Approved in-service experience • Approved training programme • Onboard training and drills • Approved laboratory equipment training	Officers
BAT	Competence in considering implications of incorrect or improper maintenance.	• Approved in-service experience • Approved training programme	Officers
BAT	Competence in what affects battery lifetime Internal short-circuit as battery ages and the chargeability of a battery with age	• Approved in-service experience • Approved training programme	Officers
BAT	Competence on the usage of battery as a form of energy storage	• Approved in-service experience • Approved training programme	Officers

AMMONIA			
Fuel tech.	**Competence area**	**Applicable Methods for demonstrating competence**	**Relevance for type of crew**
AMM	Competence in understanding the risks associated with ammonia systems and be able to take precautions and act in a proactive manner to avoid unwanted events.	• Approved in-service experience • Approved training ship experience • Approved training programme • Approved case studies and projects	All crew
AMM	Competence in personnel protection for ammonia, regarding hazardous zones and with a focus on toxicity	• Approved in-service experience • Approved training ship experience • Approved training programme • Approved case studies and projects	All crew

AMM	Competence in operating ammonia specific bunkering and fuel containment systems and equipment, such as various systems and working principles of ammonia (dual) fuel supply system: • Combustion engines (liquid vs gas) • Fuel cells (solid oxide fuel cells, proton-exchange membrane fuel cells • Boilers/gas turbines	• Approved in-service experience • Approved training ship experience • Approved training programme • Approved case and studies and projects	Officers
AMM	Competence in preparing an ammonia fuel tank for internal maintenance	• Approved in-service experience • Approved simulator training. • Approved training course	Officers
AMM	Competence in the different firefighting methods, procedures, mitigating measures and consequences for ammonia Competence in communication, alarm management, responses to an ammonia leak or spill situation, and rescue of people exposed to ammonia	• Approved in-service experience • Approved simulator training. • Approved laboratory equipment training • Approved training course • Approved distance learning/e-learning • Onboard training and drills	All crew

METHANOL			
Fuel tech.	Competence area	Applicable Methods for demonstrating competence	Relevance for type of crew
MET	Competence in the methods of methanol storage, their connections and cleaning	• Approved simulator training	Officers
MET	Competence to condition methanol tanks	• Approved simulator training	Officers
MET	Competence in the operation and maintenance of auxiliary systems related to the methanol fuel system	• Approved simulator training	Officers

HYDROGEN			
Fuel tech.	Competence area	Applicable Methods for demonstrating competence	Relevance for type of crew
HYD	Competence to respond to emergencies related to hydrogen	• Approved in-service experience • Approved simulator training. • Approved laboratory equipment training • Approved training program • Approved distance learning/e-learning • Approved case and studies and projects • Onboard training and drills	All crew

5.2.3 Learnings from other industries

The maritime industry can leverage extensive experiences from the onshore industry, which possesses considerable expertise in the production, storage, and transfer of substances and chemicals. It is important to emphasize the differences in operational environment for ship and shore industries. Ships travels world-wide in an ever changing, dynamic environment, while shore industries are usually static, one-location environments, with the possibility to lean on service and emergency personnel at a short notice. There is also a difference in the processes between production, storage, transfer, and transport. The substances of alternative fuels themselves are normally in a single state when being transported and stored, while production and transfer operation processes can be more complex. E.g., a substance is only transported in pressurized (or cooled down) liquid form when being stored and transported but can be altered to gaseous form when being produced, to be used in production (of other products/substances) or being transferred.

Ammonia production is used as a use case for this study. An ammonia production plant is a highly complex working environment, where personnel handle not only ammonia but other substances with different hazards and characteristics. Additionally, ammonia production plants produce hydrogen as part of the value chain for other substances, further adding to the complexity. Organisations with such facilities implement comprehensive training programmes to ensure personnel attain the required competence and proficiency for their respective roles. All employees must complete role-specific training before accessing the production area. Upon completion of the training, personnel are awarded a Unit of Competence certification. Detailed procedures define the permissible actions and designated locations for various roles within the plant. The training regime consists of thoroughly mapped competence matrices with separate training modules.

Training is structured around three main pillars:

- The competence required for a specific task
- The level of understanding needed for the dedicated role
- Performance capabilities of the dedicated role

This structure ensures a clear hierarchy of roles within the plant, allowing everyone to understand which roles possess the knowledge and understanding of certain aspects, which roles have the proficiency to manage and modify the plant, and which personnel are qualified to train others. To train others, the dedicated role must have completed the full certification regime specified by the power plant management system. At a specific facility, production operators are organised into a hierarchy based on their experience and certification. A learner must undergo training with a highly experienced and certified production engineer before assessment and certification can take place. The certification process typically begins with a document review of procedures and policies, followed by a walkthrough of P&ID (piping and instrumentation diagram) and other relevant documents, before entering the plant.

After entering the plant, the learner and the trainer discuss the P&ID (piping and instrumentation diagram) of the production line on a theoretical level. They cover what the components in the paperwork look like in reality, how they should function, and the specific characteristics of each component (e.g., pressure, temperature, flow, operation). Each operational task in the plant is described through a thorough and detailed SOP (Standard Operating Procedure). After initial certification as a production plant engineer assistant (a term used here for clarity), the learner undergoes more specialized training with the manufacturer of the production plant and participates in simulator scenarios. This training helps the learner understand how different processes, equipment, systems, substances, and operator actions interact.

The key success factors in such environments, as identified by participants in this study, are the conscious effort to work towards and maintain a proactive safety culture, the commitment from managers and leaders, and the implementation of extensive, highly specified training regimes. There are several learning points that the maritime industry can adopt from the onshore industry's experience with production and storage. These are listed in Table 5-3.

Table 5-3 Key learning points to use in the maritime industry

Learning point	Description	Application to the maritime industry
Safety culture	Onshore industries emphasize a strong safety culture driven by leadership commitment.	Prioritize building and maintaining a robust safety culture for working with alternative fuels like ammonia, LNG, or hydrogen.
Specified training regimes	Highly specified training regimes in complex environments like ammonia production.	Seafarers should also undergo comprehensive training that maps out the necessary competences for different roles on board, with certification/qualification schemes, aligned to specific tasks /safety critical operations, ensuring personnel are only performing duties for which they are qualified

Competence matrices	Define training levels, tasks, and certification needs for personnel.	Implement similar structures to ensure seafarers are well-versed in theoretical and practical aspects of handling alternative fuels. If competence matrixes already exist, these should be updated to include new roles and tasks
Simulator-based training	Onshore production plants use simulators to help operators understand how different systems interact and how specific actions impact overall operations	Provide simulator-based training for alternative fuel systems to handle operational tasks and emergency responses.
Standard Operating Procedures	Detailed SOPs ensure uniformity and safety in operational tasks.	Adopt or further develop SOPs for storage, transfer, bunkering, maintenance and use of alternative fuels, tailored to maritime challenges.
Experience-based hierarchy	Clear hierarchy based on experience and certification.	Maritime training can mirror this structure, pairing less experienced seafarers with certified mentors and emphasizing experience-based learning.
Handling fuels in various states	Personnel handle fuels in various states (solid, liquid, gaseous) depending on production needs.	Train maritime personnel on the dynamic use of alternative fuels in different forms onboard vessels, based on fuel supply systems and operational needs.

6. Task B2 – Proposals of structured training of seafarers

6.1 Description

Using the results from Task A and B1, reviews and subject matter experts, Task B2 focused on the identification of future training methods for seafarers on ammonia fuelled vessels, including a proposal for structured training of seafarers.

6.1.1 Objectives

Task B2 had the following objective:

Provide description of proposals of structured training of seafarers in the safe operation of ships using alternative fuels and energy systems.

6.1.2 Approach

Task B2 will outline proposed training for seafarers, with a particular focus on methods for training, such as the adaptation and integration of maritime simulators into the training programmes. Incorporating the findings from B1, A2 and A3, this section will provide a proposal of structured training of seafarers, focusing on ammonia.

The objectives of Task B2 were achieved through the following approach:

1. Review of relevant supplementary literature
2. Utilizing internal experience on industry best-practice competence
3. Investigation of other industries and professional practices which may offer alternative methods and / or equipment for meeting competence need, beyond simulator training
4. Validation with SME

The proposal of structured training of seafarers comprises examples of syllabus, schedule, methods for training, required performance, and necessary equipment for conducting such training.

6.2 Main results – Training methods

The following sections outline training methods suitable for training seafarers on ammonia as fuel, laying the groundwork for an outlined ammonia training syllabus. The section discusses 1) traditional training methods, 2) maritime simulators for training, and 3) new technologies for training.

6.2.1 Traditional training methods

Based on the findings from Task B1, training seafarers to operate ships using ammonia as fuel is crucial due to the unique properties and hazards associated with ammonia. The findings underlined the importance of comprehensive theoretical knowledge of the characteristics, safety aspects, effects, and uses of alternative fuels before engaging in more specialised training. Another important aspect of competence relevant with ammonia is behavioural competence, which revolves around soft skills and methods of working and collaborating with others. The maritime industry has been implementing methods to assess behavioural competences through the 'Behaviour Competency Assessment Framework' (Intertanko & OCIMF, 2018).

When specifying ammonia training, traditional training methods, such as classroom lectures and e-Learning will provide a good theoretical foundation. Practical exercises and onboard training, using documentation related to the ammonia fuel system, practical walk-throughs, and table-top exercises are equally essential for enhancing practical competence and safe operations.

These are well established ways of training and suitable for a number of ammonia related subjects. Interviewees highlighted the need for comprehensive understanding of fuel characteristics, and this is perceived not to be covered solely by e-Learning methods. A combination of classroom lectures and e-Learning can expedite the training process. Onboard training and emergency drills, using documentation related to the ammonia fuel system, practical walk-throughs, and table-top exercises are equally essential for safe operations. New fuels, such as ammonia, introduce new and elevated requirements for crews in terms of operation and maintenance. Combined with more strict regulations and maritime net zero goals, it is expected that an increased number of seafarers need different competences. This implies that future training of seafarers should strive towards efficiency, both in terms of training and costs, while maintaining its primary objectives and, most importantly, ensuring ship and crew safety. Innovative technologies unlock new ways of achieving efficient training. VR can offer efficient and flexible ways of conducting practical training. Furthermore, Task B1 offers some detail on general training as well as methods for demonstrating competence relevant for ammonia. Therefore, Task B2 will not go into detail on all methods for training but rather look at the further adaptation and integration of maritime simulators into training programmes, and investigate additional, technological methods for implementation in ammonia training courses.

Table 6-1 provides a general overview of training methods for ammonia training programmes, including examples of use. The overview bears similarities to Table 6-1, but it specifically addresses methods for training seafarers. It is highly recommended that a combination of methods such as use of classrooms, simulators and interactive learning be utilized to ensure imparting of technical as well as soft skills.

Table 6-1 Training methods for ammonia as fuel

Training Method	Description
Classroom lectures	Theoretical foundation for seafarers covering ship design, ammonia properties, safety requirements, fuel systems, and storage systems.
Tutorials & group activities	Encourage collaboration and problem-solving through discussions on hazard prevention, safety protocols, and emergency response procedures.
Simulator training	Experience real-world scenarios in a controlled environment, such as detecting ammonia leaks, using PPE, practicing SOPs and responding to emergencies.
Practical exercises	Hands-on experience in handling ammonia, including firefighting, gas-measuring instruments, safety equipment use and sensing familiarization with ammonia (i.e., odor).
Onboard training and drills	Training and drills conducted onboard the ship to practice emergency procedures and other operational tasks, such as bunkering or maintenance.
Workshops and on-site training	Additional learning at production plants covering the spread of toxic ammonia gas clouds and industry-specific scenarios.
Interactive learning	Use of e-learning, extended reality etc. to provide interactive and immersive learning experiences by real-life simulation.

Maritime simulators for training have been utilized for decades and provides an effective method for seafarers to practice in secure and controlled settings. Various types of simulators are in use worldwide, covering subjects such as training for bridge operations, cargo handling and emergency response. The ability to simulate numerous scenarios makes these simulators indispensable for training. Nevertheless, significant challenges include the expensive nature of full-scale simulators and the logistical complexities of organising exercises. At the same time, conventional training techniques often fall short in matching the swift progress in technology and regulatory changes.

Liquid Cargo Handling Simulators, which can replicate the process of shipboard equipment with very high fidelity, are in extensive use in various maritime education and training institutes. This training has been found extremely useful when learners are required to do tasks related to safe handling of liquefied gases as cargo, such as ammonia. In addition, the Trainer can quantify learners' skills using simulators in a very effective manner as they are working either individually or in small teams, mimicking a realistic shipboard scenario. Table 6-2 exemplifies tasks performed in Liquid Cargo Handling Simulators.

Table 6-2 Example: Liquid Cargo Handling Simulator tasks

Task	Description
1	Understanding equipment layout on deck and in machinery space
2	Understanding, knowledge, and comprehension of the related process parameters, such as the temperature, pressure, and flow rates
3	Learning the correct procedures
4	Demonstrating their skill to handle the normal and emergency situations

Task	Description
5	Ability to identify malfunctions and propose mitigative actions

For developing more specific and practical competence on ammonia as fuel, simulators would need to be set up to cover fuel related topics and operations (i.e., pipelines and layout, bunkering procedures etc.). Table 6-3 lists examples of such topics.

Table 6-3 Example: Ammonia as fuel simulator tasks

Task	Description
1	Understanding tank and pipeline layout on deck for bunkering
2	Understanding bunker tank layout and the related process parameters
3	Ability to learn and demonstrate ammonia bunkering, along with following proper procedures for the bunker tank, pipelines and machinery:
	a) Inerting and Purging b) Cooling down c) Bunkering d) Gas freeing e) Aeration f) Operation of Ammonia Release Mitigation System g) Preparations for inspection and maintenance
4	Understanding pipeline layout from tank to ammonia fuelled machinery
5	Understanding the management of exhaust gases from ammonia engine to the exhaust stack
6	Process parameters for the safe operation of ammonia fuelled machinery
	a) Checks to do before starting machinery b) Procedure for the fuel change over c) Procedure for stopping d) Ensuring safe shut down
7	Understanding of hazards and potential consequences of an ammonia leakage with corresponding emergency response actions.

These activities are essential when training seafarers to manage ammonia as a fuel. Another factor to highlight the effectiveness of simulators is that navigation and engineering staff are able to understand their respective challenges, to promote good onboard teamwork. The use of simulators should therefore be strongly considered for these tasks in relation to seafarer training and the development of training programmes for ammonia fuelled vessels. It is however important to notice that simulators cannot replace all aspects of shipboard experience, such as physical realism, environmental conditions, and interpersonal skills, and should be carefully evaluated for the different tasks.

6.2.2 New technologies for training

Innovative technologies offer new training methods for seafarers. Software integrated with cloud computing offers training methods that are safe, accessible, and realistic. Easily available technologies provide cloud-based functionality for remote participation, overcoming logistical limitations of physical attendance. Tools, such as 3D visualisations can allow learners to navigate a ship's design, identify essential components, and execute operational tasks virtually while being located anywhere in the world. This approach can be cost effective and supports repeated practice without jeopardising actual equipment. Interactive programmes and simulators provide flexibility and can be updated to align with the latest standards and technologies, ensuring that training stays current and precise. The technology is already in use and constantly developed.

This ability to push tailored training programmes throughout an organisation, independent of physical location, is called distributed learning. Future training will likely rely even more on simulation and software tools. Given its predominantly computer-based format, this type of training is particularly well-suited for organisations with a substantial remote workforce, such as shipping companies. Established methods like e-learning programmes and digital workshops, when integrated with emerging technologies like VR, can deliver distributed learning in a highly cost-effective manner, safeguarding both personnel and equipment.

6.2.2.1 Extended reality (XR)

Extended reality is an umbrella term describing the immersive technologies VR, augmented reality (AR) and mixed reality (MR). The terms are defined in Table 6-4. These are fast growing technologies that represent the most relevant above-mentioned innovative methods for enhancing training. XR-technologies are already employed in various industries for training and simulation purposes. In the maritime industry, it is used in training navigators and pilots. Furthermore, MR offers opportunities in combining real world (hands-on) training with additional digital input.

Table 6-4 Definitions of Extended Reality

XR Technologies	Description	Examples
Virtual Reality (VR)	A fully immersive environment created by hardware that simulates a computer-generated world where users can actively participate.	Gaming, simulations, VR headsets
Augmented Reality (AR)	Adds digital overlays to the existing real world. Used in applications where digital elements are superimposed onto the physical environment.	Snapchat filters, Pokémon Go
Mixed Reality (MR)	Lies between VR and AR. Blends overlays and real-world objects into a virtually rendered world, allowing for interaction with both.	Meta Quest Pro, Microsoft HoloLens

The introduction of XR could significantly change maritime training, providing a more flexible and engaging alternative to traditional training, including the need for conventional simulators. The equipment required is minimal, and in its most basic form, only a computer is necessary. Another example is the well-known use of VR and head mounted displays (HMD) combined with handheld controllers. This facilitates flexibility as it can present any given scenario without additional equipment needed. Combined with the rapidly increasing global satellite coverage, seafarers could utilize the technology from remote locations, all while cooperating and training virtually alongside colleagues. This creates vast new opportunities in sharing experience across large organisations, such as shipping companies.

6.2.2.2 Ammonia as fuel and new technologies

Given the properties and risks related to ammonia as fuel, XR can play a pivotal role in training by offering immersive and interactive experiences that traditional methods cannot match. From interviews with academic and industry experts on the use of VR mentioned, VR training seems at its most effective when training step-by-step processes or procedures, such as starting up and shutting down a system, conducting maintenance or general routine operations. However, VR can also create detailed simulations of ammonia bunkering operations or ammonia gas cloud dispersion, allowing seafarers to practice procedures in a controlled, risk-free environment. This can also include the correct handling of ammonia, understanding its chemical properties, and recognising potential hazards. The technology additionally facilitates simulating ammonia emergency response scenarios and maintenance tasks, providing a safe, realistic and flexible way of training. AR can enhance this training by overlaying critical information onto real-world equipment during hands-on onboard training sessions. This can help seafarers identify and understand the components of ammonia fuel systems, perform maintenance tasks accurately, and follow safety protocols effectively. Additionally, AR/MR can be used to guide seafarers through emergency response procedures, providing real-time instructions and visual cues to manage ammonia leaks or spills, enhancing situational awareness. Table 6-5 provides examples of scenarios where XR can be utilized for training.

Table 6-5 Scenarios for XR training

Scenario	Description
Gas cloud simulation	Simulation of size and natural behaviour of gas cloud in a specific environment
Standard Operating Procedure (SOP) training	Use of P&ID to understand operation and "hands-on" training in a VR environment
Emergency drill	Use of emergency procedures in a controlled VR environment
Component familiarization	Familiarization with components in full-scale size environment
Communication	Train communication between internal (bridge / engine dept.) and external (fire dept. / oil rig, etc.) stakeholders

6.2.2.3 Artificial Intelligence (AI)

Artificial Intelligence is an additional rapidly developing technology. It too can play a pivotal role in enhancing seafarer training, ensuring that the crew is well-prepared and competent for the challenges that ammonia brings. This chapter briefly introduces AI and suggests use cases that can be employed when creating seafarer training programmes.

When using above-mentioned XR-technology, AI will be a natural part of powering new types of simulators, increasing realism in training. Advanced AI coupled with simulators can be used to assess the performance of individuals during training sessions and tailor the learning content to address their specific needs. Its predictive abilities are useful when predicting potential risks and issues that may arise during ammonia related operations, thus being a guidance in creating training scenarios, not only the training itself. By analysing data from past incidents and current operations, AI can help identify areas where additional training is needed to prevent accidents. This proactive approach to safety ensures better understanding of actual needs, making seafarers better prepared for unforeseen challenges.

As a training method, providing digital input and predictive analysis to different scenarios, AI can improve organisational situation awareness and highlight areas for continuous improvement. Chat bots especially tailored for an organisation, or a specific need could ensure that seafarers stay informed and up to date with the latest industry standards, promoting a culture of ongoing education and improvement. Chat bot translations can also help overcome language barriers, making training courses easily accessible for a larger audience. The potential future use cases are many, and proposed use cases are listed in Table 6-6.

Table 6-6 Scenarios for AI training

Technology	Description
E-learning	AI-powered platforms offering courses on ammonia safety
AI chatbots	Intelligent chatbots providing real-time learning and support
Predictive analytics	AI systems analysing data to predict potential safety risks
Virtual and augmented reality (VR/AR)	AI-driven simulations creating immersive training environments
Tailored learning paths	AI-tailored training programs to individual/organisational needs

6.2.3 Considerations

While innovative technology, such as XR and AI, offer significant benefits it comes with a few caveats. It is crucial to use the technology appropriately and to ensure that it does not replace hands-on training entirely. It should complement conventional methods, providing a balanced approach to seafarer training. An improved learning outcome is not guaranteed merely by using the most technologically advanced tools. Excessive dependence on XR may result in a disconnection from actual conditions, possibly compromising safety and operational efficiency. The above-mentioned benefits of utilizing VR in terms of realism, immersion, and practicality also presents challenges, particularly with tactile interaction, as HMDs often rely on specific handheld controllers. Good immersion and sufficient interaction may be provided, but the tactile feel of turning a valve, holding equipment or donning PPEs is not. Furthermore, VR training, especially when involving multiple trainees connected in a single training session over a network can experience technical issues when using unstable internet infrastructure.

6.3 Ammonia training syllabus

Considering ammonia as a fuel, fundamental theoretical understanding of the subject is essential and not to be taken lightly. A comprehensive theoretical knowledge of the characteristics, safety aspects, effects, and uses of alternative fuels must be ensured, and could be best achieved through initial classroom lectures and theory. Therefore, since ammonia as a fuel is a new concept for many seafarers, it is crucial to first impart foundational knowledge about ammonia and its characteristics before incorporating technology into the training.

This section introduces a structured training proposal for seafarers on vessels using ammonia as fuel. The suggested syllabus and schedule provide an outline of the training setup, which may be modified and adapted according to future requirements.

The proposal offers a detailed outline of a course covering basic seafarer competence on ammonia fuelled ships. The recommended duration for the basic course outline is two days. However, an advanced course covering deck officers and engineers engaged in the technical operations of ammonia systems should also be created, with a recommended timeframe of four days. Although the advanced course is not outlined in this document, it should adhere to a framework similar to that of the provided basic course, aimed at seafarers directly involved with ammonia (i.e. engineers). The proposed basic course will largely be subject to conventional training methods. As outlined in section 7.2.3, this necessity arises from the essential theoretical understanding of ammonia and its properties.

The proposed course outline draws on the current Model Course for ships subject to IGF Code, 7.13 and 7.14 Basic and Advanced training for ships subject to the IGF Code, 2019 Edition. The model course has been adapted for ammonia through integration with DNV's Recommended Practice DNV-RP-0699 Competence related to the onboard use of ammonia as fuel. Section 6.3.1 provides the general framework of the course. While this outline offers an overview of relevant topics and seafarer competence, it does not delve into the specifics of each subject. Therefore, the proposal should be viewed as a starting point rather than a definitive plan, laying the groundwork for the development of a detailed course content.

6.3.1 Basic Course - General outline

6.3.1.1 Objectives

This course outline aims to equip seafarers with a fundamental comprehension of the design and operational aspects of ships subject to ammonia as fuel, including ammonia fuel and storage systems. Additionally, participants will gain an understanding of the physical and chemical properties of ammonia. The curriculum also highlights the significance of hazard prevention, safety protocols, and safety management on vessels using ammonia as fuel. Finally, it includes training on firefighting techniques and emergency response procedures tailored to ammonia-fuelled ships.

6.3.1.2 Entry requirements

To ensure that participants are well-prepared and can fully benefit from the training course, entry requirements in Table 6-7 have been established.

Table 6-7 Entry requirements basic course

Entry Requirement	Description
Fundamental maritime knowledge	Participants should possess a basic understanding of maritime concepts and practices. This foundational knowledge is essential for comprehending the course material and actively participating in discussions and activities.
Proficiency in English	Participants must have a good command of the English language, including the ability to read, write, and communicate effectively. This ensures they can follow instructions, engage in group work, and understand course content.

Entry Requirement	Description
Minimum age of 18 years	Participants must be at least 18 years old to enrol in the course. This age requirement ensures that participants have the maturity and life experience necessary to grasp the course material and contribute meaningfully to the learning environment.
Certification in Basic Occupational Safety and Security Training (BOSST)	Participants must hold a valid certification in BOSST training. This certification demonstrates that they have received essential training in occupational safety and security, which is crucial for ensuring a safe learning environment and preparing participants for real-world scenarios

6.3.1.3 Teaching facilities and equipment

This course requires an appropriate classroom equipped with desks and chairs. Furniture should be easily movable to maximize space and support group activities, or alternatively, separate rooms for each group should be accessible. The classroom must include a whiteboard, writing supplies, and equipment for delivering computer-based presentations (PPT, video, etc.).

Gas instruments and PPE should be available for demonstration and testing.

Findings in Task B1 highlights the importance of recognizing ammonia's distinct odour as an early warning of leakage. This could include familiarizing with the odour as a part of seafarer training. However, due to the toxicity level of ammonia, effective training on this subject must be conducted in safe locations and in a controlled environment.

6.3.1.4 Training methods

M1 Lectures

M2 Tutorial / group activities

M3 Demonstration

M4 Practical exercise / simulator

6.3.1.5 Teaching Aids

A1 Audio-visual equipment

A2 Questionnaire / test

A3 Instruments / safety equipment

A4 Documentation (e.g. SDS, manuals)

A5 Available relevant technology (e.g. XR)

6.3.1.6 Course outline

Table 6-8 Basic course outline

Subject Area		Hours	
		Lecture	Activity
1	**Contribute to the safe operation of a ship subject to ammonia as fuel**	**4**	**-**
1.1.	Design and operational characteristics of ships subject to ammonia as fuel		
1.2.	Basic knowledge of ships subject to ammonia as fuel, their fuel systems and fuel storage systems		
1.3.	Basic knowledge of ammonia and fuel storage systems' operations on board ships subject to ammonia as fuel		
1.4.	Basic knowledge of the physical and chemical properties of ammonia		
1.5.	Knowledge and understanding of safety requirements and safety management on board ships subject to ammonia as fuel		
2	**Take precautions to prevent hazards on a ship subject to ammonia as fuel**	**2**	**-**
2.1.	Basic knowledge of the hazards (toxicity, corrosivity and reactivity) associated with operations on ships subject to ammonia as fuel		
2.2.	Basic knowledge of hazard controls		
2.3.	Understanding of fuel characteristics of ammonia as fuel as found on a Safety Data Sheet (SDS)		
3	**Apply occupational health and safety precautions and measures**	**3**	**1**
3.1.	Awareness of function of gas-measuring instruments and similar equipment		
3.2.	Proper use of specialized safety equipment and protective devices		
3.3.	Basic knowledge of safe working practices and procedures in accordance with legislation and industry guidelines and personal shipboard safety relevant to ships subject to ammonia as fuel		
3.4.	Basic knowledge of first aid related to ammonia		
4	**Carry out firefighting operations on a ship subject to ammonia as fuel**	**1**	**-**
4.1.	Fire organisation and action to be taken on ships subject to ammonia as fuel		
4.2.	Special hazards associated with fuel systems and fuel handling on ships subject to ammonia as fuel		
4.3.	Fire-fighting agents and methods used to control and extinguish ammonia fires		
4.4.	Fire-fighting system operations		
5	**Respond to emergencies**	**0.5**	**-**
5.1.	Basic knowledge of emergency procedures, including emergency shutdown		
6	**Take precautions to prevent the leakage of ammonia**	**0.5**	**0**
6.1.	Basic knowledge of measures to be taken in the event of ammonia leakage/spillage/venting		
7	Video demonstration/case study	1	-
8	Self-assessment/debrief	2	-
9	Formal assessment (MCQ/oral exam)	1	-
Total		15	1

6.3.1.7 Course timetable

Table 6-9 Basic course timetable

Period	Day 1	Day 2
1st (1.5 hours)	*Course introduction* 1. Contribute to the safe operation of a ship subject to ammonia as fuel	1. Apply occupational health and safety precautions and measures
2nd (1.5 hours)	2. Contribute to the safe operation of a ship subject to ammonia as fuel	2. Apply occupational health and safety precautions and measures
Lunch break		
3rd (1.5 hours)	3. Contribute to the safe operation of a ship subject to ammonia as fuel 4. Take precautions to prevent hazards on a ship subject to ammonia as fuel	3. Apply occupational health and safety precautions and measures (practical) 4. Respond to emergencies
4th (1.5 hours)	5. Take precautions to prevent hazards on a ship subject to ammonia as fuel	5. Carry out firefighting operations on a ship subject to ammonia as fuel 6. Take precautions to prevent the leakage of ammonia
5th (1 -2 hours)	• Self-assessment/ debrief	• Self-assessment/ debrief • Formal assessment

6.3.2 Basic Course - Detailed outline

The attached proposal for the detailed course outline highlights the expected performance levels of attending trainees. This outline delineates the necessary competences by detailing the Knowledge, Understanding, and Proficiency (KUP) requirements for each topic.

Certain subjects are further divided into sub-topics to ensure clarity on competency expectations for seafarers operating ships that use ammonia as fuel.

The outline includes KUPs, performance criteria, training methodologies for each primary subject, as well as recommended facilities and equipment for effective training.

6.3.2.1 Course outline

Knowledge, Understanding and Proficiency	Required performance	Training methods	Teaching aids
1. Contribute to the safe operation of a ship subject to the ammonia as fuel			
1.1. Design and operational characteristics of ships subject to ammonia as fuel	Knowledge	M1	A1
1.2. Basic knowledge of ships subject to ammonia as fuel, their fuel systems and fuel storage systems	Knowledge & understanding	M1	A1
1.2.1. Types of ammonia fuel systems			
1.2.2. Storage of ammonia on board ships subject to ammonia as fuel			
1.2.3. General arrangement of fuel storage systems on board ships subject to ammonia as fuel			
1.2.4. Hazard zones and areas			

Knowledge, Understanding and Proficiency	Required performance	Training methods	Teaching aids
1.2.5. Typical fire safety plan			
1.2.6. Monitoring, control and safety systems aboard ships subject to ammonia as fuel			
1.3. Basic knowledge of ammonia and fuel storage systems' operations on board ships subject to ammonia as fuel	Knowledge	M1	A1
1.3.1. Piping systems and valves			
1.3.2. Atmospheric, compressed or cryogenic storage			
1.3.3. Relief systems and protection screens			
1.3.4. Basic bunkering operations and bunkering systems			
1.3.5. Protection against cryogenic accidents			
1.3.6. Fuel leak monitoring and detection			
1.4. Basic knowledge of the physical and chemical properties of ammonia	Knowledge & understanding	M1	A1
1.4.1. Properties and characteristics of ammonia			
1.4.2. Pressure and temperature, including vapour pressure/ temperature relationship			
1.4.3. Toxicity			
1.4.4. Corrosivity			
1.5. Knowledge and understanding of safety requirements and safety management on board ships subject to ammonia as fuel	Knowledge & understanding	M1, M2, M3	A1
1.5.1. National and international regulations related to safe handling of ammonia 1.5.2. Awareness of safety procedures as per ship's SMS documentation for safe handling of ammonia			

Knowledge, Understanding and Proficiency	Required performance	Training methods	Teaching aids
2. Take precautions to prevent hazards on a ship subject to ammonia as fuel			
2.1. Basic knowledge of the hazards associated with operations on ships subject to ammonia as fuel	Knowledge	M1, M2	A1
2.1.1. Health hazards			

Knowledge, Understanding and Proficiency	Required performance	Training methods	Teaching aids
2.1.2. Environmental hazards			
2.1.3. Reactivity hazards			
2.1.4. Corrosion hazards			
2.1.5. Ignition, explosion and flammability hazards			
2.1.6. Sources of ignition			
2.1.7. Electrostatic hazards			
2.1.8. Toxicity hazards			
2.1.9. Ammonia liquid leaks			
2.1.10. Ammonia vapour leaks and clouds			
2.1.11. Pressure hazards (only for Type C containment)			
2.2. Basic knowledge of hazard controls	Knowledge & understanding	M1	A1
2.2.1. Emptying, inerting, drying and purging techniques			
2.2.2. Ventilation			
2.2.3. Measures to prevent leakage and fire			
2.2.4. Tank temperature and pressure monitoring			
2.2.5. Gas measurement to detect leakage			
2.3. Understanding of fuel characteristics of ammonia as found on a Safety Data Sheet (SDS)	Knowledge & understanding	M1, M2, M3	A1, A4

Knowledge, Understanding and Proficiency	Required performance	Training methods	Teaching aids
3. Apply occupational health and safety precautions and measures			
3.1. Awareness of function of gas- measuring instruments and similar equipment	Proficiency	M1, M3	A1, A3
3.1.1. Gas testing			
3.2. Proper use of specialized safety equipment and protective devices	Proficiency	M3	A1, A3
3.2.1. Breathing apparatus			
3.2.2. Protective clothing (ammonia specific PPE)			

Knowledge, Understanding and Proficiency	Required performance	Training methods	Teaching aids
3.2.3. Resuscitators			
3.2.4. Rescue and escape equipment			
3.3. Basic knowledge of safe working practices and procedures in accordance with legislation and industry guidelines and personal shipboard safety relevant to ships subject to ammonia as fuel	Knowledge	M1	A1
3.3.1. Precautions to be taken before entering hazardous spaces and zones			
3.3.2. Precautions to be taken before and during repair and maintenance work			
3.3.3. Safety measures for hot and cold work			
3.4. Basic knowledge of first aid with reference to a Safety Data Sheet (SDS)	Proficiency	M1, M3	A1, A3, A4

Knowledge, Understanding and Proficiency	Required performance	Training methods	Teaching aids
4. Carry out firefighting operations on a ship subject to ammonia as fuel			
4.1. Fire organisation and action to be taken on ships subject to ammonia as fuel	Knowledge	M1	A1, A4
4.2. Special hazards associated with fuel systems and fuel handling on ships subject to ammonia as fuel	Knowledge & understanding	M1	A1
4.3. Fire-fighting agents and methods used to control and extinguish fires on board ships subject to ammonia as fuel	Proficiency	M4	A3, A5
4.4. Fire-fighting system operations	Knowledge & understanding	M1, M3, M4	A1, A3, A4, A5
4.4.1. Portable fire-fighting operations			
4.4.2. Fixed dry chemical system operations			
4.4.3. Basic knowledge of spill containment in relation to firefighting operations			
4.4.4. Practical exercises in firefighting of ammonia fire not covered in basic training (table A-VI/1-2) and model course 1.20 (Fire Prevention and Firefighting) using the correct techniques in simulated shipboard conditions to extinguish the fire.			

Knowledge, Understanding and Proficiency	Required performance	Training methods	Teaching aids
Note: Advanced technologies related to realism in emergency situations can be recreated using virtual reality scenarios to impart learning outcomes.			

Knowledge, Understanding and Proficiency	Required performance	Training methods	Teaching aids
5. Respond to emergencies			
5.1. Basic knowledge of emergency procedures, including emergency shutdown	Knowledge	M1, M2, M3	A1, A3, A5
5.1.1. Emergency organisation			
5.1.2. Alarms			
5.1.3. Emergency procedures			
5.1.4. Emergency shutdown			

Knowledge, Understanding and Proficiency	Required performance	Training methods	Teaching aids
6. Take precautions to prevent the leakage of ammonia			
6.1. Basic knowledge of measures to be taken in the event of ammonia leakage/spillage/venting	Knowledge & understanding	M1, M2	A1, A2
6.1.1. Report of relevant information to the responsible persons			
6.1.2. Awareness of shipboard spill/leakage/venting response procedures			
6.1.3. Awareness of appropriate personal protection when responding to a spill/leakage of ammonia			
6.1.4. Awareness of ammonia release mitigation system (ARMS) to contain ammonia release			

7. Task B3 – Proposal of structured training for instructors

7.1 Description

Whereas Task B2 focus on the training for seafarers, Task B3 will pay closer attention to the requirements of adequate training to instructors that will deliver training on ammonia as fuel and propose a framework that can be used as basis for future instructor training.

7.1.1 Objectives

Task B3 had the following objective:

1. Provide description of proposals of training of instructors' programmes or courses for ships using alternative fuels and energy systems

7.1.2 Approach

To ensure a structured approach, the instructor training course is based on teaching ammonia as fuel. However, the proposed outline can be tailored to any fuel or serve as a general instructor course for alternative fuels. The findings in part B1 and B2 are iterated to serve as input to B3, ensuring consistency and demonstrating their immediate relevance.

To meet the objectives for task B3, the following steps have been done:

1. Consolidate findings from B1 and B2
2. Identify requirements set in IMO model courses for instructor training (IMO 6.09, IMO 6.10)
3. Dialogue and interviews with DNV experts in competence standard development, certification of training organisations and experienced trainers (DNV Maritime Academy, DNV SeaSkill)
4. Check requirements in relevant standards and best practice relevant for training for instructors, including:
    a. IMO Model course 6.09: Training Course for Instructors
    b. IMO Model course 6.10: Competence of maritime simulator instructors
    c. DNV-ST0024 Competence of maritime teaching professionals
    d. DNV-ST-0025 Competence of maritime simulator instructors
    e. DNV-ST-0008 Learning programmes
    f. *STCW A-I/6 – Mandatory standards regarding general provisions, Standards governing the use of simulators*
5. Customize a course framework, syllabus and course outline, based on IMO Model course 6.09 Train the Trainer.

The course framework and suggested outline includes aims and objectives for the course, entry requirements, description of instructor qualifications, recommendations for course intake limitations, teaching facilities and documentation. An example of schedule and example of detailed teaching syllabi is outlined in section 8.3.3.

7.2 Main results

To ensure compliance with the STCW Convention and Code for training of instructors in the maritime domain it is recommended to build an instructor course on the IMO Model Course 6.09 structure. The purpose of the IMO model course is to assist training providers in organising and introducing new training courses to improve their quality and effectiveness. The IMO Model Course 6.09 clearly states that “it is not the intention to present instructors with a rigid teaching package which they are expected to follow blindly” (page 5). As such, the recommended framework presented here shall serve as a starting point for a train-the-trainer programme, rather than a rigid setup.

Topics covered in the proposed framework below are selected based on the assumption that the course will serve as a valuable introduction for those who have experience as instructors but need additional competence in designing, delivering, and evaluating training for alternative fuels, such as ammonia, onboard ships. The overall goal is to ensure the quality and effectiveness of the training course.

Figure 8-1 illustrates the dependencies and interactions when designing training courses for Ammonia as fuel.

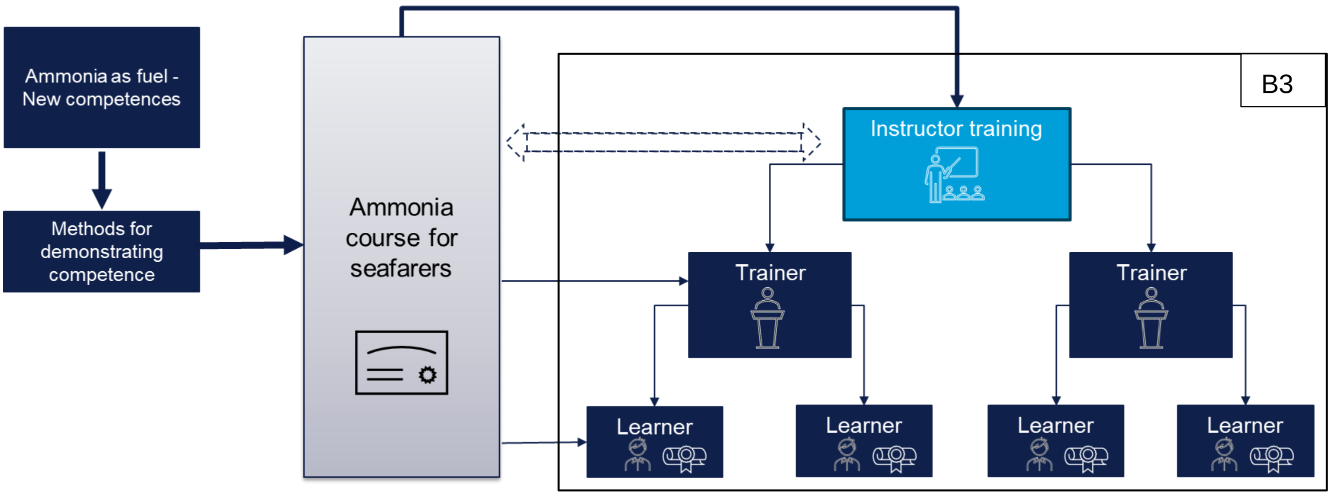

Figure 7-1: Course program interactions and dependencies

The course includes, among other things, a significant component on the use of simulators and VR technology in training. This approach has been a key learning from other industries and is also recommended as a training method in section B2.

While the basic aspects of the learning process, such as: the purpose of training, setting training objectives, learning objectives, and the principles of instructional design and learning psychology are integral to any Train-the-Trainer course, it is assumed that trainees have already received this training in other courses. Consequently, the scope of the course as well as course entry requirements have been established based on these assumptions.

7.2.1 Framework for instructor course – Train the trainer for Ammonia as fuel

The following includes a summary of the course framework, while a detailed outline of the course is presented in section 8.3.

7.2.1.1 Aims and objectives

- Facilitate delivery of training in new competences required for safe operation of ammonia as fuel onboard ships, according to STCW standards
- Shall provide useful induction for experienced instructors, introduce relevant approaches applicable for teaching competence on alternative fuels, and/or serve as reminder of skills and techniques for giving training
- It is not the aim to provide a full IMO 6.09 model course

Course objectives

- Those who successfully complete the course should be able to plan, prepare, and deliver a competence-based course on safe operation for ammonia as fuel onboard ships
- The course shall address effective teaching and instruction techniques, including selecting appropriate methods of instruction and teaching materials and evaluate the teaching and learning process for crew involved with operating ships with ammonia as fuel

7.2.1.2 Course Entry Requirements and qualifications

In general, the successful candidate should have attended the course or programme that is planned to be delivered, thereby acquiring the qualification for safe operations of ammonia as a fuel.

Candidates should possess either theoretical education or practical experience relevant to the course content. Specifically, the following qualifications are considered sufficient:

- **Theoretical Education**: Qualifications such as Master Mariner (STCW A-II/2) or Chief Engineer (STCW A-III/2).
- **Practical Experience**: Proven experience in ammonia production plants or similar technical fields.

Additionally, candidates should have:

- Basic training for personnel on ships subject to the IGF Code.
- Completion of the IMO 6.09 Train the Trainer course.
- A professional and trustworthy approach to teaching.

Depending on the use of simulator tools in training, the IMO Model Course 6.10 Train the Simulator training course may also be considered, though this requirement should be evaluated to avoid excluding qualified trainers.

7.2.1.3 Instructors

Instructors shall have experience in teaching and shall have attended a learning programme in instructional techniques. The organisation shall define and implement measures to ensure that all instructors assigned teach and assess in a consistent manner.

7.2.1.4 Course certificate

A certificate or document may be issued to indicate that the holder has successfully completed the course of training for instructors.

7.2.1.5 Course intake limitations

It is recommended the course intake to maximum 10 participants to allow sufficient opportunity for each participant to have adequate theoretical and practical instruction. This is partly due to the nature of the recommended training techniques recommended for competence course on ammonia as fuel, such as many hours of practical tasks, including application of simulator and VR technology.

7.2.1.6 Teaching facilities and equipment

Section B2 indicates that Innovative technology, such as XR and AI, should complement conventional method to ensure a balanced approach to seafarer training. As such, it is important for the instructor training to provide sufficient understanding on the pros and cons of these methods.

As presented in B2, the recommended training methods for ammonia as fuel is as follows:

- Classroom lectures
- Tutorials & Group activities
- Simulator training
- Workshop and On-site training
- Interactive learning.

The instructor training should consider these in the establishment of the instructor course. However, most of the Train the Trainer course should be possible to execute from a classroom facility and preferably with VR / simulator facilities available.

The following training methods and teaching aids are recommended:

Training methods

M1	Lectures
M2	Tutorial / group activities
M3	Demonstration
M4	Practical exercise / simulator

Teaching Aids

A1	Audio-visual equipment
A2	Questionnaire / test
A3	Instruments / safety equipment
A4	Documentation (e.g. SDS, manuals)
A5	Available relevant technology (e.g. XR)

Attention should be given to ensure adequate infrastructure for performing simulation. Furthermore, for the course to be successful, additional staff to execute the simulator training function can be considered.

7.2.1.7 Documentation

The course shall be completed by comprehensive course documentation, including informative text, references, publications, links and checklists. Other material may be added as appropriate.

7.3 Outline of Training Course

Course outline: The table which follows lists the area of *knowledge, understanding and proficiency* (KUP) covered by the course, together with the estimated total hours that are required. An instructor manual should be developed before implementing the syllabus contained in the outline below.

Subject: Instruction of competence-based training for seafarers in the safe operation of ships using alternative fuels and energy systems.

Competence: Teach a competence-based course effectively using appropriate methods and aids relevant for the safe operation of ammonia as fuel.

Table 7-1: Training course outline for Instructor training

Subject Area		Hours	
		Lecture	Activity
1.	**The regulatory landscape of alternative fuels**	**1**	**0,5**
	Understand the overview and development of conventions and codes related to alternative fuels		
2	**Planning effective learning environment for competences on alternative fuels**	**1,5**	**0,5**
	Identify appropriate training tools according to the specific roles and competence required		
	Establish an effective learning environment for teaching ammonia as fuel		
3	**Training aids and use of different teaching activities effectively**	**1**	**1**
	Demonstrate the range of teachings methods appropriate for Ammonia as fuel		
	Demonstrate and apply the use of Simulators, VR / MR, in training		
	Decide appropriate training tools		
4	**Using teaching activities effectively**	**1**	**1**
	Demonstrate a range of teaching activities appropriate for Ammonia as fuel		
5	**Produce a subject related lesson plan for Ammonia as fuel**	**1,5**	**1**
	Define the outcome of the lesson – Knowledge and competence		
	Define planning considerations according to applicable training aids		
6	**Course design & evaluation**	**2**	**3**
	Recognise factors to be considered when designing a learning programme for Ammonia as fuel		
	Develop a new course (practical part)		
Total		8	7
Sum		15	

7.3.1 Schedule

Period	Day 1	Day 2
09:00	Course introduction (30 min)	*Re-capture*
09:30 – 11:30	1. The regulatory landscape of alternative fuels 2. Planning effective learning environment for competences on alternative fuels	1. Using teaching activities effectively – Continue 2. Produce a subject related lesson plan for Ammonia as fuel
11.30: Lunch		
12:30-16:30	3. Planning effective learning environment for competences on alternative fuels 4. Training aids 5. Using teaching activities effectively	3. Produce a subject related lesson plan for Ammonia as fuel 4. Course design and evaluation
16:45-17	*Re-capture*	*Summary* *Closing*

7.3.2 Model course reference

Table 7-2 shows cross reference of subject area and corresponding topic in IMO 6.09.

Table 7-2: Model course cross reference

Subject Area		Model Course 6.09
1.	The regulatory landscape of alternative fuels	1.1
2	Planning effective learning environment for competences on alternative fuels	2.1
3	Training aids	3.1, 4.1, 4.2
4	Produce a subject related lesson plan for Ammonia as fuel	5.1, 5.2
5	Course design & evaluation	6, 7

7.3.3 Example of detailed teaching syllabi

The attached proposal for the detailed course outline highlights the key Knowledge, Understanding, and Proficiency (KUP) requirements for trainees attending each topic identified as essential for teaching the safe operation of ammonia as a fuel. While the KUP list is comprehensive, it is not exhaustive, incorporating both new requirements and existing standards from the IMO Model Course 6.09 and the competence standards for teaching professionals (DNV-ST.0024, DNV-ST-0024). As such, a complete KUP performance requirement for an instructor course should be subject to further review and tailored customization. The syllabi include high-level topics, with certain subjects further divided into sub-topics to ensure clarity on competency expectations for the safe operation of ammonia as a fuel. The outline includes KUPs, performance criteria, training methodologies for each primary subject, as well as recommended facilities and equipment for effective training.

Table 7-3: Example detailed teaching syllabi for Instructor course

Subject area	Required performance	Training methods	Teaching aids
1. The regulatory landscape of alternative fuels			
1.1. Understand the overview and development of conventions and codes relates to alternative fuels • *Determine relevant standards, policies, legal requirements and codes of practice for the program to be designed* • *Understand the alternative design process (of equivalent safety principles* • *Understand IGF code requirements* • *IMO targets for 2050 net zero shipping*	Knowledge, Understanding, Proficiency	M1, M2	A1, A2, A4
2. Planning effective learning environment for competences on alternative fuels			
2.1. Establish/Planning an effective learning environment for competence on alternative fuels • *Recognize favourable and unfavourable conditions for learning new competence related to ammonia* *For example, when VR training seems most effective (step-by-step processes, or procedure)*	Knowledge, Understanding, Proficiency	M1, M2, M3	A1, A2, A5,

Subject area	Required performance	Training methods	Teaching aids
• *Describe learning methods and styles recommended for ammonia and their influence on the teaching process* • *Determine pre-requisites for a learning programme* • *Determine critical performance objectives by considering the consequences of performance failure* • *Prepare the learning materials and equipment for delivery of a programme* • *Explain the advantages and disadvantages of the various classroom/learning environment configurations for ammonia*			
3. Training aids and use of different teaching activities effectively			
3.1. Demonstrate and select the range of teachings methods/activities appropriate for Ammonia as fuel *Such as:* o *Audio-visual equipment* o *Questionnaire / test* o *Instruments / safety equipment* o *Documentation (e.g. SDS, manuals)* o *Available relevant technology (e.g. XR)* • *Describe delivery methods and techniques, their advantages and disadvantages and when to use them* • *Explain the advantages and disadvantages of the various instructional aids* • *Demonstrate an effective way of using various instructional aids* • *Select learning materials to meet given learning objectives for a given target group*	Knowledge	M1, M3, M4	A1, A5
3.2. Demonstrate and apply the use of Simulators / VR/MR in training • *Explain the benefits and limitations of simulator training* • *Explain criteria simulators are expected to meet for optimal learning* • *Determine suitability and behavioural realism of simulators for the selected objectives and training tasks* • *Determine which simulator exercises are suitable for meeting specified learning objectives* • *Design simulator-based scenarios for training and assessment based on learning objectives or performance criteria* • *Explain how simulation exercises can be influenced by introducing realistic challenges* • *Prepare the simulator and related equipment (monitoring and recording facilities, simulator exercises / files)* • *Demonstrate the interface through which the trainee can interact with the equipment*		M1, M2, M3, M4	A1, A2, A4, A5

Subject area	Required performance	Training methods	Teaching aids
• *Assess a learner using simulation*			
4. Produce a subject related lesson plan for Ammonia as fuel			
4.1. Recognise/Define the **learning outcomes** of the lesson – Knowledge and competence • *Identify the learners'/trainee's likely knowledge and competence at the start of the lesson* • *Identify the trainees' required knowledge and competence at the end of the lesson* • *Demonstrate the ability to relate the subject matter to everyday practice of the target group* • *Identify training needs and competence gaps* • *Implement effective interpersonal and communication skills* • Develop a syllabus, based on learning objectives	Knowledge, Understanding, Proficiency	M1, M2, M3,	A1, A5,
4.2. Recognise/ Define planning considerations according to applicable training aids • *List the conditions for effective planning and conducting of learning programmes related to ammonia as fuel*			
5. Course design & evaluation			
5.1. Recognize factors to be considered when designing a learning programme for Ammonia as fuel • *Make an inventory of required and available competence when designing an ammonia course programme* • *Determine which learning activities and methods to use, considering learning objectives and target group* • *Determine which content, material and tools to use to meet defined objectives* • *Evaluate if the environment supports learning and is suitable for objectives to be achieved* • *Assess a learner using different teaching aids, such as simulator, case studies, scenarios, etc.* • *Identify and support students requiring special attention* • *Verify that performance outcomes meet or exceed formal requirements*	Knowledge, understanding, proficiency	M1, M2, M3, M4	A1. A2. A3, A4, A5
5.2. Develop a new course (practical part) • *Develop a learning programme to suit the needs of the learners* • *Conduct a program, using variation in teaching methods and techniques* • *Design simulator-based scenarios for training and assessment based on learning objectives or performance criteria*			

Subject area	Required performance	Training methods	Teaching aids
• *Use the simulator and related equipment effectively for training and guidance* • *Use the simulator for effective debriefing, scoring, evaluation and assessment*			

In summary, the main objective of the customized Train-the-Trainer/Instructor course is to ensure the quality and effectiveness of the training provided. Determining the final teaching syllabi should be subject to review to ensure it aligns well with the specific training needs of instructors. By tailoring the course content and methodologies to the unique requirements of alternative fuels, such as ammonia, the competency and preparedness of maritime instructors can be enhanced, ultimately contributing to safer and more efficient maritime operations.

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Appendix A Competence Catalogue

The competence catalogue aims to consolidate the competences found as substantiated in Task A1-3. These are categorised by fuel.

8.1 LNG

(DNV, 2022)

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
All	All	**Competence in the general knowledge and understanding of LNG, regarding LNG's properties and health hazards**	Knowledge of the applicable rules and regulations related to the use of LNG in the maritime sector Understanding of ■ what LNG is ■ how LNG differs from other marine fuels ■ the relationship between pressure and temperature ■ the flashpoint, lower explosive limit, upper explosive limit, and auto-ignition temperature of LNG ■ what happens when opening a valve used to contain LNG ■ the term "rapid phase transition" ■ the terms "dew point" and "bubble point" in relation to nitrogen and how this affects LNG ■ the terms "boil-off gas" and "vapour buoyancy"
All	All	**Competence in taking precautions and measures to reduce LNG-related risks**	Understanding of ■ the hazards associated with handling LNG (e.g. asphyxia, low temperatures) ■ the risk of expanding trapped liquid/BLEVE ■ the hazardous areas/Ex-zones on board in relation to LNG and operational limitations in those areas ■ the term 'cryogenic' and the risks it presents for humans ■ how the cryogenic properties of LNG affect standard steel components upon contact ■ the behaviour of LNG when discharged (into water/on ground) ■ the environmental impact of an operational release of LNG as compared to a release of a similar quantity of CO_2 ■ the risks of entering spaces containing nitrogen systems ■ risks of entering spaces with high-pressure cryogenic pumps Proficiency in ■ interpreting the material safety data sheet for LNG ■ basic first aid in case of injuries / physical problems due to LNG exposure ■ the use of appropriate personal protective aids when working with LNG ■ the use of available rescue and escape equipment
OPS ME ELC M&R	Deck and Engineering officers	**Competence in taking precautions to prevent risk of ignition, explosion**	<u>Warming up / heating</u> Understanding of ■ the resources, infrastructure and local conditions required for warming up (i.e. the water glycol intermediate circuit) ■ the link of the heating system with the engine cooling system ■ overpressure protection in relation to the heating system Proficiency in ■ calculating the approximate duration of warming up ■ setting temperature control points and flow distribution of the water glycol intermediate circuit ■ performing warming up procedure, always keeping the tank atmosphere in a non-explosive range

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
			Gas freeing of tanks Understanding of ■ principles and physics involved in the changing of tank atmospheres, including resources, infrastructure and local conditions required for gas-freeing ■ likely behaviour of vapour pressure during gas freeing Proficiency in ■ calculating the approximate duration of gas freeing ■ performing gas freeing, always keeping the tank atmosphere in a non-explosive range
OPS ME ELC	Engineering officers	**Competence in the inerting an LNG fuel system**	Inerting Understanding of ■ the principle of inerting ■ possible problems related to inerting and causes, such as condensate formation ■ dangers associated with incorrect inerting procedure Proficiency in ■ planning for inerting tanks, pipelines and equipment ■ determining when the inerting operation is completed based on parameters ■ determining oxygen content ■ determining dew point ■ performing a controlled change in tank atmosphere through inerting Inert gas generator Understanding of ■ the principles of operation of an inert gas generator, (e.g. a nitrogen generator) ■ the maximum allowable percentage of oxygen in the mix ■ how the inert gas/nitrogen injection and purging arrangement works ■ when the inert gas generator should be operational and what the nitrogen outlet requirements are Proficiency in ■ operating an inert gas generator to supply dry air of appropriate quality ■ operating the nitrogen generator ■ performing maintenance on the nitrogen generator ■ operating the air compressor used for nitrogen generation and distribution ■ performing maintenance on the air compressor used for nitrogen generation and distribution ■ operating the booster compressor ■ performing maintenance on the booster compressor ■ taking appropriate action in case of nitrogen quality problems Air and inert gas dryers Understanding of ■ the purpose and operating principles of air and inert gas dryers ■ the 'drying' method and its importance ■ the 'inerting' method and its importance Proficiency in ■ operating the air and inert gas dryer ■ performing maintenance on the air and inert gas dryer
OPS ME CHS	Engineering officers	**Competence in the purging of an LNG fuel system**	Understanding of the principles of air purging Proficiency in

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
			■ line up and procedures to purge tanks and pipelines ■ perform air purging ■ perform nitrogen purging ■ determine when nitrogen purging operation is completed, based on parameters
OPS ME CHS	Deck and Engineering officers	**Competence in methods of storing LNG, its transfer arrangements and tank connection space**	Storage method Understanding of the storage temperature of LNG Bunker tanks Understanding of ■ the different tanks used for LNG containment (e.g. membrane, independent types) ■ the layout and operation of the tank system ■ the indicators of leaks in the insulation system ■ pressure holding times of the bunker tanks/system ■ the importance of monitoring hold space atmosphere ■ the methods of cooling down tanks Proficiency in ■ performing inspections of the bunker support system ■ performing inspections of the insulation system Tank connection space Knowledge of the increased risk of gas leakage in the tank connection space Understanding of ■ the function of the tank connection space ■ the safe working procedure for working in the tank connection space Bunker transfer arrangement Knowledge of ■ the maximum loads/limitations of the loading arrangement (vessel side) ■ the movement limitations of the bunker transfer arrangement Understanding of ■ the importance of drip trays being kept free of (rain)water before commencing bunkering (if applicable) ■ the loading arrangement for bunkering LNG ■ the difference between high-pressure and low-pressure gas supply systems (pressurised/atmospheric) Proficiency in ■ estimating the required free space and trajectory for the loading arrangement ■ verifying that fendering does not interfere with the bunker transfer arrangement ■ preparing the line-up for bunker transfer ■ operating the manifold and the strainers ■ running the cool down procedure (if applicable) ■ adjusting valves in a correct manner during the cool down procedure ■ interpreting bunkering transfer diagrams
All	All	**Competence to plan, execute and monitor the safe bunkering of LNG**	Knowledge of safety and emergency procedures for operation of LNG-specific machinery, fuel- and control systems Bunkering preparations Knowledge of ■ the acceptable pump rates during the bunker transfer ■ the determining factors for using the vapour return system (if applicable)

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
			Understanding of ■ the tasks and responsibilities of both crew and bunkering personnel during preparation and bunkering operation ■ the need for using insulation flanges as opposed to bonding wires ■ the importance of earthing/grounding ■ measures taken on board to ensure proper grounding and static discharge during operations/bunkering Proficiency in ■ determining the condition of the bunker tanks (e.g. safe range of temperature and pressure for bunker tanks) ■ agreeing pre-bunkering formalities and operational alignment between ship and bunker operator in line with port regulations (pre-bunkering/compatibility checklist, communication lines ■ agreeing on emergency actions in combination with shore in case of emergencies ■ determining the vapour handling capacities of bunker provider and own vessel ■ determining the pressure levels of the nitrogen batteries to ensure adequate supply for the bunkering operation ■ determining the tank sequence for bunkering ■ determining the need for inerting and purging of the filling lines prior to the bunker transfer Bunker transfer Knowledge of the occurrence of 'flash gas' and what it is Understanding of ■ the physical properties of bunkers ■ the process sequences for bunkering operations Proficiency in ■ interpreting signals from the bunker control system ■ demonstrate correct and clear communication during bunkering process Quantity and quality of LNG bunkering Understanding of ■ the difficulty of calculating the quantity and quality of LNG bunkers ■ the procedure for bunker quantity and quality calculations as defined by the company Proficiency in verifying bunker quantity received
OPS ME ELC M&R	Deck and engineering officers	**Competence in the proper operation and functioning of an LNG fuel system**	Cryogenic valves and pumps understanding of ■ the design and construction of cryogenic valves ■ operation of cryogenic pumps in high-pressure gas supply systems Gas isolation valves Knowledge of how to recognise high differential pressure (high-pressure control valve) Proficiency in ■ performing routine tests on gas isolation valves/double block and bleed arrangement ■ interpreting test results of gas isolation valves/double block and bleed arrangement engine High-pressure pumps Proficiency in ■ operating a high-pressure reciprocating plunger fuel injection pump ■ monitoring pump readings ■ performing the cooling down procedure ■ performing maintenance on a high-pressure pump

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
			In tank pumps Understanding of ■ the setup and operation of the in-tank pumps ■ the critical importance of maintaining gas tight cable penetration Proficiency in ■ starting up the in-tank pumps ■ interpreting readings related to the operation of in-tank pumps Spray pumps Understanding of the purpose of spray pumps Proficiency in operating the spray pumps Level gauging systems Understanding of ■ the equipment used for overfill protection ■ principle and method of operation of various types of level gauging systems ■ the likely problems of the various level gauging systems Proficiency in ■ interpreting readings from level gauging equipment ■ performing inspections, tests and routine calibration on level gauging equipment and overfill protection equipment Vapour control Understanding of ■ the methods for handling vapours from cooling down ■ limitations for venting off vapours ■ the return of the vapours during gas freeing and warming up Proficiency in performing a manual emergency vapour release
OPS ME ELC M&R	Engineering	**Competence in venting and ventilation of an LNG fuel system**	Understanding of: ■ the critical importance of a functioning ventilation system to ensure provision of LNG to the engine ■ the importance and the function of air locks ■ the use of positive and negative pressure at various places in the system ■ the importance of relative negative pressure in the gas dangerous areas ■ why vent outlets should be regarded as potential hazardous zones ■ actions in case of ignited vents Proficiency in performing checks related to positive pressure and negative pressure conditions and equipment Double-walled piping Understanding of ■ the importance and purpose of double-walled piping ■ how to handle double-walled piping during disassembling and reassembling Proficiency in ■ performing inspection and leak tests on double-walled piping ■ performing maintenance on double-walled piping

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
OPS ME ELC M&R	Engineering	**Competence to appropriately monitor the LNG fuel systems**	Control and alarm board Proficiency in ■ interpreting readings from the process control system ■ performing fault-finding related to the control and alarm board ■ performing troubleshooting related to the control and alarm board Pressure control Understanding of ■ the equipment used for measuring pressure ■ the terms operating pressure, pressure alarm high (PAH) and pressure alarm low (PAL) ■ how to control pressure Temperature Monitoring Understanding of ■ the equipment used for temperature monitoring ■ how to control temperature Proficiency in ■ interpreting readings from temperature monitoring equipment ■ performing inspections, tests and routine calibration of temperature monitoring equipment ■ how to perform basic maintenance on relevant sensors
OPS ME ELC M&R	Engineering	**Competence in the maintenance on LNG systems**	Repairs and exchanging parts Understanding of ■ the importance of using stainless steel in piping and equipment ■ why improvised solutions using non-standard parts are dangerous Proficiency in verifying if the vessel has proper equipment on board to repair stainless steel piping
NAV OPS ME ELC M&R	Deck and engineering officers	**Competence on LNG specific safety systems**	Gas detection systems Understanding of ■ the gas detection system on board ■ the operation of the interlocks as part of the gas detection and gas control system Proficiency in ■ maintaining an adequate inventory of spare parts to ensure continuity of the gas detection system ■ calibrating the gas detection system ■ performing maintenance on the gas detection system Fire detection system Understanding of the components of the fire detection system Portable gas detection equipment Understanding of the purpose and principles of operation of different portable gas detection instruments Proficiency in ■ calibrating and use portable gas detection equipment (oxygen, methane) ■ calibrating and use a dew point meter Ex-certified equipment Understanding of ■ locations where Ex-proof lighting and equipment is required ■ the specific maintenance requirements for Ex-proof fans

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
			Proficiency in ■ Performing the inspection, maintenance and repair of Ex-certified equipment (certified people only) ■ interpreting a wiring diagram of an Ex-certified instrument ■ connecting a motor in Ex-mode ■ replacing Ex-barriers in I/O modules ■ maintaining inventory of Ex-certified spare parts, based on the criticality in relation to LNG-related components <u>Safety relief valves</u> Understanding of the working principle of a safety relief valve Proficiency in ■ performing inspections and tests on safety relief valves (qualified people only) ■ performing maintenance on safety relief valves (qualified people only) ■ performing the emergency closing procedure of safety relief valves <u>Emergency shutdown system</u> Understanding of ■ the consequences of activating an ESD call button ■ the operation and triggers of the emergency shutdown system ■ the emergency shutdown sequence ■ the difference between the safety system principles 'emergency shutdown' and 'inherently safe' Proficiency in ■ performing emergency shutdown tests ■ performing inspection and maintenance on ESD-valves
All	All	**Advanced knowledge on emergencies and contingencies on LNG**	Proficiency in ■ acting in accordance with applicable contingency plan in case of an emergency ■ determining most suitable vessel position / orientation in case of LNG emergency <u>LNG fire</u> Understanding of ■ the potential danger of trying to extinguish a fire prior to stopping a leak ■ how to recognise the heat intensity of burning LNG ■ the extinguishing agents to be used on LNG Proficiency in demonstrating the proper way to control an LNG fire (flash, jet, and pool fire) <u>Gas leak</u> Understanding of the indications of a gas leak Proficiency in ■ taking appropriate action in case of a detected gas leak ■ the various methods to locate a gas leak <u>LNG spill</u> Understanding of ■ the danger of cloud formation when LNG comes into contact with outside air and hot surfaces ■ the actions required to mitigate spill Proficiency in ■ the proper way to handle an LNG-spill

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
			■ directing a gas cloud using the effect of water spray Shore connections / emergency release of connections to shore Understanding of ■ the potential risk in connection with emergency release couplings, immediately after release ■ the type and construction of shore connection arms (if applicable) ■ the importance of emergency release or dry break couplings ■ the use of flexible hoses ■ the emergency shutdown procedure between ship and shore ■ the emergency breakout operation of shore connection Proficiency in ■ interpreting mooring requirements for a loading point ■ mooring the vessel anticipating emergency release ■ outweighing the consequences of igniting LNG or LNG release Emergency shutdown Proficiency in performing an emergency shutdown Emergency unloading/ transfer of LNG Understanding of the possibilities for emergency unloading or transfer of LNG Proficiency in performing the procedure for transferring LNG to another vessel in case of an emergency Emergency separation Understanding of: ■ criteria/situations which would trigger emergency separation during LNG bunkering ■ the steps involved in emergency separation during bunkering Proficiency in finding the local port requirements on emergency separation during LNG bunkering

8.2 Biofuels

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
All	All	**Competence in general knowledge and understanding of biofuels, regarding common biofuel properties and health hazards**	Knowledge of: ■ the different types of biofuels and their blends ■ the applicable rules and regulations related to the use of the biofuel type in the maritime sector Understanding of ■ the quality of the biofuel in use ■ the biofuel's reactivity with sealings and other material ■ the environmental impact of an operational release of biofuel as compared to a release of a similar quantity of MGO ■ the hazard associated with handling the biofuel type ■ the potential for biofuel to degrade at varying speeds Proficiency in ■ interpreting the material safety data sheet for the biofuel type ■ demonstrating the use of appropriate personal protective aids when working with a type of biofuel ■ demonstrating the use of available rescue and escape equipment
NAV OPS ME	Deck and engineering officers	**Competence in the biofuel-specific aspects related to voyage planning**	Understanding of ■ the engine's effectiveness per biofuel type ■ the biofuel's effect on emissions (NOx), which might deviate from the IMO-approved values. For example, FAME-based fuels tend to increase the NOx-emissions while HVO gives similar emissions as MGO ■ the effect of the biofuel density on the vessel range (assessed together with the net calorific value) Proficiency in estimating the net calorific value for the biofuel in use, i.e. the amount of energy available in a certain mass of fuel (MJ/kg)
CHS OPS ME ELC M&R	Deck and engineering officers Engineering ratings	**Competence in the methods of biofuel storage, their connections and cleaning**	<u>Bunker tanks</u> Understanding of ■ the layout and operation of the onboard biofuel system ■ the limited storage time of some biofuels and that the biofuel shall be avoided for auxiliary machinery/equipment not frequently used Proficiency in performing inspections of the methanol storage system <u>Storage characteristics</u> Knowledge of ■ how hydrocarbons can degrade ■ signs of degradation of the biofuel (e.g. waxing/gelling) ■ the biofuel's draining capability (can lead to poor mixability) Understanding of ■ stability/shelf life of the biofuel type ■ the terms rancidity/microbial growth ■ how to store the biofuel type, and how the following terms affect the type of biofuel: temperature (both low and high), motions, humidity, water content, tank condition. ■ how the above-mentioned factors affect the storage time of the biofuel ■ the importance of a clean tank ■ the layout and operation of the tank system <u>Tanks and piping</u> Understanding of ■ the biofuel's compatibility with sealings and other rubber-based components ■ the effect of biofuels on metallic materials (in the case of an acidic biofuel or their potential to develop acidity with time, and hence cause corrosion).

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
			■ the biofuel's viscosity and how differences in surface tension properties can cause leaks (some biofuels and blends thereof may have lower surface tension compared to conventional fuel, hence increasing the likelihood of leakage in flanges, etc.) Proficiency in ■ cleaning tanks that have or will store biofuel ■ verifying the compatibility of sealing materials and metals to the biofuel ■ monitoring and tuning the fuel temperature ■ monitoring and tuning the viscosity determining the longevity of materials exposed to the biofuel type
NAV OPS ME	Deck and engineering officers	**Competence with the regulation, rules and requirements related to biofuel**	Knowledge of ■ the applicable rules, regulations and guidance related to the use of the biofuel type as fuel in the maritime sector ■ regulation regarding blending in port/onboard Understanding of ■ biofuel-as-fuel regulations ■ the compatibility of the biofuel in use ■ the lack of industry experience regarding long-term use of biofuels Proficiency in the applicable monitoring and reporting of biofuel use (MARPOL compliance with emissions regulations)
OPS ME M&R	Deck and engineering officers Engineering ratings	**Competence in the proper operation, functioning and monitoring of an engine using biofuel**	Knowledge of ■ the lubricity of the biofuel in use. Different fuels might have different lubricity that can affect both fuel pumps and injectors (Increase wear and tear if poor lubricity) ■ the viscosity of the biofuel type in use ■ the density of the biofuel ■ the effect of density on the volumetric injection ■ how the biofuel may benefit from an alternative nozzle design ■ potential clogging of filters due to biofuels dissolving residuals and clogging filters Understanding of ■ for engines without common rail, how the difference in density of the biofuel into the fuel injection can add more or less fuel in terms of mass, in addition to calorific value ■ how to control of viscosity of fuels for use in engines ■ the importance of fuelling at the correct temperature ■ biofuel and lube oil compatibility Proficiency in ■ monitoring of fuel filters ■ filtering the biofuel ■ monitoring and tuning viscosity control of the biofuel ■ matching the lube oil with the biofuel properties ■ selecting the correct nozzle design depending on the biofuel in use
OPS ME	Deck and engineering officers Engineering ratings	**Competence in fuel preparation**	Understanding of ■ the differences in fuel separation due to differences in fuel density ■ how to purify the fuel (to adjust the density)
CHS OPS ME	Deck and engineering officers Engineering ratings	**Competence to plan, execute and monitor the safe**	Understating of ■ how the density of the biofuel can cause poor miscibility ■ importance of clean tanks

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
		bunkering of biofuel	Proficiency in ■ use of PPE ■ calculating the volumetric energy density

8.3 Methanol (Methyl/ethyl alcohols)

(DNV, 2024)

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
All	All	**Competence in general knowledge and understanding of methanol. Regarding methanol's properties and health hazards.**	Knowledge of ■ the flashpoint, lower explosive limit (LEL), upper explosive limit (UEL) and autoignition temperature of methanol ■ the potentially fatal level of methanol if ingested or inhaled ■ exposure limits of methanol ■ the fact that methanol exposure symptoms may only appear 72 hours after the fact Understanding of ■ methanol and its properties ■ the material safety data sheet (MSDS) of methanol ■ the consequences and behaviour of methanol being discharged into water, air and on deck (in vapour and liquid form) ■ methanol's corrosive & toxic properties ■ methanol poisoning, how it may occur, its effects and symptoms ■ the interaction of methanol with water and how it may cause corrosion and remain flammable ■ the potential for methanol as a pollutant
All	All	**Competence in taking precautions and measures to reduce methanol related risks**	Understanding of ■ the risks of entering spaces where methanol may be presented ■ the risks of working on machinery that contains methanol ■ the necessity of gas detection and proper ventilation for spaces containing methanol ■ the restricted areas/Ex zones related to methanol ■ the main safety features for methanol specific systems
All	All	**Competence in personal protection equipment for methanol**	Understanding of ■ the protective equipment to be used when present in spaces containing methanol ■ the protective equipment to be used when working on machinery/lines that may contain methanol ■ when to use Self-contained Breathing Apparatus and chemical suits when the likelihood of being exposed to methanol is high ■ the actions to be executed during a methanol leak alarm regarding personal protection ■ the use cases, importance, and operation of portable gas detection instruments ■ specific first aid procedures for methanol, such as avoiding contamination Proficiency in the use of methanol specific personal protective equipment
CHS OPS ME ELC M&R	Deck and engineering officers	**Competence with the regulation, rules and requirements related to methanol and related voyage planning**	Knowledge of the applicable rules, regulations and guidance related to the use of methanol as fuel in the maritime sector Understanding of ■ methanol-as-fuel regulations ■ the accurate reading of methanol fuel levels Proficiency in ■ the application of methanol related regulations pertaining to each individual voyage ■ the applicable monitoring and reporting of methanol fuel use ■ the type of permissions needed for certain voyages/port calls when using/bunkering methanol ■ mapping methanol bunkering possibilities ■ estimating required methanol fuel and consumption for a voyage ■ calculating the stability of the vessel as methanol is consumed

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
NAV ME	Deck and engineering officers	**Competence in the methods of methanol storage, their connections and cleaning**	Bunker Tanks Understanding of ■ the different types of tanks used for storing methanol ■ the advantages/disadvantages and key aspects of the various tanks used for methanol storage ■ the layout and operation of the onboard methanol fuel system ■ the importance of monitoring hold space atmosphere ■ the use of auto-shut off valves Proficiency in performing inspections of the methanol storage system Nitrogen blanketing Knowledge of the appropriate nitrogen blanketing method Understanding the usage of nitrogen blanketing in the fuel tanks Tank connections Knowledge of ■ the vulnerability of tank connections ■ the appropriate procedure for working on/near tank connections Tanks and piping Understanding of ■ the effect of methanol on materials and need for special coating ■ the material choice for components exposed to methanol ■ the double-barrier concept ■ the double-piping requirements for methanol, their location, functioning, and assembly ■ how to handle contaminated water used for methanol tank cleaning Proficiency in ■ the methods of protecting materials from the effects of methanol ■ determining the longevity of materials exposed to methanol ■ in leak-testing, inspecting, and performing maintenance on double-walled piping ■ in cleaning methanol fuel tanks
CHS OPS ME ELC M&R	Deck and engineering officers Engineering ratings	**Competence on the proper operation, functioning and monitoring of a methanol fuel system**	Understanding of ■ the fuel system's layout, arrangement, and safety features. From tank to engine. ■ the importance of keeping the fuel system separate from all other piping systems ■ equipment used for monitoring pressure and temperature ■ pressure and temperature readings ■ how to perform inspection, tests, and calibration of monitoring equipment ■ how to control temperature and pressure ■ how to perform basic maintenance on relevant sensors Pumproom Knowledge of the methanol tank supply pressure Understanding of ■ the functioning and importance of the methanol pumproom ■ the limitations and challenges that come with having an isolated pumproom ■ the entry procedure for the methanol pumproom ■ the importance of purging methanol components or lines before performing work on them

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
			■ the operation and importance of the pumproom's bilge system Methanol temperature control Knowledge of the preferred temperature for storing and delivering methanol Understanding of how the temperature of methanol can be controlled Proficiency in the cooling/heating of methanol depending on the operation, conditions, and tank location Sealing oil system Understanding of ■ the purpose of the sealing oil system for methanol ■ the operation and layout of the sealing oil system ■ how to detect and troubleshoot a malfunctioning sealing oil system Fuel booster injection system Knowledge of the required methanol injection pressure Understanding of the operation and layout of the fuel booster injection system Proficiency in ■ the testing of the fuel booster injection system ■ the monitoring of the performance of the fuel booster injection system ■ performing maintenance on the fuel booster injection system Fuel valve train Understanding of ■ the operation and layout of the fuel valve train ■ the configuration and importance of a "double block and bleed configuration" ■ how to purge the fuel valve train with nitrogen Proficiency in the testing and monitoring of the fuel valve train Fuel monitoring system Understanding of ■ the readings from the fuel control system ■ vapour return and venting regarding methanol Proficiency in the troubleshooting of the fuel system
CHS OPS ME ELC M&R	Deck and engineering officers Engineering ratings	**Competence in the proper operation, functioning and monitoring of a methanol fuelled engine**	Understanding of ■ the start-up and shut-down of a methanol fuelled engine ■ the principles of a methanol fuelled engine ■ the importance of ventilation regarding operating a methanol fuelled engine ■ the operational limitations of a methanol fuelled engine ■ the prerequisites for operating a methanol fuelled engine, including use of pilot fuel if needed ■ alarms related to a methanol fuelled engine ■ the thresholds for using methanol as a fuel in an engine ■ the process for draining, purging and removal of methanol from an engine Proficiency in the start-up and shut-down of a methanol fuelled engine

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
CHS OPS ME ELC M&R	Deck and engineering officers Engineering ratings	**Competence in the proper operation and procedures for onboard safety systems**	Understanding of ▪ the gas and fire detection systems on board ▪ the locations of the gas and fire detection systems ▪ the onboard automated safety functions ▪ the emergency shutdown procedure and its consequences related to the methanol fuel system Proficiency in ▪ performing and emergency shutdown of the methanol fuel system ▪ performing maintenance and inspections on safety system components related to the methanol fuel system ▪ the calibration of gas and fire detection systems ▪ the maintenance of gas and fire detection systems Ex-certified equipment Understanding of Ex-certified equipment, their location and importance Proficiency in ▪ performing maintenance and inspections on Ex-certified equipment operating Ex-certified machinery

CHS
OPS
ME
ELC
M&R
	Engineering officers and ratings	**Competence to plan, execute and monitor the safe bunkering of methanol**	Knowledge of safety and emergency procedures for operation of methanol specific machinery, fuel- and control systems
			
			Understanding of
			▪ the different methods for methanol bunkering
			▪ the different tasks and responsibilities for personnel involved
			▪ the process for transferring methanol
			▪ the procedure for emergency separation
			▪ port state regulation specific to methanol
			▪ required quality of methanol
			
			Proficiency in
			▪ bunkering procedures, emergency procedures, bunkering interfaces
			▪ conducting bunkering risk assessment
			▪ preparing for bunkering:
			  ○ executing bunkering checklist
			  ○ vessel alignment, loading arrangement
			  ○ tank/system readiness
			  ○ pump-rates and tank sequence
			  ○ vapour return
			  ○ grounding and static discharge
			  ○ inerting and purging of lines
			▪ conducting bunker transfer:
			  ○ operation of bunkering manifold
			  ○ understanding of measuring devices
			  ○ operation of pumping system
			  ○ communication across all parties during bunkering
			  ○ bunkering sequences
			▪ testing methanol quality

CHS OPS ME ELC	Deck and engineering officers	**Competence to respond to emergencies related to methanol**	Knowledge of ▪ the safe areas onboard for evacuation if methanol is released ▪ the appropriate extinguishing agents and techniques for fighting a methanol fire Understanding of

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
			■ the signs of a methanol leak ■ the appropriate PPE needed for different emergencies ■ the specific properties of burning methanol, especially its difficulty to be seen ■ the risk of boiling liquid expanding vapour explosion if methanol tanks are exposed to fire ■ the procedures for emergency discharge of methanol overboard and its consequences Proficiency in ■ applying the relevant contingency plans for emergencies ■ the appropriate response for handling a methanol leak ■ venting of methanol vapour
CHS OPS ME ELC	All	**Competence in performing maintenance and repairs on methanol systems**	Understanding of ■ the required parts and equipment necessary for performing maintenance or repairs on methanol systems ■ the specific equipment and procedures necessary to perform maintenance or repairs on double-walled piping ■ the effect/requirements of methanol on different materials relevant to a methanol fuel system (coatings, seals, lubrication etc.) and associated replacement material requirements Proficiency in performing maintenance and repair on methanol related systems within the expectations/limitations of the manufacturer
M&R	Deck and engineering officers Engineering ratings	**Competence to condition methanol tanks**	Gas-freeing Understanding of ■ the effects of changing tank atmospheres ■ the requirements for gas-freeing Proficiency in ■ determining the duration for gas-freeing ■ executing a gas-freeing operation for a methanol tank Inerting Understanding of ■ the purpose of inerting ■ the issues that may occur when inerting ■ risks associated with improper inerting Proficiency in ■ developing an inerting plan ■ determining that inerting has been completed ■ determining oxygen-content Purging Understanding of the principles of purging Proficiency in ■ purging procedures ■ performing nitrogen purging
CHS OPS ME ELC	Deck and engineering officers	**Competence in operating ventilation systems related to methanol spaces**	Understanding of ■ the importance of air locks ■ the use of ventilation pressures to avoid accumulation of methanol vapour ■ the workings of PV-valves

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
M&R			■ hazardous zones related to vent outlets
CHS OPS ME ELC	Deck and engineering officers	**Competence in the operation and maintenance of auxiliary systems related to the methanol fuel system**	Knowledge of the maximum allowable amount of oxygen in gas mixtures Understanding of ■ the role of an inert gas generator ■ the operation of the inert gas generator ■ how nitrogen injection and purging works ■ how a nitrogen plant functions ■ the risks of entering inerted spaces ■ the purpose of the methanol tank deluge system ■ risks associated with operating with inert gas Proficiency in ■ the operation of the inert gas generator ■ the operation of the nitrogen plant ■ in the operation ■ performing maintenance on the nitrogen plant ■ performing appropriate action in case of nitrogen quality issues
CHS OPS ME ELC M&R	Deck and engineering officers	**Competence in operating ventilation systems related to methanol spaces**	Understanding of ■ the importance of air locks ■ the use of ventilation pressures to avoid accumulation of methanol vapour ■ the workings of PV-valves ■ hazardous zones related to vent outlets

8.4 Battery-powered hybrid-electric systems

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
All	All	**General competence in the knowledge and understanding of batteries, such as properties, hazards, and risks** **Competence in taking precautions and measures to reduce battery related risks**	Knowledge of different relevant battery types with respective characteristics and properties Understanding of ■ hazardous and EX-zones and areas ■ batteries are inherently explosive in nature, and cannot be made EX-proof ■ the importance of ventilation and heat vs explosion risk Proficiency in monitoring, control, and safety systems relevant for battery systems (e.g., BMS, EMS, gas detection systems)
All	All	**Competence in personal protection equipment for battery systems**	Proficiency in choosing and using PPE for maintenance
All	All	**Competence in considering implications of incorrect or improper maintenance** **Competence in determining what aspects of maintenance should be left to service personnel**	Understanding of ■ not bypassing safety protocols ■ not handling damaged batteries ■ what should be left to specialist service personnel and what can be done by crew self
All	All	**Competence in battery fire precautions and the installed safety barriers to mitigate risks**	Knowledge of ■ a typical fire safety plan ■ de-energizing electric circuit when gas is detected ■ root causes of battery failures ○ low ambient pressure ○ overheating ○ vibration ○ shock ○ external short circuit ○ impact ○ overcharge ○ forced discharge Understanding of gas detection in battery systems (toxic and explosive) Proficiency in calibrating and maintaining gas detection systems
All	All	**Competence of different firefighting methods, procedures, mitigating measures and consequences related to battery systems** **Competence and understanding of toxic and explosive gasses related to battery systems**	Knowledge of ■ characteristics and behaviour of heat development / thermal runaway ■ characteristics and behaviour of toxic gasses ○ Hydrogen Fluoride ○ Hydrogen Cyanide ○ CO ○ Nitrogen Dioxide ○ Hydrogen Chloride ○ Benzene ○ Toluene ■ characteristics and behaviour of explosive gasses Understanding of ■ the consequences of thermal runaway and the difficulties in handling such events ■ toxic contamination of PPE used in fire-fighting

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
			■ how venting and ventilation affects the fire-fighting process and what fire-fighting measure to choose ■ risk of short circuit in battery systems when using water as a fire-fighting medium Proficiency in ■ fire-fighting techniques of fire in battery systems. Salt water may cause short circuit in battery systems. NOVEC 1230 may cause toxic gas when exposed to high temperatures ■ choosing and using PPE for fire-fighting, e.g., HAZMAT, disposal/cleaning of contaminated PPE
All	All	**Competence in the effects and first aid of toxic gasses**	Understanding the dangers to own safety when rescuing others from toxic emergencies
ME M&R ELC OPS	Deck and engineering officers Engineering ratings	**Competence on operating battery systems and safety/security mechanisms.** **Electrotechnical competence**	Knowledge of varying battery temperatures and at what temperature the battery system initiates an automatic shutdown Understanding of ■ the need for general battery competence when working on a battery powered ship and the need for special high-voltage electrical competence when required to work on or with the battery systems ■ nominal charge levels and speed for battery ■ special battery behaviour when in operation (e.g., shut-down in case of end of life or increased temperature) ■ total harmonic distortion and its effect on the battery ■ battery systems, such as build up, strings, modules and properties such as current, voltage. ■ common mode voltage, its causes and effects ■ the fact that batteries cannot be de-energised. It is not possible to emergency-discharge, as it is with for example liquid or gaseous fuels. Energy in contained in a battery system is therefore always a fire hazard. Proficiency in ■ conducting correct maintenance on the battery system ■ inspection of the battery systems, including mechanical damage and corrosion ■ functioning of a battery control system ■ monitoring current and state of charge ■ monitoring temperatures in battery cells and battery rooms ■ connecting and disconnecting batteries and battery strings from the electrical net
ME M&R ELC OPS	Deck and engineering officers Engineering ratings	**Competence in what affects battery lifetime** **Internal short-circuit as battery ages and the chargeability of a battery with age**	Understanding of ■ the expected lifespan and when to change the batteries ■ the effect of increased heat production in the battery as the battery ages ■ the limitations of quick charging and implications on the lifetime of the battery
ME M&R ELC OPS	Deck and engineering officers Engineering ratings	**Competence in operating ventilation systems related to battery spaces**	Understanding of ■ the importance of venting and ventilation system, i.e., cooling effect and off gas handling. ■ the integrated off gas duct function, location, and property (i.e., EX-zone)
ME M&R ELC OPS	Deck and engineering officers Engineering ratings	**Competence on the usage of battery as a form of energy storage**	Understanding of ■ the range of the battery ■ the operational limits of using battery as a form of energy storage, as well as alternative propulsion or emergency generator, if applicable. ■ the infrastructure needed to charge battery

8.5 Fuel cells

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
All	All	**Competence in the basic functioning of a FC and the applied safety concept**	Knowledge of ▪ the FC's specific safety concept and safety barriers ▪ of the role of the explosion resistant container within the FC ▪ the role of ventilation or inertisation as a safety barrier in the FC space ▪ the importance of retaining a double-barrier Understanding of ▪ the basic functioning of a FC ▪ the inherent explosion/fire risk of a FC, especially if an internal fuel leak within the FC occurs ▪ the differences between a SOFC, a PEMFC and a HT-PEMFC ▪ the safety features required of a FC as per guidelines ▪ the handling of high temperatures associated with a SOFC
CHS OPS ME ELC M&R	Deck and engineering officers Engineering ratings	**Competence in potential maintenance and inspection procedures on FCs**	Understanding of the limitations set by the manufacturer on conducting work on a FC Proficiency in ▪ the replacement of fuel filters for the FC ▪ the authorised maintenance and inspection procedures
CHS OPS ME ELC M&R	Deck and engineering officers Engineering ratings	**Competence in risk awareness inherent to the high temperatures of a SOFC**	Understanding of ▪ the importance of sufficient external cooling of a SOFC ▪ the fact that an SOFC can be a burn hazard ▪ the fact that an SOFC can be an ignition source ▪ the effects of potential high temperature exhaust Proficiency in limiting the spread of high temperatures from the SOFC upon cooling system failure
CHS OPS ME ELC M&R	Deck and engineering officers Engineering ratings	**Competence in preventing fuel contamination for the FC**	Knowledge of the fuel standards for FCs Understanding of ▪ how to avoid fuel contamination ▪ the effects of fuel contamination ▪ the vulnerability of fuel contamination regarding different FC types ▪ the possibility for fuel contamination when welding/working on fuel lines, which introduces the possibility of contaminants entering the fuel lines ▪ the fuel monitoring system and when a system shutdown is triggered the importance of de-sulphuring LNG fuel
NAV CHS OPS ME ELC	Deck and engineering officers Engineering ratings	**Competence in the operational limitations inherent to FCs**	Understanding of ▪ the operational limitations inherent to the different FCs ▪ the startup/shutdown time delays for FCs, especially an SOFC ▪ the consequences of certain actions on the FC service life ▪ the role of battery systems in conjunction with FCs ▪ the load responsiveness and limits of FCs
CHS OPS ME ELC	Engineering officers Engineering ratings	**Competence in the control and monitoring of the FC**	Knowledge of the type of FC failures that trigger a shutdown of the FC/fuel system Understanding of the readings and alarms from the FC and the importance of detecting internal FC failures Proficiency in the troubleshooting of the FC

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
CHS OPS ME ELC	Deck and engineering officers Engineering ratings	**Competence in handling of contingencies related to FC-related emergencies**	Knowledge of ■ the appropriate emergency procedures ■ when an ESD is triggered Understanding of ■ potential hazardous scenarios related to FC ■ the risks specific to a SOFC to cracking fuel to hydrogen within the FC ■ when crew action is needed ■ the consequences to an SOFC when it is cut off from fuel Proficiency in procedures for limiting fuel leakage inside and outside FC
CHS OPS ME ELC M&R	Deck and engineering officers Engineering ratings	**Competence in the proper operation and procedures for onboard safety systems**	Understanding of ■ the safety principles for a FC: ○ Segregation ○ Double-barrier ○ Ventilation/inertisation ○ Leakage detection ○ ESD the layout of the system regarding redundancy
CHS OPS ME ELC	Deck and engineering officers	**Competence in safeguarding the operational lifespan of the FC**	Understanding of ■ the different actions to a FC that can reduce its operational lifespan: ○ Improper temperature handling ○ Contaminated fuel ■ Load instability

8.6 Ammonia

(DNV, 2024)

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
All	-	**Competence in the general knowledge and understanding of ammonia as a fuel**	Knowledge of ■ rules and regulations regarding ammonia ■ flashpoint, lower explosive limit (LEL), upper explosive limit (UEL) and autoignition temperature of ammonia ■ of the potentially safe/fatal level of ammonia if exposure, ingested or inhaled Understanding of ■ ammonia and its properties ■ the consequences and behaviour of ammonia being discharged into water, air and on deck (in vapour and liquid form) ■ ammonia's corrosive properties ■ ammonia's toxic and poisoning properties, how it may occur, its effects and symptoms ■ relevant properties of ammonia mixtures, such as exhaust from dual fuel engines or ammonia induced lube oil Proficiency in interpreting the safety data sheet (SDS) for ammonia
All	-	**Competence in understanding the risks associated with ammonia systems and be able to take precautions and act in a proactive manner to avoid unwanted events** **Competence in personnel protection for ammonia, regarding hazardous zones and with a focus on toxicity**	Knowledge of the behaviour of ammonia when discharged into water and into air Understanding of ■ Acute Exposure Guideline Levels (AEGL) for ammonia ■ Permissible Exposure Limit (PEL) ■ of the risks of entering spaces where methanol may be present ■ the risks of working on equipment and machinery that contains ammonia ■ gas detection and proper ventilation for spaces containing ammonia systems ■ the ship specific Gas Dispersion Analysis (GDA) and potential situations which may occur ■ the use of a Self-contained Breathing Apparatus and chemical suits when the likelihood of being exposed to ammonia is present Proficiency in ■ reporting if any personnel is exposed by ammonia ■ basic first aid ■ the familiarisation process of safety related ship specific aspects ■ the ammonia specific procedures and policies ■ using personal protective equipment, including personal rescue and escape equipment ■ calibrating and using personal gas detection systems ■ recognising and acting according to specific alarms related to ammonia ■ locating and recognising dangers related to hazardous zones and potential toxic areas on board, such as tank connections paces, fuel preparation room, ventilation outlets, vent mast, bunkering station, and engine rooms escape routes, including trunks
All	-	**Competence in operating ammonia specific bunkering and fuel containment systems and equipment, such as various systems and working principles of ammonia (dual) fuel supply system:** ■ **Combustion engines (liquid vs gas)**	Knowledge of the limitations of the bunkering arrangement Understanding of ■ the different tank types for storage of ammonia ■ the design principle and requirement for piping in ammonia fuel supply systems ■ methods for containing ammonia, atmospheric tanks vs pressure tanks ■ different bunkering arrangements for ammonia, with or without vapour return - ■ system specific protective equipment, such as pressure and temperature monitoring ■ risks considered associated with the condensation of gaseous ammonia ■ how ammonia is affected by temperature considering condensation, including water content and dew point

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
		■ **Fuel cells (solid oxide fuel cells, proton-exchange membrane fuel cells** ■ **Boilers/gas turbines**	Proficiency in ■ interpreting and using readings from instruments and control systems ■ performing inspections on fuel tank support and insulation removing condensation/water from ammonia, e.g., using drain pot
OPS	-	**Competence in ammonia specific safety systems**	Understanding of ■ the different means of ammonia leak detection, such as gas -, liquid-, temperature -, and pressure detection ■ the Emergency Shutdown (ESD) system and cause and effect diagram ■ different safety related barriers, such as relief valves, spray shielding, drip trays, certified electrical equipment (EX-rated), double-walled piping, water safety systems and Ammonia Release Mitigating System (ARMS) Proficiency in ■ calibrating, maintaining and operating gas leak detection systems ■ the troubleshooting/fault-finding of ammonia specific safety systems ■ performing ESD tests ■ ensuring the operability of water safety systems in all ambient conditions, e.g., in freezing conditions ■ operating and explaining the working principles of the different ARMS solutions
OPS ME	-	**Competence in of ammonia specific hazardous zones relative to the fuel supply system.** **Competence in the principles and importance of venting and ventilation**	Understanding of ■ the risks associated with tank connection spaces and fuel preparation rooms ■ the purpose, function and typical equipment related to such zones / rooms ■ the difference between venting and ventilation ■ the importance of functioning ventilation system to ensure safe operation of the ammonia fuel system ■ catastrophic ventilation and ship specific air changes Proficiency in ■ the safe working procedures related to such zones/rooms ■ monitoring and operating ventilation systems, vent piping, and discharge system for toxic atmosphere ■ verifying proper functionality and performing the calibration of instrumentation in pressure monitoring system to ensure correct positive pressure and negative pressure conditions ■ the entry procedures for entering hazardous zones
ME	-	**Competence in bunkering ammonia**	Understanding of ■ preparing a fuel tank for safe ammonia filling (e.g. appropriate temperature and pressure) ■ the ammonia bunkering transfer ■ correct and clear communication procedures relevant for ammonia bunkering ■ the importance of cooling down liquid and vapour lines before bunkering ■ the potential necessity of additional PPE when conducting bunkering operations ■ the potential risks associated with connection and disconnection, as well as emergency release and dry breakaway couplings Proficiency in ■ inerting and purging bunkering lines ■ handling vapour capacities ■ checking the composition of bunkering arrangement, e.g., amount of water and oxygen, validated quality of purging operation (both pre- and post-bunkering) ■ safe connecting and disconnecting of ammonia bunker transfer lines
ME M&R ELEC OPS	-	**Competence in the proper operation, functioning and monitoring of various ammonia fuelled machinery**	Understanding of the principal configuration, working principle and main components of a (dual) fuel ammonia fuel supply system, from the containment system to the respective consumers. Proficiency in

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
			■ operation of the ammonia fuel supply system, and connected equipment, such as heating systems / vaporisers, pumps. gas isolation valves, boil off gas systems, exhaust systems, bilge and drainage systems, and systems to prevent condensation of gaseous ammonia ■ troubleshooting related to the control and alarm board of the ammonia fuel supply system
M&R	-	**Competence in preparing an ammonia fuel tank for internal maintenance**	Understanding of the potential for unpumpable liquids and remains to be present in ammonia tanks when emptying Proficiency in ■ the procedures for emptying an ammonia tank completely (warming up, gas freeing) ■ always keeping the tank atmosphere at a non-explosive and non-toxic range
ALL	-	**Competence in maintenance on ammonia systems**	Understanding of ■ warming up of fuel tank, aeration and gas freeing before maintenance ■ that some equipment and systems might require special training. Awareness of what maintenance not to perform ■ the need for using compatible materials in piping and equipment ■ the potential dangers for residuals of ammonia in systems directly or indirectly coupled to the ammonia fuel supply system ■ the potential residuals/traces/containment of ammonia on PPE after completing maintenance Proficiency in ■ analysing the dangers of maintenance on two systems simultaneously ■ analysing the process of the maintenance operation in order to assess and determine if the operation should be paused or aborted ■ analysing and assessing the status and degradation of system on equipment, e.g., corrosion, corrosion under insulation, vibration / stress / fatigue. ■ performing maintenance on ammonia related systems and equipment, as well as safety related systems and equipment ■ exercising post-maintenance caution, such as importance of safe distance to hazardous zones when starting up systems
ALL	-	**Competence in communication, alarm management, responses to an ammonia leak or spill situation, and rescue of people exposed to ammonia**	Understanding of ■ the different credible critical scenarios which can occur by using relevant risk assessments ■ that ammonia may be close to the sea surface in case of an abandon ship situation ■ the restrictions in visibility in case of an ammonia leak, as it may result in a dense cloud ■ the dangers of ammonia leaks, liquid and gaseous ■ the chemical reaction when ammonia is combined with water ■ the different emergency stop methods and effects ■ proper communication procedures related to the ammonia hazards during an emergency ■ what can cause an ESD scenario Proficiency in ■ determining safe locations onboard, e.g., safe haven ■ showing the location and demonstrating the function of a safe haven ■ determining most suitable vessel position/orientation considering environmental conditions and nearby infrastructure in case of an ammonia release or spill ■ communicating with other stakeholders (voice radio and alarms) ■ emergency stop and shutdown ■ demonstrating methods in locate gas leaks ■ interpreting the functionality and effects of activating ESD system ■ describing the effects on the ammonia fuel supply system in case of a blackout ■ alerting nearby stakeholders (e.g., port, ships, offshore installations) in case of an ammonia leak ■ methods for emergency discharge of ammonia ■ methods for emergency separation during ammonia bunkering
		Competence in the different firefighting methods, procedures,	Understanding of ■ the flammable properties of ammonia

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
		mitigating measures and consequences for ammonia **Competence in handling toxic and explosive ammonia gasses**	▪ the role of the Ammonia Release Mitigation System (ARMS) and double walled pipes as safety measures to tackle toxicity hazards Proficiency in demonstrating methods for extinguishing an ammonia fire

8.7 Hydrogen

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
All	-	**Competence in knowledge and understanding of hydrogen properties and health hazards**	Knowledge of ■ the relevant rules and regulations for hydrogen ■ hydrogen's extreme conditions – i.e. temperature, pressure, diffusion, flammability, ■ flashpoint, lower explosive limit (LEL), upper explosive limit (UEL) and autoignition temperature of hydrogen ■ the extreme risks of injuries when in contact with subzero gases ■ hydrogen's rapid diffusion and its potential consequences Understanding of ■ hydrogen and its properties ■ the material data sheet (MSDS) of hydrogen ■ the difference between compressed and liquid (cryogenic) Hydrogen ■ hydrogen's sensitivity to oxygen ■ the high flammability of hydrogen ■ sensitivity of hydrogen to self-ignite (350-700 bar) ■ the requirements behind EX-zones related to hydrogen ■ that oxygen can condense from air with liquid and expose risk (Cryo PPEs -240C) ■ hydrogen can displace oxygen in the air and potentially causing asphyxiation ■ what not to do when working with hydrogen as fuel ■ the risks of entering an area where hydrogen may have leaked Proficiency in ■ safe use/application PPE for hydrogen-related risks ■ correctly applying breathing apparatus as part of PPE ■ the ability to quickly respond to gas detection alarms ■ working in enclosed spaces ■ executing a proactive mindset about risk awareness for hydrogen
CHS OPS ME ELC	-	**Competence in taking precautions to prevent risk of ignition, explosion, and hydrogen fire** **Competence to plan, execute and monitor the safe bunkering of hydrogen**	Knowledge of ■ the risks involved with breaking containment of hydrogen (nitrogen can't be used for inerting because it will condense) ■ how composite materials used in compressed hydrogen tanks are affected when exposed to fire and mechanical damage ■ that a high-pressure leakage can self-ignite ■ the fact the compressed hydrogen tanks are vulnerable (impact, fire, UV) due to being made from composites ■ density of hydrogen can change extremely depending on temperature Understanding of ■ the differences and properties of compressed and liquid hydrogen ■ preventing ingress of air/nitrogen into the hydrogen system ■ procedures and risks for hydrogen bunkering operations ■ the danger of using nitrogen as an inert gas with liquid hydrogen regarding its condensation ■ how the leak detection system for hydrogen works, including its limitations ■ how static electricity builds up and how to avoid this when working in Ex areas ■ limiting air mixing with hydrogen ■ the importance of adequate ventilation in areas where hydrogen is being processed or stored ■ the importance of vacuum insultation for liquid hydrogen ■ the temperature hazards and that air solidifies at extreme cold temperatures related to liquid hydrogen ■ importance of overpressure in the hydrogen system ■ the consequences of loss of vacuum in type C tanks ■ importance that you lose the most important safety barrier when inerting/vacuum is compromised ■ importance of material type for the different hydrogen storage tanks

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
			■ the consequences of leakage ■ the risks of breaking containment ■ the effects of contamination inside liquid hydrogen piping (of condensed air and nitrogen) ■ the risks of connecting and disconnecting swappable modular hydrogen storage containers ■ not using nitrogen with liquid hydrogen in double walled piping due to nitrogen potentially leaking into the liquid hydrogen piping ■ that liquid hydrogen condenses air around tanks when leaking ■ that liquid hydrogen contamination inside piping can end up in fuel tanks when bunkering liquid hydrogen potentially leading to an explosive atmosphere if temperatures inside the tank increase ■ the differences behind “emptied, purged and gas-free” Proficiency in ■ the ability to recognise (hear) high pressure hydrogen leaks which are invisible ■ filling limits, loading limits and the difference regarding these between liquid and compressed hydrogen ■ awareness concerning the higher level of risk regarding ignition of hydrogen ■ applying grounding and bonding to prevent static electricity as a potential ignition source ■ the ability to communicate risks and safety procedures for hydrogen fire ■ the safe evacuation from hydrogen fire/ leakage ■ the steps to execute a change of swappable modular hydrogen storage container applying helium to inert liquid hydrogen
NAV	-	**Competence in the hydrogen specific aspects related to voyage planning**	Proficiency in ■ the application of hydrogen related regulations pertaining to each individual voyage ■ the type of permissions needed for certain voyages/port calls when using/bunkering hydrogen ■ mapping hydrogen bunkering possibilities ■ estimating required hydrogen fuel and consumption for a voyage calculating the stability of the vessel as hydrogen is consumed
CHS OPS ME ELC M&R	-	**Competence in the proper operation, functioning and monitoring of a hydrogen fuelled engine**	Knowledge of ■ hydrogen’s ability to diffuse through materials ■ the risks involved in high pressure storage systems ■ hydrogen properties (colourless, odourless, invisible flame, etc). ■ risk of hydrogen to self-ignite ■ hydrogen specific EX-machinery ■ potential hydrogen explosion scenarios ■ of the general dangers and explosion risk for hydrogen fuelled vessels. Understanding of ■ the functioning of the hydrogen fuel system, connections of the system and leak prevention/inspection ■ importance of maintenance requirements to prevent leaks ■ the ease of hydrogen to leak ■ how accumulation of hydrogen happens ■ importance of material type for the different hydrogen storage tanks ■ the efficiency of ventilation systems ■ risk of hydrogen presence in the exhaust ■ the consequences of hydrogen ingress to the engine crankcase Proficiency in Ex-certified equipment for hydrogen
CHS OPS ME	-	**Competence in the proper operation and procedures for onboard safety systems**	Knowledge of ■ the basic hydrogen process monitoring & control system ■ the fact that the density of hydrogen changes extremely fast

Onboard Function	Category	Competence	Knowledge, understanding and proficiency
ELC M&R			■ the properties of hydrogen at different temperatures ■ consequences of hydrogen release being exposed to oxygen Understanding of ■ the challenges of detecting hydrogen ■ the effects of ESD and when it is activated, including limited redundancy upon ESD ■ how level/pressure and temperature transmitters work on hydrogen fuel system / engine ■ determining the ratio of fullness in hydrogen vessels ■ the consequences of loss of vacuum pressure ■ the consequences of loss of inert gas pressure ■ how the leak detection system works Proficiency in the ability to effectively shut off the fuel supply upon failure
CHS OPS ME ELC M&R	-	**Competence to respond to emergencies related to hydrogen**	Knowledge of ■ the properties of hydrogen fires and the principle of “invisible fires/micro flame” ■ the effects of hydrogen leakage and that a high-pressure leak can self-ignite ■ important shutdown valves for the fuel supply system, and how to operate these in case of an emergency Understanding of ■ how the emergency shutdown system is designed and the different levels of shutdown to isolate from ignition sources ■ the principles behind first and secondary barrier for leakage point ■ how a blackout will impact the safety system and the concept of “fail safe” ■ the difference between principles of conventional firefighting and firefighting both compressed/liquid hydrogen ■ the purpose of ventilation for hydrogen and the principle of dilution ■ of the risk of accumulation of hydrogen at the vent mast Proficiency in ■ the ability to shut down the fuel supply in case of fire or leakage ■ using various types of leak detection systems/methods carrying out emergency response according to the emergency response plan

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