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ENERGY TRANSITION

H2Deri@BSP

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D1.3 H2-Derivative Port Regulatory Framework

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H2Deri@BSP - A cooperation project to develop proof-of concepts for the uptake of H_2-derivative fuels!	Lead Partner	Port of Hamburg MARKETING

Table of Contents

1 EXECUTIVE SUMMARY 3

2 INTRODUCTION 4

3 METHODOLOGY 7

4 BEST PRACTICES 9

4.1 REGULATORY FRAMEWORK 9

4.2 FUNDING FRAMEWORK 10

4.2.1 Best Practices 11

4.2.2 Sustainable Transport Investment Plan 15

5 LEARNINGS 17

6 CONCLUSION 19

7 REFERENCES 20

8 ANNEX 26

8.1 HANDBOOK: KEY REGULATORY REQUIREMENTS FOR HANDLING AMMONIA IN PORTS 26

8.2 HANDBOOK: KEY REGULATORY REQUIREMENTS FOR HANDLING METHANOL IN PORTS 89

8.3 BALTIC PORTS BUNKERING GUIDEBOOK: SAFETY REQUIREMENTS FOR H2-DERIVATIVE HANDLING 162

1 Executive Summary

The ramp-up of H_2-derivatives in European ports is not primarily hindered by technical limitations but by fragmented regulations, a lack of political clarity, and geopolitical tensions. Methanol not only has an advantage over ammonia in terms of the number of ships operating but is also somewhat more widely introduced in regulatory terms. In the development of transnational regulations, the developed manuals “Ammonia in Ports” and “Methanol in Ports” in the Annex can serve as a basis for port stakeholders planning to use H_2-derivatives. They summarize existing regulations and best practices and could contribute to the harmonization of regulations for H_2-derivatives in European ports. For the standardization of bunkering procedures, a “Baltic Ports Bunkering Guidebook” is elaborated in the Annex specifying the safety requirements for H2-Derivative handling. Regarding suitable funding programs, a wide range of instruments is available; however, bureaucratic complexity, limited practical relevance and insufficient incentives often prevent their uptake or lead to an inefficient allocation of funds. Only through consistent cooperation, shared responsibility, and political willingness can the transition to hydrogen-based shipping be made efficient, safe, and economically viable.

2 Introduction

Global shipping is the sixth largest source of CO_2 emissions, accounting for 3 percent of global CO_2 emissions. Therefore, a potential switch to climate-neutral fuels could substantially reduce CO_2 emissions and thereby contribute to a resilient and climate-neutral maritime transport system. Several fuel options are currently being considered for future maritime use, but the H_2-derivatives sector is one of the most promising. Ammonia and methanol in particular have good prospects of developing into alternative fuels for shipping, as relevant infrastructure is already in place and experience has been gained in their use as a basis for fertilizers in the case of ammonia, or formaldehyde in the case of methanol, in other industries.

Another fuel that has been established as an alternative solution to conventional fuels is LNG (liquefied natural gas, mainly methane), which is still the best-selling alternative fuel in the current sales figures of ship manufacturers [1]. However, research results from recent years show that LNG can only be considered as a transitional solution. On the one hand, it has been shown that combustion is not as clean as assumed and that methane slip occurs [2], whereby methane, which is 85 times more potent as a greenhouse gas than CO_2 over a 20-year period, is released into the atmosphere. Accordingly, in some cases, LNG does not reduce greenhouse gas emissions by up to 25% as previously assumed but instead results in an overall negative greenhouse gas emission balance compared to conventional fuels. Furthermore, it has been found that some LNG engines cannot be shut down while using shore power in ports, which will be mandatory from 2030 onwards under the EU's Alternative Fuels Infrastructure Regulation (AFIR). The problem is that the resulting boil-off gas cannot be burned when the engine is shut down [3]. This means that either the engines continue to run while the ships are in port, which violates the AFIR regulation, or expensive retrofits are required to remedy this problem. The regulation therefore does not adequately address this issue at present.

Both ammonia and methanol are easier to handle in this respect. Methanol is already liquid under normal conditions, unlike LNG, which must be stored at temperatures of −162 °C, and therefore does not cause boil-off gas effects when used in shore power systems. Ammonia only needs to be cooled to a temperature of −33 °C or stored at moderate pressures of 6-8 bar to be stored in a liquid state. This means that the boil-off effect is very low. The potential for greenhouse gas emission reductions through

ammonia and methanol is up to 95%, provided that the hydrogen required comes from electrolyzers powered by renewable electricity and green CO_2 is used in the methanol production.

For a better comparison between the three fuels, the energy densities are shown [4]:

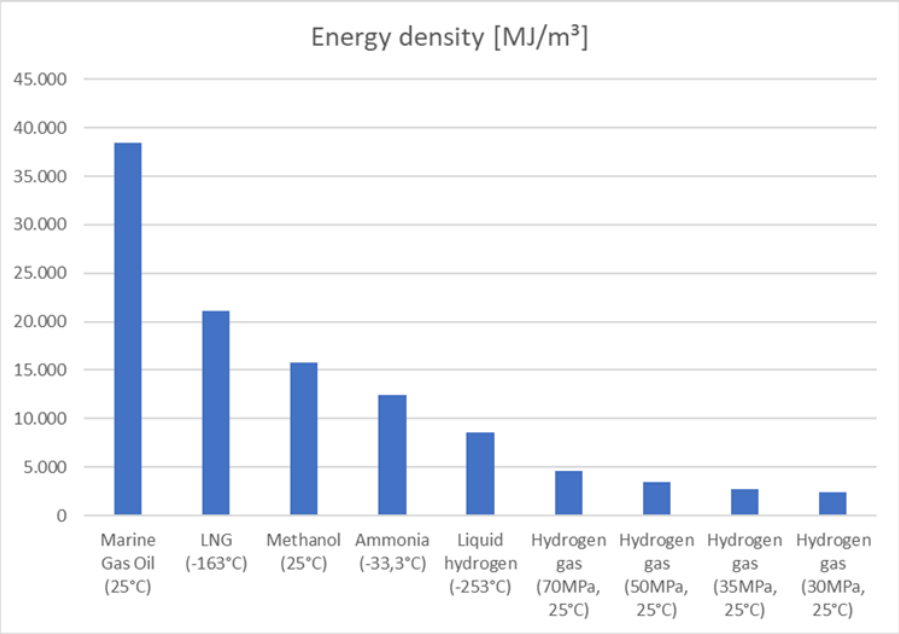

Fig. 1: Energy densities of alternative maritime fuels in comparison to MGO

The overview quickly shows that although the difference between ammonia and methanol compared to marine diesel is significant, it is much smaller compared to LNG (factor for ammonia ~1.6 and methanol ~1.3). The larger factor between MGO and LNG has not prevented the ramp-up of LNG, which indicates that the space requirements of H_2-derivatives are also manageable from a logistical and technological perspective, even if it still shows that H_2-derivatives will take up more space than other fuels. However, the effect is somewhat offset by the different storage temperatures, as the cryogenic tanks required for LNG further equalize the effective space requirements of the fuels.

The transition to alternative fuels presents challenges, but solutions must be found now to overcome these obstacles and future-proof shipping, with ammonia and methanol having a significant contribution to make. This requires standardized regulations and reliable funding frameworks to make the switch economically viable. This report covers

best practices in funding and regulatory frameworks for the usage of H_2-derivatives in Ports. In particular, it discusses best practices of funding programs with effective mechanisms and two developed manuals, “Ammonia in Ports” and “Methanol in Ports,” which show how a foundation for a uniform framework for the handling of these fuels in European ports could look.

3 Methodology

This chapter describes the process of developing the two manuals. It explains the state of the art in the regulation of H_2-derivatives in ports and lists the steps taken to develop the current version of the handbooks, considering all best practices found in the comprehensive literature review.

To gain an initial overview of the state of the art in the use of H_2-derivatives in ports, research was conducted into possible best practices. After an initial look at existing regulations and published documents, it became apparent that only few publications and best practices are currently available in this field, but a few existing sets of regulations and guidelines were found, as well as a set of regulations already applied in the ports of the Netherlands (PGS12) [5]. This regulation is updated regularly and describes the measures required for the safe storage and handling of ammonia in accordance with Dutch law.

To gather further information about existing regulations and current rules, the European partners were then asked about activities involving H_2-derivatives and possible references to existing regulations were collected. In addition, we were able to draw on the pool of our association members. This enabled German seaport operators to provide further insights into existing approval procedures for methanol bunkering activities and to report on upcoming projects involving the use of H_2-derivatives, thereby also providing information on planned concepts in the port for the safe handling of ammonia and methanol. Based on the initial research results, it was important to understand that there are currently many new developments in this field. For this reason, further information on possible developments in international ports in the handling of H_2-derivatives was gathered in numerous workshops and meetings with German, European, and international experts and companies.

All the information gathered was then consolidated into a structured catalogue of measures. The focus in creating the documents was on producing a document that was as compact and accessible as possible, making it easy for port facilities aiming to use ammonia or methanol in the port to take the first steps. The document was therefore intended to serve as a regulatory basis that could be adapted to local regulations and risk assessments, but which could nevertheless contribute to the harmonization in the handling of ammonia and methanol in European ports. The aim was not to formulate

and strictly define every regulation, which would never have been an option due to the individual interpretations and laws in the individual countries, but instead to create minimum requirements and provide a collection of suitable European and international standards that would ensure the safe handling of H_2-derivatives in ports. Measures that were partly intended for other industries were adapted for the use in ports and necessary supplementary measures were added, based on existing regulations in European ports.

The overall structure of these documents is derived from the chemical properties of both substances. While methanol is already liquid under normal conditions and ammonia only becomes liquid when cooled or pressurized, the methanol document was structured according to the rough categories of the required measures, and the ammonia manual was further subdivided within these categories to distinguish between cooled and pressurized ammonia. The categories in both manuals are identical and cover the selection of suitable locations for storing ammonia or methanol, construction, handling, safe use, maintenance, training, and protection against external threats. This means that all relevant areas for handling the two substances in ports should be described and provide an overview of the key international and European regulations and standards.

4 Best practices

This chapter focuses on best practices in terms of regulations and financing identified during the research phase. It provides an overview of global developments in H_2-derivatives at ports and lists all relevant institutions that publish relevant documents. It then provides an overview of existing funding programs in the field of alternative fuels, focusing on the most effective programs.

4.1 Regulatory Framework

After extensive research, it quickly became apparent that there are not many regulations governing the handling of ammonia and methanol in ports. The best examples of relevant documents come from the Netherlands [5] [6], Japan [7], Singapore [8], and the USA [9]. In addition, there are institutions such as the Methanol Institute, SGMF, and DNV, which regularly publish guidelines on handling H_2-derivatives. On closer inspection, these documents are usually not explicitly defined for ports or are still in development. Other countries have announced that they will introduce corresponding regulations in the coming years. Nevertheless, there are no transnational regulations that create uniform systems and aim to standardize the handling of H_2-derivatives in ports across countries. It is also striking that the lead in the number of methanol-powered ships over ammonia-powered ships, which was already discussed in the introduction, is also reflected in the number of existing regulations. The use of methanol as a marine fuel has been established for some time and is therefore already regulated in more detail and more comprehensively.

Among the documents found, the PGS 12 regulations [5] from the Netherlands stand out in particular. They describe the handling of ammonia in ports and could therefore serve as a good structural basis for the development of a European document. However, it is also noticeable here that the publication was only available in Dutch, which even created obstacles to the standardization of regulations. Nevertheless, the risk and scenario-based analysis it contains, with corresponding measures tailored to the port, is very striking and can be described as the most advanced regulation worldwide in the field of ports dealing with ammonia.

A corresponding counterpart for methanol could not be identified, but there were nevertheless numerous sources for the safe handling of methanol, as this substance is already well established in other industries, as described in the introduction. In

particular, the Methanol Institute [10] has published important general documents and guidelines that served as good sources for the creation of the “Methanol in Ports” handbook.

4.2 Funding Framework

Without financial support by governments and legally defined goals, the transition to alternative fuels would not be possible. This chapter therefore focuses on efficient funding frameworks. The European Union supports this process with a high number of established funding programs, in particular:

- Connecting Europe Facility Transport (CEF-T) (2021–2027) [11]
- Horizon Europe (2021–2027) [12]
- Sustainable Transport Investment Plan (STIP) (2025–2027) [13]
- Interreg (2021–2027) [14]
- Innovation Fund (ongoing calls until 2030) [15]
- European Hydrogen Bank (2024–2030) [16]
- InvestEU (2021–2027) [17]

Several countries have national funding programmes; just a few examples:

Country	Funding/Investment Program
Denmark	Innovationsfonden [18]
Estonia	Hydrogen Valley Estonia [19]
Finland	Low-carbon hydrogen and carbon capture 2025 [20]
France	“France 2030”: Transformation in key industry sectors [21]
Germany	IHATEC (Innovative Technologies for Ports) [22] Climate and Transformation Fund (KTF) [23]
Poland	Investments in hydrogen technologies, production, storage and transport of hydrogen (“Inwestycje w technologie wodorowe, wytwarzanie, magazynowanie i transport wodoru”) [24]
Sweden	Klimatklivet [25]

Table 1: Overview of suitable national funding programs

Online tools with search masks can save time in identifying suitable funding programs and list the desired programs. However, the official EU tool [26] is not very practical in this regard, as it only generates results based on specific search terms. During the research, one tool stood out: the one offered by the German Maritime Center (DMZ) [27], where you first click through a series of defined questions and then receive a list of funding programs tailored to your needs. Developing and refining these tools could also contribute to improving the funding process.

Barriers preventing companies from accessing funding programs

First of all, bureaucratic hurdles and complex application procedures prevent organisations from applying [28]. Then there are economic and financial challenges, funding is too low or the incentive to commercialize is not substantial enough [29]. Uncertainty regarding new political developments or even more important, comprehensive political commitment to energy transition is another factor to slow down the transition [30]. Especially the geopolitical tensions and restructuring of trading relationships is stressing the commitment in alternative technologies. Alternative fuels often require production facilities and logistics infrastructure before they can be used and long before profits can be made, which affects willingness to use subsidies and implement projects [31]. Finally, another aspect of the limited willingness is the chicken-and-egg problem. Interviews with companies, shipping operators and port authorities indicate a general willingness to support the transition, however, port stakeholders emphasize the currently low number of ammonia- and methanol-fueled vessels, while shipping companies point to the limited availability of suitable port infrastructure and green fuels.

These hurdles can limit the effectivity of funding programs but there are also positive examples were funding significantly accelerated the process of transition and where already today progress is noticeable, as described in the next section.

4.2.1 Best Practices

4.2.1.1 Port of Rotterdam

Rotterdam decided in 2019 to implement a circular economy. Rotterdam Circular has been initiated, and is being led, by the Municipal Executive and by the Port of Rotterdam Authority. Rotterdam's ambition for 2030 is for circular economy to be widespread

practice and the city, port and region have defined a clear goal for 2050: a sustainable port and industry [32].

For this purpose, the Rotterdam Climate Agreement facilitates the so-called klimaattafels (climate tables), which have established over 50 climate agreements with concrete measures that contribute to the CO_2 emission reduction goal. Six tables have been determined: 1) clean energy, 2) mobility, 3) port and industry, 4) circularity, 5) built environment and 6) healthcare. For each of these tables, representatives of enterprises and organisations, established companies as well as start-ups, cooperate to develop innovative concepts to realise the goal [33].

What funding has the Port of Rotterdam received in order to implement their roadmap to a circular economy?

The Port of Rotterdam Authority has been a major recipient and facilitator of funding and financial instruments aimed at supporting alternative energy, decarbonisation and energy transition initiatives. These funding streams include European Union grants, national/institutional investments, municipal subsidies, and innovative financial products linked to energy transition infrastructure. Key funding examples include:

1. EU and European Funding for Transition Projects

- ~€25 million EU grant for a *"green port project"* consortium led by the Port of Rotterdam Authority, awarded under the EU's Horizon 2020 programme to develop pilot and demonstration projects focusing on sustainable logistics and alternative energy carriers (green hydrogen, ammonia, batteries, shore power, etc.) [34].
- Porthos CO_2 transport backbone funding: The CO_2 transport and storage project in the Rotterdam area received €6.5 million for studies and over €102 million for infrastructure works co-funded by the EU's CEF Energy programme, supporting decarbonisation and carbon capture capacity in the port region [35].

2. National and Institutional Investments

- €25 million Invest-NL funding for shore power infrastructure at Rotterdam World Gateway (RWG), enabling moored ships to plug into green electricity and significantly reduce emissions from diesel generators. This financing also

enables access to European subsidy programs like AFIF (Alternative Fuels Infrastructure Facility) [36].

3. Municipal and Local Subsidies

- The Municipality of Rotterdam awarded ~€2 million in subsidies to four port companies for installing shore power systems, promoting electrification of vessel shore supply and reducing local emissions [37].
- Rotterdam's broader Carbonbid initiative and other municipal schemes offer companies financial support of up to €700 000 each for emissions-reduction projects in the port area [38].

4. Energy Transition Funds and Innovation Budgets

- Rotterdam's Energy Transition Fund has invested €50 million into sustainable innovation projects (electrification, sustainable mobility, energy storage, circular economy) as part of its broader €100 million budget that benefits technology relevant to the port and surrounding region [39].

5. Corporate and Financial Market Instruments

- The Port Authority issued a dedicated €50 million carbon capture and storage (CCS) bond, the first of its kind, to finance its equity investment in the Porthos project – securing long-term capital for CO_2 transport and storage infrastructure [40].

6. Other Related Energy Transition Support

- Beyond direct Port Authority funding, surrounding policy and incentive schemes – such as reduced port fees for ships using sustainable fuels and SES (sustainable energy solutions) subsidies in Rotterdam – contribute indirectly to alternative energy uptake and infrastructure scaling in the port region [41].

7. Connecting Europe Facility Maritime (CEF-T)

- €15+ million for shore power, hydrogen bunkering, and cold ironing infrastructure (2021–2027), specifically targeting TEN-T Core Ports like Rotterdam [11].

8. North Sea Energy Cooperation (NSEC) / Hollandse Kust (Noord) – AC Offshore Grid

- €100+ million EU-Dutch co-funding for Rotterdam's role as offshore wind integration hub, enabling green hydrogen production and port-based electrolysis [42].

9. Green Deal Funds & Just Transition Fund (JTF)

- €50 million JTF allocation for port worker reskilling and hydrogen infrastructure development in Rotterdam's energy transition corridor [43].

Summarizing, the Port of Rotterdam has secured over €425 million in funding and investments across the nine listed programs, with approximately ~€300 million from EU, €77 million from national and public funding streams, and €50 million through private financial instruments like the Port Authority's pioneering CCS bond. This comprehensive funding portfolio—spanning European grants, national investments, local subsidies, and innovative financial products—strengthening its position as Europe's premier hub for energy transition and sustainable maritime logistics [44].

The combination of binding legal commitments and systematic use of available funding instruments has led to measurable progress. Port of Rotterdam is mentioned very prominently on every list asking for the most advanced port regarding energy transition [45]. The International Association of Ports and Harbours (IAPH), together with Port of Rotterdam developed a new standard, the Port Readiness Tool in 2024 [46]. The tool helps to self-assess, plan, and communicate the readiness of a port to handle, bunker, or receive low- and zero-carbon, alternative, and sustainable fuels.

The port of Rotterdam uses the Port Readiness Level assessment tool to prepare for all new marine fuels. The port has already fully implemented this method for LNG and, to a large degree, for methanol. For ammonia, the pilot concludes level 6 and raises the port's readiness to level 7, with all safety procedures ready to allow bunkering on a project basis. With this enhanced readiness, the port of Rotterdam is ensuring that it is prepared for bunkering of the first ammonia-fuelled ships. The learnings of the pilot and the established procedures will be disseminated to the EU, other ports and relevant parties [47].

4.2.1.2 IHATEC

One of the best practices of funding programs for port infrastructure in Germany is the Innovative Port Technologies (IHATEC). With the current funding period until December 31, 2026, the Federal Ministry of Transport (BMV) supports research and development projects that contribute to the development or adaptation of innovative technologies in German seaports and inland ports.

Between 2021 and 2025, the Federal Ministry of Transport and Digital Infrastructure (BMVI) allocated approximately €66 million for innovative port technologies. According to the budget, €10.3 million is available for new grants in 2026 [22]. As such, the funding programme that started in 2016, is considered a great success because of its focus on digitalization and innovative technologies, such as the use of AI, while maintaining a high degree of practical relevance [48]. The success is noticeable by the contribution of application to the channeled and supported projects. There are many projects ready for implementation that have to be rejected because the funding volume is insufficient. In this case, the funding program can be considered effective, as the existing incentives are sufficient to generate strong demand from companies, in contrast to the challenges outlined in the previous chapter. One concrete example is the project DigiTank, which focuses on digitizing and modernizing tank terminal operations in ports. Its main goals are to improve safety, efficiency, sustainability, and working conditions in handling liquid and gaseous substances [49].

4.2.2 Sustainable Transport Investment Plan

The most current investment plan from the EU is the Sustainable Transport Investment Plan (STIP). To meet the fuel targets set out in the ReFuelEU Aviation [50] and FuelEU Maritime [51] regulations, around 20 million tons of sustainable alternative fuels will be needed by 2035. This is why the European Union published its STIP in November 2025. The EU wants to put measures in place for at least €2.9 billion by the end of 2027 [13]:

- Key investment barriers are to be removed and the financial gap in the short-term is to be bridged, InvestEU will mobilise at least €2 billion for sustainable alternative fuels until 2027.
- The Commission will propose €300 million by end of this year to support the production of hydrogen for sustainable aviation (SAF) and maritime (SMF) fuels through the European Hydrogen Bank.

- The Commission will support R&I projects with around €133 million under Horizon Europe.
- The Commission will mobilise €153 million for synthetic aviation fuel projects and €293 million for maritime fuel projects under the Innovation Fund.

It remains to be seen whether the funds will be used as efficiently as in the examples described above. Nevertheless, it should be noted that the EU is clearly committed to sustainability and has explicitly recognised the needs of the maritime sector.

5 Learnings

Overall, there is a need for the harmonization in the regulation of handling and storing H_2-derivatives in European ports. In addition to the fragmented regulations in ports, significant regulatory gaps persist regarding the bunkering of these substances. There is currently still a great deal of uncertainty on both sides. Although methanol and ammonia are considered as alternative fuels of the future, it remains unclear when they will reach large-scale deployment, which is also influenced by the geopolitical situation, e.g., the recent postponement of the IMO's Net Zero Framework due to pressure from the US. In the past, it has been shown that new standards are always met with resistance at first, and clear incentives and effective regulations are needed to facilitate the transition and make it more attractive. It can be said that methanol has already made a breakthrough in practice, which is also reflected in the regulations, while ammonia is still lagging behind, but neither substance has yet reached the market scale that is desirable to meet the climate neutrality targets.

Regarding funding frameworks, the case of Rotterdam illustrates how a holistic strategy (EU, national, municipal, and private sources) together with strong political commitment, strengthening the pioneering role of the European port developments in shore power, H_2-derivative bunkering, and CCS. IHATEC stands out for its practical relevance and technology openness, despite high demand exceeding available funds, thanks to streamlined two-stage applications and focus on deployable innovations like DigiTank. Diverse financing, clear criteria, and political anchoring are the identified properties to drive measurable progress in H_2-derivatives and port decarbonization.

An important lever for progress in both areas is the systematic use of existing alliances and partnerships, combined with clearly defined shared objectives. Only in this way will it be possible to generate significant progress in the transition globally and establish a sustainable transformation in shipping. Another very important point, which is also closely related to the one just mentioned, is to eliminate competition between individual ports as far as possible, especially within unions such as the EU. Functioning regulations should not only be introduced nationally but also be made available and prepared at the European level so that they can be implemented in other countries without significant duplication of effort. This would greatly accelerate the ramp-up and also greatly simplify and standardize the regulations.

Currently, the approach is still very fragmented, with many countries now beginning to create regulations and, in most cases, implementing them only in individual ports. The bunkering procedures are almost exclusively special permits, which means that they require a great deal of regulatory effort to apply for and are still far from being standardized. There are already a lot of regulations and guidelines focusing on the handling of H_2-derivatives, but very few that include the port as a storage location.

6 Conclusion

In summary, it can be said that the ramp-up of H_2-derivatives in European ports is not being hindered by technical progress, but primarily by regulatory and structural problems. Fragmented regulations without transnational solutions and recurring geopolitical uncertainties repeatedly slow down the process, which could or should have been much further along by now. Not only are there more ships powered by methanol, but methanol also has a slight advantage over ammonia in terms of regulations.

The created manuals “Ammonia in Ports” and “Methanol in Ports” (see Annex) help by providing an overview of existing standards and best practices to facilitate the start for port facilities planning to use H_2-derivatives. These handbooks could serve as the foundation for developing a unified European guideline that comprehensively standardizes relevant regulations for H_2-derivatives. This guideline should cover both handling and bunkering operations, creating a flexible yet harmonized regulatory framework across Europe that drives efficiency gains and interoperability between member states.

If you look at existing funding programs, there are now a variety of options for obtaining support for the transformation, but in most cases the bureaucratic effort involved is disproportionate to the economic efficiency of these investments. In addition, the tenders often lack practical relevance, which means that the funds are not even paid out. However, positive examples also show that measurable progress can be achieved through diversified financing, clearly defined and practical criteria, and political commitment.

Europe has reached a point where competition between ports and member states should be subordinated to the development of common standards wherever these generate mutual benefits. Only through consistent cooperation, shared responsibility, and political willingness can the transition to hydrogen-based shipping be made efficient, safe, and economically viable.

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8 Annex

8.1 Handbook: Key regulatory requirements for handling Ammonia in Ports

Interreg Baltic Sea Region

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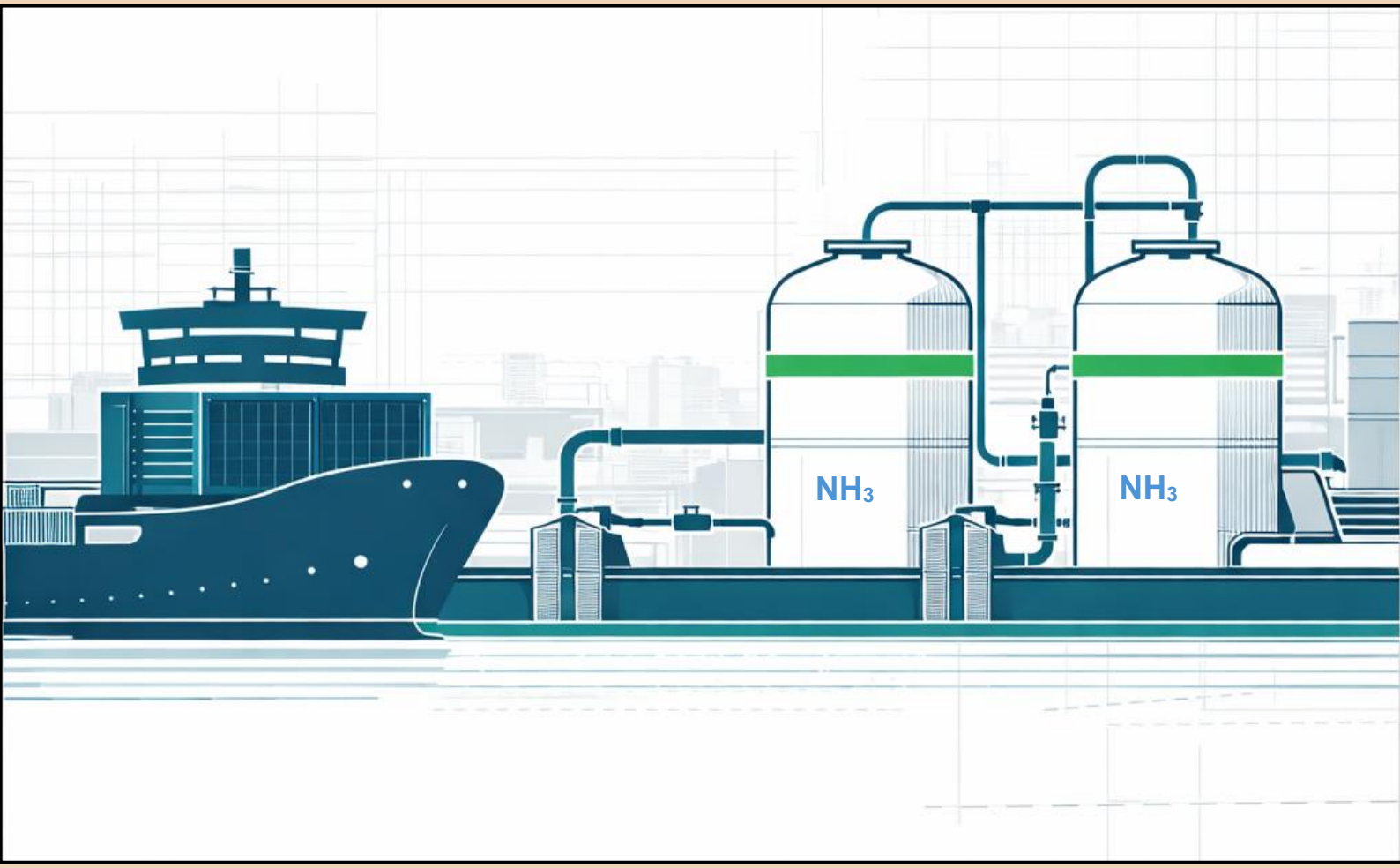
ENERGY TRANSITION H2Deri@BSP

AMMONIA IN PORTS

HANDBOOK



Author: Dr. Reiner Brüning

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proof-of concepts for the uptake of H_2-derivative fuels!

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Table of Contents

TABLE OF CONTENTS 28

1 INTRODUCTION 29

1.1 AMMONIA AS MARINE FUEL - ENABLING MARITIME DECARBONIZATION: 29
1.2 PURPOSE AND USE OF THE DOCUMENT 30
1.3 AMMONIA IN A NUTSHELL 30

2 REGULATORY MEASURES 32

2.1 SITE PLANNING AND INFRASTRUCTURE SAFETY 33
2.2 STORAGE TANK DESIGN AND CONSTRUCTION 37
2.3 SAFETY SYSTEMS AND INSTRUMENTATION 44
2.4 PRODUCT HANDLING AND TRANSFER SYSTEMS 49
2.5 OPERATIONAL PROCEDURES AND CONTROLS 57
2.6 DETECTION AND MONITORING SYSTEMS 66
2.7 INSPECTION, MAINTENANCE AND TESTING 70
2.8 EMERGENCY PREPAREDNESS AND RESPONSE 75
2.9 MODERN REQUIREMENTS 82

3 REFERENCES 86

4 ABBREVIATIONS AND ACRONYMS 88

1 Introduction

1.1 Ammonia as Marine Fuel - Enabling Maritime Decarbonization:

Shipping is the sixth largest CO_2 emitter worldwide, with CO_2 emissions of over 700 million tons per year, accounting for 3% of total global CO_2 emissions. In addition, the total amount of CO_2 emissions related to shipping is still rising (see Fig. 1). To initiate a transformation, alternative fuels are needed, and one of the most promising candidates, which can reduce emissions by up to 95% compared to fossil fuels, is ammonia. Once ammonia is produced from renewable sources such as green ammonia from green hydrogen and atmospheric nitrogen, it can be a nearly completely climate-neutral fuel – provided N_2O emissions are effectively controlled.

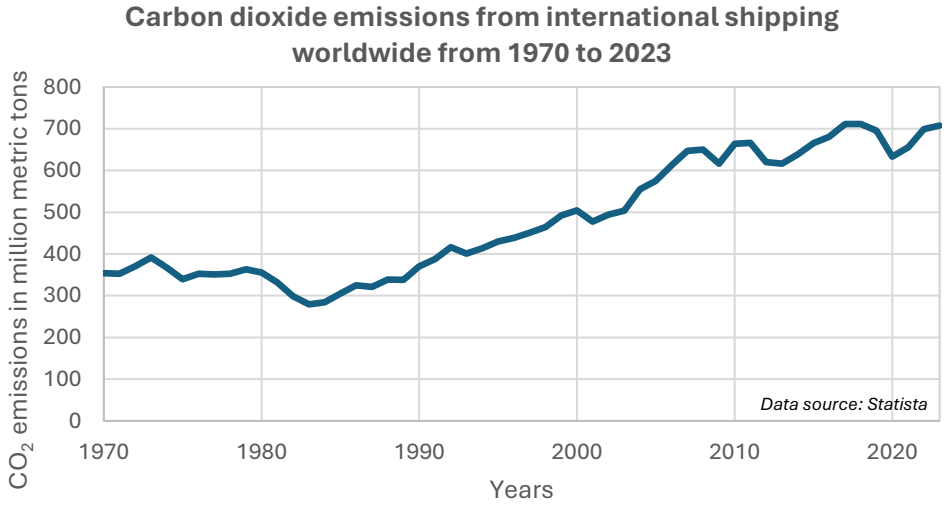

Fig. 1: Development of yearly CO_2 emissions by global shipping.

The development of ammonia-powered ships has been gaining momentum in recent years. As of February 2026, there are now almost 50 ammonia-compatible ships. Since ammonia is the basis for all nitrogen fertilizers and has global applications, there is already a lot of suitable production and transport infrastructure in place. Due to the push within the maritime industry to find suitable alternative fuels for shipping, ammonia will play a very important role in the coming decades.

1.2 Purpose and how to use the document

This manual serves as a guide for port authorities, terminal operators, and port companies planning to use or store ammonia within the port and providing an overview of relevant steps and international or European standards to be considered (e.g. Seveso-III, EN and best practices).

The handbook is divided into nine categories covering the installation of an ammonia storage facility, the handling of ammonia in the port area, and the protection of facilities against external influences. Since there are two types of storage forms for ammonia, the measures are divided into different groups. Measures for the storage in a pressure vessel are marked with a “P” and measures for the refrigerated storage of ammonia are marked with a “C”. If the measure is applicable to both storage forms, it is marked with a “C+P.” Additionally, all measure titles are color-coded: blue for „C“ measures, orange for „P“ measures, and black for „C+P“ measures. Even though converting an existing tank to an ammonia-compatible tank is not a very common practice, the document also contains instructions for converting these tanks. All relevant sections are marked in purple and are intended to provide a rough introduction to the necessary steps.

The regulatory framework emphasizes that the specific challenges involved in handling ammonia in ports, particularly due to its high toxicity, strong corrosive effect, and rapid vapor dispersion, require special knowledge and increased safety measures compared to conventional petroleum facilities. It is intended as a planning and compliance tool and does not replace the technical and detailed special requirements at individual port locations. In addition to this manual, users should identify applicable measures and consult the referenced standards for further details. Port facilities implementing ammonia operations should view this framework as a foundation for developing site-specific procedures and safety management systems that protect workers, the public, and the environment while enabling efficient and reliable fuel supply operations.

1.3 Ammonia in a nutshell

Under normal conditions, ammonia is a colorless gas with a pungent odor and requires special handling due to its unique properties:

- **Liquefaction:** Ammonia can be converted to the liquid state either by cooling (-33°C) or by applying low pressure (8-10 bar at 20°C). This means that cryogenic tanks or pressure tanks are required for compressed storage.
- **Toxicity:** Ammonia is highly toxic. Exposure to ammonia vapors can cause irritation and damage to the eyes, nose, throat, and lungs. At higher concentrations, ammonia can even be fatal. Also in low concentrations, the smell of ammonia is unpleasant and pungent to humans.
- **Corrosiveness:** High reactivity with copper, zinc, and carbon steel, which means that the use of stainless steel or other special coatings is essential. Reaction with water produces corrosive ammonium hydroxide solutions.
- **Flammability:** Due to its relatively narrow flammability range of 15-28% in air and high ignition energy, ammonia is less likely to ignite than hydrocarbons. If combustion does occur, however, toxic nitrogen oxides are produced.
- **Water solubility**: Ammonia is highly soluble in water, depending on temperature and partial pressure. Ammonia water poses a long-term hazard to aquatic organisms and their environment. Therefore, leakage or spillage of ammonia must be avoided under all circumstances, especially during transport by sea.
- **Vapor behavior**: Ammonia is lighter than air (vapor density of 0.6) and therefore rises very quickly, which can lead to dangerous air stratification, especially in enclosed spaces.

Due to these specific properties, the handling of ammonia requires adequate preventive safety measures and appropriate facilities to ensure safe and reliable operations within the port area.

2 Regulatory Measures

1 Site planning and infrastructure safety

Physical location, layout, access control, and basic infrastructure requirements

2 Storage Tank Design and Construction

Tank specifications, materials, structural requirements, and protection systems

3 Safety Systems and Instrumentation

Control systems, monitoring, protective devices, alarms, and safety instrumentation

4 Product Handling and Transfer Systems

Piping, loading/unloading equipment, material compatibility, and transfer operations

5 Operational Procedures and Controls

Operating procedures, training, process control, and quality management

6 Detection and Monitoring Systems

Gas detection, leak detection, environmental monitoring, and alarm systems

7 Inspection, Maintenance and Testing

Periodic inspection requirements, maintenance programs, and testing protocols

8 Emergency Preparedness and Response

Emergency plans, protective equipment, firefighting, and crisis management

9 Modern Requirements

Cybersecurity, climate resilience, physical security threats, and sustainability

2.1 Site Planning and Infrastructure Safety

Scope: Physical location, layout, access control, and basic infrastructure requirements

M1: Basic Safety (C+P)

- Regulatory Compliance: Adherence to all applicable national and international regulations governing hazardous materials storage and handling.
- Good Engineering Practice: Application of recognized codes and standards (EN, ISO) throughout facility lifecycle.
- Operational Discipline: Maintaining cleanliness, order, and systematic prevention of hazardous conditions through rigorous housekeeping protocols.
- Competent Workforce: All work performed by qualified, trained personnel with documented competencies for ammonia-specific hazards.
- Defense in Depth: Multiple independent barriers prevent minor incidents from escalating into major events.

Note: Ammonia is immediately dangerous to life or health (IDLH) at concentrations above 300 ppm. Facility planning must account for toxic cloud dispersion scenarios using tools such as ALOHA or PHAST.

M2: Site Selection and Collision Protection (C+P)

- The ammonia storage facility is positioned, considering vehicle speeds and traffic, to avoid collision risks.
- If safe placement is not possible, install a sufficiently shielding structure.
- Applicable throughout facility life, new and existing installations.

M3: Terrain Delineation and Accessibility (C+P)

- The facility area is secured against unauthorized entry (using fences, ditches, or building walls, e.g. height 1.8 m).
- Access gates/doors are locked after hours

BUT

- Ammonia storage facility must be accessible via at least two entrances for emergency services.
- Entrances are monitored when open; alternatives like camera surveillance may apply.
- Roads and paved areas are maintained for uninterrupted emergency access.
- Storage tanks, loading areas, and buildings must be reachable by at least two independent roads with clear access on at least two sides.
- Perimeter marked with hazard signage including GHS pictograms (H314 Corrosive, H331 Toxic, H400 Environmental) and “TOXIC GAS - CORROSIVE” warnings in local language(s) and English. (per ISO 7010)
- Wind direction indicators (wind socks) visible from all facility entrances and loading areas.

M4: Prevent Heat Radiation Load (C+P)

- Sufficient distance from buildings/structures with fire risks to keep ammonia facilities below 10 kW/m^2 heat radiation load.
- Additional measures (e.g. fireproofing, plant cooling) required if sufficient distance is not possible.

Note: While ammonia itself has limited flammability (flammable range 15-28% in air), facilities must be protected from external fire sources that could cause pressure vessel failure (Boiling Liquid Expanding Vapor Explosion, BLEVE) or compromise tank integrity.

M5: Distance to Above-Ground Stationary Pressure Storage (C+P)

- Maintain at least 150 m between ammonia storage tanks and any above-ground stationary pressure storage (>150 m^3) where BLEVE is a possible scenario.
- Assesses risks of projectiles from vessel explosions.

M6: Internal Safety Distances (C+P)

- Distances between the ammonia facility and buildings must comply with e.g. EIGA Doc 75/21; for toxic release.
- Maintain minimum 10 m between storm drains and loading/unloading areas to prevent ammonia ingress.

- Toxic dispersion modeling per ALOHA, PHAST, or equivalent methodology required for determining safety distances to occupied buildings.
- Control room and permanently occupied buildings equipped with positive pressure ventilation and ammonia detection at air intakes with automatic damper closure.
- Emergency assembly points located upwind (based on prevailing wind direction) and minimum 300 m from storage tanks.
- Hazardous Area Classification:
    - Facility areas where flammable ammonia-air mixtures may occur shall be classified according to EN 60079-10-1 or equivalent (e.g., NPR 7910).
    - Zone classification determines equipment requirements per ATEX 2014/34/EU.

Location	Typical Zone	Radius / Extent
Inside storage tank (vapor space)	Zone 0	Entire vapor space
Pressure relief valve discharge	Zone 1	3 m radius around outlet
Loading arm connections	Zone 1	1.5 m radius during operations
Pump seals and compressor seals	Zone 1	1 m radius
Flanged connections (outdoor)	Zone 2	1 m radius
General tank farm area	Zone 2 or non-hazardous	Based on ventilation assessment

Table 1: Typical zone classification for ammonia facilities

Note: These are typical classifications. Actual zone extents must be determined by qualified personnel based on site-specific assessment according to EN 60079-10-1.

M7: Loading and unloading area – distance from property boundary and public road (C+P)

- Minimum 15 m from property boundary/public road
- if boundary is water, reduction by water width (max 10 m).

M8: Tank truck loading and unloading area (C+P)

- Loading/unloading on designated site section, connected to process sewer (see also M70)
- Section of road is closed to other traffic by barriers or other suitable closure.
- Loading/unloading connections equipped with dry-break (dry-disconnect) couplings to minimize ammonia release during connection/disconnection operations.
- Excess flow valves installed on all liquid ammonia transfer lines to limit release in case of hose or connection failure.
- Breakaway couplings installed on loading arms to prevent catastrophic failure if vehicle moves during transfer.

M9: Tanker loading and unloading area – shielding from through traffic (C+P)

- Loading/unloading area on private road; if adjacent road <10 m, shield with guardrail/rampart (withstands traffic impact); min 2.5 m from adjacent road.
- Preferable to separate the loading by modality type.

M10: Loading and unloading bay railroad tank car (C+P)

- Loading/unloading on designated track section, connected to process sewer (M70), signaling/locking system to prevent entry during operation, derailment mechanisms.

M11: Loading and unloading area – marine and inland vessels (C+P)

- Loading/unloading only at place designated/permitted by port authority.
- More details to the bunkering process (see Baltic Ports Bunkering Guidebook in the Annex)

2.2 Storage Tank Design and Construction

Scope: Tank specifications, materials, structural requirements, and protection systems

M12: Design Standard (C)

- Tanks for refrigerated ammonia storage use the EN-14620 series, with certain stricter requirements (see following measures).
- Minimum design pressure is 100 mbar.
- Air-testing for leak-tightness of the external tank (see M122).

Note: Refrigerated ammonia is stored at -33°C at atmospheric pressure. Thermal stress during cooldown and warmup cycles is critical for tank integrity; maximum temperature change rate 1°C/hour for tanks >1,000 m^3.

M13: Form of Construction (C)

- Full containment tank required: inner and outer tank walls both designed to retain liquid; no penetrations except via the top (with few exceptions).
- Application of perlite as insulation is not permitted.
- Roof is welded and self-supporting.
- Full containment design must account for instantaneous release of entire inner tank contents (cold spill scenario with rapid vaporization).
- Secondary containment sized for 110% of largest tank volume plus freeboard for rainwater accumulation.

M14: Construction Material (C)

- **Material Requirements:**
  - Minimum yield strength: 215–355 MPa (EN 10028-3, table 4).
  - Permitted steel grades: P275NL2 and P355NL2.
  - Softer weld filler material is used, just above the sheet strength.
  - Weld hardness max.: 225 HV.

  - Use P275NL2 cold-resistant carbon steel as much as possible; P355NL2 may be used for specific parts needing higher yield strength.
- **Welding Requirements:**
  - In accordance with the relevant tank construction standard or EN-ISO 15614-1.
  - Welding method approval is part of the inspection/testing program (refers to M122, M123).
- All instrumentation in refrigerated ammonia service rated for cryogenic operation (minimum -40°C ambient rating).
- Safety-critical instruments installed in 2oo3 (two-out-of-three) voting configuration for high reliability and reduced spurious trip rate.
- Instrument impulse lines heat-traced where ammonia freezing or hydrate formation is possible.
  - Welders must be qualified to EN-ISO 9606 series.
- Prohibited materials in ammonia service: copper, brass, bronze, zinc, galvanized steel, and silver-containing alloys (ammonia forms corrosive metal-ammonia complexes).
- All pressure-containing welds subject to 100% volumetric examination (radiographic or ultrasonic testing per EN ISO 17636/EN ISO 17640).

Note: Ammonia causes stress corrosion cracking (SCC) in carbon steel under specific conditions. Water content in ammonia must be maintained at 0.2-0.5 wt% to inhibit SCC.

M15: Concrete Protective Wall (C)

- The tank must be equipped with a concrete protective wall nearly as high as the tank, connecting to the roof slope.
- The wall must resist:
  - Static pressure: 0.3 bar for 300 ms.
  - Projectile/fragment impact: e.g., 150 kg valve at 50 m/s; 200 kg object at 100 m/s.
  - Heat radiation load: 10 kW/m^2 from external fire scenarios.
- Manholes for inspection are allowed in this wall if they are also resistant to these loads.

M16: Foundation Design (C)

- Tank and concrete wall must be on an elevated pile foundation transferring all loads to suitable base soil.

- Design complies with EN-14620-1:2024 section 7.1.10.
- Free space under the tank: ≥1.60 m for new, ≥1.00 m for existing tanks (for ventilation and inspection).

M17: Lock Pump Housing (C)

- Pump housing design: Equipped with a lock (sluice) to prevent ammonia release during maintenance.
- The lock can be flushed with nitrogen and equipped with a presence sensor to detect the pump.

M18: Lifting Installation (C)

- Tank is fitted with a fixed lifting device on the roof for pulling internal pumps vertically out.
- The hoist allows horizontal movement over the tank edge for safe lowering.
- Built so that tank integrity remains even if load is accidentally released.

M19: Cool down upon commissioning (C)

- A piping system with nozzles is provided for cooling the storage tank to achieve complete evaporation and/or distribution of the liquid ammonia.
- This cooling system is designed to meet specified cooling rates (linked to M79).
- The cooling line is typically an atomizer-equipped ring installed at the top of the vapor space inside the tank.

M20: Capacity and redundancy BOG processing system under atmospheric storage (C)

- The Boil-Off Gas (BOG) processing system must be redundant: during compressor maintenance or failure, at least one additional compressor is available (requirement is a minimum of three compressors in practice).
- Each compressor's minimum required capacity matches the needs for boil-off gas in a static storage situation and during possible inflow (e.g., stopped loading).
- If BOG processing is insufficient, filling (loading) of the storage tank must be stopped automatically.
- The BOG system includes both compressor(s) and a refrigeration unit, returning condensed ammonia to storage.

M21: Emergency power supply BOG processing system during atmospheric storage (C)

- The BOG processing system must have a secondary power supply (e.g., internal generator or emergency power unit).
- Emergency/secondary power must allow operation of at least one compressor at required minimum capacity.
- An uninterruptible power supply (UPS) is provided for control systems, with sufficient battery capacity (to last until emergency power activates or at least 1 hour for internal generation).
- Monthly tests must prove operability of the UPS and emergency systems; full system functionality is tested annually.

M22: Drainage of inerts from BOG processing system (C)

- All expected emissions (inerts and ammonia) from the BOG processing system are handled by a vapor processing plant.
- A vent flare is not considered a mitigation system: inerts are purged and processed, not simply vented.

M23: Location of connections (C)

- All tanks' connections (inlets, outlets, vapor discharge, safety/instruments) are installed at the top of the atmospheric storage tank.
- Only penetrations for inspection robots into the annular space are allowed through the secondary steel wall, and only above maximum liquid level.
- Two manholes in the secondary wall are permitted for access during construction/maintenance, which must be welded closed and heat-treated after use.
- For existing double-containment tanks, outlets and maintenance manholes through wall/bottom are allowed.

M24: Drain connections (C)

- Up to four drains are allowed through the floor or wall in the annular space between primary and secondary containment to drain condensate.
- Drain connections must be robust: not larger than DN 100 (4 inches), not smaller than DN 50 (2 inches).

- Valves with lockable closed position are installed for maintenance and testing on instrumentation lines in the drains.
- For existing double-containment tanks, DN 200 (8 inches) drains through the secondary containment wall/bottom are permitted.

M25: Maximum number and capacity (P)

- Limit to two ammonia pressure storage tanks per site, each max. 1,000 tons.
- For existing situations, and when replacing existing pressurized storage tanks, more than two pressurized storage tanks may be present with a total maximum of 2,000 tons.
- Exceptions possible for large Seveso sites with hydrogen backbone, after authority consultation.

M26: Design criteria (P)

- Design tanks for full vacuum, pressure resistance of up to 20 bar, and temperatures from –33°C to +50°C.
- Horizontal tanks: Max. two support points to reduce stress.
- Existing tanks with lower design values require additional safeguards (e.g., cooling, instrumentation).

M27: Dedicated installation (P)

- Entire pressurized ammonia storage, including piping and accessories, must be dedicated to ammonia (no mixing with other substances except water content adjustment).

M28: Construction material (P)

- Steel with minimum yield strength 215–355 MPa (P275NL2 or P355NL2).
- Weld filler marginally stronger than base material; hardness ≤ 225 HV.
- Welding performed according to EN 14620-2 standards by certified welders (EN-ISO 9606).
- Post-weld heat treatment (PWHT) mandatory for all welds.
- Stainless steel only if proven resistant to SCC.
- Existing tanks: Material properties must be verifiable by certificates. If unavailable, risk-based inspection required.

M29: Low-stress annealing / Post Weld Heat Treatment (P)

- New tanks must undergo full PWHT.
- No welded mounting fittings inside tank; allowed externally.
- All penetrations post-weld treated.
- Existing tanks exempt.

M30: Safety wall (P)

- Install safety wall at least 1 m above tank's highest point to protect against jet spray and horizontal discharge.
- Wall and floor form liquid-tight containment for ammonia leaks.
- Wall must resist: static pressure (0.3 bar, 300 ms), impact of heavy fragments/projectiles (e.g., 150 kg valve at 50 m/s, 0.25 m^2 impact area), and heat radiation of 10 kW/m^2 from surrounding fires.
- Penetrations below max liquid level must be liquid-tight and cold-resistant.
- New builds: At least two escape routes. Existing: May deviate based on risk assessment.
- Manholes/doors allowed if meeting protection criteria.

M31: Finishing and insulation (P)

- Thermal insulation must be non-combustible (EN ISO 1182) and not promote fire spread (EN 13501-1).

M32: Construction form of existing atmospheric storage tanks (C)

- Existing tanks must be at least double-walled storage tanks (double containment).
- Both inner and outer tanks designed to contain the stored liquid and withstand cold shock in case of leaks.
- In case of inner tank failure, liquid remains within the structure; limited gaseous ammonia may be released.
- Penetrations through walls allowed only for pump suction line and drain line, protected from external impact.
- No other connections permitted up to max filling level unless welded manholes or nozzles for maintenance.

- Containment facility is provided for leakage scenarios considering pipe bursts and valve closing times.
- Roof is self-supporting and welded to inner tank wall.
- Use of perlite insulation is prohibited.

M33: Design foundation of existing atmospheric storage tanks (C)

- Existing tanks may have a heating system in the foundation to keep temperature above 0°C.
- Heating system should have redundancy so if one system fails, temperature control is maintained.
- Heating controlled by at least two temperature controllers monitoring bottom plate with alarms.
- Temperature controllers are monitored in the control panel and control room.

2.3 Safety Systems and Instrumentation

Scope: Control systems, monitoring, protective devices, alarms, and safety instrumentation

M34: Instrumentation and protection (C)

- Ensure the atmospheric storage tank and its associated systems have instrumentation and safeguards to guarantee safe and reliable commissioning, operation, decommissioning, and maintenance.
- Provide sufficient redundancy, particularly for pressure, temperature, and level measurement (duplicate level measurement by two independent methods), with readings displayed in the control room or to the operator.
- Maintain all instrumentation and safeguards during tank operation.
- Include a temperature measurement and pre-alarm on the supply line, with values visible to the operator.

M35: High-level protection (C)

- Install a high-level protection system in the storage tank, in addition to independent overfill protection (per M36 and M78).
    - Set a pre-alarm to activate at a level that provides at least 15 minutes to intervene before overfilling can occur.
- Independent high-high level switch (physically separate from primary level transmitter) triggers automatic pump shutdown and inlet valve closure.

M36: Instrumental safeguards (C)

- Equip the storage tank with independent instrument safeguards:
    - Overpressure protection with SIL 3 classification, stopping supply near the tank inlet (preferably with automatic stopping/tripping of loading), based on pressure measurement, set to prevent activation of pressure relief valves.
    - Overfill protection with at least SIL 2 classification, stopping supply near the tank inlet, based on level measurement.

  - Underpressure safety device (SIL 2), stopping discharge near the tank inlet (preferably with automatic stopping/tripping of discharge), set to prevent pressure relief valves from activating.
  - Backflow prevention to avoid hot ammonia flowing back into the tank, comprised of two check valves in series with periodic monitoring and an independent instrumented backflow preventer (SIL 2) that stops backflow if pumps fail.
- Safety Instrumented System (SIS) designed, installed, and maintained per IEC 61508/61511.
- Proof test intervals: SIL 3 systems tested minimum annually, SIL 2 systems tested minimum every 2 years.
- All SIS components designed for safe failure (fail-safe design: valves fail closed, alarms fail to alarm state).

M37: Pressure relief and pressure control valves (C)

- Equip the storage tank with the following safeguards for excess pressure:
  - A pressure regulating valve discharging to a flare installation (EN-ISO 25457 compliant), set to prevent outdoor air discharge activation; flare must have support gas, backup, and prevent oxygen backflow to the tank.
  - Pressure relief valves that discharge to the outside air at a safe location; valves must be of the 'pilot operated' type (EN-ISO 4126-4).
- Calculate the number of relief valves needed based on maximum expected pressure buildup.

M38: Design pressure relief and pressure control valves (C)

- Configure relief inlets to pass through the suspended roof to prevent cold vapors from entering the warm space between the outer and suspended roof during pressure relief.
  - This design ensures faster pressure relief and prevents damage to the hanging roof.

M39: Low pressure protection (C)

- An atmospheric storage tank is protected against a pressure lower than the minimum allowable operating pressure using vacuum relief valves.
- The vacuum relief valves are of the weight-loaded type.

- The number of vacuum relief valves required is calculated based on the total air inflow and the specified set point values, as per EN-ISO 28300.

M40: Redundancy due to maintenance (C)

- In addition to M37 (overpressure protection) and M39 (vacuum protection), at least one additional overpressure and one additional underpressure relief valve must be installed for maintenance and inspection.
- The valves associated with the pressure relief valves are interlocked so that only one safety can be removed at any given time. A change-over valve can be used, which prevents more than one connection being closed simultaneously during maintenance.

M41: Preventing outflow (C)

- For existing tanks using external pumps to limit outflow, several valves are installed in the annular space:
  - Hand valve placed against the primary tank wall.
  - Automatic safety valve (ESD valve) placed after manual valve.
  - Additional automatic safety valve (ESD valve) shortly after penetration through concrete outer wall.
- These valves allow inspection and maintenance and provide safety via pipe burst detection.
- Gas detection combined with camera monitoring is used to trigger emergency stops if leaks detected.

M42: Grounding and lightning protection (C)

- Effective lightning protection must be provided for the storage tank.
- Both the inner and outer tanks must be earthed using grounding electrodes with a dispersion resistance not exceeding 2.5 Ohms.
- Earthing points are evenly distributed along the tank perimeter (max. 20 m apart) and made of the same material as the tank wall.
- Stainless steel is used for electrode connections; copper parts require additional protection against ammonia degradation.
- Earthing must comply with EN-IEC 62305-3.

M43: Instrumentation and protection systems (P)

- Provide reliable, redundant instrumentation for pressure, oxygen, temperature, and level (two independent level methods).
- Measurements must be visible in control room or operator station.
- Supply line: Temperature measurement with pre-alarm visible to operator.
- Existing tanks may be exempt from structural modifications for temperature sensors.
- Oxygen measurement not required for stainless steel tanks.

M44: High-level protection (P)

- Install high-level pre-alarm activating before independent overfill protection triggers.

M45: Instrumental safeguards (P)

- Independent overpressure protection (SIL 1): Stops supply at tank inlet, pressure-based.
- Independent overfill protection (SIL 2): Stops supply at tank inlet, level-based.
- Exceptions if continuous gas discharge mitigates consequences (SIL/LOPA study required).
- Applies to both new and existing installations.

M46: Pressure relief valves (P)

- Equip tanks with pressure relief valves discharging to safe location, preferably to ammonia gas processing network, not atmosphere.

M47: Redundancy for maintenance (P)

- Install at least one redundant pressure relief valve for maintenance; ensures continuous protection.
- Valves interlocked so only one can be removed/isolated at a time (use change-over valves if needed).

M48: Grounding and lightning protection (P)

- Effective lightning protection according to location risk.

- Grounding electrodes with earth dispersion resistance ≤2.5 Ohms; connection parts stainless steel (copper protected if used).
- Earthing points distributed ≤20 m apart.
- Earthing in accordance with EN-IEC 62305-3.
    - Risk analysis determines required protection class (EN-IEC 62305 series).

2.4 Product Handling and Transfer Systems

Scope: Piping, loading/unloading equipment, material compatibility, and transfer operations

M49: Prohibition of threaded connections (C+P)

- Threaded connections are prohibited in the primary containment system.
- Instrumentation may have threaded connections (max 20 mm) only if a flanged or welded valve is installed between instrumentation and primary system.
- For existing pressure storage tanks with threaded connections, risks are addressed via Risk Based Inspection (RBI).

M50: Location of connections tank (P)

- All connections of pressure storage tanks are made through the top (inlets, outlets, vapor discharge, safety devices, instruments).
- An exception is a bottom outlet for liquid discharge and a drain is permitted.
- All filler connections have check valves unless other devices provide equivalent safety.
- Take-off lines ≤ 20 tons/hour have flow restrictors or safety devices near the tank.
- All connections have hand valves for maintenance, except for instruments penetrating the tank.
- For existing tanks, installing oxygen or temperature measurement nozzles can be done via manholes if needed.

M51: Material of product lines (C+P)

- Pipes, valves and fittings transporting ammonia shall be resistant to ammonia:
  - Cold-resistant carbon steel pipes are kept between -33°C and -12°C by circulating liquid ammonia continuously, except during maintenance;
  - Stainless steel piping allowed between -33°C to ambient temperature, at least RVS 316L for uninsulated pipes or 304L for insulated pipes with vapor barrier.

- Coatings are applied to prevent external corrosion; corrosion under insulation (CUI) is prevented by avoiding temperature cycling.

M52: Segmentation of ammonia pipelines (C+P)

- Segmentation limits for overhead ammonia pipes depend on diameter:
  - ≤ 10": max segment length 1000 m
  - >10": diameters have shorter max segment lengths as per table

Nominal Pipe Diameter	DN (mm)	Max. Segment Length	Max. Segment Volume
≤ 10"	≤ DN 250	1,000 m	50 m^3
12"	DN 300	700 m	50 m^3
14"	DN 350	520 m	50 m^3
16"	DN 400	400 m	50 m^3
18"	DN 450	315 m	50 m^3
20"	DN 500	255 m	50 m^3
24"	DN 600	175 m	50 m^3
> 24"	> DN 600	Based on 50 m^3 limit	50 m^3

Table 2: Maximum Segment Length for Overhead Ammonia Pipelines

Note: Maximum segment volume of 50 m^3 is the governing criterion for larger diameters.

- Segmentation methods include: remote-controlled shut-off valves and gas locks >3 m high (only for cold ammonia pipes).
- Gas locks accumulate gas to form break points that prevent liquid flowing out of pipeline segments.
- Isolation valves or powered shut-off valves are recommended at site or plant boundaries and at pipeline elevations exceeding gas lock limits.

M53: Pressure relief product lines (C)

- Product lines that can be blocked have thermal relief valves (TRVs) venting without release to atmosphere.

- If fire is a scenario, an additional or second TRV with slightly higher set pressure may be installed for fire protection.

M54: Leak detection system for product lines (C+P)

- Product lines with design flow ≥ 20 t/h must have leak detection installed.
- System must automatically detect leaks, stop pumps, and isolate the affected line.
- Use mass flow measurement (in/out) plus at least one additional method: acoustic, fiber optic thermal, infrared, vibration, or local/site gas detection.
- Beware: Vapor bubbles in ammonia lines may cause false alarms; lines must be pressurized or cooled before measurement starts.

M55: Location of product lines (C)

- Lay product lines in gutters with rainwater drainage where possible.
- Where gutters are not feasible (e.g., pipes on scaffolds), provide separate collection at loading arms.
- If product lines share gutters with flammable hydrocarbon lines, take additional measures to exclude heat radiation (M4).
- New builds: Prefer separate routing; existing sites: supplementary cooling or thermal relief valves if separation not possible.

M56: Location of connections (P)

- All connections (inlets, outlets, vapor discharge, safety devices, instruments) made through the top of the pressure storage tank.
- Exception: bottom outlet allowed for complete liquid ammonia discharge and drain (see M57).
- All filler connections have a check valve (or equivalent protection).
- Take-off lines ≤20 t/h: flow restrictor or instrumental safety device directly at/in the pressure storage tank.
- All connections: at least one hand valve for maintenance; exceptions for instrument penetrations (e.g., temperature tapes).

M57: Drain connections (P)

- Complete emptying: drain through tank bottom permitted for new tanks (max DN50, robust, sealed with valve + blind plate).
- Existing tanks: larger drains possible (max DN200).

M58: Preventing liquid outflow (P)

- For liquid ammonia discharge: at least one hand valve at tank wall; two automatic safety valves, e.g. emergency shutdown (ESD) valves, after hand valve, first ESD valve as close as possible inside safety wall.
- ESD valves automatically close by a line break or pressure drop in discharge line is detected, triggered by the safety control system (SIL 2 according to EN-IEC 61508/61511 standards) to quickly stop flow and prevent any liquid release.
- Additional: gas detection as alarm with camera for manual ESD activation.

M59: Emergency Shutdown at Pressure Tank Inlet (P)

In addition to M58 an automatic inlet ESD valve must be installed to prevent uncontrolled pressure or temperature buildup:

- Location: On the main ammonia supply line at or within 2 meters of the tank inlet
- Trigger conditions: Automatically closes when:
  - Pressure exceeds design pressure + 10% (SIL 2 transmitter-based)
  - Temperature rises above max. design temperature (SIL 2)
  - Overfill condition detected (level sensor, SIL 2)
- Design: Pilot-operated solenoid-controlled, normally closed (fail-safe)
- Backup: Manual block valve upstream; one additional relief valve remains active during maintenance
- Testing: Annual functionality test; response time ≤200 ms documented

M60: (Emergency) provision emptying containment facility of safety wall (P)

- For jet spray scenario: penetration through bottom of safety wall (max DN100) for emergency liquid ammonia discharge; valve + blind plate; pumps/hoses on site for transfer.
- Rainwater drainage: separate drain, closed by default, opened only after visual/pH check.
- Emergency plan (M130) defines handling of collected ammonia.

M61: Pressure relief product lines at pressure storage (P)

- Blocked-in product lines equipped with non-atmospheric thermal relief valves (TRVs).
- If fire is a credible scenario: TRV capacity explained for this purpose, or second TRV with higher set pressure for fire scenario.

M62: Location of product lines at pressure storage (P)

- Product + flammable lines in same gutter: additional measures against heat radiation (see M4).
- Product lines identification per ISO 20560
- If separation not possible in existing infrastructure: additional cooling or thermal relief valves for fire scenario.

M63: Safe loading/unloading facility design (C+P)

- Loading/unloading system designed to minimize human error during coupling/uncoupling and loading.
- Examples: different vapor/liquid connections, dedicated system.

M64: Loading installation – connection of loading arms (C)

- Only fixed loading arms for liquid; hoses allowed for vapor return.
- Remote-controlled valves as close as possible to loading arm connection; check valve for loading to higher-pressure transport.
- Loading arm ends: valves + emergency break coupling; vapor space of transport not in communication with storage tank (vapors to separate vapor treatment).
- Draining facility at loading/unloading site; no draining with hot ammonia gas from ship after cold loading.
- Nitrogen flush for inerting before loading.
- Ship loading arms: remote-controlled quick-connect/disconnect (QC/DC), mechanically protected against unintentional opening; foot valve (product valve) as close as possible to loading arm.

M65: Loading installation – connection of loading arms at pressure storage (P)

- Only fixed loading arms for liquid; hoses allowed for vapor return.
- Remote-controlled valves as close as possible to loading arm connection; backflow preventer for loading to higher-pressure transport.
- Loading arm ends: valves + emergency break coupling; vapor space of transport not in communication with storage tank during loading; during unloading, vapor connection allowed if backflow preventer present.
- Vapors from transport to separate vapor treatment, not BOG system.
- Gas detector in discharge line stops unloading if gas detected.
- Draining facility at loading/unloading site; no draining with hot ammonia gas from ship after cold loading.
- Nitrogen flush for inerting; piping not under ammonia conditions inertized.
- Ship loading arms: remote-controlled QC/DC, mechanically protected against unintentional opening; foot valve (product valve) as close as possible.
- Existing facilities using hoses in transition period: depressurize by releasing vapors to vapor treatment; do not purge with nitrogen or air.

M66: Loading and unloading lines (C+P)

- Lines resistant to maximum pressure and thermal expansion.
- All ammonia piping color-coded per ISO 14726 or local equivalent: typically yellow base with “AMMONIA - TOXIC” labels at maximum 3-meter intervals.
- Flow direction arrows displayed at all valves and branch connections.
- Piping identification includes: product name, hazard class, flow direction, maximum operating pressure, and emergency contact information.

M67: Loading installation marine and inland vessels – emergency break coupling (C+P)

- Emergency break coupling disengagement (or excessive deflection/drift): automatic close of remote safety valves + stop loading.
- Pre-alarm and second alarm ensure flow stops before break coupling disengages.
- DN150+ ship loading arms: hydraulic emergency break coupling.
- All travel distances included in envelope calculation (terminal specification, M74).

M68: Loading installation tank cars/rail tank cars – loading and unloading arms (C+P)

- Loading/unloading arms include: gland connections, balanced suspension, locking system, cut-off, separate liquid/gas arms, drainage, stowed position switch, flow restrictor (≤150% nominal, or safety valve on overcapacity), emergency break coupling (<1 kg ammonia loss in incident).
- Optional: connection check instrument, emergency release, filter.

M69: Loading and unloading area – roadway protection (C+P)

- Technical devices prevent tanker/rail tank car from moving away while connected.
- Mechanical handling equipment for rail cars locked to loading/unloading equipment.

M70: Tank car/rail tank car loading and unloading area – 'containment' (C+P)

- Secondary containment for spill prevention: weighbridge basement, sloped/raised-edge sewer, or other system; prevent mixing with water.
- Containment size based on spill scenario (type, cause, location, outflow rate, pressure, response time, % flash, calculation).

M71: Material of fittings (C+P)

- All materials used in fittings resistant to ammonia.
- Copper, silver, zinc, and their alloys prohibited.
- Contact between mercury and ammonia not allowed.

M72: Design of fittings and gaskets (C+P)

- All fittings pre-checked for suitable ammonia-resistant materials.
- All valves pretested for leak tightness with helium test (EN-ISO 15848).
- Only closed pumps without mechanical seals used; mechanical seals with leak detection allowed for compressors.
- Gaskets non-explosive and low emission (e.g., spiral wound with solid outer ring).

M73: Fire-tested valves (C+P)

- Valves exposed to heat load >10 kW/m^2 must be fire tested.

- Manufacturer's certificate demonstrating compliance required.

2.5 Operational Procedures and Controls

Scope: Operating procedures, training, process control, and quality management

M74: Terminal Specification (C+P)

- The terminal specification consists of detailed documentation on storage and transport modes within the hazardous substances storage and handling area.
- It covers: connection and transport requirements, pressure and temperature limits, inert and water content requirements, geometry, load rates, pump pressures, connection details, Material compatibility requirements, Emergency shutdown procedures and systems, Vapor handling and recovery systems, Refrigeration system specifications (for atmospheric tanks), Safety instrumentation requirements (alarms, sensors, interlocks), Sampling and quality control procedures, Grounding and bonding requirements, Communication protocols during loading/unloading, Environmental monitoring requirements, Personnel qualification and training requirements
- Also includes requirements for restraint systems, calculations/drawings for loading arm reach, and operational details related to ensuring safe loading/unloading.
- For pressure tanks, the maximum received temperature is limited to 80% of the temperature corresponding to the design pressure.
- For atmospheric tanks, the maximum temperature to be received is set by the tank's design minus additional safety margins.

M75: Addressing safeguards and operating outside design conditions (C)

- When safeguards such as those in M35, M36, M37, and M39 are activated (triggered), this is treated as an undesirable event and recorded and analyzed (incident investigation into cause, effect, and preventive measures).
- Any operation outside the tank's design conditions is similarly treated as an undesirable event, analyzed, and approved by an independent expert for ammonia storage tanks.

M76: Addressing safeguards and operating outside design conditions (P)

- Activating safeguards (e.g., M44, M45, M46) is considered an undesired event and must be recorded and analyzed.
- Any operation outside the specified tank design parameters must be documented and investigated as an adverse event. This includes identifying root causes, assessing impacts, and defining corrective and preventive measures. The investigation and its findings must be reviewed and approved by an accredited independent inspection body.

M77: Operational procedures (C)

- Maintain procedures for commissioning/decommissioning, all phases of normal operation (including testing, maintenance, inspection), action on deviations, maintenance during production.
- Procedures address (temporary) safety measures.
- Written operating procedures maintained at all operator stations covering: normal operations, startup/shutdown sequences, abnormal situation response, emergency procedures, and routine maintenance activities.
- Procedures reviewed and updated minimum annually and within 30 days after any incident, near-miss, or process change.
- Pre-startup safety review (PSSR) required before initial startup and after any modification or extended shutdown (>30 days).

M78: Control of storage conditions (C)

- Continuously monitor pressure, temperature, and level in atmospheric storage tank.
- Settings allow intervention before overfill or overpressure protections trigger.

M79: Operational procedures for commissioning and decommissioning atmospheric storage (C)

- Before commissioning: tank and lines cleaned, dewatered, flushed with nitrogen until O_2 <4%, then with ammonia until O_2 <0.5%.
- Cooling filled by controlled ammonia supply, bottom temp decreased at <1°C/hour to –33°C.

- Ammonia analyzed for water content (≥0.2 wt%, <0.5 wt%) within 1 week after filling.
- Decommissioning: empty as far as possible, slowly evaporate remaining ammonia (<1°C/hr), flush with nitrogen then air.

M80: Water content (C)

- Water content in ammonia storage must be at least 0.2 wt% and lower than 0.5 wt%
- A certain water content is required in ammonia to prevent stress corrosion cracking and to protect storage tank integrity.
- Checked at least 24 hours after filling via sample from circulating pump.

M81: Prevent/reduce oxygen entry (C)

- Nitrogen for purging contains <5 ppm O_2.
- Limit entry of inerts, prevent ammonia return to tank during product loading.
- BOG compressor suction equipped with vacuum relief device.
- Oxygen content measured monthly and after maintenance.

M82: Operational controls (C)

- Visual leak inspection on all plant components related to atmospheric storage at least every 8 hours.

M83: Lifting operations (C+P)

- Procedure for lifting/hoisting above ammonia-carrying parts: no hoisting unless part emptied and depressurized, unless risk analysis demonstrates sufficient protection.
- Risk analysis includes:
  - minimum lift height
  - double securing of load
  - load suitability
  - infrastructure protection
  - lifting supervisor in radio contact
  - operations limited to good visibility and wind (not above force
  - approved lifting plan

- o clear plant overview attached to permit.

M84: Modifications and repairs (C)

- Modifications and repairs to the ammonia storage facility require approval from an independent expert or accredited inspection body in accordance with national implementation of the EU Pressure Equipment Directive (PED 2014/68/EU).
- Requirement does not apply if the work concerns designated pressure equipment subject to separate national regulations for pressure equipment modifications.

M85: Training and education (C)

- Training program for all operational staff on the ammonia plant is in place.
- Mandatory training topics: process safety, ammonia release risks, hazardous process aspects, and procedures for commissioning/decommissioning.
- - Operator training curriculum includes: ammonia physical and chemical properties, toxicity and health effects including regulatory exposure limits (EU-OEL: 20 ppm 8-hour TWA, 50 ppm 15-minute STEL; IDLH 300 ppm per NIOSH), proper use of respiratory protection (Self-contained breathing apparatus (SCBA) and escape respirators), spill response procedures, first aid for ammonia exposure (eye/skin contact, inhalation), and emergency evacuation procedures.
- Refresher training conducted minimum annually with documented competency assessment (written test and practical demonstration).
- All personnel working in ammonia handling areas must complete facility-specific safety orientation before unescorted access is granted.
- Training records maintained for duration of employment plus minimum 5 years.

M86: Operational Control – Availability of Procedures and Instructions (C+P)

- Loading operations may only occur when written procedural documentation and work instructions are in place.
- These procedures must clearly state the conditions to be met during all phases of the loading operation.
- Applicability: All loading/unloading activities for both new and existing installations.

M87: Control Conditions Ammonia for Unloading (C)

- The unloading procedure must explain how incoming ammonia is tested and compared with the terminal's specification.
- Key tests include water content (wt%), temperature, and temperature/pressure ratio.
- Ammonia is not transferred to the storage tank if the temperature is higher than specification or if the water content is below 0.2 wt%. If the latter, steps must be taken (such as inline blending) to raise water content before filling.
- Deviations in the pressure/temperature ratio may indicate inert gases (e.g., nitrogen or oxygen); these must be removed before unloading.

M88: Procedure for Loading (C)

- Loading must follow internal, pre-established written procedures, covering:
  - Personal protective equipment (PPE) requirements.
  - Ensuring transport containers hold only ammonia or inert, non-flammable gases with compliant oxygen levels.
  - Verifying all pathways are appropriately routed for safe transfer.
  - Confirming there is sufficient space in the receiving tank to avoid overfilling.
  - Vapor returns must connect to a vapor treatment system.
  - Tankers must have proper grounding; loading cannot commence otherwise.
  - Use of a deadman's switch for tanker loading/unloading.
  - Automatic locks for railcar bottom valves.
  - Periodic checks for leaks and process progress during loading.

M89: Operational control – loading and unloading area general (C+P)

- Regular transshipment activities only take place at specially equipped and identifiable loading/unloading sites.
- As soon as a tank wagon or rail tank wagon is connected, the area is closed off with a physical blockade (e.g., barrier).
- No other vehicles (except ammonia transport) may be present at the site.

M90: Mooring of tankers (C+P)

- Tankers are moored to prevent excessive stress or damage to connected cables or loading arms during loading/unloading.

M91: Load and unload tank cars and rail tank cars – prevent runaway (C+P)

- During coupling/uncoupling or transshipment, tank cars/rail tank wagons are immobilized (e.g., with hand brakes, wheel chocks) to prevent movement.

M92: Operational control – supervision during loading (C+P)

- During loading, at least one trained company official is present at a safe location to intervene if necessary.
- During ship loading, a designated person is also on board to intervene; effective communication is ensured.
- Camera surveillance with gas detection is permitted as an alternative if immediate action is possible from the control room.

M93: Filling control during loading (C+P)

- For loading tank cars/rail tank cars, overfilling is prevented by two independent methods:
  - 1st method: Flow measurement stopping loading at calculated maximum.
  - 2nd method: Choice of vapor return with liquid detection, infrared camera for level, or weighbridge check.
- Both methods have a pre-alarm for early intervention and automatic stop for high-high alarm.

M94: Control of storage conditions (P)

- Continuously monitor pressure, temperature, oxygen content, and level in the tank.
- Settings are configured to allow timely action before safety devices are triggered.

M95: Operational procedure for commissioning and decommissioning (P)

- Commissioning: remove water/oil, leak test with nitrogen, flush with nitrogen (<0.5% O_2), flush ammonia gas, cool gradually with liquid ammonia, measure O_2 and remove if detected.

- Decommissioning: empty to minimum, evaporate remaining ammonia, verify tank is ammonia-free, flush with nitrogen (<2% NH_3), then air (>19% O_2), remove oil, collect/dispose emissions via vapor treatment.
- Similar steps for product lines.

M96: Training and education (P)

- Training/education for all staff involved covers: process safety, ammonia release risks, hazardous process steps (see M98), commissioning/decommissioning procedures (M95).

M97: Prevent/reduce oxygen amount tank (P)

- Nitrogen gas used to make the storage tank inert must have a very low oxygen content, < 5 ppm, to prevent any reactions that could cause corrosion or safety risks.
- During product loading, measures must be taken to prevent unwanted gases from entering the tank, and to avoid any ammonia gases from flowing back into the storage tank.

M98: Discharge of oxygen and inerts (P)

- Oxygen detected above the threshold is immediately purged via BOG or vapor processing plant.
- O_2 measurement has alarm/recording; continuous logbook is maintained.
- 250 ppm O_2 in gas phase = operation outside of design conditions (per M76).

M99: Discharge of oxygen and inerts (P)

- If oxygen is detected above the detection limit in a pressurized storage tank, it must be immediately removed via a BOG processing system or vapor processing plant.
- The oxygen measurement must be equipped with alarm and recording systems. A logbook is maintained to demonstrate continuous recording of oxygen content.
- If more than 250 ppm oxygen is detected in the gas phase of the pressurized storage tank, this is considered "operating outside design conditions" and must be documented and analyzed in accordance with relevant safety standards. The appropriate national authority or accredited inspection body must be notified as

required by the national implementation of the Seveso Directive (2012/18/EU) or equivalent regulations.

- For facilities with continuous gas discharge systems capable of effectively removing oxygen, immediate notification may not be required, provided that the oxygen removal system functions properly and oxygen levels return to acceptable levels within a defined timeframe.

M100: Contents and filling rate (P)

- Pressurized storage tanks are filled to a maximum of 80% by volume.
- A higher fill level is permitted only if the minimum filling temperature as stated in the table below is maintained and there is a functioning temperature safety device.

filling temperature [°C]	fill level [%]
-33	80,0
-30	80,5
-25	81,2
-20	82,0
-15	82,8
-10	83,6
-5	84,5
0	85,4
5	86,3
10	87,3
15	88,3
20	89,4
25	90,5
30	91,7
35	92,9
40	94,2
45	95,5
50	97,0

Table 3: Maximum fill level of pressure storage tanks at different filling temperatures

M101: Control conditions ammonia for unloading (P)

- The unloading procedure for pressure storage must specify that incoming ammonia is evaluated against the terminal specification (M74), which includes at least: water content (wt%), temperature, pressure/temperature ratio.
- Ammonia must not be transferred to the pressurized storage tank if the incoming temperature exceeds the terminal specification.
- The pressure/temperature ratio must agree with the ammonia vapor pressure curve; if there is a deviation (indicating inerts/oxygen), these are removed before transfer, usually through a vapor processing plant.

M102: Procedure for loading (P)

- Loading is conducted only according to written, internal procedures addressing at least:
  - Proper PPE and escape masks where necessary;
  - Means of transport contains only ammonia or nitrogen or a non-flammable/inert gas with allowed oxygen content;
  - Equipment is arranged to ensure product flow only to intended place before pumping begins;
  - Sufficient free space in the receiving containment is confirmed and overfilling prevented;
  - Vapor return, if used, is connected to a vapor handling facility or protected by a backflow preventer;
  - Demonstrable effective grounding for tankers, with loading not started unless grounding is verified;
  - Use of deadman's switch by the driver during loading/unloading;
  - Automatic locking system engaged on bottom valve of rail tank cars;
  - Regular checks for leaks and loading progress.

M103: Temperature protection (P)

- The temperature of ammonia introduced into the pressure storage tank does not exceed the maximum temperature stated in the terminal specification.

2.6 Detection and Monitoring Systems

Scope: Gas detection, leak detection, environmental monitoring, and alarm systems

M104: Overflow and leak detection (C)

- No overflow is allowed on atmospheric storage tanks.
- The annular space (between inner and outer tanks) must have detection systems with alarms to identify both condensate and liquid ammonia presence.
- When liquid is detected in this space, it must be immediately removed using a specific device described in M24.

M105: Loading and unloading bay – alarm system (C+P)

- Audible/visual alarm operable from multiple positions.
- Ammonia gas detector (M111) stops loading on leak detection.

M106: Loading and unloading bay – emergency stop (C+P)

- Remote-controlled shut-off/ESD valves also closable from supervised location + ≥2 safe positions; preferably near escape routes.

M107: Overflow protection flash vessel (C+P)

- Independent SIL 1 overfill protection on flash vessel for cooling hot ammonia; stops supply, prevents liquid entering gas outlet.

M108: Version heat exchanger for heating liquid ammonia (C+P)

- Heat exchanger designed to prevent leakage to heating medium (e.g., double spiral exchanger).
- Intermediate medium recommended (e.g., ammonia).

M109: Instrumentation and protection for heat exchangers for heating liquid ammonia (C+P)

- Heat exchanger equipped with continuous temperature, pressure, and level monitoring.
- Overpressure protection present, with relief not discharging to the atmosphere.

M110: Heat exchanger leak detection system (C+P)

- Detection system installed to identify ammonia leakage into the intermediate medium.
- System also detects leakage from intermediate medium into heating medium.
- Detection method can be pressure, pH, or conductivity measurement, matching the medium.

M111: Continuously operating gas detection system (C+P)

- Ammonia gas detection system installed and active in all relevant facility locations.
- Minimum detection locations: annular space of double containment tanks, inside/outside safety wall of pressure tanks, compressors, flash vessel, heat exchanger, pumps, vapor processing plant, loading/unloading areas, control rooms, shelters.
- At loading/unloading: pre-alarm at 30 ppm, loading stops at 198 ppm.
- Number and position of detectors based on scenario analysis in Safety Design Dossier (SDD)

Note: According to the following norms: EN 50270, EN 50402 and IEC 62990-1

Self-Diagnostic and Testing Requirements:

- Each ammonia gas detector must have built-in self-diagnostic capability to detect hardware/sensor failures.
- Alarm must be raised (visual + audible) if detector fails or goes offline.
- At minimum, one automated bump test per detector per 24 hours.
- Fixed ammonia detectors installed at: tank dome connections, pump seals, compressor shaft seals, loading/unloading stations, control room HVAC air intakes, and facility boundaries (downwind based on prevailing wind).

- Detector specifications: measurement range 0-500 ppm minimum, response time T90 <30 seconds, accuracy ±10% of reading or ±5 ppm (whichever is greater).
- Alarm setpoints: Low alarm 25 ppm (investigate and ventilate), High alarm 50 ppm (evacuate non-essential personnel, prepare for emergency), High-high alarm 150 ppm (initiate emergency shutdown, full evacuation).
- Portable ammonia detectors available for maintenance personnel; units capable of detecting 0-100 ppm with audible/visual alarm using calibration gas (0.5% ammonia in nitrogen, ±10% accuracy).
- If bump test fails, detector must automatically switch to alarm state and notify operator.
- Fallback: Manual override available — if automated system fails, manual gas testing (portable detector) can be performed by qualified personnel within 4 hours.
- Failure to restore detector functionality within 24 hours requires: (a) activation of substitute detector at same location, or (b) operational restriction (e.g., no loading until detector restored).

M112: Safety Design Dossier for ammonia gas detection (C+P)

- Safety Design Dossier (SDD) for ammonia gas detection submitted to competent authority for approval.
- SDD must be positively assessed by accredited inspection body before approval.
- the SDD contains at least the following information:
    - The results of a scenario analysis showing the expected scenarios (nature and magnitude) for each installation/activity;
    - Where, given the scenario analysis, which substances are going to be detected;
    - The specification of the type of detector/detection principle;
    - the alarm values;
    - the intended actions and controls based on the alarm values;
- SDD describes scenarios, substances to detect, detector types, alarm levels, control actions, inspection, testing, maintenance.

M113: Implementation and inspection of ammonia gas detection per SDD (C+P)

- Gas detection systems built according to approved SDD.
- Independently inspected on delivery and at least annually by accredited type A inspection body.

- System not operated unless proven fully operational with positive inspection report.
- If SDD amended, resubmission and approval required before modification.

M114: Five-year assessment of the gas detection SDD (C+P)

- SDD should be reassessed every five years by accredited inspection body.
- Assessment includes differences in standards, new requirements; report available to competent authority.

2.7 Inspection, Maintenance and Testing

Scope: Periodic inspection requirements, maintenance programs, and testing protocols

M115: Inspection of fire water network and hydrants (C+P)

- The fire water network and all hydrants are visually inspected periodically.
- Functionality of hydrants, fire water monitors, stationary and semi-stationary water supply is tested at least annually.

M116: Testing of emergency power supply (C+P)

- The emergency power supply (used for critical safety systems) is tested monthly; full system (under load) is tested annually.

M117: Testing of stationary vapor dispersion prevention facilities (C+P)

- Stationary devices (e.g., water curtains, monitors) for vapor dispersion prevention are inspected every month and fully tested annually.

M118: Loading installation – periodic inspections (C+P)

- For good reliability, at least once a year, the condition of the loading and unloading installation is checked by:
  - Visual external inspection of pipes for external deterioration, correct location, and support.
  - Visual external inspection and reliability check of valves, instruments, and safeguards.

M119: Loading installation – recording of inspection results, modifications, and repairs (C+P)

- A record system shall be kept for all inspections, modifications, and repairs performed on the loading and unloading installation.
- The modification/repair data and the findings from tests, maintenance, and inspections are recorded in this system.

M120: Periodic inspection (C)

- Annually:
  - Visual inspection of the concrete wall for deterioration, damage, or loss of integrity.
  - Visual external inspection of pipes for deterioration, location, and support.
  - Visual external inspection and operability check of valves, instruments, and safeguards.
- Once every four to six years:
  - Visual inspection of the foundation.
  - If concrete corrosion is evident (discoloration, surface spalling >5 mm depth), reduce inspection interval to every 2 years.
- Concrete Corrosion Management:
  - Corrosion in ammonia environments is primarily due to nitrogen oxide formation. If corrosion rate exceeds 1 mm/year or structural integrity is questioned, engage structural engineer and competent authority for assessment.

M121: Independent Inspection Oversight and Reporting (C+P)

- All critical inspections needs to be conducted by an accredited Type A Inspection Body or independent expert qualified per applicable standards (EN-ISO 17020, PED, Seveso III).
- Inspection reports should be in line with national regulations.
- All reports must include minimum information:
  - Tank/Equipment identity (ID, materials, installation year, design specs)
  - Inspection date and interval since last inspection
  - Scope of inspection (methods, standards applied, areas covered)
  - Findings (defects, non-conformities, degradation, SCC evidence)
  - Corrective action plan with remediation timelines
  - Inspector certification and signature

- Critical defects (non-compliances affecting safety) must be reported to the competent authority within 24 hours. Plant operation must cease until defects are remedied and re-inspection confirms compliance.
- All inspection records and supporting documentation must be archived for minimum 10 years and remain accessible to the competent authority at all times.
- Annual Compliance Summary Report aggregating all inspection findings and corrective actions must be provided to the authority by year-end.

M122: Inspection and maintenance program (C)

- The ammonia storage facility and all installation parts are inspected and maintained according to an approved inspection and maintenance program.
- Approval comes from a designated inspection body or independent expert as appropriate.
- Documentation of inspections and maintenance is required before returning to service.

M123: Testing safety devices and instrumentation (C)

- Safety devices, including over/under-pressure protection, are tested at least annually or as per the inspection and maintenance program.
- Instrumentation (for example: level, pressure, temperature, oxygen content) is functionally tested annually to ensure correct function and alarm capability.

M124: Cooling facility and devices to prevent/limit vapor dispersion – control and maintenance (C)

- Inspection and maintenance of cooling and vapor containment facilities are conducted per documented maintenance plans and applicable technical standards.
- A records system of the inspections performed is established and maintained.
- Registration includes new construction, modifications, periodic inspections, maintenance, failures, and relevant safety events.

M125: Periodic inspection (P):

By performing periodic inspections, in addition to checking for leaks as described in M96, the reliability of the ammonia storage facility is monitored. The required periodic inspections are:

Annually:

- A visual inspection of the security wall for deterioration, damage, and maintenance of integrity;
- A visual inspection of the pressure storage tank support structure for deterioration, damage, and maintenance of integrity;
- A visual external inspection of the pipes to check for external deterioration, location, and support. For insulated piping, a visual inspection of the insulation is sufficient. The insulation shall be removed only in those places where it is necessary for conducting investigations or where, based on the visual external inspection, there is reason to do so;
- A visual external inspection and verification of the functionality of valves, instruments, and safeguards.

M126: Inspection and testing safeguards at pressure storage (P)

- Inspection and testing of safeguards are carried out at the pressure storage installation.
- The test frequency of instrumental safeguards (such as those referred to in M45 and M58) follows from the SIL verification.
- Ensure that all relevant safeguards are included in the testing program and that documentation of tests and results is maintained.

M127: Consideration of periodic inspection for pressure storage (P)

- The relevant environmental/Seveso permit of storing pressurized ammonia must ensure that, during the mandatory testing, maintenance, and inspection as required under the Pressure Equipment Directive (PED), the corrosion mechanism SCC is explicitly examined by the responsible inspector.
- All relevant failure mechanisms shall be determined and assessed using internationally recognized standards, such as EN 13445-5 (Damage Mechanisms Affecting Fixed Equipment in the Refining Industry), or equivalent national/international technical codes and standards.

M128: Loading equipment – checking for proper operation (C+P)

- The loading and unloading installation is periodically tested for operability of the valves and proper functioning of the alarm and security systems.
- When abnormalities are found, corrective action is taken immediately.
- Regularity is based on the frequencies recommended by the manufacturer.

M129: Inspection and maintenance program of existing ammonia storage facility in atmospheric storage (C)

- For parts of the facility covered by the Pressure Equipment Directive (PED), the inspection program must be reviewed and approved by a notified body or accredited inspection organization, in line with national implementations of the PED.
- For components not subject to the PED (such as atmospheric refrigerated ammonia storage tanks), the inspection program should be approved by an independent ammonia storage tank expert and the responsible national environmental authority.
- The independent expert must supervise or review all periodic and extraordinary inspections conducted.
- After maintenance or inspection with tank out of operation, recommissioning is only permitted with formal approval by an independent expert.
- For existing double containment atmospheric storage tanks, the interval for major in-service inspections should not exceed 12 years (or a shorter interval determined by a risk-based inspection (RBI) approach).
- In-service inspection must ensure accessibility (inspection ports, annular gaps, etc.) of all relevant welding seams, tank base and roof, as specified in recognized guidance.
- Out-of-service inspections should be carried out according to the intervals determined by RBI methodologies.
- If in-service NDT (e.g. robotic or remote inspection, pulse-echo, etc.) is not possible for specific areas due to obstacles, an out-of-service inspection of these areas shall be conducted at appropriate intervals.
- Robotic and non-destructive inspections (NDT) using state-of-the-art techniques are recommended to evaluate weld integrity and detect cracks (incl. SCC).

2.8 Emergency Preparedness and Response

Scope: Emergency plans, protective equipment, firefighting, and crisis management

M130: Emergency plan (C+P)

- The emergency plan, as required by the Seveso Directive and the national occupational health and safety legislation, shall include specific concerns for ammonia:
  - Exposure to ammonia in liquid and gaseous form.
  - Evacuation (at elevation and ground level).
  - Fire combined with toxic gas cloud from ammonia and emission of nitrogen oxides during fire.
  - Salvage and cleanup of an ammonia pool.
  - Procedure for managing a primary tank leak.
- The emergency plan must be submitted to the competent authority under the applicable environmental and major-accident legislation for approval.
- Emergency Response Plan includes toxic release scenarios with pre-calculated evacuation zones based on dispersion modeling for various release rates and weather conditions.
- Coordination procedures with local emergency services, hospitals (for ammonia exposure treatment), and neighboring facilities documented. Joint emergency exercises conducted minimum annually.
- Public notification procedures established for releases that may impact areas outside facility boundary.

Note: Large ammonia releases may require evacuation of areas up to 1.6 km downwind depending on release rate, duration, and atmospheric stability. Initial isolation zone minimum 100 m in all directions per ERG Guide 125 or equivalent European guidance (e.g., ERI-Cards, national emergency response guidelines).

M131: Work Platform Evacuation (C+P)

- The emergency plan must describe how to evacuate persons from work platforms on top of the tank.
- Fire department assistance (e.g., with high rescue vehicles) requires prior positive advice from the regional emergency management authority or Fire Department.

M132: Operating Installation in Emergency Situations (C+P)

- The ammonia storage installation must remain operable during emergencies for a limited time.
- Provisions must allow the plant to be secured safely within that limited time.

M133: Shelter Locations (C+P)

- A shelter-in-place must be present at loading/unloading sites, or PPE must be provided to reach a shelter or safe zone.
- Shelter must offer at least 8 hours of protection and comply with EEMUA Publication 186 or equivalent standards.

M134: Wind Bag or Wind Vane (C+P)

- A wind bag or wind vane must be installed near the ammonia storage component.
- It must be clearly visible in the dark.

M135: Loading and Unloading Area – Personal Protective Equipment (C+P)

- Breathing masks or full-face masks with ammonia filters and special clothing must be available near the loading/unloading area.
- Operators must wear this protective equipment when coupling or uncoupling transport connections.
- Sufficient escape masks must be present with unobstructed access.
- A frost-free safety shower with eye showers (compliant with EN 15154).
- Minimum PPE for routine ammonia operations: chemical splash goggles or face shield, ammonia-resistant gloves (butyl rubber minimum 0.35 mm thickness or neoprene), long-sleeved clothing, and safety footwear.

- Full-face air-purifying respirator with ammonia cartridge (minimum protection factor 50) required when ammonia concentration may exceed 20 ppm (EU-OEL) but remain below 300 ppm.
- SCBA with minimum 30-minute capacity required for: emergency response, concentrations exceeding 300 ppm or unknown, confined space entry, and any IDLH atmosphere.
- Emergency escape respirators (minimum 15-minute capacity, hood-type preferred) available within 15 meters of all ammonia handling areas; minimum one escape unit per two workers.
- Full chemical-resistant suit (Level B minimum) required for spill response and decontamination activities.
- A (15–37 °C) must be available at the loading/unloading bay.

M136: Fire Extinguisher at Loading/Unloading (C+P)

- At least one portable fire extinguisher (43A/233B) must be present at the loading/unloading bay.
- The extinguisher must meet EN 3-7 and be maintained according to EN
- It must be freely accessible and always ready for use.

M137: Vapor Dispersion Control During Loading (C+P)

- A stationary system, automatically activated by ammonia detection, must be installed at loading locations.
- If using a water curtain, it must fully enclose the site and meet a minimum capacity of TNC / V = 33 (Total Nozzle Capacity/Volume).
- If using water monitors, at least two must be present per bay, each with ≥ 2000 l/min flow and remote operation from a secure location.

M138: Vapor Dispersion Control at Other Plant Components (C+P)

- Vapor control must be installed at components like the heat exchanger, flash vessel, and BOG system.
- This may include:
  - Two remote-controlled water monitors (≥ 2000 l/min), or
  - A water curtain enclosing the entire site (TNC / V = 33).

M139: Cooling Facilities (C+P)

- If used to reduce heat radiation (≥10 kW/m^2), cooling facilities must provide:
  - ≥ 2 l/min/m^2 for heat radiation
  - ≥ 10 l/min/m^2 if exposed to direct flame
- This must be detailed in the SDD.

M140: Safety Design Dossier for (Semi)Stationary Facilities and Cooling Water Supply (C+P)

All (semi)stationary installations (e.g., water curtains, monitors, cooling systems, and fire-fighting water systems) for ammonia handling must comply with a standardized SDD.

- The SDD must be approved by an accredited notified body (Notified Body under EU directives) or by the competent port or environmental authority in the relevant Member State.
- The SDD follows a standardized format and must include:
  - Scope and boundaries of the system
  - Description of the facility and its environment
  - Process descriptions
  - Risk and scenario analyses
  - Safety provisions, structural and organizational measures
  - Reference to relevant European and international laws and standards, including justified deviations
  - Technical drawings, design choices, and documentation on inspection and certification
- If formal certification from an accredited inspection body is not feasible, compliance may be demonstrated by a Declaration of Conformity supported by a formal risk assessment prepared by a qualified independent party.

M141: SDD Approval, Assessment, and Ongoing Inspection (C+P)

- Prior to submission, the SDD and any addenda must be assessed by an accredited notified body or equivalent Type A inspection body with expertise in fire protection and ammonia handling systems.
- The application for SDD approval must include the inspection body's assessment report.
- Upon delivery of (semi)stationary systems, an initial conformity inspection by the accredited body is mandatory to demonstrate compliance with the approved SDD.

- Annual inspections must be conducted to verify ongoing conformity.
- Any non-conformities detected must be reported promptly to the competent port or environmental authority, together with a corrective action plan.
- The SDD and the associated system should be reviewed and reassessed at least every five years by a competent SDD coordinator and the accredited inspection body, with any required updates submitted for approval.
- If standard certification is not achievable, a Declaration of Conformity, supported by a comprehensive risk assessment, may be used to demonstrate regulatory compliance.

M142: Design of Fire Protection and Cooling Facilities (C+P)

- (Semi-)stationary fire protection facilities (measures M137, M138, M139), the (cooling) water system, and fire hydrants shall be designed according to EN 12845 (fixed firefighting systems – sprinkler systems) or equivalent standards approved by the competent authority.
- The (cooling) water network must be a loop system with block valves. The block valves are positioned so that, even if part of the fire water network is out of service, enough (cooling) water remains available for every part of the ammonia storage facility.
- A legible, up-to-date, to-scale drawing of the (cooling) water network must be available. It must show at least:
    - Locations of firewater pumps and cooling facilities
    - Locations and diameters of pipelines
    - Locations of block valves
    - Locations and numbers of fire hydrants and water monitors
- System capacity and pressure for the firewater pumps and cooling facilities must be documented at the system level and be available during emergency response.
- The applicable European standards shall be chosen based on the design choices taken by the operator. The SDD must record these choices and specify which standards are followed. The SDD is part of the facility operating permit application (in accordance with Seveso III requirements where applicable).

M143: Capacity and pressure of firefighting/cooling water network (C+P)

- The fire/chilled water network and pumping system are designed to deliver the minimum amount of water required for the maximum scenario.
- The amount of water is tailored to both prevent or limit the spread of an ammonia vapor and to cool facilities where a heat radiation load greater than 10 kW/m^2 may occur and where escalation is possible.
- The pumping system (together with the (cooling) water network) is dimensioned for the maximum expected pressure required at every location within the ammonia storage facility.
- The required dynamic (working) pressure is determined for each (semi-)stationary facility. For above-ground fire hydrants, a minimum dynamic pressure of 1 bar (100 kPa) is required. This requirement does not apply to monitor combinations.
- Firewater pumps can be started from a safe location. The maximum required time to manually start the firewater pumps is tailored to the scenarios to be distinguished.

M144: Minimum duration of water supply (C+P)

- Ensure the required amount of water is available for at least 4 hours under all circumstances.
- Deviations from the 4-hour minimum can be approved by the relevant safety authority based on detailed scenarios.

M145: Reduced pump system availability (C+P)

- In case of reduced availability of the pump system (e.g., during maintenance or repair):
  - Provide at least 100% of required capacity for cooling and water screens.
  - Provide at least 75% of capacity for fire hydrants.
- Alternative pumping capacity must be available, e.g., spare pumps, fireboat connection, or interconnection with a neighboring facility's water system.
- Locations and capacities of alternative pumping facilities and operation instructions must be documented.

M146: Taking out of service part of firefighting/cooling water network (C+P)

- When part of the firefighting/cooling water network is taken out of service, determine alternative water supply means for that portion.

- Cooling water must be available at least halfway down the eligible street and on at least two sides of a facility.
- Temporary changes longer than 2 hours must be communicated to the regional emergency management authority or company fire department.
- Include changes such as stationary facilities no longer powered, semi-stationary facilities used or fed by the fire department, or changes in mobile combat aspects.

M147: Matching firefighting/chilled water system to firefighting vehicles (C+P)

- Coordinate the connections and operation of the firefighting/cooling water system to ensure compatibility with firefighting vehicles.
- Ensure delivery pressure is suitable for firefighting deployment needs.

M148: Fire hydrants (C+P)

- A sufficient number of above-ground fire hydrants and fire hydrant/monitor combinations are installed on the firefighting/cooling water network.
- Fire hydrants comply with EN 14384 or an equivalent standard.
- The required number depends on the site's fire and toxic risk scenarios.
- Fire hydrants are spaced 50 to 80 meters apart, except on open undeveloped land.
- Fire hydrants are protected from freezing.

M149: Fire hydrants - connections and identification (C+P)

- Each fire hydrant has at least two connection options equipped with valves of at least 67 mm passage diameter and storz coupling with standard ridge distances.
- If fire hydrants have valves with a 100 mm passage, the coupling ridge distance is 115 mm.
- Reducer couplings are available on site for different dimensions.
- Fire hydrants have a unique number clearly marked nearby.
- Hydrants can be opened using a commonly used hydrant key or fixed controls like a handwheel.

2.9 Modern Requirements

Scope: Cybersecurity, climate resilience, physical security threats, and sustainability

M150: Industrial Cybersecurity for Control Systems (C+P)

- Industrial control systems (SCADA, DCS, PLC) and safety instrumented systems protected per IEC 62443, NIS2 Directive (Art. 21) or equivalent.
- Network segmentation:
  - Operational technology (OT) separated from information technology (IT)
  - Firewall at OT/IT boundary
  - Safety systems (SIS) isolated from process control where practical
- Access control:
  - User authentication and role-based permissions
  - Multi-factor authentication for remote access
  - VPN required for external connections
  - Session logging maintained
- Physical security of control hardware:
  - PLCs, servers, networking equipment in locked cabinets or control room
  - Access logging for control room and equipment areas
- Security maintenance:
  - Regular security updates and patches per vendor recommendations
  - Vulnerability assessments annually minimum
  - Security incidents investigated and documented
- Backup systems:
  - Control configurations backed up offline (not network-connected)
  - Backups tested quarterly
  - Recovery procedures documented

Recommendation:

- Encrypted wireless protocols and key rotation are strongly recommended, particularly if wireless links are operational.
- A documented cybersecurity incident response plan specific to industrial control systems should be maintained and regularly tested.

M151: Cybersecurity - Emergency Control Independence (C+P)

- Critical safety functions independent of control systems:
  - Manual emergency shutdown pushbuttons (hardwired, not through PLC)
  - Manual valve operation capability (handwheels on critical valves)
  - Backup manual level indication (sight glasses, dip sticks)
- Cybersecurity incident response:
  - Procedures for control system compromise
  - Manual operation capability until systems restored
  - Emergency shutdown independent of compromised systems
- Personnel training on cybersecurity awareness: phishing recognition, password security, suspicious activity reporting.

M152: Climate Resilience - Design Parameters (C+P)

- Facility design accounts for climate change projections (IPCC AR6):
  - Facility robustness per EN 1990
  - Temperature extremes: design for +10°C above historic maximum and -10°C below historic minimum
  - Wind loads: 150% of current local design wind speed standards (EN 1991)
  - Precipitation: drainage systems sized for 100-year storm plus 25% margin
- Flood protection (if facility in projected 100-year flood zone):
  - Critical equipment elevated above projected flood level
  - Waterproof barriers for below-grade infrastructure
  - Emergency drainage capacity with backup power
- Sea level rise (coastal facilities):
  - Long-term planning accounts for 0.5-1 meter sea level rise over facility lifetime
  - Critical infrastructure elevated or protected accordingly
- Climate risk assessment updated every 5 years or after severe weather events.

M153: Extreme Weather Preparedness (C+P)

- Severe weather monitoring and response:
  - Weather alert system providing real-time warnings
  - Pre-storm procedures: secure loose items, verify backup power, test emergency systems

    - Operations curtailment criteria defined (wind speed thresholds, storm warnings)
- Post-storm inspection:
    - Facility inspected for damage before resuming operations
    - Structural integrity, tank stability, piping, electrical systems verified
- Extended power outage preparedness:
    - Emergency generator fuel supply for 72 hours minimum
    - Manual monitoring procedures for extended outages
    - Alarm systems connected to security response

M154: Physical Security - Critical Infrastructure Protection (C+P)

- Control room hardening:
    - Backup control capability at separate location if control room compromised
    - Emergency systems (ESD, fire suppression) protected and redundant
- Drone countermeasures (optional, for high-risk facilities):
    - Drone detection systems (radar, RF, visual)
    - Response protocols for unauthorized drone activity
    - Coordination with local authorities
- Personnel security measures:
    - Visitor registration and escort in operational areas
    - Access control cards or keys tracked and controlled
    - Contractor access limited to authorized areas and supervised
- Emergency lockdown capability:
    - Procedures for security threats
    - Secure access control at all entry points
    - Communication capability to alert personnel and authorities

M155: Sustainability Assessment and Life Cycle Considerations (C+P)

- Major infrastructure projects subject to sustainability assessment per EU Taxonomy requirements:
    - New storage tanks or significant modifications
    - New loading/unloading infrastructure
    - Projects seeking EU green financing or public funding
- Carbon footprinting per ISO 14067 or EN 17472:
    - Scope 1: Direct emissions from facility operations
    - Scope 2: Indirect emissions from purchased energy

    - Scope 3: Embodied carbon in materials, transport, construction
- EU Taxonomy environmental objectives considered:
    - Climate change mitigation (primary)
    - Climate change adaptation
    - Circular economy (material reuse, recycling)
    - Pollution prevention
    - Water and marine resource protection
- Construction and demolition waste (CDW):
    - Minimum 70% reuse or recycling of non-hazardous CDW per EU Taxonomy
    - Material recovery plan documented before construction
- Material selection informed by environmental assessment:
    - Recyclable materials prioritized where technically feasible
    - Environmental Product Declarations (EPDs) per EN 15804 requested from suppliers for major components
    - Results documented and considered in design decisions
- Assessment documentation retained for facility lifetime; updated for major modifications.

Note: Full Life Cycle Assessment (LCA) per ISO 14040/14044 and EN 17472 recommended for projects >€5 million or where required by funding conditions, environmental permits, or corporate ESG commitments.

3 References

- ABS: Requirements for Ammonia Fueled Vessels
- ABS: Ammonia Bunkering – Technical and Operational Advisory
- ATEX Directive 2014/34/EU: Equipment for Explosive Atmospheres
- DNV: Alternative Fuels for Containerships (Guidance Paper)
- DNV: Ammonia in Shipping – Tracing the Emergence of a New Fuel
- DNV: Gas Fuelled Ammonia Class Notation
- DNV: Safe Introduction of Alternative Fuels – Ammonia and Hydrogen as Ship Fuels (White Paper)
- DNV-RP-0699: Competence Related to the Use of Ammonia as Fuel
- EEMUA Publication 186
- Green Shipping Programme: Ammonia Safety Handbook
- IACS UR H1: Control of Ammonia
- IGC Code: International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
- IGF Code: International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels
- IMO MSC.1/Circ.1687: Interim Guidelines for the Safety of Ships Using Ammonia as Fuel
- IMO Resolution A.1050(27): Recommendations for Entering Enclosed Spaces Aboard Ships
- IPCC AR6: Sixth Assessment Report of Climate Change
- ISO 7105: Anhydrous Ammonia for Industrial Use
- Lloyd's Register: Rules for Ships Using Gases or Other Low-Flashpoint Fuels
- Maritime Technologies Forum (MTF): Guidelines for Developing and Implementing a Safety Management System for Ammonia-Fuelled Ships
- EN 3-7: Portable Fire Extinguishers
- EN 10028: Flat Products Made of Steel for Pressure Purposes
- EN 13445: Unfired Pressure Vessels
- EN 13501-1: Fire Classification of Construction Products and Building Elements
- EN 14384: Pillar Fire Hydrants
- EN 14620: Design and Manufacture of Site Built Steel Tanks for Refrigerated Liquefied Gases
- EN 50270: Electromagnetic Compatibility – Gas Detection Apparatus

- EN 50402: Functional Safety of Gas Detection Systems
- EN-IEC 61508: Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems
- EN-IEC 61511: Functional Safety – Safety Instrumented Systems for the Process Industry
- EN-IEC 62305-3: Protection Against Lightning
- EN-ISO 4126-4: Safety Devices – Pilot-Operated Safety Valves
- EN-ISO 7010: Graphical Symbols – Safety Signs
- EN-ISO 9606: Qualification Testing of Welders
- EN-ISO 14001: Environmental Management Systems
- EN-ISO 15614-1: Specification and Qualification of Welding Procedures
- EN-ISO 15848: Industrial Valves – Fugitive Emissions Testing
- EN-ISO 25457: Flare Details for Petroleum and Natural Gas Industries
- EN-ISO 28300: Venting of Tanks for Petroleum and Natural Gas Industries
- EN-ISO 45001: Occupational Health and Safety Management Systems
- IEC 62990-1: Gas Detectors – Performance Requirements
- ISO 20560-1: Safety Information for the Content of Piping Systems
- NIS2-Directive (2022/2555)
- NPR 7910: Hazardous Area Classification (ATEX Zones)
- Perplexity.ai, Claude.ai: As a summary tool; The content reflects the project's activities. AI were used for the generation of the cover page, and no personal data was used for this purpose.
- PED 2014/68/EU: Pressure Equipment Directive
- PGS 12: Dutch national guideline for ammonia storage and transfer
- Seveso III Directive 2012/18/EU: Control of Major-Accident Hazards Involving Dangerous Substances
- SOLAS: International Convention for the Safety of Life at Sea
- Statista: Carbon dioxide emissions from international shipping worldwide from 1970 to 2023
- STCW Code: Seafarers' Training, Certification and Watchkeeping

4 Abbreviations and Acronyms

- ALOHA: Areal Locations of Hazardous Atmospheres
- BLEVE: Boiling Liquid Expanding Vapor Explosion
- BOG: Boil-Off Gas
- (C): Cold Storage (Atmospheric)
- (C+P): Measures for cold and pressurized ammonia
- CCPS: Center for Chemical Process Safety
- CUI: Corrosion Under Insulation
- DCS: Distributed Control System
- DN: Diameter Nominal
- EN: European Standard
- ERG: Emergency Response Guidebook
- ESD: Emergency Shutdown
- ESG: Environmental, Social, Governance
- GHS: Globally Harmonized System
- HVAC: Heating, Ventilation and Air Conditioning
- IDLH: Immediately Dangerous to Life or Health
- IEC: International Electrotechnical Commission
- IGC: International Gas Carrier (Code)
- IGF: International Gas Fuel (Code)
- IoT: Internet of Things
- IPCC: Intergovernmental Panel on Climate Change
- ISA: International Society of Automation
- ISO: International Organization for Standardization
- IT: Information Technology
- LCA: Life Cycle Assessment
- LOPA: Layer of Protection Analysis
- MTF: Maritime Technologies Forum
- NDT: Non-Destructive Testing
- OEL: Occupational Exposure Limits
- OT: Operational Technology
- (P): Pressurized Storage
- PED: Pressure Equipment Directive
- PHAST: Process Hazard Analysis Software Tool

- PLC: Programmable Logic Controller
- PPE: Personal Protective Equipment
- PSSR: Pre-Startup Safety Review
- PWHT: Post-Weld Heat Treatment
- QC: Quality Control
- RBI: Risk-Based Inspection
- SCADA: Supervisory Control and Data Acquisition
- SCBA: Self-Contained Breathing Apparatus
- SCC: Stress Corrosion Cracking
- SDD: Safety Design Dossier
- SIL: Safety Integrity Level
- SIS: Safety Instrumented System
- SOLAS: Safety of Life at Sea
- STEL: Short-Term Exposure Limit
- TNC: Total Nozzle Capacity
- TRV: Thermal Relief Valve
- UPS: Uninterruptible Power Supply
- VPN: Virtual Private Network
- wt%: weight percent

8.2 Handbook: Key regulatory requirements for handling Methanol in Ports

Interreg Baltic Sea Region

Co-funded by the European Union

ENERGY TRANSITION H2Deri@BSP

METHANOL IN PORTS

HANDBOOK

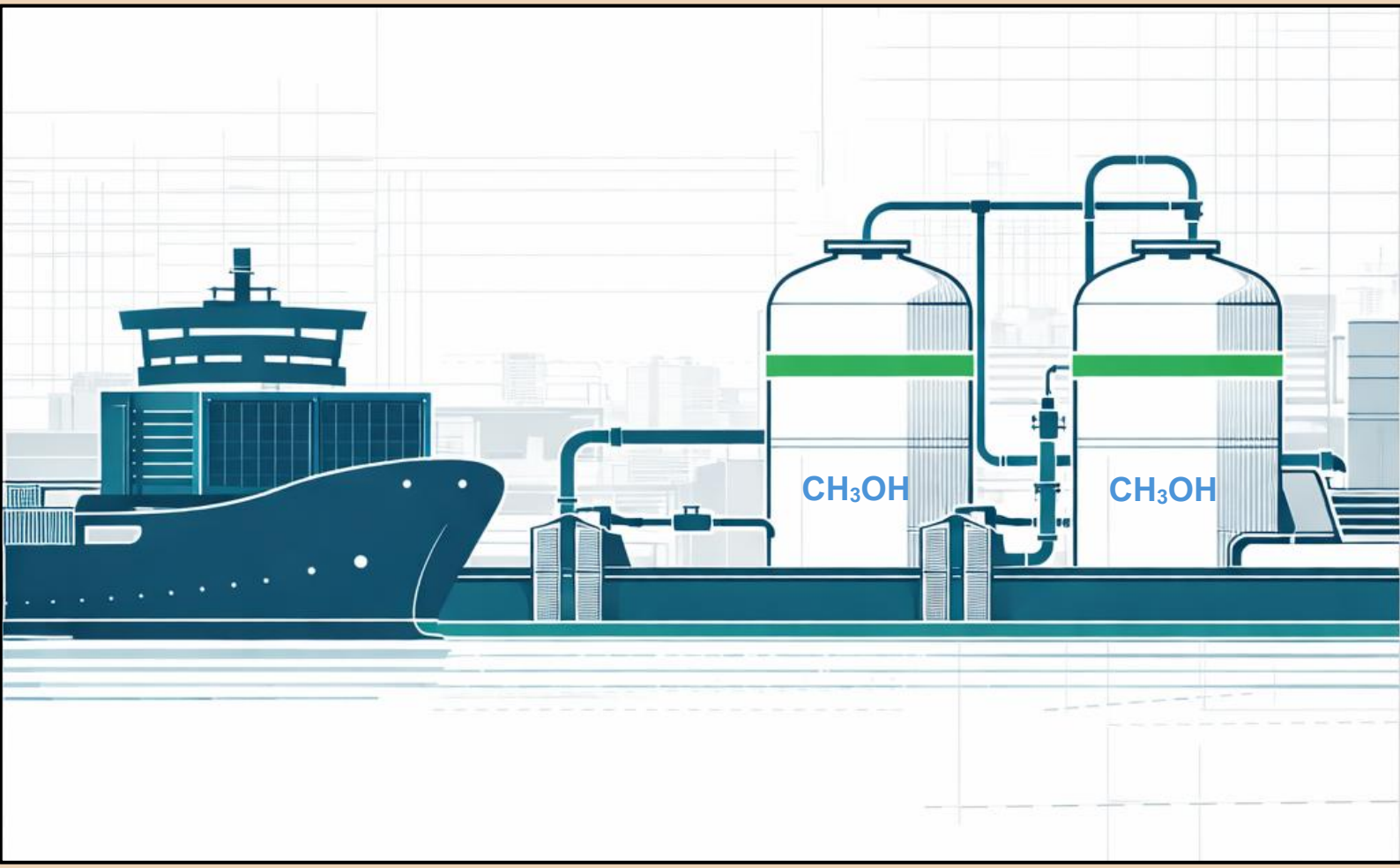

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Table of Contents

TABLE OF CONTENTS 89

1 INTRODUCTION 92

1.1 Methanol as Marine Fuel - Enabling Maritime Decarbonization: 92
1.2 Purpose and how to use this document 93
1.3 Methanol in a nutshell 93

2 REGULATORY MEASURES 95

OVERVIEW OF MEASURE CHAPTERS 95

2.1 Site Planning and Infrastructure Safety 96
2.2 Storage Tank Design and Construction 101
2.3 Safety Systems and Instrumentation 108
2.4 Product Handling and Transfer Systems 114
2.5 Operational Procedures and Controls 124
2.6 Detection and Monitoring Systems 134
2.7 Inspection, Maintenance and Testing 139
2.8 Emergency Preparedness and Response 145
2.9 Modern Requirements 155

3 REFERENCES 159

4 ABBREVIATIONS AND ACRONYMS 161

1 Introduction

1.1 Methanol as Marine Fuel - Enabling Maritime Decarbonization:

Shipping is the sixth largest CO_2 emitter worldwide, with CO_2 emissions of 700 million tons per year, accounting for 3% of total global CO_2 emissions. In addition, the total amount of CO_2 emissions related to shipping is still rising (see Fig. 1). To initiate a transformation, alternative fuels are needed, and one of the most promising candidates, which can reduce emissions by up to 95% compared to fossil fuels, is methanol. Once methanol is produced from renewable sources, such as e-methanol from green hydrogen and captured CO_2 or bio-methanol from biomass, it can be an almost completely climate-neutral fuel.

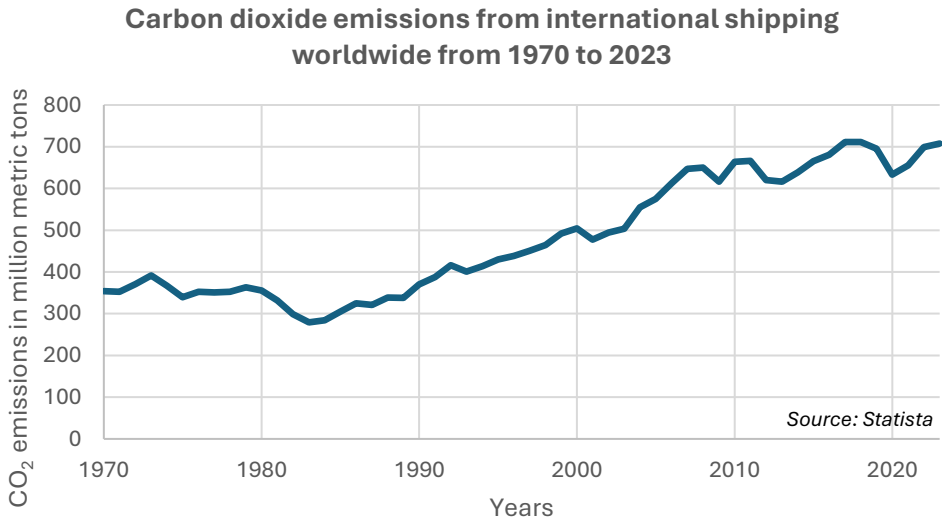

Fig. 1: Development of yearly CO_2 Emissions by global shipping

The development of methanol-powered ships has already begun, with almost 500 methanol-compatible ships in service in February 2026. The major advantages of methanol include its liquid state under normal conditions, its compatibility with modified conventional engines, and the already established global production and transport infrastructure. Due to the need for alternative fuels within the maritime sector, methanol will play a central role in the decarbonization of shipping.

1.2 Purpose and how to use this document

This manual serves as a guide for port authorities, terminal operators, and port companies planning to use or store methanol within the port and providing an overview of relevant steps and international standards to be considered (e.g. Seveso-III, EN, and best practices). The handbook is divided into nine categories covering the installation of a methanol storage facility, the handling of methanol in the port area, and the protection of facilities against external influences.

The regulatory framework emphasizes that the specific challenges involved in handling methanol in ports, particularly due to its high toxicity, flammability, and water solubility require special knowledge and increased safety measures compared to conventional petroleum facilities. It is intended as a planning and compliance tool and does not replace the technical and detailed special requirements at individual port locations. In addition to this manual, users should identify applicable measures and consult the referenced standards for further details. Port facilities implementing methanol operations should view this framework as a foundation for developing site-specific procedures and safety management systems that protect workers, the public, and the environment while enabling efficient and reliable fuel supply operations.

In addition to measures relating to the construction of new methanol-compatible tanks, measures for converting other tanks to methanol-compatible tanks are also described. This is common practice, as methanol is compatible with many atmospheric EN 14015 tanks designed for compatible liquids (e.g., gasoline, biofuels). These conversion measures are marked in purple and consist mainly of three main measures (MX01 – MX03). They include a checklist for checking the necessary structural conditions, material compatibility and modification, and commissioning.

Further, all other measures must also be fulfilled, unless otherwise specified; these exceptions are also marked in purple. Many of the new construction measures should already be fulfilled for existing tanks, but it is nevertheless advisable to take the complete set of measures into account during conversion and to verify them through site-specific risk assessments.

1.3 Methanol in a nutshell

Methanol (CH_3OH), also known as methyl alcohol, is an important chemical feedstock and emerging marine fuel with special handling characteristics. It is a clear, colorless

liquid at normal conditions with a distinctive alcohol odor and presents specific hazards:

- **Flammability**:
  - Methanol is a highly flammable liquid and can be ignited at vapor concentrations between 6 Vol.-% (LEL) and 36 Vol.-% (UEL)
  - Spontaneous combustion occurs at 440 °C. The flash point is comparatively low at 9 °C.
  - Methanol burns with a barely visible bluish flame. Flame detectors are therefore necessary and provide early warning.
- **Toxicity**:
  - Methanol is toxic. It attacks certain organs and the central nervous system, which can lead to long-term damage or death. Symptoms can include coughing, headaches, dizziness, nausea, or visual disturbances. Methanol is easily absorbed through all routes of exposure, including the skin.
- **Water Solubility**:
  - Methanol is 100% miscible with water. Special measures are required in the event of spills.
  - Different containment strategies than for hydrocarbons are needed.
- **Vapor Behavior**:
  - Methanol is slightly heavier than air (vapor density 1.11). It accumulates in low-lying areas and can create explosion hazards in confined spaces.

Strict safety regulations and special equipment are required for the safe storage and handling of methanol in ports.

2 Regulatory Measures

Overview of Measure Chapters

1	**Site planning and infrastructure safety**
	Physical location, layout, access control, and basic infrastructure requirements
2	**Storage Tank Design and Construction**
	Tank specifications, materials, structural requirements, and protection systems
3	**Safety Systems and Instrumentation**
	Control systems, monitoring, protective devices, alarms, and safety instrumentation
4	**Product Handling and Transfer Systems**
	Piping, loading/unloading equipment, material compatibility, and transfer operations
5	**Operational Procedures and Controls**
	Operating procedures, training, process control, and quality management
6	**Detection and Monitoring Systems**
	Gas detection, leak detection, environmental monitoring, and alarm systems
7	**Inspection, Maintenance and Testing**
	Periodic inspection requirements, maintenance programs, and testing protocols
8	**Emergency Preparedness and Response**
	Emergency plans, protective equipment, firefighting, and crisis management
9	**Modern Requirements**
	Cybersecurity, climate resilience, physical security threats, and sustainability

2.1 Site Planning and Infrastructure Safety

Scope: Physical location, layout, access control, and basic infrastructure requirements

M1: Site Selection and General Facility Planning

- The methanol storage facility location selected based on assessment of proximity to residential areas, public roads, fire services, and emergency response capabilities.
- Topography, prevailing wind direction, and environmental factors (flood risk, groundwater, soil conditions) evaluated and documented.
- Site layout ensures minimum separation distances from adjacent facilities per national regulations.
- Facility accessible by emergency vehicles with adequate turning radii.
- Groundwater protection assessment and soil permeability testing conducted before construction.

Note: Methanol vapors are heavier than air and travel along the ground following wind patterns.

M2: Collision Protection and Vehicle Safety

- Storage tanks, loading equipment, pumps, and critical piping protected against vehicle collision through bollards, guardrails, or concrete barriers.
- Barriers designed to withstand impact from heaviest expected vehicles.
- Minimum clearance 1.5-3 meters maintained between traffic routes and process equipment.
- Speed limit maximum 15 km/h in tank farm and loading areas.

M3: Perimeter Security and Access Control

- Facility area secured with fencing minimum 1.8 meters height.
- Access gates equipped with locks.

- Perimeter marked with hazard signage:
  - Globally Harmonized System (GHS) pictograms (H225, H301, H311, H331, H370)
  - "FLAMMABLE LIQUID - TOXIC IF SWALLOWED/INHALED/SKIN CONTACT – DAMAGES ORGANS" warnings
  - Signage in local language(s) and English
- Minimum two separate entrances accessible for emergency services at all times.
- Escape routes clearly marked and maintained unobstructed.

M4: Emergency Access Routes

- All storage tanks, loading areas, and critical equipment accessible via minimum two independent roadways.
- Emergency access roads minimum 6 meters width with minimum turning radius 12 meters.
- Road load-bearing capacity minimum 16 tons axle load.
- Clear height minimum 4.5 meters for overhead obstructions.
- No parking, storage, or equipment placement on emergency access routes.
- Minimum two sides of each storage tank accessible for firefighting operations.

M5: Safety Distances - Heat Radiation and Fire Protection

- Separation distance maintained from buildings and structures with fire risks to keep methanol facilities below 10 kW/m^2 thermal radiation exposure (based on worst-case pool fire scenarios identified in the safety assessment).
- Heat radiation distances shall be determined by quantitative risk assessment using recognized fire radiation models, in line with applicable European / national regulations and guidance (e.g. TRGS 509 and industry guidance such as EIGA Doc 75/21 or equivalent).
- If separation distance is not achievable:
  - Thermal barriers or fire-resistant walls (minimum 2-hour fire rating, equivalent to REI 120 according to EN 13501-2).
  - Water spray/deluge cooling systems (minimum 10 L/min/m^2).
  - Reflective white or aluminum paint on tank surfaces.

Note: Methanol burns with nearly invisible, pale blue flame; fire detection relies on thermal radiation and smoke.

M6: Safety Distances - Pressure Storage Protection

- Methanol atmospheric storage requires minimum separation per local risk assessment (typically 100-150 m) from high-pressure storage vessels (>150 m^3).
- Risk assessment includes vessel rupture, projectile hazards, and blast effects.

M7: Internal Facility Spacing

- Minimum 10 meters separation between storm drains, sewers, and methanol loading/unloading areas.
- All drains within 15 meters of methanol areas equipped with vapor traps, liquid seals, or sealed covers.
- Below-grade spaces (pits, basements, cable trenches) within 15 meters of methanol operations must be vapor-sealed or continuously ventilated with gas detection.
- Incompatible materials storage (oxidizing agents, strong acids) physically separated minimum 15 meters or by fire-rated barrier.

  Note: Methanol vapors heavier than air (vapor density 1.11) and accumulate in low-lying areas.

M8: Spill Containment and Environmental Protection

- Secondary containment required around all above-ground methanol storage tanks.
- Containment capacity minimum 110% of largest tank volume plus firefighting water (typically 10 L/min/m^2 tank surface for 4 hours).
- Construction: impermeable concrete, plastic-lined earthen (High-Density Polyethylene (HDPE) minimum 1.5mm), or welded steel; minimum wall height 1 meter above maximum liquid level.
- Floor sloped toward collection sump (maximum 1% slope) with leak detection and level monitoring.
- Drain valves normally closed and locked; drainage only after visual and chemical verification (no methanol present).
- Contaminated water sent to treatment system or licensed disposal; discharge limits per local regulations (typically <1 mg/L methanol).
- Monthly visual inspection; annual integrity testing; documentation maintained minimum 10 years.

Note: Methanol is 100% water-miscible; all collected liquids treated as contaminated until proven otherwise.

M9: Drainage and Wastewater Treatment System

- Segregated drainage system:
  - Process area drains: collect potential methanol contamination
  - Clean area drains: collect uncontaminated rainwater
  - No cross-connection permitted
- Process drainage:
  - Drain design prevents vapor escape (liquid seals minimum 15 cm depth or sealed covers)
  - Collection sump with level monitoring and high-level alarm
  - Sump pump capacity minimum 2×maximum of anticipated inflow rate
- Wastewater treatment: on-site biological treatment or licensed disposal facility.
- Effluent monitoring for methanol concentration before discharge.
- Emergency provisions: temporary storage capacity and portable pumping equipment available.
- Documentation: as-built drawings, monthly analysis records, annual system review.

M10: Tank Truck Loading Area - Distance from Property Boundary

- Minimum 15 meters separation between loading area and property boundary or public roadway.
- If boundary adjacent to water body, distance reduced by water width (maximum: 10 meters reduction).
- Setback distances comply with national requirements (e.g. TRGS 509).

M11: Tank Truck Loading Area - Traffic Control and Containment

- Loading/unloading on designated paved area connected to process drainage system.
- Traffic barriers or gates close access during operations.
- Wheel chocks (minimum 250mm height, non-sparking material) and parking brake applied.

- Signage: "NO ENTRY - LOADING OPERATION IN PROGRESS" and "FLAMMABLE LIQUID".
- Ground markings identify parking position and hose connection points.
- Dip-tube or bottom filling systems used to minimize splash and static electricity.
- Spill containment pad with drain; containment minimum 5-10 m^3.

M12: Railroad Tank Car Loading Area - Track Control and Protection

- Loading on designated track section isolated from main traffic.
- Blue flag protection, derail device, and lockout system on track switches.
- Track section connected to spill containment and process drainage.
- Tank car brakes applied and wheels chocked during operations.
- Remote-controlled shut-off valves at hose connections.

M13: Marine and Inland Vessel Bunkering Area - Port Authority Compliance

- Methanol bunkering only at locations designated and licensed by port authority.
- Coordination with vessel master, pilot, and port authority required before operations.
- Security perimeter minimum 25 meters radius during operations.

Note: More details in Baltic Ports Bunkering Guidebook in the Annex

M14: Marine Bunkering Operations - Safety Integration

- Vessel moored adequately to prevent movement.
- Connections pressure-tested before transfer (minimum 1.5× operating pressure).
- Communication protocol established (radio plus visual signals).
- Qualified personnel positioned at connection points: minimum two shore-side, two vessel-side.
- Operations suspended if: wind speed exceeds 10 m/s, wave height exceeds 1 meter, visibility less than 500 meters, or thunderstorm activity within 10 km.
- Ship/Shore Safety Checklist completed before transfer per ISGOTT or equivalent.

Note: More details in Baltic Ports Bunkering Guidebook in the Annex

2.2 Storage Tank Design and Construction

Scope: Tank specifications, materials, structural requirements, and protection systems

M15: Design Standard for Atmospheric Storage

- Methanol storage tanks designed to EN 14015 for atmospheric pressure operation (up to 0.17 bar).
- Design temperature range: -40°C to +93°C.
- Tank bottom uniformly supported on stable foundation per EN 14015.
- Design accounts for deadweight, liquid load, wind loads, seismic forces, and thermal expansion.

M16: Tank Construction Type

- Single-wall atmospheric tank construction acceptable.
- Permitted configurations: fixed cone roof, fixed dome roof, external floating roof, internal floating roof.
- Internal floating roof preferred: reduces vapor space 85-90%, prevents air/water entry.
- All fabrication and welding per EN 14015, or equivalent national standards.

M17: Tank Materials - Gaskets and Seals

- Gasket materials: PTFE (Teflon), Kalrez, or spiral wound with graphite filler.
- Materials prohibited: Buna-N/nitrile, natural rubber, butyl rubber, EPDM, neoprene, most Viton types.
- Hoses: PTFE inner liner; internal wire coil for electrical continuity; marked "METHANOL SERVICE"; replaced every 5 years minimum.
- Flame arresters: stainless steel construction only; aluminum prohibited.
- Pump seals: carbon-graphite or silicon carbide.

M18: Tank Foundation Design

- Tank bottom uniformly supported per EN 14015.
- Foundation options: compacted gravel/stone, concrete ringwall, reinforced concrete slab, or mat foundation.
- Foundation design accounts for deadweight, liquid load, seismic forces, wind loads, and soil settlement.
- Foundation surface shall be level, with a maximum deviation of <1 cm per meter radius, in accordance with EN 14015 and the project specification.
- Adequate drainage around tank perimeter.

M19: Tank Roof Design

- Fixed roof: welded cone or dome; minimum slope 1:12; all penetrations equipped with flame arresters.
- Internal floating roof: aluminum or steel pan; pontoon-supported or contact deck; dual rim seals; access hatches, gauge wells, automatic vents; anti-rotation guides; drain valves with check valves.

M20: Tank Venting and Pressure Relief

- Normal venting: pressure and vacuum relief valves per EN 14015; typical settings +2.5 to 10 mbar and -2.5 to -10 mbar.
- Flame arresters mandatory on all vent openings.
- Vent discharge minimum 4 meters above grade, directed away from traffic and personnel.
- Emergency venting: sized per EN 14015 for fire exposure.
- Nitrogen blanketing optional: high-purity nitrogen (<5 ppm oxygen).

M21: Tank Connections and Nozzles

- Primary connections:
  - Fill line: bottom or side entry with dip tube (submerged 2-3 meters)
  - Outlet line: bottom outlet with isolation valve outside containment
  - Vapor return: top connection (if vapor recovery used)
  - Drain: double block-and-bleed valve system
  - Sample connection: top or side with isolation valve
  - Instrumentation: level, temperature, pressure (minimum DN25)

  - Manway: minimum 600 mm diameter
- All primary containment connections shall be flanged in accordance with EN 1092-1, with a minimum pressure rating of PN16 (or higher where required by design pressure and temperature).
- Threaded connections prohibited on main tank nozzles; instrument connections ≤DN20 may be threaded if isolation valve installed.
- Bolts and fasteners: stainless steel or hot-dip galvanized.

M22: Corrosion Protection

- Carbon steel tanks: Impressed current or sacrificial anode cathodic protection shall be provided where required, designed, operated and monitored in accordance with EN 12954 (and EN 13636 for buried tanks or associated piping). Regular performance checks (e.g. at least annually) and potential measurements shall verify that protection criteria from EN 12954 are met.
- External carbon steel surfaces shall be protected by suitable coating systems designed and maintained in accordance with ISO 12944 , considering the relevant corrosivity category and expected durability.
- Stainless steel tanks: Cathodic protection is normally not required if appropriate stainless steel grades are selected for the environment and properly fabricated.
- Internal coatings for carbon steel: Where internal linings are used, inspection and renewal intervals shall follow the coating manufacturer's recommendations and the site's inspection programme (typically 5–7 years), with regular visual inspection for pitting and corrosion.

M23: Tank Inspection and Testing - New Construction

- Hydrostatic testing: fill with clean water to design level; hold minimum 24 hours; visual inspection for leaks, deformation, settlement; drain and dry before service.
- Weld testing: visual inspection per EN 14015; vacuum box testing on shell-to-bottom and roof-to-shell welds; radiographic, magnetic particle, or ultrasonic testing per standard requirements.
- Certification: test report issued by authorized Inspector or equivalent; all defects documented and repaired.

M24: Internal Floating Roof Specifications

- Deck: removable; aluminum or steel pan; pontoon or leg supports; minimal clearance to shell and fixed roof (300-600 mm).
- Rim seals: primary and secondary seals; methanol-compatible materials; maintains <1000 ppm concentration.
- Deck fittings: access hatches (minimum 600 mm diameter), sample lines with flexible hoses, drain valves with check valves, anti-rotation guides (minimum 2).
- Maintenance: inspection and seal replacement every 10-15 years or per manufacturer recommendation.

M25: Tank Nameplate and Identification

- Permanent nameplate per EN 14015: tank ID, construction date, design standard, design pressure and temperature, capacity, material specification, manufacturer, inspector name and date.
- Product identification: "METHANOL" in letters minimum 150 mm height on minimum 4 sides; GHS pictograms H225, H301, H311, H331,H370; "FLAMMABLE LIQUID – TOXIC – DAMAGES ORGANS" warning; emergency contact information.

M26: Thermal Expansion Allowance

- Methanol thermal expansion coefficient: 0.0012 /°C.
- Tank nominal capacity set at 85-90% of total volume.
- Freeboard minimum 10-15% for thermal expansion.
- Maximum fill limit 95% under any condition.
- Fill line temperature measurement with pre-alarm if exceeding design limit (typically 40-50°C).

M27: External Coating and Painting

- External steel surfaces shall be coated with light-coloured (e.g. white) or reflective aluminum/silver paint to reduce solar heat absorption. Protective paint systems shall be selected, applied and maintained in accordance with EN ISO 12944, considering the relevant corrosivity category (e.g. C3–C5) and required durability.
- For typical harbour environments, coating systems with at least medium to high durability (≈ 7–15 years or more) should be used; inspection and maintenance intervals shall follow the coating manufacturer's recommendations and the

site's inspection programme (often in the range of 5–10 years to first major repair).
- Internal surfaces of carbon steel tanks, where internal linings are applied, shall be inspected regularly and refurbished as required based on condition, service environment and manufacturer guidance (typically every 5–10 years).
- Floating roofs made of aluminium shall be protected against corrosion where necessary (e.g. at steel interfaces and fittings) and inspected regularly for coating damage and corrosion.

M28: Seismic and Wind Design

- Tank design accounts for site-specific seismic and wind loads per applicable codes.
- Seismic: site parameters from national maps (Eurocode 8); shell thickness verified per EN 14015; piping designed with flexibility; anchorage if analysis indicates uplift or sliding.
- Wind: speeds per local code (Eurocode 1 EN 1991); empty tank stability, shell buckling, roof uplift verified.
- Foundation design accounts for combined loads; settlement analysis performed.

M29: Static Electricity Control

- Fill rate limitations:
  - Maximum fill velocity 1 m/s until dip tube submerged
  - After submersion, maximum 7 m/s
  - Dip tubes terminate within 150 mm of tank bottom
- Grounding and bonding:
  - All conductive components bonded to common ground
  - Ground resistance maximum 10 ohms (preferably <1 ohm)
  - Bonding cables minimum 16 mm^2 copper
  - Connections verified before transfer operations
  - Truck grounding verified before loading
- Relaxation time: minimum 30 seconds after filling before sampling or gauging; 2-3 minutes if high-velocity filling or line contained different product.
- Design per EN IEC 60079-32-1.

Note: Methanol has low electrical conductivity; static electricity accumulation during filling is significant ignition risk.

M30: Product Quality Specifications

- Water content monitoring: maximum limits set according to application (e.g. marine fuel in line with ISO 6583:2024 grade selected; typical chemical feedstock values ≤0.1% by weight; other uses as defined in purchase specifications).
- Water content testing: Karl Fischer titration or an equivalent validated analytical method.
- Sampling frequency: after each receipt, at least weekly during storage, and before each delivery (or as required by contractual specifications and risk assessment).
- Quality parameters monitored as appropriate for the intended use, for example:
- Methanol purity (typically ≥99.85% for standard chemical grade methanol according to IMPCA or equivalent specifications).
- Water content.
- Inorganic chloride content (e.g. ≤0.5 mg/kg for marine fuel, per fuel-quality specification).
- Appearance (clear, colourless, free of suspended matter).
- Sampling from mid depth via a dedicated sampling connection, using clean, dry, sealed sample containers suitable for methanol service.
- Contamination prevention measures: nitrogen blanketing where feasible; internal floating roof or other vapour space minimisation to limit atmospheric contact; regular inspection for water accumulation; prompt draining and corrective action if free water is detected.

MX01: Existing Tanks: Assessment and Preparation

- Existing tanks converted to methanol service only after comprehensive assessment:
  - **Structural suitability:**
    - Tank construction per EN 14015 verified
    - No significant corrosion, structural damage, or foundation settlement
    - Design pressure/temperature adequate for methanol service (-40°C to +93°C)
  - **Previous service review:**
    - Tank history documented (products stored, repairs, incidents)
    - Tanks previously storing incompatible products (strong acids, oxidizers) generally excluded

- **Cleaning and decontamination:**
  - Tank drained, sludge/sediment removed
  - Interior washed until previous product undetectable (sampling required)
  - Tank entry per confined space procedures (per M80)
  - Visual inspection confirms cleanliness
- **Internal inspection before conversion:**
  - Tank bottom: ultrasonic thickness testing, 100% coverage preferred; minimum 3 mm retirement thickness
  - Shell and roof: visual inspection and Ultrasonic Testing (UT) at representative locations
  - Repairs completed before conversion approved

- Assessment documented; approved by facility management before proceeding with modifications.

MX02: Existing Tanks: Material Compatibility and Modification Requirements

- ALL materials contacting methanol verified compatible before conversion:
  - **Critical replacements required:**
    - Gaskets and seals: ALL replaced with PTFE, Kalrez, or spiral wound with graphite (per M17)
    - Roof seals (floating roof): replaced with methanol-compatible materials
    - Valve stem packing: graphite or compatible material
    - Internal coating (carbon steel tanks): existing coating removed if incompatible; new methanol-compatible coating applied
  - **Materials prohibited (must be replaced):**
    - Buna-N/nitrile, natural rubber, EPDM, neoprene, most Viton types
    - Aluminum components, galvanized steel
  - **Mandatory modifications:**
    - Flame arresters installed on ALL vent openings (per M20)
    - Dip tube or bottom fill system for static electricity control (per M29)
    - Grounding system verified: resistance ≤10 ohms; bonding connections accessible
  - **Instrumentation upgrades:**
    - High-high level alarm with overfill prevention (SIL 1 minimum) installed if not present (per M33)
    - Redundant level measurement if not present (per M31)
- Pressure testing after modifications: 1.5× design pressure for 4 hours minimum.
- Material certificates for all replacements maintained in facility records.

2.3 Safety Systems and Instrumentation

Scope: Control systems, monitoring, protective devices, alarms, and safety instrumentation

M31: Instrumentation and Control Philosophy

- Methanol storage tanks and associated systems equipped with instrumentation to ensure safe commissioning, operation, and maintenance.
- All critical measurements (level, pressure, temperature) provided with redundancy: minimum two independent measurement methods or sensors.
- All instrument readings displayed in control room or accessible to operators.
- Instrumentation maintained and calibrated per manufacturer recommendations; calibration records documented.

M32: Level Measurement and Monitoring

- Tank level measurement by minimum two independent methods:
  - Primary: radar, guided wave radar, or servo gauge
  - Secondary: float-type gauge, pressure transmitter, or ultrasonic
- Level transmitters provide continuous signal to control system.
- Local level indication (sight glass or gauge board) visible from tank access platform.
- Level measurement range: 0-100% of tank height with accuracy ±10 mm or ±0.5% of range.

M33: High-Level Alarm and Protection

- High-level alarm (HLA) set at 90% of tank capacity or as determined by thermal expansion calculation (per M26).
- High-high level alarm (HHLA) set at 95% of tank capacity.
- HHLA triggers automatic actions:
  - Stop incoming flow (close inlet valve or stop transfer pump)
  - Audible and visual alarm in control room and at loading area

    - Lockout of further filling until manually reset after level decreases
- Alarms based on independent level measurement from normal level indication.

M34: Overfill Prevention System

- Independent overfill prevention system with minimum SIL 1 (Safety Integrity Level 1) per IEC 61508/61511.
- System consists of:
    - Dedicated level switch or transmitter (separate from normal level measurement)
    - Logic solver (Programmable Logic Controller (PLC), relay, or dedicated safety controller)
    - Final element (automated valve closure or pump shutdown)
- Overfill prevention activates at 95% tank capacity; automatically stops all filling operations.
- System tested per SIL verification requirements (minimum annually for SIL 1).
- Manual reset required after activation; investigation and documentation of cause mandatory before restart.

M35: Pressure Measurement and Monitoring

- Tank vapor space pressure continuously monitored.
- Pressure transmitter range: -20 mbar to +20 mbar (or per tank design pressure/vacuum rating).
- Pressure reading displayed in control room.
- Pressure alarms:
    - High pressure alarm at 80% of relief valve set point
    - Low pressure alarm at 80% of vacuum relief valve set point

M36: Temperature Measurement

- Tank liquid temperature monitored:
    - Minimum one temperature sensor in tank (mid-level or per tank size: multiple sensors for tanks >5,000 m^3)
    - Temperature measurement on fill line (before tank inlet)
- Fill line temperature alarm if exceeding maximum design temperature or operational limit (typically 40-50°C).
- Temperature readings displayed in control room.

- Temperature measurement range: -50°C to +100°C with accuracy ±1°C.

M37: Pressure Relief Valve Monitoring

- Pressure relief valves (per M20) equipped with position indicators or acoustic monitors to detect discharge.
- Relief valve discharge detected and alarmed in control room.
- Alarm triggers investigation and documentation; continued discharge beyond set time (e.g., 5 minutes) triggers emergency response procedures.

M38: Pump Instrumentation and Protection

- Transfer pumps equipped with:
  - Discharge pressure transmitter
  - Motor current monitoring
  - Vibration monitoring (for pumps >50 kW or critical service)
  - Seal leak detection (for mechanically sealed pumps)
- Pump protection:
  - Low suction pressure shutdown (prevents cavitation)
  - High discharge pressure shutdown
  - Motor overload protection
  - High vibration alarm and shutdown
- Emergency shutdown capability from control room and local pump area.

M39: Emergency Shutdown System (ESD)

- Facility-wide emergency shutdown system installed.
- ESD system architecture:
  - Manual ESD activation from minimum two locations (control room and field location near tank/loading area)
  - Automatic ESD triggers: fire detection, gas detection (if installed per chapter 2.6), high-high level, extreme pressure deviation
  - ESD actions: close all automated isolation valves, stop all transfer pumps, activate alarms
- ESD valves: fail-safe close (spring return or fail-safe actuator); closure time maximum 30 seconds.
- ESD system tested quarterly; full functional test annually; documentation maintained.

M40: Control Room and Human-Machine Interface (HMI)

- Control room provides centralized monitoring and control of methanol storage and transfer operations.
- HMI displays:
  - Tank levels, pressures, temperatures (real-time trending)
  - Pump status and flow rates
  - Alarm summary and historical alarm log
  - Loading/unloading operation status
  - Emergency shutdown system status
- Alarm management per IEC 62682 or equivalent:
  - Alarms prioritized (critical, high, medium, low)
  - Alarm shelving and acknowledgment capability
  - Alarm rate monitoring (avoid alarm floods)
- Control room staffed during all loading/unloading operations or remote monitoring with rapid response capability.

M41: Uninterruptible Power Supply (UPS)

- Critical instrumentation and control systems powered by UPS.
- UPS capacity: minimum 30 minutes runtime for:
  - Level, pressure, temperature monitoring
  - Emergency shutdown system
  - Control room HMI and communication systems
  - Emergency lighting and alarm systems
- UPS battery tested monthly; load test annually; batteries replaced per manufacturer recommendations.

M42: Communication Systems

- Facility equipped with reliable communication systems:
  - Two-way radio system covering entire facility (handheld radios for operators, fixed radios in control room)
  - Telephone/intercom system (control room to loading areas, pump stations, tank areas)
  - Public address (PA) system for emergency announcements
  - Emergency notification system (automatic call-out to fire department, management, emergency responders)

- Communication systems tested monthly; backup power provided (UPS or batteries).

M43: Instrumentation Failure and Failsafe Design

- Instrumentation designed with failsafe philosophy:
  - Level transmitter failure: activate high-level alarm
  - Pressure transmitter failure: activate alarm
  - Flow transmitter failure: stop loading operation
  - Control valve actuator failure: valve moves to safe position (typically closed for inlet valves)
- Critical instruments provide fault detection and self-diagnostics.
- Instrument failure generates alarm in control room; operators verify system status and take appropriate action.

M44: Calibration and Maintenance Program

- All safety instrumentation calibrated per written schedule:
  - Level transmitters: annually minimum
  - Pressure transmitters: annually minimum
  - Temperature sensors: biennially minimum
  - Flow meters: annually minimum
  - Safety instrumented systems (SIL-rated): per SIL verification calculation (typically 6-12 months)
- Calibration performed by qualified technicians using traceable standards.
- Calibration certificates and records maintained minimum 10 years.
- Preventive maintenance performed per manufacturer recommendations; documentation maintained.

M45: Documentation and As-Built Drawings

- Complete instrumentation documentation maintained:
  - Instrument datasheets and specifications
  - Instrument location drawings (plan and elevation)
  - Piping and instrumentation diagrams (P&IDs) showing all instruments, control valves, interlocks
  - Control system logic diagrams (ladder logic, function block diagrams)

    - Safety instrumented system (SIS) documentation: SIL calculations, proof test procedures
    - Cause and effect matrices (alarms and shutdowns)
- As-built drawings updated after modifications; change management process enforced.
- Documentation accessible to operators, maintenance personnel, and emergency responders.

2.4 Product Handling and Transfer Systems

Scope: Piping, loading/unloading equipment, material compatibility, and transfer operations

M46: Piping Design Standards

- All methanol piping shall be designed, constructed, inspected and tested in accordance with EN 13480 (Metallic industrial piping) and applicable pressure equipment regulations.
- Design pressure: minimum 10 bar or 1.5 × maximum operating pressure, whichever is greater.
- Design temperature range: −50 °C to +100 °C (or per site-specific requirements).
- Piping supports shall be designed to accommodate thermal expansion, vibration and external loads, in line with EN 13480 design rules.
- Stress analysis shall be performed for critical piping systems (e.g. high pressure, large diameter, elevated temperature, complex routing, or where required by EN 13480 / project specifications).

M47: Piping Materials

- Carbon steel: EN 10216 or equivalent; suitable for ambient temperature methanol service.
- Stainless steel: Types 304L or 316L (316L preferred for coastal environments).
- Piping material selection consistent with connected equipment (tanks, pumps, valves).
- Materials prohibited: aluminum alloys, galvanized steel, copper, zinc, lead alloys.
- External coating for corrosion protection: epoxy, polyurethane, or equivalent; underground piping with cathodic protection per EN 12954.

M48: Valve Selection and Specification

- All valves in methanol service selected for compatibility:
  - Body material: carbon steel or stainless steel (316L preferred)
  - Trim material: stainless steel
  - Seats: PTFE (preferred), Kalrez, or metal-to-metal
- Isolation valves: ball valves or gate valves; minimum Class 150 (PN16).
- Control valves: globe valves or ball valves with pneumatic or electric actuators; fail-safe position defined (typically fail-closed for inlet lines).
- Check valves: swing check or spring-loaded check valves on pump discharge and fill lines.
- Emergency shutdown (ESD) valves: automated actuated valves (pneumatic or electric); fail-safe closed; closure time maximum 30 seconds.
- Valve stem seals: bellows-sealed or packed with graphite packing.

M49: Gaskets and Sealing Materials

- Gasket materials compatible with methanol: PTFE (Teflon), spiral wound with graphite filler, Kammprofile with graphite, or Kalrez.
- Flange gaskets: full-face or ring-type per flange standard; gasket rating matched to flange class.
- Threaded connections: PTFE tape compatible with methanol; threaded connections limited to instrument connections ≤DN20.

M50: Hoses and Flexible Connections

- Hoses for methanol service: PTFE inner liner; wire-reinforced for pressure rating and electrical continuity.
- Hose identification: clearly marked "METHANOL SERVICE" with date of manufacture and maximum working pressure.
- Hose pressure rating: minimum 10 bar or 4×maximum operating pressure, whichever is greater.
- Hose end fittings: stainless steel; crimped or reusable fittings per manufacturer specification.
- Hose inspection: visual inspection before each use; pressure test annually; replacement every 5 years maximum or per manufacturer recommendation.
- Hose storage: protected from sunlight, ozone, and mechanical damage; hung or stored on racks (not coiled on ground).

M51: Loading Arms (Truck and Railcar)

- Loading arms: fixed rigid pipe construction or articulated swing-arm design.
- Loading arm materials: stainless steel preferred; carbon steel acceptable with appropriate coatings.
- Loading arm features:
    - Dry-break coupling at arm end (prevents spillage during connection/disconnection)
    - Integrated vapor return connection (if vapor recovery system used)
    - Emergency breakaway coupling: activates if vehicle moves unexpectedly; closes both sides automatically; maximum spillage 1 liter
    - Position interlocks: loading permitted only when arm in safe operating envelope
- Bottom loading preferred: dip tube extends to tank bottom; minimizes splash and static electricity.
- Top loading (if unavoidable): splash-filling prohibited; use dip tube or fill pipe extending below liquid surface.

M52: Marine Loading Arms

- Marine loading arms: articulated arms with 3 or 4 swivel joints; designed for ship/barge motion (tide, waves, current).
- Loading arm materials: stainless steel preferred for marine environment.
- Loading arm design: balance system (counterweights or hydraulic) to allow operator movement with minimal force.
- Emergency release coupling (ERC): mechanical or hydraulic release if ship drifts beyond safe distance; coupling separates and both sides close automatically; maximum spillage 5 liters.
- Loading arm envelope: clearly defined operating limits (horizontal, vertical, rotation); position monitoring with alarms and interlocks.
- Vapor return arm: separate arm for vapor recovery during loading (if required).
- Marine loading arms tested per OCIMF (Oil Companies International Marine Forum) guidelines or equivalent.

Note: See more details on safe bunkering operations in Baltic Ports Bunkering Guidebook in the Annex

M53: Pumps - Selection and Design

- Methanol transfer pumps: centrifugal pumps (most common) or positive displacement pumps (for precise flow control or high pressure).
- Pump materials:
  - Casing: stainless steel 316L preferred (304L acceptable); carbon steel with appropriate coatings for non-critical applications
  - Impeller: stainless steel 316L or 304L.
  - Shaft: stainless steel.
- Pump seals:
  - Mechanical seals with carbon-graphite or silicon carbide faces; seal design and installation in accordance with EN 12756 (or equivalent), with suitable flush, buffer or barrier fluid systems specified by the seal manufacturer to minimise leakage and emissions.
  - Magnetic drive (seal-less) pumps: preferred for leak-free operation; no dynamic seals.
- Pump capacity: sized for maximum required flow rate plus 10–20% margin; multiple pumps provided for redundancy where required.
- Pump discharge pressure: sufficient to overcome static head, friction losses, and downstream equipment pressure drop.

M54: Pump Installation and Protection

- Pumps installed on concrete foundations with vibration isolation (where required).
- Suction piping: short, straight run; minimum elbows; eccentric reducer (flat side up) at pump suction to avoid air pockets.
- Pump suction strainer: Y-type or basket strainer (20-40 mesh); differential pressure indicator; cleaned regularly.
- Pump discharge: check valve and isolation valve immediately after pump discharge.
- Pump protection (integrated with instrumentation per chapter 2.3):
  - Low suction pressure shutdown
  - High discharge pressure shutdown
  - Motor overload protection
  - High vibration alarm/shutdown (for critical pumps)
  - Seal leak detection (drain to safe location; alarm on leakage)
- Emergency shutdown: local pushbutton at pump and remote from control room.

M55: Static Electricity Control in Transfer Operations

- Critical: Methanol has low electrical conductivity; static electricity generation during transfer operations is significant ignition hazard.
- Grounding and bonding:
  - All transfer equipment bonded: tanks, pumps, piping, loading arms, hoses, trucks, railcars
  - Bonding cables: minimum 16 mm^2 copper; connections cleaned and verified before operations
  - Ground resistance: maximum 10 ohms (preferably <1 ohm); measured and documented
- Truck/railcar grounding verification system:
  - Automatic grounding verification before loading permitted
  - Grounding clamp attached to designated grounding point on vehicle
  - Resistance continuously monitored; loading stopped if resistance exceeds 10 ohms
  - Visual indication (green light) confirms proper grounding
  - System tested monthly
- Fill rate control:
  - Initial fill rate maximum 1 m/s velocity until outlet submerged (minimum 0.3 meters submergence)
  - After submersion, velocity increased to maximum 7 m/s
  - Flow rate monitored; automatic shutdown if exceeding safe velocity
  - Bottom loading preferred to minimize splash
- Relaxation time:
  - Minimum 30 seconds after filling stops before opening hatches, sampling, or gauging
  - Minimum 2-3 minutes if high-velocity filling, line switching, or different product previously in line
- Design per EN IEC 60079-32-1 or equivalent.

M56: Loading/Unloading Instrumentation

- Loading arms equipped with:
  - Flow measurement: mass or volumetric flow meter; accuracy ±0.5% of reading
  - Pressure transmitter on loading line
  - Emergency shutdown valves (actuated, fail-safe close)
- Loading operations monitoring:

  - Total volume loaded/unloaded displayed and recorded
  - Flow rate monitored and alarmed if exceeding maximum safe rate (per M55)
  - Automatic shutdown on high flow rate or low pressure (hose rupture detection)
- Preset batch controller for truck loading:
  - Operator enters desired quantity
  - Loading stops automatically at preset volume
  - High-high cutoff (typically +2% of preset) as backup
- Loading totalizer: cumulative volume totals for daily/monthly reconciliation; tamper-proof.

M57: Vapor Recovery System (if applicable)

- Vapor recovery during loading operations: vapors displaced from truck/railcar/ship returned to storage tank or vapor treatment system.
- Vapor return line: sized for maximum vapor displacement rate; minimum DN50 for truck loading, DN100 for ship loading.
- Vapor return connection: dry-break coupling on loading arm; connected before liquid transfer begins.
- Vapor line flame arrester: stainless steel construction; installed on vapor return line before tank; protects tank from external ignition source.
- Vapor balance system: tank vapor space pressure maintained within acceptable range during loading; pressure relief valve on vapor line if required.
- Vapor recovery not required for atmospheric tanks with adequate venting; however, recommended for environmental and safety reasons (reduces emissions and vapor cloud formation).

M58: Leak Detection for Transfer Lines

- Transfer lines equipped with leak detection where practical:
  - Buried piping: leak detection wire, fiber optic sensing, or secondary containment with monitoring
  - Above-ground piping in sensitive areas: visual inspection, drip pans with leak detection, or gas detection
- Leak detection methods:
  - Mass balance: compare flow out vs. flow in; alarm on discrepancy >2%
  - Pressure monitoring: monitor line pressure during static periods; alarm on pressure drop

  - Acoustic leak detection: sensors detect sound of escaping liquid
  - Visual inspection: regular inspection of above-ground piping (daily during operations)
- Leak detection alarm: triggers in control room; automatic isolation of affected section if confirmed leak.

M59: Pipeline Segmentation and Isolation

- Long transfer pipelines (>500 meters) segmented with isolation valves: maximum segment length 500-1000 meters.
- Isolation valves: remotely operated (motorized or pneumatic) or manual valves at strategic locations (site boundaries, before/after pumps, at elevation changes).
- Isolation valve locations:
  - Entry/exit points of facility boundaries
  - Before and after major equipment (pumps, loading racks)
  - High points (to facilitate draining and air removal)
- Pipeline drainage: low-point drains with double block-and-bleed valves; drain to safe location (containment or treatment system).

M60: Thermal Relief Protection

- Piping sections that can be isolated (blocked-in) while full of liquid equipped with thermal relief valves (TRVs).
- TRV application: between isolation valves where thermal expansion could cause over-pressure (e.g., pipe exposed to sunlight, pipe sections between block valves).
- TRV sizing: per EN 13480; adequate capacity for thermal expansion scenario.
- TRV discharge: to safe location (atmosphere at safe height, containment, or vapor recovery system); not to confined space.

M61: Expansion Joints and Flexibility

- Piping systems designed with flexibility to accommodate:
  - Thermal expansion/contraction
  - Tank settlement
  - Equipment vibration
  - Seismic movement
- Flexibility provided by:

  - Expansion loops (L-bends, Z-bends)
  - Metallic expansion joints (bellows-type; only where loops not feasible)
  - Flexible hoses at equipment connections (pumps, loading arms)
- Expansion joints: stainless steel bellows; tie rods to limit movement; designed per EN 14917.
- Expansion joints inspected annually; replaced per manufacturer recommendation or if signs of fatigue/damage.

M62: Piping Identification and Marking

- All methanol piping clearly identified:
  - Color coding: per ISO 14726 (yellow YE for flammable liquids) or local standard.
  - Labeling: "METHANOL" with directional flow arrows at regular intervals (maximum 10 meters) and at all valves, connections, and wall penetrations
  - Hazard markings: GHS pictograms (H225, H301, H311, H331, H370) at strategic locations
- Valve identification: each valve tagged with unique number; valve position labeled (open/closed).
- Underground piping: marker posts at changes of direction, valves, and regular intervals (maximum 50 meters).

M63: Pressure Testing and Commissioning

- All new or modified piping pressure tested before commissioning:
  - Hydrostatic test: 1.5× design pressure for minimum 4 hours; water or other compatible test fluid
  - Pneumatic test (if hydrostatic not feasible): 1.1× design pressure with inert gas (nitrogen); incremental pressurization; additional safety precautions (personnel exclusion zone)
- Leak test: visual inspection during pressure test; no leakage permitted at flanges, valves, welds.
- Flushing: piping flushed with water or methanol before commissioning to remove construction debris, mill scale, welding slag.
- Documentation: pressure test certificate issued by qualified inspector; test charts, procedures, and results maintained.

M64: Above-Ground Piping Installation

- Above-ground piping shall be installed on pipe racks, pipe bridges, or sleepers.
- Pipe supports shall be spaced and designed in accordance with EN 13480 and the project piping design specification, considering pipe weight (empty, operating, test), insulation, and external loads (e.g. wind, snow, thermal expansion).
- Pipe support materials: carbon or stainless steel with appropriate corrosion protection; where piping is insulated, suitable design measures (e.g. saddles, pads, or non-absorbent inserts) shall be used at support contact points to minimise Corrosion under insulation (CUI).
- Piping clearances: minimum 0.5 m from walkways, structures and other equipment; minimum 2.0 m above grade at pedestrian crossings (or in accordance with site-specific safety requirements and applicable regulations).
- Piping slope: minimum 1:100 towards low points and drain points to allow complete drainage and avoidance of trapped liquid.

M65: Underground Piping Installation

- Underground piping: externally coated and wrapped for corrosion protection; cathodic protection system installed per EN 12954.
- Burial depth: minimum 0.8 meters below grade (or below frost line in cold climates); minimum 1.2 meters under roads or traffic areas.
- Bedding: piping laid on compacted sand or fine gravel bed (minimum 150 mm); backfilled with sand or fine material (no rocks); compacted in layers.
- Warning tape: buried 0.3 meters above piping; marked "CAUTION - METHANOL PIPELINE BURIED BELOW".
- Marker posts: installed at pipeline route changes, valves, and regular intervals; marked with "METHANOL PIPELINE" and emergency contact information.
- As-built drawings: precise location and depth of underground piping documented; drawings accessible for future excavation or maintenance.

M66: Spill Containment for Transfer Areas

- All transfer areas (loading racks, pump stations) equipped with spill containment:
  - Concrete pads with raised edges or curbs (minimum 100 mm height)
  - Floor sloped toward collection sump

    - Containment capacity: minimum volume of largest single hose or loading arm capacity plus 10%
- Sump with leak detection and level alarm; sump pumped to treatment system or containment (per M8).
- Drip pans under pumps, valves, flanges where leaks possible; drip pans drained regularly.

M67: Winterization and Freeze Protection

- Piping and equipment exposed to freezing temperatures protected:
    - Insulation: thermal insulation on piping; thickness per heat loss calculation
    - Heat tracing: electric or steam heat tracing where required to maintain minimum temperature (typically +5°C minimum)
    - Drainage: piping designed for complete drainage; drain valves at low points; draining procedures documented
- Heat tracing controlled by thermostats; temperature monitored and alarmed.
- Winterization checklist: prepared and executed before winter season; includes testing of heat tracing, insulation inspection, verification of drainage procedures.

M68: Maintenance Access and Safety

- Piping and equipment arranged to allow safe maintenance access:
    - Valves accessible from grade or platforms (maximum 2 meters height without platform)
    - Flanges accessible for bolt removal and gasket replacement
    - Instruments accessible for calibration and maintenance
- Platforms, ladders, stairs per EN ISO 14122 standards: guardrails, toe boards, non-slip surfaces.
- Isolation and lockout points: clearly identified; sufficient space for isolation procedures and lockout/tagout devices.

2.5 Operational Procedures and Controls

Scope: Operating procedures, training, process control and quality management

M69: Operational Procedures Documentation

- Written procedures maintained for all phases of operation:
  - Commissioning and decommissioning (tanks, piping, equipment)
  - Normal operations (filling, storage, transfer, loading/unloading)
  - Abnormal situations and emergency response
  - Maintenance during production
  - Inspection and testing activities
- Procedures address temporary safety measures during maintenance or modifications.
- Procedures accessible to all relevant personnel; updated after incidents or process changes.
- Change management process ensures procedures updated before implementing operational changes.

M70: Commissioning Procedures

- Before commissioning, facility preparation:
  - Tanks and piping cleaned and dewatered
  - Leak testing with nitrogen or air (per design pressure requirements)
  - Flushing with nitrogen until oxygen content <0.5%
  - Visual inspection for construction debris, tools, foreign objects
- Initial filling with methanol conducted at controlled rate; monitoring for leaks, pressure, temperature.
- Water content verified within specification (per M77) before tank placed in service.
- Commissioning witnessed and approved by qualified personnel; commissioning report documented.

M71: Decommissioning Procedures

- Tank or system decommissioning:
  - Empty to maximum extent possible
  - Residual methanol removed by draining and/or evaporation
  - Flushing with nitrogen until methanol concentration <100 ppm
  - Flushing with air until oxygen content >19% (if entry required)
  - Gas testing before any hot work or confined space entry
- All liquid methanol and contaminated flushing fluids sent to treatment or disposal per environmental regulations.
- Decommissioning documented; vessel tagged "OUT OF SERVICE" until recommissioned.

M72: Control of Storage Conditions

- Tank liquid level, temperature, and pressure continuously monitored (per chapter 2.3).
- Operator response to abnormal conditions:
  - Level approaching high alarm: reduce or stop filling; investigate cause
  - Temperature exceeding normal range: investigate source (ambient heating, product temperature); implement cooling if necessary
  - Pressure deviation: verify venting system operation; check for blockage or malfunction
- Monitoring system settings allow intervention before safety systems (alarms, shutdowns) activate.
- Operating limits documented in facility operating manual; deviations recorded and investigated.

M73: Tank Filling Operations

- Tank filling conducted per written procedure addressing:
  - Verification of available tank capacity before starting transfer
  - Confirmation of correct product (methanol grade, specification)
  - Grounding and bonding verification (per M29)
  - Fill rate control (per M29 static electricity limits)
  - Continuous monitoring of level, pressure, flow rate
  - Operator presence during filling operations

- Filling stopped immediately if abnormal conditions detected (high level alarm, pressure deviation, leak indication).
- Filling operations logged: date, time, quantity, source, operator name.

M74: Tank Discharge Operations

- Tank discharge (unloading) conducted per written procedure:
  - Verification of receiving vessel/truck capacity
  - Grounding and bonding verification
  - Valve lineup verification before starting transfer
  - Flow rate monitoring
  - Prevention of tank low-level conditions (maintain minimum liquid level to prevent pump cavitation or vapor entrainment)
- Discharge operations logged: date, time, quantity, destination, operator name.

M75: Loading and Unloading - General Requirements

- Loading/unloading operations conducted only when written procedures available and followed.
- Pre-operation checklist completed before each operation:
  - Correct truck/railcar/vessel positioned and secured
  - Grounding verified (per M29)
  - Emergency equipment accessible (fire extinguisher, spill kit, PPE)
  - Communication established between operator and driver/vessel personnel
  - Weather conditions acceptable (no thunderstorms, extreme wind)
- Loading/unloading area access restricted; physical barriers in place; signage posted.

M76: Product Quality Verification (Operational)

- Methanol quality verified before acceptance into storage:
  - Water content: maximum per application specification (marine fuel <0.5%; chemical feedstock <0.1%)
  - Visual inspection: clear, free of suspended matter or contamination
  - Temperature: within acceptable range for storage tank
  - Odor: characteristic methanol odor (detection of off-odors indicates contamination)

- Sampling:
  - Samples collected from mid-depth of tank or from transfer line
  - Sample containers clean, dry, glass or PTFE-lined
  - Chain of custody maintained for laboratory samples
- Testing frequency:
  - Upon each receipt (before acceptance into storage)
  - Weekly during storage (for long-term storage)
  - Before each delivery (to verify specification compliance)
- Laboratory analysis: Karl Fischer titration for water content; additional testing per customer specification.
- Out-of-specification product segregated; disposition determined (blending, treatment, or return to supplier).

M77: Water Content Management

- Methanol water content maintained within specification limits.
- Water contamination sources minimized:
  - Nitrogen blanketing (if used) prevents atmospheric moisture ingress
  - Internal floating roof (if installed) minimizes vapor space and condensation
  - Tank venting equipped with desiccant breathers (optional; for critical applications)
- Water accumulation in tank bottom monitored:
  - Regular inspection for water layer (water settles below methanol)
  - Water drainage if detected (per environmental controls)
  - Investigation of water source (condensation, leaking roof, contaminated receipt)
- Water content adjustment: if methanol too dry, controlled water addition per specification; if too wet, blending with drier product or treatment.

M78: Contamination Prevention

- Measures to prevent methanol contamination:
  - Dedicated storage tanks (methanol only; no product switching)
  - Dedicated piping and transfer equipment (or thorough flushing if shared)
  - Clean filling procedures (no introduction of dirt, rust, or foreign matter)
  - Proper tank maintenance (internal coating integrity, roof seals)
- If contamination detected:
  - Product segregated and analyzed

- Source of contamination identified and corrected
- Tank cleaned if necessary before return to service

M79: Operator Training and Competency

- All personnel involved in methanol operations trained on:
  - Methanol hazards (flammability, toxicity, invisible flame)
  - Safe handling procedures (filling, transfer, loading, unloading)
  - Emergency response (spill response, fire, exposure, evacuation)
  - Personal protective equipment use (gloves, face shields, emergency breathing apparatus)
  - Static electricity hazards and control measures
  - Environmental protection (spill prevention, wastewater management)
- Training program includes:
  - Initial training before assignment to methanol operations
  - Refresher training annually minimum
  - Competency assessment (written test, practical demonstration)
  - Documentation of training completion
- Operators qualified and authorized before performing critical operations (tank filling, loading trucks, emergency response).

M80: Permit-to-Work System

- Permit-to-work system implemented for non-routine activities:
  - Hot work (welding, cutting, grinding) in or near methanol areas
  - Confined space entry (tanks, vessels, pits)
  - Line breaking (opening flanges, disconnecting hoses)
  - Excavation near underground piping
  - Maintenance on pressurized systems
- Permit requirements:
  - Hazard identification and risk assessment
  - Isolation and energy control (lockout/tagout)
  - Gas testing (before and during work)
  - PPE requirements specified
  - Emergency response provisions
  - Authorized signatures (supervisor, safety officer, operator)
- Permit valid for specified duration (typically one shift or one day); renewed if work extends beyond period.

- Permits reviewed and closed after work completion; lessons learned documented if incidents occur.

M81: Lockout/Tagout Procedures

- Energy isolation (lockout/tagout) procedures for maintenance and repair:
  - Equipment de-energized and isolated (electrical, mechanical, hydraulic, pneumatic, gravity)
  - Isolation points locked with personal locks (one lock per worker)
  - Tags identify reason for lockout, date, and responsible person
  - Verification of zero energy state before work begins
- Methanol-specific considerations:
  - Piping and equipment drained and depressurized before opening
  - Residual methanol flushed with nitrogen or water (depending on work type)
  - Gas testing confirms methanol concentration <0.6% before entry or hot work
- Only authorized person who applied lock may remove it; exceptions require formal management-of-change procedure.

M82: Hot Work Controls

- Hot work in methanol areas strictly controlled:
  - Hot work permit required (per M80)
  - Area cleared of methanol vapors (gas testing confirms <0.6%)
  - Fire watch posted with extinguisher and communication to emergency services
  - Continuous gas monitoring during hot work (work stopped if methanol detected)
- Minimum 15-meter exclusion zone around hot work; methanol transfer operations stopped in adjacent areas.
- Post-work fire watch: area monitored for minimum 30 minutes after hot work completion.

M83: Personal Protective Equipment (PPE)

- Minimum PPE for methanol operations:
  - Safety glasses or face shield (splash protection)

  - Chemical-resistant gloves (nitrile or neoprene for incidental contact; butyl rubber for immersion)
  - Safety footwear (chemical-resistant where spillage possible)
  - Flame-resistant clothing (where fire risk present)
- Additional PPE for specific tasks:
  - Full face shield for connecting/disconnecting hoses or opening flanges
  - Chemical-resistant apron or suit for tank cleaning or spill cleanup
  - Self-contained breathing apparatus (SCBA) or supplied-air respirator for emergency response or confined space entry
- Emergency escape masks (air-purifying respirator with organic vapor cartridge, e.g. EN 14387 type AX) available at strategic locations; minimum one per two workers.
- PPE inspection before use; damaged PPE removed from service and replaced.

M84: Housekeeping and Facility Maintenance

- Good housekeeping practices maintained:
  - Tank farm and loading areas kept clean and free of debris, spilled product, or accumulated waste
  - Drains kept clear and functional
  - Access routes and emergency exits unobstructed
  - Signage legible and properly positioned
  - Lighting adequate for day and night operations
- Preventive maintenance program:
  - Equipment inspected and maintained per manufacturer recommendations and facility schedules
  - Deficiencies corrected promptly; equipment tagged "OUT OF SERVICE" until repaired
  - Maintenance records documented (date, work performed, parts replaced, technician name)
- Grounds maintenance: vegetation controlled around tanks and piping to allow inspection and emergency access; drainage ditches kept clear.

M85: Management of Change (MOC)

- Formal management-of-change process for facility modifications:
  - Hardware changes (new equipment, piping modifications, instrument replacements)
  - Procedural changes (operating procedures, maintenance practices)

  - Organizational changes (staffing, responsibilities, contractor use)
  - Temporary modifications (bypasses, temporary piping, out-of-service equipment)
- MOC process includes:
  - Description of proposed change and justification
  - Hazard identification and risk assessment
  - Review of safety, environmental, and operational impacts
  - Update of drawings, procedures, and training materials
  - Authorization by facility management before implementation
  - Post-implementation review to verify change successful
- Emergency changes: temporary approval permitted for safety-critical repairs; formal MOC completed within 48 hours.

M86: Incident Reporting and Investigation

- All incidents involving methanol reported and investigated:
  - Spills (any quantity released to environment)
  - Fires or vapor releases
  - Equipment failures (pump failures, valve leaks, instrument malfunctions)
  - Injury or exposure incidents
  - Near-misses (incidents that could have caused harm but did not)
- Incident investigation:
  - Immediate response and containment
  - Root cause analysis (what happened, why it happened, how to prevent recurrence)
  - Corrective actions identified and implemented
  - Investigation report documented within 30 days
  - Lessons learned communicated to all personnel
- Trends analysis: periodic review of incidents to identify systemic issues or recurring problems.

M87: Operational Record Keeping

- Operational records maintained:
  - Daily operating logs (tank levels, transfers, incidents, operator notes)
  - Loading/unloading records (quantity, date, time, truck/vessel identification)
  - Quality control data (water content, laboratory results)
  - Maintenance and inspection records (per chapter 2.7)

  - Training records (per M79)
  - Permit-to-work records (per M80)
  - Incident reports (per M86)
- Records retention: minimum 5 years for operational records; 10 years for safety-critical records (inspections, incidents, modifications); indefinitely for as-built drawings and design documents.
- Records accessible to regulatory authorities, insurance inspectors, and facility management.

M88: Communication and Coordination

- Effective communication maintained:
  - Shift handovers: outgoing and incoming operators review status, ongoing activities, abnormal conditions
  - Management briefings: regular (weekly/monthly) meetings on safety performance, incidents, planned work
  - Contractor coordination: contractors briefed on facility hazards, procedures, emergency response before starting work
  - Emergency services coordination: fire department and emergency responders familiar with facility layout, hazards, and emergency contacts
- Communication systems tested regularly (radios, phones, alarms); backup systems available.

M89: Grounding and Bonding Verification (Operational)

- Grounding verification performed before each truck/railcar loading operation:
  - Grounding clamp attached to designated grounding point on vehicle
  - Grounding monitor confirms resistance <10 ohms
  - Green light or visual confirmation indicates proper grounding
  - Loading interlock prevents operation if grounding not verified
- Hoses and loading arms bonded to facility grounding system; bonding continuity verified annually (per chapter 2.7).
- Static electricity incidents investigated to identify and correct grounding failures.

MX03: Existing Tanks: Commissioning of Converted Tanks

- Converted tanks commissioned per specific procedure before methanol introduction:
  - **Pre-commissioning verification:**

        - All modifications completed and pressure tested
        - Material replacements documented with certificates
        - Instrumentation calibrated and safety systems functionally tested
        - Personnel trained on methanol-specific hazards (per M79)
    - **Initial methanol fill:**
        - Nitrogen purging: tank purged until oxygen content <0.5%
        - Controlled fill rate: maximum 1 m/s velocity until dip tube submerged
        - Continuous monitoring: level, pressure, temperature, leak detection
        - Water content verification after fill: per specification (typically <0.5% for marine fuel)
    - **Enhanced monitoring period:**
        - First 30 days: daily visual inspection for leaks, coating condition (via manway if accessible)
        - First 6 months: monthly external inspection instead of annual
        - First year: coating condition assessment at 6 months and 12 months
    - **Documentation:**
        - Commissioning completion certificate issued
        - As-built drawings updated showing all modifications
        - Regulatory notification (if required by local authority)
- Conversion documented; tanks with conversion issues identified early and corrective actions implemented.

2.6 Detection and Monitoring Systems

Scope: Gas detection, leak detection, environmental monitoring, and alarm systems

M90: Gas Detection System - General Requirements

- Methanol vapor detection system installed at all locations where methanol vapor accumulation possible:
  - Loading/unloading areas (truck, rail, marine)
  - Pump stations and transfer equipment areas
  - Tank dike areas (if not fully open-air)
  - Confined spaces and below-grade areas within 15 meters of methanol operations
  - Indoor areas where methanol stored or handled
- Detection system provides:
  - Continuous monitoring (24/7 operation)
  - Alarms at two levels: low-level warning and high-level action
  - Visual and audible alarms in control room and local area
  - Integration with control systems for automatic actions (per chapter 2.3)

M91: Gas Detection - Detector Specifications

- Methanol vapor detectors: electrochemical or catalytic bead type; suitable for methanol detection in flammable range.
- Detector placement:
  - Low-level locations (methanol vapor slightly heavier than air; accumulates in low areas)
  - Breathing zone height (1.5 meters) at operator work locations
  - Near potential leak sources (pumps, valves, hose connections, loading arms)
- Detector coverage: number and positioning determined by scenario analysis considering:
  - Wind direction and ventilation patterns
  - Potential leak rates and locations

    - Response time requirements
- Detector specifications:
    - Detection range: 0-100% LEL (Lower Explosive Limit)
    - Accuracy: ±5% of reading
    - Response time: <30 seconds (T90)

M92: Gas Detection - Alarm Levels and Actions

- Alarm setpoints:
    - Low alarm (warning): 0.6-1.2%; alerts operators to investigate
    - High alarm (action): 1.5-1.8%; triggers automatic actions:
        - Stop loading/unloading operations
        - Close ESD valves (if configured)
        - Activate visual/audible alarms
        - Notify emergency responders (if configured)
- Operators respond to alarms:
    - Investigate source of vapor release
    - Implement corrective actions (stop transfer, close valves, isolate equipment)
    - Evacuate personnel from affected area if necessary
    - Reset alarm only after vapor concentration returns to safe levels and source corrected

M93: Gas Detection - Calibration and Testing

- Gas detectors calibrated regularly:
    - Bump test (functionality check with test gas): weekly minimum
    - Full calibration: monthly minimum or per manufacturer recommendation
    - Calibration gas: certified methanol/air mixture at known concentration
- Detector maintenance:
    - Sensors replaced per manufacturer life expectancy (typically 2-3 years for electrochemical; 5 years for catalytic)
    - Visual inspection for physical damage, contamination, or obstruction
    - Malfunction investigated and corrected immediately; detector replaced if defective
- Calibration and maintenance records documented; accessible for audits.

M94: Fire Detection System

- Fire detection system installed in areas where methanol fire risk present:
  - Loading/unloading areas
  - Pump stations and enclosed equipment areas
  - Control rooms and electrical rooms (adjacent to methanol areas)
- Fire detector types:
  - Flame detectors (UV/IR or multi-spectrum): detect methanol's invisible flame
  - Heat detectors: backup for flame detection
  - Smoke detectors: not reliable for methanol fires (clean-burning); used only in occupied buildings
- Fire detection system connected to:
  - Fire alarm panel with audible/visual alarms
  - Automatic fire suppression systems (if installed per chapter 2.8)
  - Emergency notification to fire department

M95: Leak Detection - Liquid Methanol

- Liquid methanol leak detection where practical:
  - Drip pans or collection sumps under pumps, valves, flanges with level switches or visual inspection
  - Mass balance monitoring: compare flow in vs. flow out; alarm on discrepancy >2%
  - Visual inspection: regular operator rounds (per M84) to identify leaks early
- Leak detection in secondary containment (dikes):
  - Level monitoring in collection sumps (per M8, M9)
  - Alarm on liquid accumulation indicates leak from primary containment

M96: Environmental Monitoring

- Wastewater monitoring (per M8):
  - Methanol concentration in process wastewater before discharge
  - pH monitoring to verify neutralization
  - Discharge flow rate monitoring and totalization
- Stormwater monitoring:
  - Visual inspection before discharge from clean water drains
  - pH and methanol spot-testing if contamination suspected
  - Automatic isolation if contamination detected
- Air emissions monitoring (if required by environmental permit):
  - Tank vent emissions (VOC monitoring if required)

- Loading vapor recovery efficiency

M97: Monitoring System Reliability

- All detection and monitoring systems designed for high reliability:
  - Redundant sensors for critical measurements (per chapter 2.3)
  - Fail-safe design: sensor failure generates alarm
  - Backup power (UPS) for critical detection systems
  - Self-diagnostics: systems report faults and malfunctions
- System availability targets:
  - Gas detection: 98% uptime minimum
  - Fire detection: 99% uptime minimum
  - Critical process monitoring (level, pressure): 99.5% uptime minimum
- System downtime documented; extended outages investigated and corrective actions implemented.

M98: Integration with Control and Safety Systems

- Detection systems integrated with facility control and safety systems (per chapter 2.3):
  - Gas detection alarms displayed in control room
  - Fire detection triggers emergency response protocols
  - Leak detection initiates isolation and containment actions
- Integration allows coordinated response:
  - High gas concentration → stop loading + close valves + activate alarms
  - Fire detection → activate suppression + notify fire department + initiate evacuation
- Integration architecture maintains independence of safety systems from process control (separate safety PLC or dedicated safety system).

M99: Operator Interface and Alarm Management

- All detection and monitoring alarms presented to operators via HMI (per chapter 2.3).
- Alarm management:
  - Alarms prioritized: critical (immediate action required), high (prompt action), low (monitoring)

  - Alarm rationalization: avoid alarm floods; suppress non-critical alarms during known transients
  - Alarm acknowledgement required; alarms remain visible until condition corrected
- Operators trained on alarm response (per M79); alarm response procedures documented

2.7 Inspection, Maintenance and Testing

Scope: Periodic inspection requirements, maintenance programs and testing protocols

M100: Inspection and Maintenance Program

- Comprehensive inspection and maintenance program established for all methanol storage and handling equipment.
- Program based on a risk-based inspection approach according to EN 16991 and recognised industry guidance for above-ground storage tanks (e.g. EEMUA 159), supplemented by manufacturer recommendations and applicable regulatory requirements.
- Program defines inspection and maintenance schedules, required competencies of inspection personnel, and documentation procedures in accordance with EN 13460 (maintenance documentation) or equivalent.
- Inspections performed by suitably qualified and competent personnel (e.g. certified tank inspectors, certified welding inspectors, or manufacturer-trained technicians) appropriate to the scope of work.
- Program reviewed and updated at least annually and after significant modifications, incidents, or changes in operating conditions

M101: Tank External Inspection

- Annual visual inspection of atmospheric storage tanks:
  - Tank shell: corrosion, distortion, dents, cracks
  - Roof: damage, ponding water, structural integrity
  - Foundation: settlement, cracking, deterioration
  - External coatings: condition assessment
  - Appurtenances (ladders, platforms): structural integrity
- Settlement monitoring: shell circumference measured annually at multiple elevations; excessive settlement (>1:200 slope) investigated.
- Inspection documented with photographs; deficiencies categorized and corrective actions prioritized.

M102: Tank Internal Inspection

- Internal inspection frequency: every 10 years maximum; more frequently based on risk assessment or corrosion rate.
- Inspection scope:
  - Tank bottom: ultrasonic thickness testing (UT); minimum 20% coverage
  - Shell plates: visual inspection; UT at representative locations
  - Roof underside: visual inspection; structural assessment
  - Internal coatings (if present): condition and thickness assessment
  - Internal floating roof (if present): pontoon integrity, seal condition, fittings
- Tank entry per confined space procedures; isolated, drained, cleaned, ventilated, and gas-tested (oxygen >19.5%, methanol <0.6% = 10% LEL).
- Inspection report documented; repair recommendations prioritized; submitted to regulatory authority if required.

M103: Tank Bottom Integrity

- Bottom plate minimum thickness for new construction in accordance with the applicable tank design standard (e.g. EN 14015) and project specification; for atmospheric methanol storage tanks, new floor plates are typically in the range of 5–6 mm including any specified corrosion allowance.
- Minimum remaining (retirement) thickness of the bottom determined by a risk-based integrity assessment in line with EN 16991 and recognised tank inspection guidance (e.g. EEMUA 159); in practice.
- Bottom inspection performed by internal inspection during planned outages or by suitable in-service methods (e.g. vacuum box testing, acoustic emission, magnetic flux leakage, ultrasonic floor scanning).
- Leak detection provided by monitored secondary containment (e.g. double-bottom with leak detection) and/or groundwater monitoring wells where required by the site's environmental permit.
- Bottom repairs carried out by welded patches or insert plates for localised corrosion, and by sectional or complete bottom replacement in case of widespread deterioration, in accordance with recognised tank repair guidance such as EEMUA 159.

M104: Piping Inspection

- Above-ground piping:

  - Monthly: visual inspection during operations for leaks, corrosion, support condition
  - Annually: detailed visual inspection; coating assessment; valve and flange inspection
- Underground piping:
  - Cathodic protection monitoring: potential measurements at test stations annually (per EN 12954)
  - External inspection during excavation if exposed
- Piping thickness testing: ultrasonic measurements at representative locations; every 5 years minimum; high-risk areas (elbows, tees) prioritized.
- CUI: insulation removed at representative locations (5-10%); visual inspection and UT testing.

M105: Valve Inspection and Testing

- Manual valves: annual operation test (full stroke); stem packing adjusted if leaking.
- Automated valves (ESD, control valves):
  - Quarterly: partial stroke test
  - Annually: full stroke test; response time measurement; actuator inspection
- Relief valves: inspection every 3-5 years; removed and bench-tested; set pressure verified.
- Check valves: annual functional test; internal inspection every 3-5 years.
- Inspection results recorded; deficiencies corrected before return to service.

M106: Pump Inspection and Maintenance

- Centrifugal pumps:
  - Daily: visual and auditory check during operation
  - Monthly: vibration measurement and trending
  - Annually: coupling inspection; seal inspection; bearing lubrication
  - Every 3-5 years: internal inspection; impeller and wear ring assessment
- Magnetic drive pumps: quarterly temperature monitoring; annual internal inspection.
- Pump performance monitoring: flow rate, discharge pressure, power consumption trended; degradation indicates maintenance required.
- Maintenance records: operating hours, parts replaced, performance data documented.

M107: Loading Equipment Inspection

- Loading arms (truck, rail, marine):
  - Before each use: visual inspection for damage, leaks
  - Monthly: swivel joints, couplings, breakaway devices, position interlocks inspected
  - Annually: load test of breakaway coupling; balance system adjustment
- Hoses and flexible connections:
  - Before each use: visual inspection
  - Annually: pressure test at 1.5× working pressure
  - Replacement: every 5 years maximum
- Inspection findings and test results documented.

M108: Instrumentation Calibration

- Instrument calibration per schedule:
  - Level transmitters: annually
  - Pressure transmitters: annually
  - Temperature sensors: biennially
  - Flow meters: annually
  - Gas detectors: monthly bump test and calibration
- Calibration against traceable reference standard; adjusted to within tolerance (typically ±1% of span).
- Calibration certificates issued; records maintained minimum 5 years.
- Out-of-tolerance instruments: investigated; repaired or replaced if beyond adjustment capability.

M109: Safety Instrumented System (SIS) Testing

- Safety instrumented systems tested per IEC 61508/61511:
  - SIL 1: every 2-3 years
  - SIL 2: every 1-2 years
- Proof test procedure: sensor tested, logic solver tested, final element tested (valve stroke, closure time measurement).
- Proof test documentation: results recorded; failures corrected; test interval adjusted if necessary.

M110: Electrical and Grounding System Inspection

- Electrical systems:
  - Annually: infrared thermography of electrical panels; hazardous area equipment inspection
  - Every 3 years: detailed inspection; insulation resistance testing; protective relay testing
- Grounding system:
  - Annually: ground resistance measurement at facility ground grid and tank grounding points; maximum 10 ohms (preferably <1 ohm)
- Emergency power systems (generators, UPS): monthly functional test; annual load bank test.

M111: Fire Protection System Inspection

- Fire water system:
  - Monthly: visual inspection of hydrants, valves, accessibility
  - Annually: functional test; hydrants flowed; pump performance test; valve inspection
- Fire suppression systems (if installed): foam concentrate tested annually; actuating devices tested; nozzles inspected.
- Fire extinguishers: monthly visual inspection; annual maintenance per EN 3.
- Inspection per CEA 4001.

M112: Structural Inspection

- Tank foundations and support structures: annual visual inspection for settlement, cracking, deterioration.
- Pipe supports and racks: annual visual inspection for corrosion, loose bolts, settlement.
- Ladders, platforms, stairs: annual inspection per EN ISO 14122.
- Structural deficiencies evaluated by engineer; repairs prioritized.

M113: Coating and Painting Maintenance

- External coatings:
  - Annually: visual inspection for rust, blistering, peeling
  - Repainting: every 5-7 years typical; spot repairs as needed
- Internal coatings (if present): inspection during internal tank inspection; recoating if deteriorated.

- Surface preparation before repainting per coating manufacturer specification.

M114: Inspection and Maintenance Records

- All inspection, maintenance, and testing documented:
  - Inspection reports: date, inspector, findings, photographs, recommendations
  - Maintenance records: work performed, parts replaced, completion date
  - Test results: calibration certificates, pressure tests, functional tests
  - Deficiency tracking: corrective actions, responsible person, completion date
- Records organized by equipment; accessible for audits.
- Record retention: inspection/maintenance records minimum 10 years; as-built drawings indefinitely.

2.8 Emergency Preparedness and Response

Scope: Emergency plans, protective equipment, firefighting systems, spill response, and crisis management

M115: Emergency Response Plan

- Comprehensive emergency response plan developed, documented, and maintained for methanol facility.
- Plan addresses credible emergency scenarios:
  - Fire (tank fire, pool fire, equipment fire)
  - Spill or release (liquid methanol release, vapor cloud)
  - Personnel exposure (inhalation, skin contact, ingestion)
  - Natural disasters (earthquake, flood, extreme weather)
  - Security incidents (sabotage, unauthorized access)
- Plan includes:
  - Roles and responsibilities (incident commander, emergency responders, support personnel)
  - Notification and communication procedures (internal, external, regulatory authorities)
  - Evacuation procedures and assembly points
  - Emergency equipment locations and operation
  - Coordination with external emergency services (fire department, medical, environmental response)
  - Post-incident procedures (investigation, recovery, remediation)
- Plan submitted to competent authority (fire department, port authority, environmental agency) for approval where required by regulation.
- Plan reviewed and updated annually; revised after incidents or facility changes.

M116: Emergency Training and Drills

- All personnel trained on emergency response procedures:
  - Initial training before assignment to methanol operations
  - Annual refresher training minimum

    - Training includes recognition of emergency conditions, alarm response, evacuation routes, assembly points
- Emergency drills conducted:
    - Fire drill: annually minimum; tests evacuation, alarm systems, fire brigade response
    - Spill response drill: annually minimum; tests spill containment, cleanup procedures, notifications
    - Tabletop exercises: scenarios discussed and response procedures reviewed
- Drills documented: participants, scenario, observations, improvement actions identified.
- External emergency services (fire department) invited to participate in drills.

M117: Methanol Fire Characteristics and Detection

- Critical safety information: Methanol burns with nearly invisible, pale blue flame in daylight; difficult to see without thermal imaging equipment.
- Fire detection methods:
    - Flame detectors: UV/IR or multi-spectrum type; detect invisible methanol flame (per chapters 2.3 or 2.6)
    - Heat detectors: backup for flame detection
    - Thermal imaging cameras: recommended for emergency responders to visualize methanol fires
- Personnel awareness:
    - Training emphasizes invisible flame hazard
    - Approach suspected fire areas with caution; use thermal imaging or heat sensation test (radiated heat felt before flame seen)
    - Never assume area is safe because no visible flame

M118: Fire Extinguishing Methods

- Methanol fire extinguishing agents:
    - Alcohol-resistant foam (AR-AFFF): primary method for large fires; forms vapor-suppressing blanket on methanol surface
    - Dry chemical (ABC or BC type): effective for small fires; does not prevent re-ignition
    - Carbon dioxide (CO_2): effective in enclosed spaces; higher concentration required than for hydrocarbon fires

    - Water spray (fog pattern): can be used for cooling or dilution; large quantities required (minimum 4:1 water-to-methanol ratio to render non-flammable)
- Methods NOT effective:
    - Standard aqueous film-forming foam (AFFF): destroyed by methanol; alcohol-resistant type required
    - Water jet (solid stream): spreads fire; only fog pattern acceptable
- Small fires (portable extinguisher range): dry chemical extinguisher (minimum 43A/233B rating per M126).
- Large fires: alcohol-resistant foam applied by fire department or facility fire brigade; water spray for cooling adjacent tanks/equipment.

M119: Personal Protective Equipment - Emergency Response

- Emergency PPE available at strategic locations:
    - Full face shield or splash goggles
    - Chemical-resistant gloves (butyl rubber preferred for methanol)
    - Chemical-resistant suit or apron
    - Emergency escape respirator (air-purifying with organic vapor cartridge) or self-contained breathing apparatus (SCBA)
- PPE for spill response and firefighting:
    - Fire brigade: full structural firefighting gear (coat, pants, helmet, boots, gloves); SCBA mandatory
    - Spill response team: chemical-resistant suit (Level B); SCBA or supplied-air respirator; chemical-resistant boots and gloves
- PPE inspection and maintenance: monthly inspection; damaged equipment replaced; SCBA air cylinders refilled after use and annually.
- Training on PPE donning, use, limitations, and decontamination.

M120: Emergency Decontamination and First Aid

- Decontamination facilities:
    - Safety showers: located at loading areas, pump stations, tank access points; frost-free or heat-traced; water temperature 15-37°C; flow rate minimum 75 liters/minute
    - Eyewash stations: located with safety showers; flow rate minimum 6 liters/minute; tested weekly
- First aid procedures for methanol exposure:

  - Skin contact: remove contaminated clothing; flush skin with large quantities of water for minimum 15 minutes; seek medical attention
  - Eye contact: flush eyes with water or eyewash for minimum 15 minutes; remove contact lenses if present; seek immediate medical attention
  - Inhalation: move person to fresh air; seek medical attention; provide oxygen if available and trained
  - Ingestion: do NOT induce vomiting; seek immediate medical attention (methanol ingestion can cause blindness or death)
- Medical treatment information: methanol poisoning treated with ethanol or fomepizole as antidote; prompt medical treatment critical.
- First aid supplies: maintained at facility; first aid trained personnel on-site during operations.

M121: Spill Response Procedures

- Immediate actions upon spill discovery:
  - Alert personnel; activate alarm if necessary
  - Stop source of spill if safe to do so (close valve, stop pump)
  - Eliminate ignition sources (no smoking, engines off, isolate electrical equipment)
  - Evacuate non-essential personnel from spill area
  - Don appropriate PPE before approaching spill
- Spill containment:
  - Small spills (<50 liters): absorb with absorbent material (sand, vermiculite, commercial absorbent pads)
  - Large spills (>50 liters): contain with dikes, berms, or absorbent booms; prevent entry to drains, sewers, or water bodies
  - Spilled methanol collected in containers; disposed per hazardous waste regulations
- Vapor control:
  - Water spray (fog pattern) to knock down vapors; direct spray away from spill to avoid spreading liquid
  - Ventilation of enclosed areas
- Cleanup:
  - Contaminated soil or absorbent material collected and disposed as hazardous waste
  - Area flushed with water; contaminated water sent to treatment system
  - Air monitoring confirms area safe before permitting re-entry

- Spill response equipment: spill kits, absorbent materials, protective equipment pre-positioned at strategic locations.

M122: Environmental Protection During Emergencies

- Prevent environmental contamination:
  - Spilled methanol contained within secondary containment (dikes) or prevented from entering storm drains, sewers, or water bodies
  - Drain valves closed during emergency to prevent release beyond facility boundary
  - Booms deployed in water bodies if methanol reaches drainage ditches or waterways
- Notification requirements:
  - Environmental authorities notified immediately if methanol released beyond facility boundary or enters water body
  - Quantity released estimated; environmental impact assessed
- Remediation:
  - Contaminated soil excavated and disposed if necessary
  - Groundwater monitoring initiated if subsurface contamination suspected
  - Surface water monitoring downstream if waterway impacted

M123: Firefighting Water System Design - Cooling and Protection

- Firefighting water system designed primarily for COOLING exposed equipment and tanks during fire, NOT for extinguishing methanol fires.
- System capacity calculation:
  - Tank fire: water application rate minimum 10 L/min/m^2 of tank surface
  - Duration: minimum 4 hours continuous supply
  - Example: 1000 m^2 tank surface × 10 L/min/m^2 × 240 minutes = 2,400 m^3 water required
- System components:
  - Water supply: dedicated storage tank, connection to municipal water, or reliable natural source (river, sea)
  - Fire pumps: minimum two pumps (duty and standby); automatic start on pressure drop; combined capacity meets demand
  - Distribution network: loop system with isolation valves; designed per EN 12845 or equivalent
  - Fire hydrants: spacing 50-80 meters; connections minimum DN65 (Storz coupling or equivalent)

- System design per EN 12845, EN 14816, or equivalent European standards.

M124: Firefighting Water System Maintenance

- Monthly inspection: hydrants, valves, accessibility verified.
- Annual functional test: hydrants flowed; pump performance tested (flow vs. pressure curve verified); system pressure at most remote hydrant measured.
- Weekly pump test: pumps started and run briefly; fuel level checked (diesel pumps); battery condition verified (electric start).
- System maintained frost-free in cold climates: drain valves, heat tracing, or insulation as appropriate.
- Test results documented; deficiencies corrected promptly.

M125: Fixed Fire Suppression Systems (if applicable)

- Fixed foam systems for large atmospheric tanks (if required by risk assessment or regulation):
  - Foam type: alcohol-resistant concentrate (AR-AFFF or fluoroprotein)
  - Application rate: per EN 13565 (typically 4-6 L/min/m^2 of tank surface)
  - Foam delivery: fixed foam chambers on tank rim or foam generators
  - Foam concentrate supply: adequate quantity for design application duration (typically 30 minutes)
- Deluge systems for loading areas or equipment (if required):
  - Water spray nozzles covering equipment
  - Automatic actuation by fire detection or manual activation
  - Design per EN 14816
- Systems tested annually: foam concentrate quality verified; foam expansion ratio tested; actuation devices tested; discharge nozzles inspected.

M126: Portable Fire Extinguishers

- Portable extinguishers located at:
  - Loading/unloading areas: minimum one per bay
  - Pump stations: minimum one per pump
  - Tank access points: minimum one per tank
  - Control rooms and buildings
  - Emergency equipment cabinets
- Extinguisher type and rating:

  - Dry chemical (ABC or BC type): minimum 43A/233B rating
  - CO_2 extinguishers: acceptable for electrical fires; minimum 5 kg capacity
- Extinguisher spacing: maximum 15 meters travel distance from any point to nearest extinguisher.
- Extinguishers inspected monthly (visual check); maintained annually per EN 3; hydrostatic test per schedule (typically 12 years for dry chemical).
- Personnel trained on extinguisher use; "PASS" method (Pull, Aim, Squeeze, Sweep) emphasized.

M127: Vapor Dispersion Control

- Vapor dispersion systems at loading areas (if required by risk assessment):
  - Water curtain: ring of spray nozzles surrounding loading area; activates automatically on gas detection or manually; total nozzle capacity (TNC) designed to contain and dilute vapor cloud
  - Water monitors: remotely controlled high-capacity nozzles (minimum 2000 L/min each); minimum two per loading bay; directed at vapor source
- System activation:
  - Automatic: triggered by gas detection alarm (high-level alarm per chapter 2.6)
  - Manual: push-button at control room and local safe locations
- System capacity sufficient to control credible vapor release scenarios; design per facility risk assessment and local fire code.

M128: Emergency Communication Systems

Communication infrastructure per M42 applies, with the following emergency-specific requirements:

- Dedicated emergency channel:
  - Separate radio frequency reserved for emergency communications only
  - Channel tested monthly; all emergency responders trained on use
- Pre-recorded emergency messages:
  - Standardized PA announcements for: fire, evacuation, gas release, shelter-in-place
  - Messages available in local language(s) and English
  - Activation from control room and backup location
- Distinct alarm tones:
  - Audible and visual alarms at strategic locations

    - Different tones for different emergencies (fire, evacuation, spill)
    - Alarm meaning posted at all work areas
- External emergency contacts:
    - Emergency services (fire, ambulance, police) on speed dial
    - Regulatory authorities (environmental agency, port authority) contact list posted
    - Management on-call list maintained and updated weekly
- Redundancy and testing:
    - Backup power (UPS or generator) for all emergency communication systems
    - Monthly communication system tests documented

M129: Evacuation Procedures and Assembly Points

- Evacuation routes clearly marked; minimum two independent routes from each work area.
- Evacuation triggers:
    - Fire alarm activation
    - Gas detection high-alarm
    - Emergency announcement via PA system
    - Siren or air horn (audible throughout facility)
- Evacuation procedure:
    - Personnel immediately cease operations (safe shutdown if time permits)
    - Proceed to nearest exit; do not use elevators
    - Report to designated assembly point
    - Remain at assembly point until accountability complete and clearance given
- Assembly points:
    - Located upwind and minimum 100 meters from facility
    - Clearly marked with signs
    - Protected from weather (shelter or designated building)
- Accountability: supervisors verify all personnel accounted for; report missing persons to incident commander immediately.
- Evacuation drills conducted annually (per M116).

M130: Wind Indication

- Wind direction indicator (wind sock or wind vane) installed at facility; visible from control room and key outdoor locations.

- Wind sock illuminated for night visibility.
- Wind direction critical for:
  - Evacuation planning (move upwind from spill or vapor release)
  - Vapor dispersion prediction
  - Firefighting operations planning

M131: Emergency Shutdown Procedures

- Emergency shutdown (ESD) initiated when:
  - Fire detected or reported
  - Major leak or spill
  - Safety system failure
  - Natural disaster (earthquake, severe weather)
- ESD actions (per chapter 2.3):
  - Stop all transfer operations
  - Close automated isolation valves
  - Stop pumps
  - Activate alarms
  - Notify emergency services
- ESD activation: manual push-buttons at control room and minimum two field locations (near tanks, loading areas).
- Post-ESD: facility inspected for damage; system integrity verified before restart.

M132: Fire Brigade (if applicable)

- Facility fire brigade established for large facilities or where public fire department response time exceeds 10 minutes.
- Coordination with public fire department: memorandum of understanding defines roles, responsibilities, command structure during emergencies.

M133: Post-Incident Investigation and Reporting

- All emergency incidents investigated:
  - Incident investigation team: facility management, safety officer, operations personnel, subject matter experts as needed
  - Investigation timeline: initiated within 24 hours; report completed within 30 days

    - Investigation includes: incident timeline, root cause analysis, contributing factors, corrective actions
- Regulatory reporting:
    - Immediate notification: fire department, environmental agency, port authority per regulatory requirements
    - Written report: submitted within timeframe specified by regulation (typically 7-30 days)
    - Report includes: incident description, quantity released, environmental impact, corrective actions
- Lessons learned:
    - Findings communicated to all personnel
    - Corrective actions tracked to completion
    - Emergency response plan and procedures updated if necessary

M134: Mutual Aid Agreements

- Mutual aid agreements established with neighboring facilities for emergency support:
    - Fire suppression assistance (equipment, personnel, foam supplies)
    - Emergency shelter for evacuated personnel
    - Backup communication systems
    - Emergency equipment loan (pumps, generators, spill response equipment)
- Agreements documented in writing; contact lists maintained and updated; tested periodically through joint drills.

M135: Emergency Equipment Locations and Lighting

- Emergency equipment locations marked on facility emergency maps; posted in control room and at entry points.
- Emergency lighting:
    - Portable lights and flashlights with spare batteries at strategic locations
    - Battery-powered emergency lights in control room, pump stations, and loading areas
- Reference: For specific equipment requirements see M119 (Emergency PPE), M120 (First Aid), M121 (Spill Response Kits), M126 (Fire Extinguishers).

2.9 Modern Requirements

Scope: Cybersecurity, climate resilience, and modern security threats

M136: Industrial Cybersecurity for Control Systems

- Industrial control systems (Supervisory Control and Data Acquisition (SCADA), Distributed Control System (DCS), PLC) and safety instrumented systems protected per IEC 62443, NIS2 Directive (Art. 21) or equivalent.
- Network segmentation:
  - Operational technology (OT) separated from information technology (IT)
  - Firewall at OT/IT boundary
  - Safety systems (SIS) isolated from process control where practical
- Access control:
  - User authentication and role-based permissions
  - Multi-factor authentication for remote access
  - VPN required for external connections
  - Session logging maintained
- Physical security of control hardware:
  - PLCs, servers, networking equipment in locked cabinets or control room
  - Access logging for control room and equipment areas
- Security maintenance:
  - Regular security updates and patches per vendor recommendations
  - Vulnerability assessments annually minimum
  - Security incidents investigated and documented
- Backup systems:
  - Control configurations backed up offline (not network-connected)
  - Backups tested quarterly
  - Recovery procedures documented

Recommendation:

- Encrypted wireless protocols and key rotation are strongly recommended, particularly if wireless links are operational.
- A documented cybersecurity incident response plan specific to industrial control systems should be maintained and regularly tested.

M137: Cybersecurity - Emergency Control Independence

- Critical safety functions independent of control systems:
  - Manual emergency shutdown pushbuttons (hardwired, not through PLC)
  - Manual valve operation capability (handwheels on critical valves)
  - Backup manual level indication (sight glasses, dip sticks)
- Cybersecurity incident response:
  - Procedures for control system compromise
  - Manual operation capability until systems restored
  - Emergency shutdown independent of compromised systems
- Personnel training on cybersecurity awareness: phishing recognition, password security, suspicious activity reporting.

M138: Climate Resilience - Design Parameters

- Facility design accounts for climate change projections (IPCC AR6):
  - Temperature extremes: design for +10°C above historic maximum and -10°C below historic minimum
  - Wind loads: 150% of current local design wind speed standards (EN 1991)
  - Precipitation: drainage systems sized for 100-year storm plus 25% margin
- Flood protection (if facility in projected 100-year flood zone):
  - Critical equipment elevated above projected flood level
  - Waterproof barriers for below-grade infrastructure
  - Emergency drainage capacity with backup power
- Sea level rise (coastal facilities):
  - Long-term planning accounts for 0.5-1 meter sea level rise over facility lifetime
  - Critical infrastructure elevated or protected accordingly
- Climate risk assessment updated every 5 years or after severe weather events.

M139: Extreme Weather Preparedness

- Severe weather monitoring and response:
  - Weather alert system providing real-time warnings
  - Pre-storm procedures: secure loose items, verify backup power, test emergency systems
  - Operations curtailment criteria defined (wind speed thresholds, storm warnings)

- Post-storm inspection:
  - Facility inspected for damage before resuming operations
  - Structural integrity, tank stability, piping, electrical systems verified
- Extended power outage preparedness:
  - Emergency generator fuel supply for 72 hours minimum
  - Manual monitoring procedures for extended outages
  - Alarm systems connected to security response

M140: Physical Security - Critical Infrastructure Protection

- Control room hardening:
  - Backup control capability at separate location if control room compromised
  - Emergency systems (ESD, fire suppression) protected and redundant
- Drone countermeasures (optional, for high-risk facilities):
  - Drone detection systems (radar, RF, visual)
  - Response protocols for unauthorized drone activity
  - Coordination with local authorities
- Personnel security measures:
  - Visitor registration and escort in operational areas
  - Access control cards or keys tracked and controlled
  - Contractor access limited to authorized areas and supervised
- Emergency lockdown capability:
  - Procedures for security threats
  - Secure access control at all entry points
  - Communication capability to alert personnel and authorities

M141: Sustainability Assessment and Life Cycle Considerations

- Major infrastructure projects subject to sustainability assessment per EU Taxonomy requirements:
  - New storage tanks or significant modifications
  - New loading/unloading infrastructure
  - Projects seeking EU green financing or public funding
- Carbon footprinting per ISO 14067 or EN 17472:
  - Scope 1: Direct emissions from facility operations
  - Scope 2: Indirect emissions from purchased energy
  - Scope 3: Embodied carbon in materials, transport, construction
- EU Taxonomy environmental objectives considered:

    - Climate change mitigation (primary)
    - Climate change adaptation
    - Circular economy (material reuse, recycling)
    - Pollution prevention
    - Water and marine resource protection
- Construction and demolition waste (CDW):
    - Minimum 70% reuse or recycling of non-hazardous CDW per EU Taxonomy
    - Material recovery plan documented before construction
- Material selection informed by environmental assessment:
    - Recyclable materials prioritized where technically feasible
    - Environmental Product Declarations (EPDs) per EN 15804 requested from suppliers for major components
    - Results documented and considered in design decisions
- Assessment documentation retained for facility lifetime; updated for major modifications.

Note: Full Life Cycle Assessment (LCA) per ISO 14040/14044 and EN 17472 recommended for projects >€5 million or where required by funding conditions, environmental permits, or corporate ESG commitments.

3 References

- DNV: Alternative Fuels Insight Tool
- EIGA Doc 75/21 Methodology for determination of safety and separation distances
- EN 1092-1: Flanges and their joints - Circular flanges for pipes, valves, fittings and accessories
- EN 12954: Cathodic Protection of Buried or Immersed Metallic Structures
- EN 13480: Metallic Industrial Piping
- EN 13565: Fixed Firefighting Systems - Foam Systems
- EN 14015: Specification for the design and manufacture of site built, vertical, cylindrical, flat-bottomed, above ground, welded, steel tanks
- EN 3: Portable Fire Extinguishers
- EN 60079 series: Explosive Atmospheres (Equipment and Protection Systems)
- EN ISO 14122: Safety of Machinery - Permanent Means of Access to Machinery
- EN ISO 15614-1: Specification and qualification of welding procedures for metallic materials
- EU Taxonomy Regulation (2020/852): Sustainable Finance
- Eurocode 1 (EN 1991): Actions on Structures
- Eurocode 8: Design of structures for earthquake resistance
- IEC 61508: Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems
- IEC 61511: Functional Safety - Safety Instrumented Systems for the Process Industry Sector
- IEC 62443: Industrial Communication Networks - Network and System Security
- IPCC AR6: Sixth Assessment Report of Climate Change
- ISO 14040: Environmental Management - Life Cycle Assessment - Principles and Framework
- ISO 14044: Environmental Management - Life Cycle Assessment - Requirements and Guidelines
- ISO 14726: Ships and Marine Technology - Identification Colours for the Content of Pipes
- ISO 45001: Occupational Health and Safety Management Systems
- ISO 6583:2024 Methanol as a fuel for marine applications
- ISO 9606: Qualification testing of welders
- Methanol Institute: Atmospheric Above Ground Tank Storage of Methanol
- Methanol Institute: Compatibility of Elastomers in Neat Methanol Service
- Methanol Institute: Compatibility of Metals & Alloys in Neat Methanol Service
- Methanol Institute: Safe Handling Manual (5th Edition)

- OCIMF: Oil Companies International Marine Forum - Guidelines for Marine Loading Arms
- Perplexity.ai, Claude.ai: As a summary tool; The content reflects the project's activities. AI were used for the generation of the cover page, and no personal data was used for this purpose.
- PGS 15: Storage of packaged hazardous substance

4 Abbreviations and Acronyms

- AED: Automated External Defibrillator
- AR-AFFF: Alcohol-Resistant Aqueous Film-Forming Foam
- CCTV: Closed-Circuit Television
- CUI: Corrosion Under Insulation
- DCS: Distributed Control System
- DN: Diameter Nominal
- EN: European Norm / European Standard
- EPDM: Ethylene Propylene Diene Monomer
- ERC: Emergency Release Coupling
- ESD: Emergency Shutdown
- ESG: Environmental, Social, and Governance
- GHS: Globally Harmonized System
- HDPE: High-Density Polyethylene
- HHLA: High-High Level Alarm
- HLA: High-Level Alarm
- HMI: Human-Machine Interface
- IEC: International Electrotechnical Commission
- IPCC: Intergovernmental Panel on Climate Change
- ISO: International Organization for Standardization
- IT: Information Technology
- LCA: Life Cycle Assessment
- LEL: Lower Explosive Limit
- MOC: Management of Change
- MT: Magnetic Particle Testing
- OCIMF: Oil Companies International Marine Forum
- OT: Operational Technology
- P&ID: Piping and Instrumentation Diagram
- PA: Public Address
- PLC: Programmable Logic Controller
- PN: Pressure Nominal (flange rating)
- PPE: Personal Protective Equipment
- PTFE: Polytetrafluoroethylene (Teflon)
- RF: Radio Frequency
- RT: Radiographic Testing
- SCADA: Supervisory Control and Data Acquisition
- SCBA: Self-Contained Breathing Apparatus
- SIL: Safety Integrity Level
- SIS: Safety Instrumented System

- TNC: Total Nozzle Capacity
- TRV: Thermal Relief Valve
- UEL: Upper Explosive Limit
- UPS: Uninterruptible Power Supply
- UT: Ultrasonic Testing
- UV/IR: Ultraviolet/Infrared
- VFD: Variable Frequency Drive
- VOC: Volatile Organic Compounds
- VPN: Virtual Private Network
- ppm: Parts per million

Annex 8.3 Baltic Ports Bunkering Guidebook: Safety requirements for H2-Derivative handling

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Baltic Ports Bunkering Guidebook

Methanol and Ammonia as Marine Fuels

Authors

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H2Deri@BSP - A cooperation project to develop proof-of concepts for the uptake of H2 derivative fuels!

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Executive Summary

The transition to climate-neutral port operations in the Baltic Sea region requires a clear and coherent approach for the safe use of hydrogen-derived fuels. Methanol and ammonia are emerging as key energy carriers for maritime decarbonisation. However, port regulations, permitting procedures, and safety requirements vary widely between countries and individual ports, creating challenges for operators, regulators, and infrastructure developers planning for large-scale deployment of these alternative fuels.

The Interreg H2 Derivatives @ Baltic Sea Ports project, through Work Package 1.3, addresses this challenge by developing a harmonised framework for methanol and ammonia operations, presented in this Port Safety Handling Guidebook for Methanol and Ammonia as Marine Fuels. By reviewing EU, IMO, and other relevant international regulations, identifying best practices, and engaging partner ports, this work supports the safe, consistent, and scalable adoption of methanol and ammonia across the region.

This document serves primarily as an implementation guide for ports and port authorities, providing a practical framework to establish and maintain safe bunkering operations for ammonia and methanol within their jurisdiction. It provides core knowledge on bunkering, as well as fuel-specific considerations, to assist ports in achieving compliance with safety standards and best practices. It does not replace, amend, or supersede national legislation, port by-laws, or mandatory regulatory requirements, and is neither a design manual nor a legal interpretation. The guide is written from the port perspective, outlining the responsibilities and actions required by the port authority, while also addressing the roles and obligations of stakeholders such as ship operators, fuel suppliers, and terminal operators who wish to conduct bunkering operations.

The guide is intended for those directly responsible for bunkering safety and operations, including port safety officers and their safety teams. It will also be of value to national and local authorities, emergency response and support services, terminal operators, and other stakeholders as fuel suppliers and ship operators involved in bunkering or receiving ammonia and methanol fuels, providing them with clear guidance on what is expected when operating in the port.

Content

Executive Summary 2
List of Figures/Tables 7
Abbreviations 8
Introduction 10
Use of this Guidebook – Structure and Approach 11
Disclaimer 11
Methodology 12
Ports Roadmap to Bunkering 1. 15
How to Use the Ports Roadmap to Bunkering 1.1 16
Structure of the roadmap 1.1.1 16
Link to IAPH Port Readiness Levels (PRL) 1.1.2 16
How the roadmap works with this guidebook 1.1.3 18
Step 1 – Assess the Business Case and Strategic Rationale 18
Step 2 – Build Internal Knowledge and Assign Ownership 18
Step 3 – Establish Governance and Competent Authority Roles 19
Step 4 – Understand the Regulatory and Standards Landscape 19
GATE 1 – Strategic Readiness and Internal Alignment 20
Step 5 – Wider Stakeholder and Public Engagement 21
Step 6 – Identify Potential Bunkering Locations 21
Step 7 – Define Bunkering Scenarios and Fuel Suitability 22
Step 8 – Undertake Risk Assessments and Define Controlled Areas 22
GATE 2 – Strategic Feasibility and Stakeholder Alignment Check 23
Step 9 – Infrastructure Development and Readiness 24
Step 10 – Develop Licensing, Permitting, and Authorisation Processes 25
Step 11 – Define Documentation and Operational Controls 25
Step 12 – Training, Competence 26
Step 13 – Establish Emergency Preparedness and Response 27
GATE 3 – Operational Readiness and Commitment Check 27
Step 14 – Pilot Operations and Controlled Introduction 29
GATE 4 – Pilot Validation and Scale-Up Decision 29
Step 15 – Transition to Business-as-Usual Operations 30
Key Bunkering Knowledge 2. 31
International Regulatory Framework & Guidelines 2.1 31
IMO regulatory framework 2.1.1 32

International standards 2.1.2 33
National and regional regulations 2.1.3 33
Industry guidelines 2.1.4 36
Stakeholders Identification 2.2 38
Key stakeholder responsibility matrix 2.2.1 39
Operational roles during bunkering 2.2.2 42
Port authority – role & responsibilities 2.2.3 42
Bunkering Supply Scenarios 2.3 45
The Four Stages Approach for Vessels Operators 2.4 46
Bunker System (Transfer System) 2.5 46
Handling and human-factor considerations 2.5.1 47
Hazardous Areas, Toxic Areas, Safety Zones and SIMOPs 2.6 47
Hazardous area 2.6.1 49
Safety zone 2.6.2 49
Monitoring and security area 2.6.3 49
Marine exclusion zone 2.6.4 50
Assessment zone 2.6.5 50
Toxic area 2.6.6 50
SIMOPs integration 2.6.7 51
Bunkering Documentation 2.7 51
Typical documents included in the bunkering management plan 2.7.1 53
Documentation - Port review and approval 2.7.2 54
Fuel Knowledge 3. 55
Marine Fuels- Properties Summary 3.1 55
Methanol Core knowledge 3.2 56
General & basic properties 3.2.1 56
Safety – Fire, explosion and toxicity 3.2.2 57
As cargo and as fuel 3.2.3 58
Environmental impact GHG & Pollutants 3.2.4 59
Ammonia Core knowledge 3.3 59
General & basic properties 3.3.1 59
Safety – Fire, explosion and toxicity 3.3.2 60
As cargo and as fuel 3.3.3 61
Environmental impact GHG & pollutants 3.3.4 62
Lifecycle Analysis for Methanol and Ammonia 3.4 63

Implementation Guidance 4 65
Port governance, strategy and engagement 4.1 66
Role of ports across the four stages for vessel operators 4.1.1 66
Link to the IAPH port readiness level framework 4.1.2 67
Stakeholder engagement (internal and external) 4.1.3 67
Site selection, permitting and port planning tools 4.2 70
Site identification, design and risk assessment 4.2.1 70
Port bunkering map 4.2.2 71
Bunkering licensing process 4.2.3 72
Nautical safety assessments 4.2.4 77
Vessel traffic services and vessel traffic management 4.2.5 79
Risk assessment framework and controlled areas 4.3 80
Risk assessment, controlled areas HAZOP and SIMOPs 4.3.1 80
Vent mast releases and gas dispersion considerations 4.3.2 85
Assessment Zone: Purpose, Implications and Relevance for Port 4.3.3 87
Fuel-specific safety zone determination 4.4 89
Methanol: Determination and size of safety zones 4.4.1 89
Ammonia: Determination and size of safety/toxic zones 4.4.2 94
Core operational controls 4.5 99
Bunkering compatibility assessment 4.5.1 99
Bunkering checklist 4.5.2 101
Bunkering emergency shutdown (ESD) 4.5.3 103
Communication protocols 4.5.4 106
Enforcement protocols 4.5.5 107
Training requirements and safety drills 4.5.6 108
Emergency management and response 4.6 114
Emergency preparedness 4.6.1 114
Incidents reporting and lessons learned 4.6.2 118
Special and non-routine cases 4.7 120
Methanol or ammonia as fuel at ports without a bunkering framework 4.7.1 120
Quantity and quality of fuel 4.7.2 122
Support services, e.g. maintenance and gas freeing 4.7.3 124
Debunkering 4.7.4 125
References 128

Appendix A: Bunkering Documentation for Ports 129
Port Documents Review Matrix A.1 129
Documentation Expectations by Operation Maturity Level A.2 131
Documentation Expectations Aligned with IAPH PRLs A.3 132
Appendix B: Bunkering Site Identification Process 136
Establish governance and ownership B.1 137
Identify candidate bunkering locations B.2 138
Define applicable bunkering supply scenarios B.3 138
Screen fuel suitability by location B.4 138
Undertake site-level risk assessment B.5 139
Define operational envelopes and constraints B.6 139
Engage external stakeholders B.7 139
Develop the bunkering map and site register B.8 140
Integrate into permitting and port procedures B.9 140
Apepndix C: Port checklist: reviewing a proposed safety zone 141
Additional considerations for ports C.1 142
Appendix D: Further considerations on HAZID, HAZOP and SIMOPs 144
Hazard Identification (HAZID) D.1 144
Hazard and Operability Study (HAZOP) D.2 145
SIMOPs (Simultaneous Operations) Assessment D.3 147
Appendix E: Ports Roadmap Checklist 149

List of Figures/Tables

Figure 1-1: Checklist for Roadmap to bunkering (see Appendix E)..... 9
Figure 2-1: Bunkering Stakeholder Diagram..... 38
Figure 2-2: Bunkering Supply Scenarios..... 45
Figure 2-3: Bunkering zones schematic..... 48
Figure 3-1: Typical fuel emission factors (Source: Bureau Veritas, Outlook for Alternative Fuels, 2022).....64
Figure 4-1: Methanol flammability and toxicity ppm levels of interest..... 90
Figure 4-2: Ammonia flammability and toxicity ppm levels of interest..... 94
Figure 4-3: IAPH bunkering checklist.....101

Table 1-1 Ports Roadmap Vs IAPH PRLs..... 17
Table 2-1: Stakeholder responsibility matrix..... 40
Table 2-2: Bunkering operational roles..... 42
Table 2-3: Bunker system key components..... 47
Table 3-1: Marine fuels - Properties comparison summary..... 55
Table 3-2: Ammonia concentration and effects..... 60
Table 4-1: Methanol acute exposure guideline levels (US EPA, 2016)..... 91
Table 4-2: Ammonia acute exposure guideline levels (US EPA, 2016).....96
Table A-1: Port Documents Review Matrix.....129
Table A-2: Documentation Expectations by Operation Maturity Level.....131

Abbreviations

ADR – European Agreement concerning the International Carriage of Dangerous Goods by Road
AEA – Ammonia Energy Association
AEGL – Acute Exposure Guideline Levels
AEGL-1 / AEGL-2 / AEGL-3 – Acute Exposure Guideline Level bands
BSL – Bunkering Safety Link
BSV – Bunker Supply Vessel
CFD – Computational Fluid Dynamics
EPA – Environmental Protection Agency (United States)
ERC – Emergency Release Coupler
EMSA – European Maritime Safety Agency
ESD – Emergency Shutdown
GHG – Greenhouse Gas
HAZID – Hazard Identification
HAZOP – Hazard and Operability Study
IBC Code – International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk
IACS – International Association of Classification Societies
IDLH – Immediately Dangerous to Life or Health
IGC Code – International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
IGF Code – International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels
IMDG Code – International Maritime Dangerous Goods Code
IMO – International Maritime Organization
IAPH – International Association of Ports and Harbors
ISGOTT – International Safety Guide for Oil Tankers and Terminals
ISO – International Organization for Standardization
JBP – Joint Bunkering Plan
JPBO – Joint Plan of Bunkering Operation
LCA – Life-Cycle Assessment
LEL – Lower Explosive Limit
LFL – Lower Flammable Limit
MGO – Marine Gas Oil
MIE – Minimum Ignition Energy
MI – Methanol Institute
OCIMF – Oil Companies International Marine Forum
OELs – Occupational Exposure Limits
PIC – Person in Charge
POAC – Person in Overall Advisory Control
PPE – Personal Protective Equipment
PRL – Port Readiness Level (IAPH PRL for Marine Fuels)
PRV – Pressure Relief Valve
QCA – Quantitative Consequence Assessment
QRA – Quantitative Risk Assessment
QualRA – Qualitative Risk Assessment
SCBA – Self-Contained Breathing Apparatus
SCR – Selective Catalytic Reduction

SGMF – Society for Gas as a Marine Fuel
SIGTTO – Society of International Gas Tanker and Terminal Operators
SIMOPs – Simultaneous Operations
SIRE – Ship Inspection Report Programme
STS – Ship-to-Ship
STEL – Short-Term Exposure Limit
TWA – Time-Weighted Average
VTS – Vessel Traffic Services

Introduction

The transition toward low- and zero-carbon shipping requires ports to adopt safe, practical, and consistent approaches to alternative fuel handling. As methanol and ammonia gain prominence as hydrogen-derived marine fuels, ports should be prepared to manage their bunkering safely and in alignment with evolving regulatory expectations. The Baltic Ports Bunkering Guidebook for Methanol and Ammonia as Marine Fuels has been developed to support this transition by providing a clear implementation framework tailored to port authorities and their stakeholders.

The guide recognises that ports are at different stages of readiness and face varying regulatory environments, infrastructure constraints, and commercial drivers. The Guidebook does not seek to prescribe a single approach or replace national regulations or international standards. Instead, it provides ports with a coherent framework, shared terminology, and practical guidance to help them make informed, defensible decisions when enabling methanol and ammonia bunkering.

Central to the Guidebook is a staged **Ports Roadmap to Bunkering**, which supports ports in progressing from early strategic intent through pilot operations to business-as-usual bunkering. The guidance emphasises risk-based decision-making, use of existing industry standards and tools, and early engagement with stakeholders and regulators. By applying this Guidebook, ports can build confidence, consistency, and transparency in how methanol and ammonia bunkering is assessed, authorised, and managed within the port environment.

Clarification on the Use of the Term "Port"

This Guidebook addresses the role of "ports" in the introduction and oversight of alternative fuel bunkering operations. However, it is recognised that the legal responsibilities, statutory powers, enforcement capability, and organisational structures of ports vary significantly across jurisdictions. Different legal systems use different terminology and institutional arrangements, such as port authority, harbour authority, harbour master, maritime administration, terminal operator, municipal authority, or other designated competent authority.

In some jurisdictions, the port authority is a public-law body with statutory powers. In others, the port operator may be a private entity acting under concession, while regulatory oversight is exercised by a separate national maritime administration or transport ministry. The harbour master may hold specific powers relating to navigational safety and operational control within port limits. Environmental, occupational health and safety, and major hazard regulations may be enforced by separate national or regional authorities.

Acknowledging these differences, this Guidebook cannot prescribe jurisdiction-specific governance models. **The term "port" is therefore used in a functional sense**, referring to the entity or group of entities that hold responsibility and accountability within a given jurisdiction for authorising, overseeing, and enforcing bunkering activities within port limits. **Each jurisdiction should define, within its own legal and regulatory framework, which authority or combination of authorities fulfils this role.**

As responsibilities may be shared between multiple organisations. Clear identification of roles, statutory powers, and decision-making responsibilities within each jurisdiction is therefore essential before implementing methanol or ammonia bunkering operations.

Use of this Guidebook – Structure and Approach

This Guidebook is structured to support ports at different stages of readiness for methanol and ammonia bunkering, from early strategic consideration through to business-as-usual operations.

It is organised into five complementary chapters:

- **Ports Roadmap to Bunkering**, which provides a staged, decision-gated pathway;
- **Key Bunkering Knowledge**, covering foundational concepts applicable across fuels and supply scenarios;
- **Fuel Knowledge**, addressing methanol and ammonia characteristics, hazards, and risk drivers;
- **Implementation Guidance**, offering practical direction for ports on governance, site selection, risk assessment, licensing, operations, training, and emergency preparedness;
- **Appendices**, providing tools, checklists, and reference material to support application in practice.

The Guidebook is intended to be used flexibly. Ports may focus on the sections most relevant to their current readiness level and return to others as their framework and experience evolve.

Disclaimer

This Guidebook provides non-binding guidance intended to support ports and port authorities in the safe planning and implementation of methanol and ammonia bunkering operations. It does not replace, amend, or supersede national legislation, port by-laws, or mandatory regulatory requirements, and is neither a design manual nor a legal interpretation. Ports are expected to integrate the guidance contained in this document into their own local regulatory frameworks, procedures, and authorisation processes, in accordance with applicable national laws and the requirements of the competent authorities. Where differences arise, national legislation and port-specific rules shall prevail.

Methodology

This Guidebook has been developed through a structured, collaborative and iterative process combining research, practitioner input and partner review.

The work began with background research and the development of a proposed chapter structure and content list. This initial phase included a review of existing regulatory instruments, relevant industry guidance, and emerging practices related to methanol and ammonia bunkering, together with experience drawn from LNG implementation in ports. The objective was to establish a solid analytical foundation and identify the key themes requiring structured guidance.

A structured workshop was subsequently convened with project partners and invited stakeholders. Participants were invited to comment on and refine the proposed content list, identify priority risk areas, highlight governance challenges, and share practical port-level constraints and lessons learned from pilot and early-stage projects. These discussions were instrumental in shaping the overall architecture of the Guidebook and ensuring that it addressed concrete operational and regulatory questions rather than theoretical considerations.

Following the workshops, the authors undertook detailed research and drafting. This phase combined further review of international instruments and standards, analysis of existing bunkering frameworks including LNG, assessment of fuel-specific hazard characteristics for methanol and ammonia, and the direct professional experience of the authors in alternative fuel projects. The drafting process sought to translate these inputs into a coherent roadmap and governance framework applicable across jurisdictions.

A full draft was then circulated to all project partners for structured review. Comments were consolidated, discussed and systematically addressed, with particular attention given to technical accuracy, regulatory neutrality and practical applicability across different legal and institutional contexts.

Finally, a dedicated review meeting with core partners was held to validate the near-final draft. This meeting ensured alignment on terminology, scope, governance assumptions and the overall balance between flexibility and clarity. Final refinements were incorporated prior to issue.

Throughout the development process, inputs from formal research and the practical experience of partners and authors were continuously integrated.

Rationale for a roadmap and framework approach

The decision to structure the Guidebook around a staged roadmap and implementation framework reflects the current state of industry development.

Ports and regulators are still in an experience-building phase for methanol and ammonia bunkering. Unlike conventional fuels, and unlike LNG today, there is not yet a consolidated body of widely accepted “best practice” for these fuels. Operational data, life-cycle evidence, and long-term case studies remain limited.

In this context, prescribing fixed models, detailed checklists or uniform technical solutions would be premature. Instead, the Guidebook adopts:

- a staged roadmap with defined decision gates;
- a governance and risk-based framework;
- a scalable implementation logic.

The roadmap provides structure without rigidity. It enables ports to:

- build internal capability;
- engage stakeholders progressively;
- validate feasibility through risk assessment;
- move from pilot to business-as-usual in a controlled manner.

This approach reflects several three underlying realities:

- First, responsibilities for bunkering oversight are often shared across multiple entities. In many jurisdictions, port authorities, harbour masters, national regulators, environmental agencies, terminal operators and emergency services each hold defined roles. A framework-based approach helps to clarify interfaces, decision-making responsibilities and escalation pathways without imposing a single governance model that may not align with national legal structures.
- Second, methanol and ammonia present distinct hazard profiles. Differences in flammability, toxicity and dispersion behaviour mean that controls cannot be assumed transferable from one fuel to another without analysis. A structured framework ensures that operational envelopes, safety zones and documentation requirements are derived from fuel-specific risk assessment rather than presumed equivalence.
- Third, regulatory expectations continue to develop at both national and international levels. A flexible framework enables ports to align with existing legislation, incorporate evolving standards, and adapt to new guidance without requiring fundamental restructuring of their governance model. In this way, the roadmap and framework together provide a stable yet adaptable foundation for safe implementation during a period of technical and regulatory evolution.

Fuel-Agnostic Design with LNG as Reference

Although this Guidebook focuses on methanol and ammonia, the roadmap and overarching framework are intentionally fuel-agnostic. The governance logic, staged development model, risk-based control philosophy, and documentation structure are designed to be applicable to other alternative marine fuels, as this follows international established practise. In this respect, the framework establishes a transferable decision-making architecture rather than a fuel-specific technical manual.

The LNG implementation pathway has been used as a reference point, as LNG represents the most mature example of alternative fuel integration within port environments. Its evolution from pilot projects to routine operations provides valuable lessons in staged development, permitting structures, risk assessment methodologies, and the progressive refinement of documentation and oversight.

At the same time, the Guidebook does not assume direct equivalence between LNG and methanol or ammonia. The distinct physical, chemical and toxicological characteristics of these fuels have been explicitly presented within the framework, and fuel-specific differences are addressed where they materially affect risk assessment, operational controls or emergency preparedness.

Summary

The methodology combines structured research, multi-stakeholder input, expert drafting, iterative review, and validation. The resulting roadmap and framework reflect the current transitional phase of methanol and ammonia bunkering:

- structured, but not prescriptive;
- risk-based, but proportionate;
- scalable, but defensible;
- fuel-agnostic in structure, yet fuel-specific in hazard treatment.

This approach enables ports to progress safely from strategic consideration to pilot operations and ultimately to business-as-usual bunkering, while remaining adaptable to evolving regulation and operational experience.

Ports Roadmap to Bunkering 1.

This ports roadmap provides a practical, step-by-step pathway to support the introduction of methanol and ammonia bunkering, from initial consideration through to routine, business-as-usual operations (see figure 1-1 and appendix E).

It is intended as practical tool to supports ports that are progressing from pilot projects to mature operations.

While the steps are presented in a logical sequence, ports may adapt the order, revisit steps, or progress in parallel depending on local context, regulatory frameworks, and commercial drivers.

Ports Roadmap to Bunkering

CHECKLIST for steps and decision gates for alternative fuels bunkering
The ports roadmap is structured into 15 implementation steps, grouped into four development phases, and punctuated by four decision gates.

Phase A – Strategic foundation *(Steps 1–4 | Gate 1)*

Step 1 – Assess the business case and strategic rationale
Clarify why alternative fuel bunkering is relevant to the port, which fuels are in scope, and over what timeframe.

Step 2 – Build internal knowledge and assign ownership
Establish baseline fuel knowledge and assign clear internal responsibility across safety, marine, environment, and permitting functions.

Step 3 – Establish governance and competent authority roles
Define decision authority, escalation paths, and internal risk acceptance principles.

Step 4 – Understand the regulatory and standards landscape
Identify applicable national and international regulations, standards, and guidance, and where early regulator engagement is needed.

Gate 1 – Strategic Readiness and Internal Alignment
Decision focus: Is there a clear strategic case and sufficient internal alignment to proceed?
Confirms that:
- A strategic rationale and indicative timeline are defined
- Internal ownership and governance are clear
- Regulatory context is understood at a high level
- No fundamental barriers are evident

Phase B – Feasibility and alignment *(Steps 5–8 | Gate 2)*

Step 5 – Wider stakeholder and public engagement
Engage regulators, terminals, emergency services, port users, and - where relevant - local authorities and the public

Step 6 – Identify potential bunkering locations
Proactively screen and shortlist candidate locations based on navigational, spatial, and emergency response considerations.

Step 7 – Define bunkering scenarios and fuel suitability
Identify feasible supply modes and fuel-specific constraints for each candidate location.

Step 8 – Undertake risk assessments and define controlled areas
Review risk assessments to define safety zones, toxic areas (where applicable), SIMOPs constraints, and operational limits.

Gate 2 – Strategic feasibility and stakeholder alignment check
Decision focus: Can bunkering be supported in principle within the port's operational, regulatory, and social context?
Confirms that:
- Stakeholders and regulators are broadly aligned
- Feasible locations and bunkering scenarios are identified
- Risks can be managed within agreed criteria
- No prohibitive constraints remain

Phase C – Implementation and authorisation *(Steps 9–13 | Gate 3)*

Step 9 – Infrastructure development
Address any physical, spatial, or access constraints needed to support controlled bunkering.

Step 10 – Licensing, permitting, and authorisation processes
Establish proportionate licensing and approval processes aligned with national requirements.

Step 11 – Documentation and operational controls
Define documentation requirements to support safe operations and oversight.

Step 12 – Training and competence
Ensure port personnel, terminals, contractors, and emergency services are trained and prepared.

Step 13 – Emergency preparedness and response
Integrate fuel-specific scenarios into port emergency planning and conduct joint exercises.

Gate 3 – Operational authorisation decision
Decision focus: Can the port authorise first or pilot bunkering operations under controlled conditions?
Confirms that:
- Infrastructure, procedures, and controls are in place
- Roles and responsibilities are clear
- Personnel and responders are trained
- Emergency arrangements are tested

Phase D – Operation and scale-up *(Steps 14–15 | Gate 4)*

Step 14 – Pilot operations and controlled introduction
Conduct first or pilot operations with enhanced oversight to validate assumptions and controls.

Gate 4 – Pilot validation and scale-up decision
Decision focus: Can operations transition beyond pilots?
Confirms that:
- Pilot operations have validated assumptions
- Procedures and controls work in practice
- Lessons learned are embedded

Step 15 – Transition to business-as-usual operations
Progressively integrate bunkering into routine port operations, maintaining a risk-based approach.

Figure 1-1: Checklist for Roadmap to bunkering (see Appendix E)

How to Use the Ports Roadmap to Bunkering 1.1

The ports roadmap is structured into 15 implementation steps, grouped into four development phases, and punctuated by four decision gates.

The steps reflect how ports typically develop new operational activities in practice: starting with strategic intent and basic knowledge, then building governance, stakeholder alignment, technical understanding, operational controls, and emergency preparedness before moving into pilots and scale-up.

Structure of the roadmap 1.1.1

- **15 steps** describe what ports typically need to do, in logical sequence.
- **4 gates** provide structured decision points where ports pause, review progress, and decide whether to proceed, adjust, or stop.
- Each gate represents an increasing level of commitment, resource use, and operational responsibility.

The roadmap is not prescriptive. Ports may:

- adapt the order of steps,
- revisit earlier steps,
- progress in parallel,
- or repeat steps as experience grows or scope changes.

Link to IAPH Port Readiness Levels (PRL) 1.1.2

The IAPH Port Readiness Level for Marine Fuels (PRL-MF) framework is recognised in this guidebook. There is no intention to substitute, replicate or replace that framework.

This guidebook primarily addresses the early stages of preparation and is particularly suited to supporting ports operating at the early to mid PRL-MF levels. It provides structured knowledge and practical guidance to support implementation. The Roadmap presented in Chapter 1 offers one possible approach for these early stages; however, ports remain free to select any methodology to achieve operational readiness. None of the approaches referenced in the document are mandatory.

Where a port elects to use the PRL-MF framework as its primary assessment tool, the technical information and guidance provided in Chapters 2, 3, 4 and the Appendices remain fully applicable and can support progression through the PRL levels.

The mapping presented between the two approaches (see Table 1-1) is explicitly described as indicative rather than prescriptive. There is no intention to formally align or merge the two systems. They can coexist, and a port may choose to apply one approach over the other.

Table 1-1 Ports Roadmap Vs IAPH PRLs

Ports Roadmap Steps & Gates	IAPH Phases and PRLs	
Step 1 – Assess the Business Case and Strategic Rationale	**Research**	PRL 1 Foundational background information
Step 2 – Build Internal Knowledge and Assign Ownership		
Step 3 – Establish Governance and Competent Authority Roles		PRL 2 Stakeholder interest and feasibility assessment
Step 4 – Understand the Regulatory and Standards Landscape		
GATE 1 – Strategic Readiness and Internal Alignment		PRL 3 Detailed research, analysis and conclusions
Step 5 – Wider Stakeholder and Public Engagement		
Step 6 – Identify Potential Bunkering Locations		
Step 7 – Define Bunkering Scenarios and Fuel Suitability		PRL 4 Framework for bunkering of target fuel drafted, timeline developed
Step 8 – Undertake Risk Assessments and Define Controlled Areas		
GATE 2 – Strategic Feasibility and Stakeholder Alignment Check		
Step 9 – Infrastructure Development and Readiness	**Development**	PRL 5 Framework for bunkering of target fuel implemented and tested
Step 10 – Develop Licensing, Permitting, and Authorisation Processes		
Step 11 – Define Documentation and Operational Controls		PRL 6 Pilot-scale demonstration of bunkering of target fuel
Step 12 – Training and Competence		
Step 13 – Establish Emergency Preparedness and Response		PRL 7 Bunkering of target fuel established on project basis
GATE 3 – Operational Readiness and Commitment Check		
Step 14 – Pilot Operations and Controlled Introduction		PRL 8 Full capabilities for bunkering of target fuel
GATE 4 – Pilot Validation and Scale-Up Decision		
Step 15 – Transition to Business-as-Usual Operations	**Deployment**	PRL 9 Market penetration and growth for bunkering of target fuel

- The mapping is indicative rather than prescriptive.
- The roadmap provides actionable steps to help ports progress through PRLs, while the IAPH PRL framework provides the maturity benchmark.
- The roadmap places particular emphasis on the early phases of readiness, helping ports build strategic intent, internal capability, stakeholder alignment, and a robust foundation for safe implementation.
- Progression is evidence-based, not automatic - each gate supports a deliberate decision to move forward.

How the roadmap works with this guidebook 1.1.3

This roadmap is a navigation tool, not a standalone instruction manual.

- Each step in the roadmap refers to specific sections and appendices of this Guidebook.
- Those sections provide detailed guidance, technical considerations, checklists, and examples relevant to that step.
- Ports are encouraged to use the roadmap to identify what they need to address next, then consult the referenced sections for how to do it.

Used together, the roadmap and the Guidebook allow ports to:

- progress in a structured, risk-based manner;
- avoid unnecessary duplication or premature investment;
- build confidence with regulators, operators, emergency services, and the public;
- transition safely from pilot activities to business-as-usual methanol and ammonia bunkering.

Step 1 – Assess the Business Case and Strategic Rationale

Ports should begin by understanding why methanol and/or ammonia bunkering is relevant to their port.

Key drivers may include:

- Expected demand from shipping lines and fuel suppliers;
- National or regional decarbonisation strategies and regulatory drivers;
- Positioning the port as a clean fuel hub or early mover;
- Alignment with existing cargo flows (e.g. methanol or ammonia already handled as cargo);
- Competitive positioning relative to neighbouring ports.

At this stage, the focus is strategic, not technical. The outcome should be a clear internal view on:

- which fuels are of interest (methanol, ammonia, or both);
- the anticipated timeframe (near-term pilots vs medium-term deployment);
- whether the port intends to actively facilitate bunkering or simply enable it under defined conditions.

Step 2 – Build Internal Knowledge and Assign Ownership

Before engaging externally, ports should establish a minimum internal knowledge base.

Actions typically include:

- Assigning a dedicated lead or small cross-functional team responsible for alternative fuel bunkering;
- Ensuring baseline understanding of methanol and ammonia properties, hazards, and operational implications;
- Clarifying internal roles across safety, marine operations, environment, permitting, legal, and communications.

Fuel-specific background knowledge is provided in:

- Chapter 3 – Fuel Knowledge

This step is critical to ensure that early decisions are informed and consistent, and that the port can engage credibly with regulators, suppliers, and vessel operators.

Step 3 – Establish Governance and Competent Authority Roles

Ports should define how decisions will be made and who holds authority.

This includes:

- Clarifying whether the port authority acts as competent authority in full or in part;
- Defining decision-making responsibilities and escalation paths;
- Establishing internal risk acceptance principles;

Guidance on governance and stakeholder roles is provided in:

- Section 2.2 - Stakeholders identification
- Section 4.1.1 – Role of ports across the four stages for vessel operators
- Section 4.1.2 – Link to the IAPH port readiness level framework

Early clarity on governance avoids delays and inconsistent decisions later.

Step 4 – Understand the Regulatory and Standards Landscape

Ports should identify which regulatory instruments apply and where gaps may exist.

This includes:

- National legislation and port permit conditions;
- International conventions and IMO instruments;
- Applicable ISO standards and industry guidelines.

At this stage, ports should not attempt to create new rules, but rather understand:

- what already applies;
- what may need to be adapted;
- where regulators need to be engaged early.

Relevant material is covered in:

- Section 2.1 - International Regulatory Framework & Guidelines

GATE 1 – Strategic Readiness and Internal Alignment

Gate 1 marks the point at which a port decides whether it is appropriate to move beyond internal exploration and proceed towards structured engagement and implementation planning for methanol and/or ammonia bunkering. Up to this stage, activities are primarily internal, exploratory, and strategic in nature, with limited external engagement.

Up to this point steps are intentionally non-technical and non-committal, focusing on strategic fit, internal capability, and regulatory awareness rather than detailed design or operational decisions.

Gate 1 Decision Focus

Before proceeding beyond Gate 1, the port should confirm that:

- There is a clear strategic rationale for considering methanol and/or ammonia bunkering, aligned with port objectives and market signals.
- An indicative timeline has been established (e.g. near-term pilots, medium-term deployment).
- Internal ownership and accountability are defined, with named leads or teams.
- Governance arrangements and competent authority roles are sufficiently clear to support further work.
- The port has a baseline understanding of:
    - fuels properties and risks, and
    - applicable regulations, standards, and guidance.
- Initial engagement with national regulators or competent authorities, where necessary, has confirmed that no fundamental barriers are evident at this stage.

Constraints and Commitments at Gate 1

At Gate 1:

- External engagement is typically limited to high-level discussions with national administrations, regulators, or matter experts.
- Financial exposure is minimal, generally limited to internal resources, desk studies, or advisory support.
- There is no commitment to permit bunkering operations or invest in infrastructure.
- Decisions remain reversible, allowing the port to pause, defer, or exit without material consequence.

Gate 1 Output

Successful completion of Gate 1 should result in:

- A documented strategic position on methanol and/or ammonia bunkering.
- Agreement to proceed to structured stakeholder engagement, site screening, and risk-based assessment in subsequent stages.
- Confirmation that the port has the resources, capacity, and mandate to move forward.

Only once Gate 1 is passed should the port proceed to more outward-facing activities, including wider stakeholder engagement, site identification, and preparatory risk assessment work.

Step 5 – Wider Stakeholder and Public Engagement

Once the regulatory landscape and governance framework are understood, ports should initiate early engagement with wider stakeholders, including:

- national and local regulators;
- terminal operators and berth owners;
- shipowners and bunkering suppliers;
- emergency services;
- neighbouring industries and port users;
- where relevant, local authorities and the public.

Early, transparent engagement:

- builds trust and social acceptance;
- reduces the risk of late objections or misunderstandings;
- helps align emergency planning and operational expectations.

Relevant material is covered in:

- Section 4.1.3 – Stakeholder engagement

This step is particularly important for ammonia, given its toxicity and public perception.

Step 6 – Identify Potential Bunkering Locations

Rather than assessing each request ad-hoc, ports are encouraged to proactively identify candidate locations.

This typically involves:

- Screening berths, quays, anchorages, and interfaces;
- Considering navigation, traffic, and manoeuvring constraints;
- Reviewing proximity to people, buildings, and sensitive receptors;
- Understanding emergency response access and limitations;
- Recognising that some locations may be suitable for one fuel but not another.

At this stage, locations may be identified as:

- suitable,
- potentially suitable with constraints,
- or not suitable / require further development.

Guidance is provided in:

- Section 4.2.1 – Site identification, design and risk assessment
- Section 4.2.2 – Port bunkering map
- Appendix B – Bunkering site identification process

This step is typically carried out in conjunction with steps 7 and 8 below.

Step 7 – Define Bunkering Scenarios and Fuel Suitability

For each candidate location, ports should identify:

- feasible bunkering supply scenarios (ship-to-ship, shore-to-ship, mobile-to-ship);
- physical constraints (hose reach, manifold access, road access);
- fuel-specific limitations (flammability for methanol, toxicity for ammonia).

Guidance is provided in:

- Section 2.3 – Bunkering supply scenarios
- Section 2.5 – Bunker transfer system

This step ensures that later risk assessments are focused and realistic.

Step 8 – Undertake Risk Assessments and Define Controlled Areas

Risk assessment forms the analytical foundation for all subsequent decisions.

From a port perspective, this includes:

- Qualitative and quantitative risk assessments;
- Consequence and dispersion analyses;
- HAZID / HAZOP
- SIMOPs studies;
- Definition of hazardous areas, safety zones, toxic areas (where applicable), and marine exclusion zones.

Ports typically review and approve these assessments rather than produce them.

Key port actions and decisions at this stage include confirming, in coordination with the national regulator and other competent authorities:

- **Regulatory expectations**, including:
  - the type(s) of risk assessment required;
  - applicable risk acceptance criteria;
  - applicable toxic exposure limits for methanol and ammonia.
- **Assessment assumptions**, specifically for the purpose of defining safety and toxic areas:
  - credible release scenarios;
  - representative release or hole sizes.
- **Operational boundaries**, including:
  - limitations and constraints arising from port layout, neighbouring activities, and navigation;
  - the definition of an assessment zone within which bunkering may be evaluated or conditionally permitted.

The outputs of this step underpin permitting decisions, controlled-area enforcement, SIMOPs management, and emergency preparedness planning, and should be documented in a manner that supports consistent and defensible decision-making by the port.

Guidance is provided in:

- Section 2.6 – Hazardous area, toxic area, safety zones and SIMOPs
- Section 4.3 – Risk assessment framework and controlled areas
- Section 4.4 – Fuel-specific safety zone determination
- Appendix C – Port checklist: reviewing a proposed safety zone
- Appendix D - Further considerations on HAZID, HAZOP and SIMOPs

GATE 2 – Strategic Feasibility and Stakeholder Alignment Check

By this stage, the port has moved beyond internal scoping and has engaged with a wider group of external stakeholders, including regulators, terminals, emergency services, port users, and-where relevant-the public. Activities undertaken between Steps 5 and 8 are resource-intensive and mark a transition from strategic intent to practical feasibility.

Gate 2 provides a structured pause to confirm whether the port is ready to proceed further.

At Gate 2, the port should confirm that:

- **Stakeholder alignment has been established**
  - Key national and local regulators have been engaged and their expectations understood.
  - Terminal operators, berth owners, and emergency services are aligned with the proposed approach.
  - For ammonia in particular, public and local authority concerns have been identified, addressed, or appropriately managed.
  - There is a shared understanding of roles, responsibilities, and escalation pathways.
- **Technical feasibility is sufficiently understood**
  - Candidate bunkering locations have been identified and screened.
  - Feasible bunkering scenarios and fuel suitability have been defined.
  - Risk assessments have demonstrated that risks can be managed within acceptable criteria through defined controls and operational limits.
  - Controlled areas (hazardous areas, safety zones, toxic areas where applicable, marine exclusion zones) are broadly compatible with port layout and operations.
- **Regulatory and risk acceptance clarity has been achieved**
  - The type and depth of risk assessments required are agreed with the competent authority.
  - Risk acceptance criteria and applicable exposure thresholds are defined.
  - No fundamental regulatory barriers have been identified that would prevent progression.
- **Organisational readiness is adequate**
  - The port has sufficient internal capability, knowledge, and resources to move into more detailed design, permitting, and implementation activities.
  - Interfaces between departments (marine, safety, environment, permitting, communications) are functioning effectively.
- **Financial exposure remains controlled**
  - Costs and resource commitments are higher than at Gate 1 but remain proportionate and manageable.
  - No irreversible infrastructure or contractual commitments have been made at this stage.

Decision at Gate 2

At Gate 2, the port should make an explicit decision to:

- proceed to detailed implementation planning, licensing, infrastructure development, and training;
- pause to address identified gaps or stakeholder concerns; or
- revise scope (e.g. fuel type, locations, or timelines) based on findings.

Gate 2 – Output

Successful completion of Gate 2 should result in the following tangible outputs:

- A shared understanding with regulators and key stakeholders of what is feasible and under which conditions methanol and/or ammonia bunkering may proceed.
- A port bunkering map, with locations classified as:
  - suitable,
  - conditionally suitable, or
  - not suitable / require further development.
- A clear definition of feasible bunkering scenarios and fuels for each candidate location.
- Agreed principles for risk assessment, including:
  - risk assessment type(s);
  - risk acceptance criteria;
  - exposure thresholds;
  - credible release scenarios.
- Preliminary definition of controlled areas and operational constraints sufficient to support permitting and emergency planning.
- A go / pause / revise decision by the port authority on whether to proceed to:
  - licensing and permitting,
  - infrastructure development,
  - training and operational readiness.

Passing Gate 2 indicates that methanol and/or ammonia bunkering is credible, achievable, and supportable within the port's regulatory, operational, and social context, and that the port can move forward with confidence toward controlled implementation and business-as-usual operations.

Step 9 – Infrastructure Development and Readiness

Following the previous steps and the development of the port bunkering map, some locations may be identified as conditionally suitable or as requiring further development before bunkering can be safely permitted.

Infrastructure considerations may include, as applicable:

- Berth and quay strength, layout, and load-bearing capacity;
- Available quay space and the ability to establish and enforce safety and segregation zones;
- Access arrangements for bunker supply vessels, barges, or road tankers;
- Availability and adequacy of utilities, including power, lighting, communications, drainage, and containment;
- Emergency access and egress routes for responders and evacuation;

- Need for fixed or temporary infrastructure, such as bunding, barriers, monitoring systems, or traffic controls.

Not all locations need to be fully developed at the outset. Some areas may be unsuitable for bunkering initially but could be adapted or upgraded over time as operational experience grows, demand increases, and the port transitions from pilot activities to business-as-usual operations. Ports are therefore encouraged to view infrastructure readiness as a progressive and scalable process, aligned with their overall bunkering roadmap and Port Readiness Level.

Step 10 – Develop Licensing, Permitting, and Authorisation Processes

Based on the risk assessment outcomes, ports should establish a proportionate licensing framework.

Key principles include:

- Alignment with national permits;
- Clear requirements for bunker suppliers;
- Avoiding duplication of existing industry documentation;
- Using recognised frameworks (e.g. IAPH, SGMF) where possible.

Guidance is provided in:

- Section 4.2.3 - Bunkering licensing process

Step 11 – Define Documentation and Operational Controls

Ports should specify which documents are required and how they are used.

This includes:

- Bunkering Management Plans;
- Compatibility assessments;
- Joint Plan of Bunkering Operation;
- Bunkering checklists.

Guidance is provided in:

- Section 2.7 - Bunkering Documentation
- Section 4.5 – Core operational controls
- Appendix A – Bunkering documentation for ports

Clarification Note – Documentation Requirements:

Step 11, from a port perspective, focuses on defining the documentation requirements that operators should submit in order to obtain authorisation for bunkering (see Step 10). Ports do not typically prepare operational bunkering documents themselves; rather, they specify, review, and evaluate the documentation submitted by bunker suppliers, terminals, and receiving vessels.

Section 2.7 of this Guidebook provides an overview of the types of documents typically required to support safe bunkering operations. Appendix A provides a more detailed review of the documentation elements, including guidance on what ports should request, review, and verify as part of their approval process.

Step 12 – Training, Competence

Before bunkering operations commence, ports should ensure that all relevant personnel are trained, competent, and prepared to safely manage, supervise, and respond to methanol and ammonia bunkering activities.

This includes, as applicable:

- Training port authority personnel, including safety officers, harbour masters, VTS, and enforcement staff;
- Ensuring terminal staff and contractors involved in or exposed to bunkering operations are appropriately trained;
- Ensuring emergency response services are trained, equipped, and familiar with fuel-specific hazards and response procedures;
- Conducting joint drills and exercises, involving ships, bunker suppliers, terminals, port services, and emergency responders, where appropriate.

Training requirements should be proportionate to the fuel type, with enhanced emphasis for ammonia, and shuld reflect:

- bunkering frequency and operational complexity;
- proximity to populated or sensitive areas;
- the port's role as competent authority.

Guidance is provided in:

- Section 4.5.6 – Training requirements and safety drills

Training and competence form a critical prerequisite for authorisation and should be reviewed and refreshed as operations evolve, lessons are learned, and bunkering transitions from pilot activities to business-as-usual operations.

Clarification Note – Training Responsibilities:

Section 4.5.6 clarifies that ports are responsible for training their own personnel to a level commensurate with their authority and operational responsibilities. Personnel employed by operators, suppliers, terminals or contractors remain the responsibility of their respective employers.

However, as part of the bunkering licensing and authorisation process, ports should verify that all parties involved demonstrate appropriate training and competence. Ports may define minimum

training standards for stakeholders operating within their jurisdiction and require evidence of compliance during permitting.

Where training is not explicitly mandated by national or international regulation, ports may still establish minimum competence requirements as a condition of authorisation, ensuring safe and consistent operational practices.

Step 13 – Establish Emergency Preparedness and Response

Before bunkering operations commence, ports should ensure that emergency preparedness and response arrangements are established and integrated into the port's existing emergency management framework.

This includes, as applicable:

- Emergency response planning addressing methanol and ammonia scenarios, including spills, fires, toxic releases, and escalation pathways;
- Coordination with external response organisations, including fire brigades, medical services, coastguard, and Vessel Traffic Services (VTS);
- Training and drills, including fuel-specific response scenarios and joint exercises with relevant stakeholders;
- Clear communication, notification, and escalation procedures, ensuring rapid decision-making and coordinated action.

Emergency preparedness should reflect the port's role as competent authority and be proportionate to the fuels handled, operational frequency, and proximity to populated or sensitive areas.

Guidance is provided in:

- Section 4.5.6 – Training requirements and safety drills
- Section 4.6 – Emergency management and response

GATE 3 – Operational Readiness and Commitment Check

Gate 3 represents the transition from feasibility and framework development to operational readiness. By this stage, the port has moved beyond concept and assessment and has made tangible commitments in terms of infrastructure, organisation, procedures, and preparedness.

Activities leading to Gate 3 (Steps 9–13) typically involve financial investment, organisational change, and increased operational responsibility. Gate 3 therefore provides a formal decision point to confirm that the port is ready to authorise and support first bunkering operations in a controlled and safe manner.

Gate 3 – Readiness Verification

At Gate 3, the port should confirm that the following are in place:

- **Infrastructure and Physical Readiness**
  - Bunkering locations are either fully ready or clearly defined as conditionally suitable with documented constraints.
  - Any required infrastructure upgrades (fixed or temporary) have been completed or formally approved.
  - Safety zones, segregation arrangements, access control, drainage, and emergency access routes are practical and enforceable.
- **Licensing, Permitting, and Governance**
  - A licensing and authorisation framework is established and aligned with national permits, regulatory requirements, and risk assessment outcomes.
  - Roles and responsibilities between the port authority, bunker suppliers, terminal operators, and receiving vessels are clearly defined.
  - The port organisation is ready to administer licences, permits, and compliance monitoring.
- **Documentation and Operational Controls**
  - Documentation requirements are defined, proportionate, and published, including Bunkering Management Plans, compatibility assessments, Joint Plans of Bunkering Operation, and bunkering checklists.
  - Documentation supports safe operations and oversight without unnecessary duplication.
  - Clear processes exist for review, approval, and updates.
- **Training and Human Readiness**
  - Port personnel, terminal staff, contractors, VTS, and emergency services are trained and competent for their respective roles.
  - Joint drills and exercises have been conducted or scheduled.
  - Training records, competence tracking, and refresher arrangements are in place.
- **Emergency Preparedness and Response**
  - Emergency response plans for methanol and ammonia are complete and integrated into the port's emergency framework.
  - Coordination with external responders is tested and understood.
  - Communication, notification, and escalation procedures are clear and rehearsed.

Gate 3 – Output

Successful completion of Gate 3 should result in:

- Formal readiness to authorise first bunkering operations, under controlled conditions.
- Approved bunkering locations with defined operational envelopes and constraints.
- Operational licensing and permitting processes in force.
- Trained and competent personnel across the port, terminals, and emergency services.
- Emergency preparedness arrangements validated through exercises or drills.
- A clear decision to proceed with:
  - pilot or first-of-kind operations, or
  - limited business-as-usual operations under defined conditions.

Passing Gate 3 confirms that the port has moved from planning to execution readiness, with the capability to safely manage methanol and/or ammonia bunkering operations and to respond effectively should incidents occur.

Step 14 – Pilot Operations and Controlled Introduction

Many ports will initially introduce methanol and ammonia bunkering through pilot or first-of-kind operations, supported by enhanced oversight and conservative operational controls.
These early operations may involve:

- operation-specific approvals or permits;
- additional constraints on locations, volumes, or simultaneous operations;
- increased monitoring and reporting requirements.

Pilot operations should be used to:

- validate risk assessment assumptions;
- test procedures, documentation, and coordination mechanisms;
- identify gaps, improvements, and lessons learned.

GATE 4 – Pilot Validation and Scale-Up Decision

Gate 4 represents the decision point between controlled pilot operations and the transition to business-as-usual bunkering.

At Gate 4, the port should confirm that:

- Pilot or first-of-kind operations have been completed without unacceptable incidents or unmanaged risks.
- Risk assessment assumptions, safety zones, SIMOPs controls, and emergency arrangements have been validated in practice.
- Procedures, documentation, communication, and coordination mechanisms function effectively under real operating conditions.
- Lessons learned have been captured, reviewed, and incorporated into updated procedures, permits, and training.
- Stakeholders, regulators, and emergency services remain aligned and supportive.

Gate 4 – Output

Successful completion of Gate 4 results in:

- A clear decision to scale up, maintain, or pause methanol and/or ammonia bunkering activities;
- Agreement on whether operations may transition from operation-specific approvals to general or standing licences;
- Confirmation that the port is ready to move from pilot controls to business-as-usual operations, while maintaining a risk-based approach.

Passing Gate 4 confirms that methanol and/or ammonia bunkering is no longer experimental for the port, but an established activity supported by operational experience and continuous improvement.

Step 15 – Transition to Business-as-Usual Operations

As operational experience increases and confidence is established, ports may progressively transition methanol and ammonia bunkering to business-as-usual operations.

This transition may include:

- streamlining and consolidating documentation;
- expanding the range of approved bunkering locations and scenarios;
- moving from operation-specific approvals to general or standing licences;
- reducing administrative burden while maintaining robust safety controls.

This evolution should remain risk-based, supported by evidence from operational experience, and aligned with national regulatory expectations and port governance arrangements.

Key Bunkering Knowledge 2.

SCOPE AND INTENT:

This chapter provides the **foundational bunkering knowledge** applicable to both methanol and ammonia. It introduces the regulatory framework, key stakeholders and roles, bunkering supply scenarios, transfer systems, safety zones, SIMOPs, and core documentation. This Part establishes common terminology, concepts, and processes that are referenced throughout the Guidebook. It is intended to give ports and stakeholders a shared understanding of how bunkering operations are structured before considering fuel-specific characteristics or implementation actions.

International Regulatory Framework & Guidelines 2.1

This section outlines the current international regulatory landscape for methanol and ammonia as marine fuels. Both fuels remain in an experience-building phase, with regulators and industry collecting operational lessons from early adopters. Methanol already has growing practical use within the fleet, while ammonia is at an earlier stage, with activity focused on research, risk assessments, and pilot projects. As experience increases, the regulatory framework is expected to evolve rapidly. Until dedicated provisions are fully developed, the established LNG regulatory framework provides a useful reference, recognising that the specific properties and risks of methanol and ammonia differ and should be addressed accordingly (see Chapter 3).

KEY TAKEAWAYS:

1. **Methanol and ammonia are emerging marine fuels**, but both remain in an **experience-building phase**, meaning regulations are still evolving as practical knowledge increases.
2. Both fuels fall under the **IMO IGF Code** for low-flashpoint fuels; however, **fuel-specific provisions are incomplete**, and IMO currently relies on **interim guidelines** for methanol/ethanol (MSC.1/Circ.1621) and ammonia (MSC.1/Circ.1687).
3. Ships transporting methanol or ammonia **as cargo and using it as fuel** are regulated separately under the **IGC or IBC Code**.
4. **ISO standards are being developed** to support methanol and ammonia fuel systems; ISO 6583:2024 is already published for methanol. LNG standards ISO 20519, ISO/TS 16901 and ISO/TS 18683 provide a **useful reference** until dedicated standards mature.
5. **National and regional regulations vary widely** and may impose additional requirements on chemical storage, hazardous-substance handling, land-use constraints, occupational safety, and road transport (e.g., ADR). Ports should confirm all applicable national rules.
6. Ports should **ensure national requirements are reflected in port specific procedures** including risk assessments, safety-zone definitions, SIMOPs management, permitting, and operator guidance.
7. A broad range of industry guidelines is available to support implementation, including:
   - **EMSA** studies on ammonia safety and alternative fuels;
   - **IAPH** port readiness frameworks for alternative fuels;
   - **SGMF** bunkering guidelines for methanol and ammonia;
   - **OCIMF – ISGOTT and SIRE 2.0** safety and assurance for vessels and terminals;
   - **IACS/classification societies** rules for alternative-fuel ship design;
   - **SIGTTO** guidance for gas carriers and gas-handling safety;

- **Methanol Institute and Ammonia Energy Association** publications on safe production, handling, and use.

8. Until fuel-specific rules are fully developed, LNG regulatory frameworks can be used as a baseline reference, provided methanol- and ammonia-specific properties and risks are properly accounted for.

CHALLENGES AND GAPS:

1. The international regulatory framework remains fragmented, reflecting the early experience-building phase. It will take time-potentially several years-before requirements converge and a fully consolidated set of rules emerges. This is not unusual: LNG followed a similar path in its early adoption, with gradual alignment achieved only after sufficient operational experience was gained.
2. Ongoing regulatory, standards, and guideline development is focused primarily on ship design and operations, while gaps remain in related areas such as training, and competence requirements. These are expected to be addressed as experience grows and as IMO, ISO, and industry bodies incorporate lessons learned over the next two to three years.
3. Baseline knowledge and competence are still developing across the sector. Methanol and ammonia introduce new risk profiles-flammability, toxicity, corrosivity-and require improved understanding from all stakeholders. Ports should therefore invest early in familiarisation, training, and capacity building as part of their preparation for alternative-fuel bunkering.

IMO regulatory framework 2.1.1

https://imo-epublications.org/

IGF Code

Under the IMO safety framework, methanol and ammonia fall within the International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels (IGF Code). As low-flashpoint fuels, but their specific regulatory provisions are still under development.

At present, IMO has issued interim guidelines, recognising the ongoing experience-building phase. These guidelines are not yet mandatory; however, as operational experience grows, new provisions are expected to be developed, adopted and, where appropriate, incorporated into the mandatory requirements of the IGF Code.

Ammonia: Interim guidelines for ships using ammonia as fuel - MSC.1/Circ.1687

Methanol/Ethanol: Interim guidelines for ships using methyl/ethyl alcohol as fuel - MSC.1/Circ.1621

https://futurefuels.imo.org/safety-guidelines/

IGC and IBC Codes

A particular case applies to ships using cargo as fuel. Vessels carrying methanol or ammonia that also use these products as fuel are often among the first adopters. Their safety requirements fall primarily under the IGC Code (for liquefied gases) and the IBC Code (for chemical cargoes).

International standards 2.1.2

Work is also progressing under the International Organization for Standardization (ISO) to support the safe use of methanol and ammonia as marine fuels. At present, the following standard has been published:

1. *ISO 6583:2024* - Methanol as a fuel for marine applications: General requirements and specifications.

The following standards are currently under development:

2. *ISO/CD 24941* - Ships and marine technology: Piping and machinery - Safety guidelines for engine rooms of ammonia-fuelled vessels.
3. *ISO/DIS 23397* - Ships and marine technology: Ammonia fuel systems for ships - Vocabulary.

Further ISO work is expected as operational experience increases. In addition, *ISO 20519:2021 - Specification for bunkering of liquefied natural gas fuelled vessels* provides a well-established reference for the design and operation of bunker systems and bunkering procedures. Although ISO 20519 is specific to LNG, its principles and functional requirements for bunkering system configuration, safety management, and operational control are broadly applicable and can be adapted for methanol and ammonia bunkering, taking into account the distinct properties and hazards of these fuels.

Of particular relevance from a port perspective, *ISO/TS 16901:2022 - Guidance on performing risk assessment in the design of onshore LNG installations including the ship/shore interface* provides a structured approach to risk assessment at the interface between vessels and shore-based installations. While developed for LNG, the standard offers a useful methodological reference for ports assessing fixed or semi-fixed methanol and ammonia bunkering installations, especially where ship–shore interfaces, onshore storage, and transfer systems are involved.

Finally, although not developed specifically for methanol or ammonia, *ISO/TS 18683 - Guidelines for safety and risk assessment of LNG fuel bunkering operations* provides a robust methodological framework for assessing bunkering risks, safety distances, and hazard zones. This framework can be tailored to methanol and ammonia bunkering, provided that fuel-specific characteristics and risks are duly considered.

National and regional regulations 2.1.3

National and regional regulations governing the use, handling, storage, and bunkering of methanol and ammonia vary significantly between countries and even between individual ports. These requirements reflect local legislation on chemical safety, environmental protection, occupational health, hazardous-substance storage, and transport. As such, they are port-specific and are not covered in this Guidebook. However, several general considerations and recommendations are provided to support port authorities in identifying and complying with applicable national requirements.

General requirements (varying by country/region)

Port authorities should be aware that national and regional regulations may include:

- Chemical safety and environmental protection rules governing the handling of toxic and hazardous substances.

- Permitting and licensing requirements for the onshore storage of methanol and ammonia, including quantity thresholds and Seveso-type regulations.
- Occupational health and safety (HSE) obligations, particularly regarding exposure limits, ventilation, leak detection, and emergency equipment.
- Transport regulations such as national legislation related to the ADR for road vehicles carrying dangerous goods into the port (e.g. tank trucks or mobile fuel units).
- Land-use planning constraints, including maximum permissible distances from populated areas or environmentally sensitive zones.
- National criteria for individual and societal risk, which may influence the definition of safety zones and separation distances for bunkering operations (see Section 4.4).

Specific considerations for bunkering operations

- Regulations may apply differently depending on the bunkering method:
  - Ship-to-ship bunkering may fall primarily under maritime legislation and port bylaws.
  - Shore-to-ship bunkering may require additional compliance with national chemical storage, industrial-safety, and fixed-installation requirements.
  - Mobile-to-ship bunkering (e.g. truck-to-ship, ISO tank, portable container) should comply with ADR and equivalent national transport rules, including driver certification, vehicle design, tank approval, labelling, and documentation.
- Temporary fuel storage onshore may trigger additional permitting, hazard studies, or quantity limitations.

Recommendations for port authorities

Port authorities should:

- Consult their national maritime administration, HSE authorities, and environmental agencies to identify applicable requirements for methanol and ammonia.
- Verify whether national rules impose limits or conditions on onshore storage of these substances, including fixed and temporary installations.
- Inform bunkering operators of national transport requirements (e.g. ADR) that apply to vehicles bringing methanol or ammonia into the port area.
- Ensure that national regulatory criteria are integrated into local risk assessments, the definition of safety zones, and SIMOPs management (see Section 4.3).
- Ensure that national/regional obligations are integrated with the recommendations within this document as pot specific procedures are established.

Note – Mobile-to-Ship (Truck-to-Ship) Bunkering: Interface Between Road and Marine Regulations:

For mobile-to-ship bunkering, and in particular truck-to-ship (TTS) operations, ports should recognise that two distinct regulatory regimes interface: the road transport domain and the maritime domain.

This interface can create uncertainty or tension if responsibilities and applicable rules are not clearly defined. In practice, many authorities and port operators address this by defining operational domains and assigning the governing regulatory framework accordingly.

Road Domain (ADR-led – truck side)
Applies up to a clearly defined transfer boundary, typically including:

- Truck tank and associated equipment;
- Truck-mounted pump and transfer systems on the vehicle;
- Truck-side emergency systems;
- Driver responsibilities and certification;
- Parking arrangements, wheel chocks, traffic management, and vehicle control.

Within this domain, the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) and relevant national road transport regulations normally apply, even though the vehicle is physically located within the port area.

Marine Domain (Marine-led – ship side)
Applies from the ship's manifold inwards, typically including:

- Ship manifold and onboard piping systems;
- Shipboard valves and control systems;
- Shipboard Emergency Shutdown (ESD) systems;
- Crew responsibilities;
- Ship Safety Management System (SMS) under SOLAS/ISM Code.

Within this domain, maritime legislation, flag-state requirements, port by-laws, and applicable IMO instruments apply.

Port Consideration
The transfer interface (hose connection, coupling, or emergency release arrangement) represents a shared responsibility domain and should be clearly defined in procedures, compatibility assessments, and risk assessments. Ports are encouraged to:

- Clearly define the regulatory boundary in licensing and permitting documentation;
- Ensure coordination between maritime authorities and national road transport authorities;
- Avoid imposing conflicting or duplicative requirements;
- Address the interface explicitly in HAZID/HAZOP, compatibility assessments, and operational checklists.

A clear allocation of responsibilities between the road and marine domains reduces regulatory ambiguity, supports enforcement, and improves operational safety during mobile-to-ship bunkering.

Industry guidelines 2.1.4

Several industry bodies and associations have already begun to develop frameworks of guidelines for the safe use, handling, and bunkering of methanol and ammonia as marine fuels. The following are some of the key reference sources recognised by the maritime industry:

European Maritime Safety Agency (EMSA)

https://www.emsa.europa.eu/sustainable-shipping/alternative-fuels.html

EMSA maintains a dedicated programme on alternative fuels and power sources for shipping, covering synthetic fuels (e.g., e methanol, e ammonia), ammonia, biofuels, hydrogen, battery and energy storage systems, and shore side electricity.

Of particular relevance is EMSA's report "Study Investigating the Safety of Ammonia as Fuel on Ships", which provides an analysis of ammonia as a marine fuel. The study addresses fuel properties, toxicity, and corrosivity; system reliability; hazard identification (HAZID) and risk assessments for both generic and specific ship designs; leak-consequence modelling; and port-level considerations, including SIMOPs and bunkering operation scenarios.

International Association of Ports and Harbors (IAPH)

https://fuelreadyports.org/

IAPH has been active in assessing port readiness for alternative fuels, and developed a tool to provide a port-level perspective (infrastructure, operations, regulatory alignment) to support safe adoption of methanol and ammonia bunkering. Several other industry guidelines and technical references often cite IAPH's port readiness criteria as relevant baseline for ports considering bunkering operations.

The Society for Gas as Marine Fuel (SGMF)

https://sgmf.info/shop/

SGMF has published dedicated "Bunkering Guidelines for Methanol" and "Bunkering Guidelines for Ammonia", along with an Emergency Response Guide for Ammonia. These provide practical guidance on bunkering procedures, hazard mitigation, and safety zones for low-flashpoint fuels.

OCIMF – ISGOTT and SIRE

https://www.ocimf.org/programmes/sire-2-0

Guidance developed by the Oil Companies International Marine Forum (OCIMF) is widely used in ports and terminals and remains relevant to methanol and ammonia bunkering, particularly where liquid transfer operations take place at berths or terminals.

The International Safety Guide for Oil Tankers and Terminals (ISGOTT) provides established industry guidance for the safe handling of Oil and petro products including transfer between ships and terminals. Although primarily focused on petroleum products, many of its principles-such as ship–shore communication, transfer management, SIMOPs control, emergency shutdown arrangements, and human-factor considerations-are directly applicable to methanol bunkering and, with appropriate adaptation, to ammonia bunkering.

The Ship Inspection Report Programme (SIRE) 2.0 is a widely used vessel inspection scheme that supports assurance of tanker safety management, vessel condition, and crew competence. While not a

regulatory requirement, SIRE may be used by terminals and ports as a complementary tool when assessing the suitability of bunker vessels or fuel carriers involved in methanol or ammonia bunkering.

ISGOTT and SIRE should be applied as supporting industry references and adapted to reflect the specific hazards of methanol and ammonia. They do not replace fuel-specific regulations, risk assessments, or port-level requirements.

IACS and classification societies

https://iacs.org.uk/

IACS and classification societies, are updating and issuing technical requirements for ships using methanol and ammonia as fuels. These requirements complement, and further elaborate on, the interim guidelines published by IMO, providing more detailed design and construction provisions. Their role is particularly important during this experience-building phase, as classification society rules often serve as the practical bridge between evolving IMO regulations and the needs of early adopters.

The Society of International Gas Tanker and Terminal Operators (SIGTTO)

https://www.sigtto.org/publications/

SIGTTO provides guidance primarily for vessels transporting liquefied gases, including methanol and ammonia when carried as cargo. As such, its publications are also relevant for bunkering vessels handling these fuels. SIGTTO's experience with gas carrier safety, cargo handling, and terminal operations offers a well-established reference framework that supports the development of safe bunkering practices for alternative fuels.

Methanol Institute, Ammonia Energy Association and International Methanol Producers and Consumers Association

The Methanol Institute (MI) and the Ammonia Energy Association (AEA) focus primarily on developing the global markets for methanol and ammonia. While their mandates are largely commercial, both organisations actively contribute technical knowledge on the safe production, handling, and use of these products across various industrial sectors. They have published several reports and guidance documents relevant to the maritime sector, making their material a useful complement to the more formal maritime regulatory and technical frameworks produced by IMO, ISO, SGMF and others.

The International Methanol Producers and Consumers Association (IMPCA) represents global methanol producers and consumers and provides market data, best practice guidance, and industry coordination. Although not a maritime regulatory body, IMPCA publications and technical resources on methanol properties, handling, logistics, and safety may support ports and operators in understanding supply chain considerations and product stewardship aspects relevant to methanol bunkering.

https://methanol.org/marine/

https://ammoniaenergy.org/

https://impca.eu/

Stakeholders Identification 2.2

Safe methanol and ammonia bunkering involves a broad set of organisations, each with different interests, responsibilities, and authority. These stakeholders may be involved at different stages-from design and planning to preparation and final bunkering operations.

Their roles should be clearly identified at the outset and reviewed whenever the bunkering location, supply scenario, or operational conditions change. Effective coordination and clarity on responsibilities are essential for ensuring safe, compliant, and efficient bunkering operations.

Figure 2-1 below presents a typical bunkering stakeholder relationship diagram. The roles and responsibilities of the various stakeholders illustrated are further explained in the following sections.

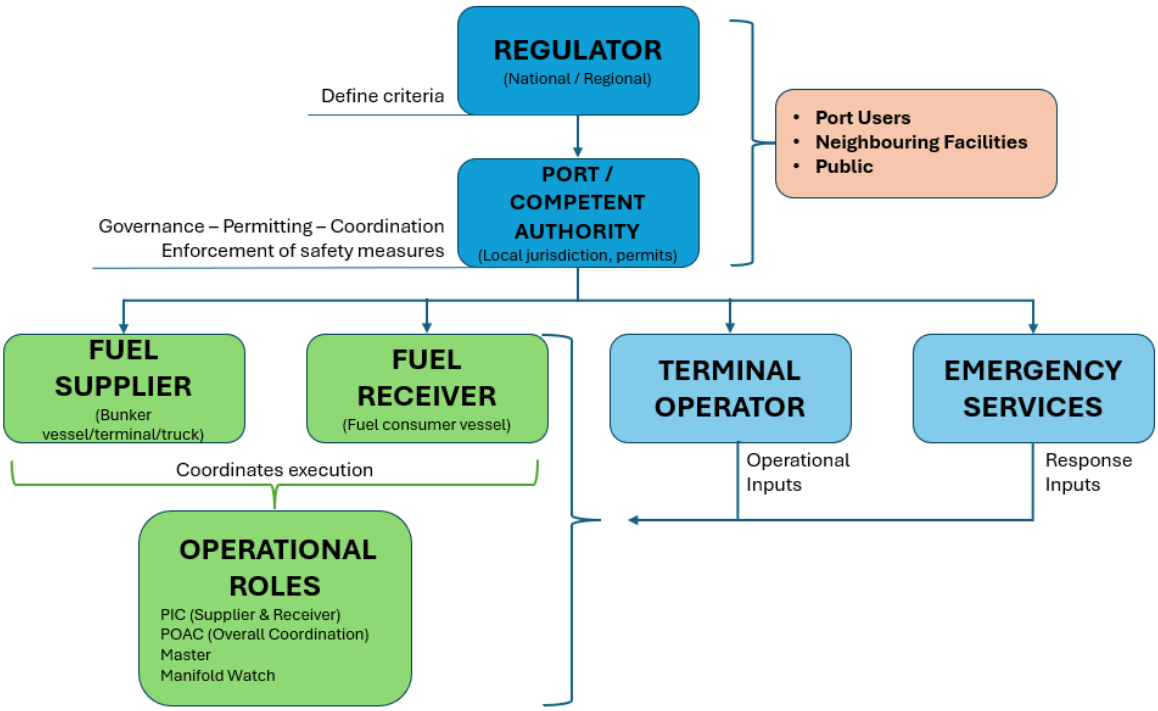

Figure 2-1: Bunkering Stakeholder Diagram

Stakeholders should be identified at each stage of the bunkering development process and whenever there are changes in:

- bunkering location
- supply scenario (ship-to-ship, shore-to-ship, mobile-to-ship)
- facility design or operating conditions

Stakeholders are identified because they may:

- directly participate in the operation
- hold jurisdiction over the area or operation
- have a legal or operational interest
- operate in proximity to the bunkering site
- be impacted directly or indirectly by the activity

All relevant organisations should therefore understand the operation, contribute their expertise, and participate consistently throughout development.

KEY TAKEAWAYS:

1. Methanol and ammonia bunkering requires multiple stakeholders, each with distinct operational, legal, and safety-related responsibilities.
2. Stakeholder identification should occur early and be updated as the project evolves.
3. Stakeholders include fuel suppliers, receiving ships, designers, regulators, port authorities, terminal operators, emergency services, port users, neighbours, and the public.
4. A competent authority may change depending on the stage of development (e.g., flag state/class during design; regulator/port authority during operations).
5. Every stakeholder should contribute information, participate in risk assessment as needed, and support the implementation of agreed mitigation measures.
6. Operational roles (e.g., Person-in-Charge, POAC, manifold watch) should be assigned to trained and competent personnel to ensure safe execution of the bunkering operation.

CHALLENGES AND GAPS:

1. The complexity of methanol and ammonia bunkering often leads to overlapping responsibilities, especially where regulatory, port, and operational authorities intersect. Clarifying stakeholder roles early is essential.
2. A lack of standardised stakeholder engagement processes across ports can lead to inconsistent expectations and interactions during planning and risk assessment.

Key stakeholder responsibility matrix 2.2.1

The following stakeholders (see table 2-1) are typically involved in the design, planning, preparation, or execution of methanol and ammonia bunkering operations (*Ref: ISO/TS 18683:2021*).

Table 2-1: Stakeholder responsibility matrix

Stakeholder		Primary role	Key Responsibilities
Fuel Supplier [3]	May be a bunker vessel operator, terminal operator, truck fleet operator, or producer.	Provides and operates bunkering facility or supply source	Supply-side risk assessment input; system specifications; operating procedures; ensuring safe transfer operations.
Fuel Receiver	Vessel owner, operator, or charterer.	Operates vessel receiving fuel	Vessel information; crew training; receiving procedures; participating in compatibility and risk assessment.
Designer	Includes designers of vessels, bunkering facilities, pipelines, or equipment.	Designs systems used in bunkering	Provide design criteria, equipment specifications, and engineering input to risk assessments.
Regulator	National or regional authority with jurisdiction over the bunkering location or activity.	National or regional legal authority	Defines acceptance criteria; applies relevant legislation; approves risk assessments where required.
Port Authority [1] [2]	Local authority with jurisdiction over port operations and safety.	Local authority with jurisdiction over bunkering	Port-level risk assessment; permitting; coordination with other port users; enforcement of safety measures.
Competent Authority [1]	May shift between Class/Flag, Regulator, and Port Authority, depending on the stage of development.	Entity with legal or operational oversight (varies by stage)	Approves designs, sets criteria, validates risk assessment, oversees operations.

Stakeholder		Primary role	Key Responsibilities
Terminal Operator	Operator of the terminal where bunkering occurs (not necessarily fuel-specific).	Manages terminal where bunkering occurs	Provide operational constraints; ensure compatibility with cargo/terminal operations; coordinate SIMOPs.
Emergency Services	Fire brigade, medical services, police, and specialised hazardous-materials teams.	Respond to incidents	Provide emergency response planning input; verify access requirements and intervention capabilities.
Port Users	Other operators within port boundaries (land or water).	Operate within the port environment	Provide operational schedules or constraints; adapt activities if required during bunkering operations.
Neighbouring Facilities and the Public	Entities located near the port who could be affected by bunkering.	Those potentially affected by operations	Provide information as needed; may require consultation depending on risk assessment outcomes.

[1] The port authority often acts, in whole or in part, as the **competent authority** for the bunkering location. The term *competent authority* refers to any organisation that has legal or operational jurisdiction over the bunkering area, the activities taking place there, or the assets involved. – The competent authority may change as the bunkering operation progresses from design to planning and then to actual operations. In some cases, more than one organisation may share competent-authority responsibilities. – Generally, during the planning and operational stages, the national regulator sets the risk-assessment acceptance criteria, while the port authority typically acts as the competent authority to ensure that the risk-assessment process and operational controls are properly implemented.

[2] See section 2.2.3 for additional insights on port authority role and responsibilities

[3] The fuel supplier may or may not be the owner of the fuel ("molecule owner"). Where commercial ownership and operational supply are separated, responsibilities for fuel quality, quantity, liability, and compliance should be clearly defined. Regardless of ownership structure, the licensed stakeholder remains accountable to the port for the safe and compliant execution of the bunkering operation.

Operational roles during bunkering 2.2.2

Safe execution of bunkering requires a set of trained, designated operational roles (see table 2-2):

Table 2-2: Bunkering operational roles

Stakeholder	Primary role	Key Responsibilities
Bunkering Organisation	The operator managing the bunkering facility (bunker vessel, terminal, truck fleet).	Responsible for executing supplier-side procedures.
Receiving Ship Operator	Operates the receiving vessel.	Ensures crew are trained and PPE and procedures are followed.
Master(s)	Ultimately responsible for the safety of the vessel (bunker vessel or receiving ship).	May delegate to an “acting master”.
Person in Charge (PIC)	Responsible for managing the bunkering operation for either supplier or receiver.	One PIC per side; both must coordinate and communicate continuously.
Person in Overall Advisory Control (POAC)	Coordinates the operation between supplier and receiver.	Typically one of the PICs; ensures synchronised, safe execution.
Manifold Watch	Personnel monitoring the transfer equipment and operation.	Reports directly to their respective PICs.

Port authority – role & responsibilities 2.2.3

The port authority is a central stakeholder in methanol and ammonia bunkering. In many cases it acts, wholly or in part, as the competent authority for the bunkering location, with jurisdiction over port waters, berths, terminals and access routes. In this role, the port authority links international and national regulatory requirements with the practical realities of local port operations and infrastructure.

Its main responsibilities span all stages of the bunkering lifecycle and typically include the following.

Governance, jurisdiction and competent-authority role

1. Acting as the competent authority for the bunkering area (or sharing this role with national regulators), including:

    - interpreting and applying national legislation and port bylaws to methanol and ammonia bunkering
    - setting, or helping define, local requirements for risk assessment, safety zones and SIMOPs management
    - establishing port-specific rules and conditions for alternative fuel bunkering.

2. Developing or updating port regulations and procedures to reflect methanol and ammonia hazards, including low-flashpoint fuel handling, toxic exposure, spill control and fire response.

Location planning, risk assessment and permitting

1. Participating actively in location planning for bunkering, including:
   - assessing the suitability of proposed bunkering locations within the port (quays, anchorages, terminals)
   - considering interactions with existing port traffic, nearby terminals, public areas and environmentally sensitive zones.
2. Establishing or applying risk-acceptance criteria for methanol and ammonia bunkering and ensuring that design and operational risk assessments submitted by operators meet these criteria.
3. Reviewing and, where mandated, approving:
   - bunkering design and operational risk assessments
   - proposed safety zones, monitoring and security areas and marine exclusion zones
   - SIMOPs proposals and any restrictions on concurrent operations at the berth or terminal.
4. Operating or contributing to an accreditation, licensing and authorisation scheme for bunkering organisations and receiving ships within the port jurisdiction, including inspection and audit arrangements.

Planning and preparation of specific operations

1. During the planning and preparation stages, working with shipowners, suppliers and terminal operators to:
   - clarify applicable port requirements and approval processes
   - review the planned bunkering location, safety distances and traffic-control measures
   - validate that preparatory work by supplier and receiver reflects local conditions and constraints.
2. Ensuring that port-level SIMOPs management is in place, including rules for cargo operations, passenger movements, road traffic and other activities in proximity to the bunkering operation.

Operational oversight, authorisation and enforcement

1. Granting final authorisation (where required) for individual bunkering operations and overseeing compliance during the operation, often in coordination with the national regulator.
2. Implementing and enforcing:
   - access control to the safety zone and surrounding monitoring/security areas
   - marine exclusion zones and traffic-control measures for passing vessels
   - any temporary restrictions on port activities that could adversely affect bunkering safety.
3. Monitoring bunkering performance against port requirements and, where necessary, suspending or stopping operations if conditions deviate from the agreed plan or safety is compromised.

Emergency preparedness, response and training

1. Developing and maintaining port-level emergency response plans that cover methanol and ammonia release scenarios, fires and explosions, and coordinating these with the contingency plans of ship operators, bunker suppliers and terminals.
2. Coordinating with local emergency services (fire, medical, police, civil protection) to ensure that:
    - roles and responsibilities are clear
    - response routes, muster points and resources are compatible with bunkering locations and safety zones.
3. Ensuring that port personnel who interact with methanol- or ammonia-fuelled vessels, or with bunkering facilities, receive appropriate training and that enforcement officers and emergency responders are trained in the specific hazards of these fuels.

Communication, coordination and continuous improvement

1. Acting as a focal point for communication with other port users, neighbouring facilities and the public, informing them as appropriate about planned bunkering activities and any associated restrictions.
2. Facilitating the exchange of lessons learned from early methanol and ammonia bunkering operations, and using this feedback to refine port rules, procedures and risk-control measures over time.

In summary, the port authority's role extends beyond issuing permits: it provides the governance framework, coordinates stakeholders and ensures that methanol and ammonia bunkering is integrated safely into the wider port system throughout the design, planning, preparation and operational stages.

Clarification Note – Roles and Responsibilities of "Ports":

Roles and responsibilities differ between ports and jurisdictions. These functions are not automatically or uniformly assigned to a port authority.

Legal responsibilities, statutory powers, enforcement capabilities and organisational structures vary significantly across jurisdictions. Different systems use different institutional arrangements and terminology, such as port authority, harbour authority, harbour master, maritime administration, terminal operator, municipal authority or other designated competent authority.

In some cases, the port authority is a public-law body with statutory powers. In others, operations may be managed by private operators under concession, with regulatory oversight exercised by separate national authorities. Environmental, occupational health and safety, and major hazard regulations may also fall under distinct agencies.

This distribution can create legal and administrative complexity, which is well recognised in the maritime sector.

Accordingly, the term "port" in this Guidebook is used in a functional sense. It refers to the entity or combination of entities holding responsibility and accountability for authorising, overseeing and enforcing bunkering activities within port limits. **Each jurisdiction should clarify and define these roles within its own legal framework.**

Bunkering Supply Scenarios 2.3

Methanol and ammonia bunkering can be carried out using three main supply scenarios: ship-to-ship, shore-to-ship, and mobile-to-ship. These scenarios differ in terms of equipment, operational constraints, and port-specific conditions. The choice of scenario depends on factors such as bunkering volume, required transfer rate, vessel manifold arrangements, SIMOPs, local traffic and weather conditions, and the availability of suitable bunkering infrastructure.

A visual overview of the three scenarios is provided in the accompanying Figure 2-2.

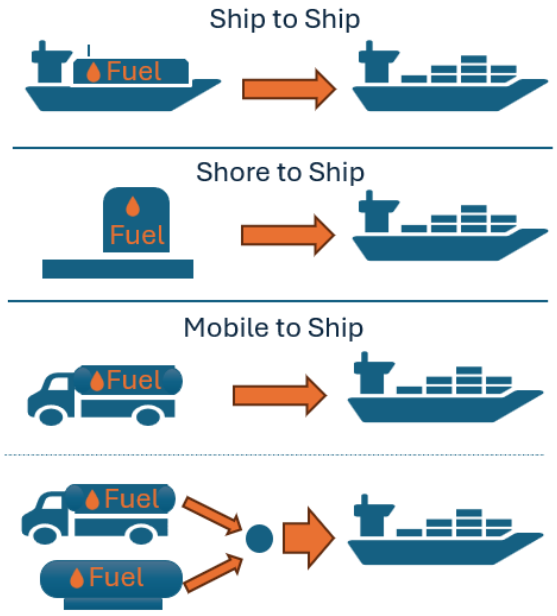

Figure 2-2: Bunkering Supply Scenarios

- **Ship-to-Ship (STS):** Fuel is transferred from a bunker vessel, barge, or floating installation to the receiving vessel.
- **Shore-to-Ship:** Fuel is supplied from a fixed facility or terminal located ashore.
- **Mobile-to-Ship:** Fuel is delivered via mobile units such as trucks, portable tanks, or ISO containers positioned quayside.

Each scenario has advantages and constraints that should be assessed for every operation. A vessel may use more than one scenario throughout its lifetime, depending on location and infrastructure availability.

This Guidebook addresses all three bunkering scenarios. Where requirements or considerations differ-for example in safety zones, equipment interfaces, or SIMOPs-these are highlighted in the relevant sections of the document.

The Four Stages Approach for Vessels Operators 2.4

The safe introduction of methanol and ammonia bunkering is best approached as a progressive, staged process. This Guidebook acknowledge a four-stage structure proposed by SGMF in their bunkering guidelines that reflects the lifecycle of bunkering development, from early concept through to operational execution.

This approach is primarily oriented toward the fuel supplier and fuel receiver, and describes how these stakeholders develop and execute bunkering operations and engage with other parties, including ports and competent authorities (*reference is made to the SGMF bunkering guidelines for methanol and ammonia*).

The four stages are:

1. **Design Stage** – where the bunkering concept, location, systems, and high-level safety framework are defined.
2. **Planning Stage** – where risk assessments, compatibility assessments, documentation, and permitting are developed and reviewed.
3. **Preparation Stage** – where operation-specific arrangements are finalised, documentation is confirmed, and readiness is verified.
4. **Operational Stage** – where bunkering is conducted under approved conditions, with oversight, monitoring, and emergency preparedness in place.

NOTE:

While this four stages framework is primarily intended to describe how vessel operators and bunker suppliers plan and execute bunkering operations, it is included here for reference, as it provides important context for how ports interact with bunkering stakeholders. The approach does not in itself describe how ports develop their internal frameworks, infrastructure, or readiness for bunkering, which is addressed separately in this Guidebook.

Bunker System (Transfer System) 2.5

The bunker system, also commonly referred to as the transfer system, is the set of equipment used to safely transfer methanol or ammonia between the fuel supplier and the receiving vessel. It forms the physical and functional link between the two parties and is a critical element of bunkering safety.

At a high level, the bunker system comprises all equipment located between the bunkering manifold flange of the supplying facility (shore installation, bunker vessel, or mobile unit) and the manifold of the receiving vessel. Depending on the supply scenario, the system may consist of hoses, rigid transfer arms, or a combination of both, together with safety, isolation, and emergency release components (see table 2-3).

While the detailed design and configuration of bunker systems vary by fuel and application, their functional purpose is the same across all bunkering operations:

1. to enable controlled fuel transfer,
2. to allow rapid isolation and disconnection of the system in abnormal conditions, and
3. to prevent uncontrolled release of fuel if operational limits are exceeded.

ISO 20519:2021 Specification for bunkering of liquefied natural gas fuelled vessels provides detailed definitions and configurations for LNG bunker systems. Although this standard is LNG-specific, the functional principles of the bunker system components are directly applicable to methanol and ammonia bunkering. Differences arise from the physical, chemical and safety properties of methanol and ammonia (e.g. toxicity, corrosivity, vapour behaviour), which influence material selection, sealing arrangements, safety distances, and operating procedures. These fuel-specific aspects are addressed elsewhere in this Guidebook.

Table 2-3: Bunker system key components

Component	High-level function
Bunkering Safety Link (BSL)	Provides communication between supplier and receiver ESD systems to ensure coordinated shutdown.
ESD System	Initiates safe shutdown of the bunkering operation in emergency or abnormal conditions.
Hose or Transfer Arm	Physical conduit used to transfer liquid fuel (and vapour return where applicable).
Connector (Flange or Dry-Disconnect Coupling)	Mechanical interface connecting the transfer system to the vessel manifold.
Emergency Release Coupler (ERC)	Enables rapid, safe physical separation of the transfer system to prevent fuel release if limits are exceeded.

Handling and human-factor considerations 2.5.1

The handling and operation of bunker system components require careful consideration of human-factor aspects. Hoses, transfer arms, connectors and emergency release devices may be heavy, bulky, and subject to movement due to vessel motion, tide, or weather. Their weight, reach, and manoeuvrability can directly affect safe connection, monitoring, and disconnection.

Operators should ensure that lifting arrangements, access, lighting, and working clearances are adequate, and that personnel involved are properly trained and familiar with the specific equipment used. Human-factor considerations should be addressed during system selection, risk assessment, and operational planning to reduce the risk of handling errors and unsafe working conditions.

Hazardous Areas, Toxic Areas, Safety Zones and SIMOPs 2.6

Methanol and ammonia bunkering operations require the definition and management of several distinct but related areas around the bunkering location. These areas are established to control risks associated with flammability, toxicity, and operational interactions, and to ensure that bunkering can be safely integrated into the port environment.

The definition of these areas is normally based on the outcomes of a risk assessment, taking into account fuel properties, transfer systems, bunkering scenarios, and local port conditions. While the

detailed technical definition is typically prepared by designers and operators, ports-often acting as the competent authority-play a central role in reviewing, approving, coordinating, and enforcing these areas.

The five areas commonly used are (see figure 2-3):

- Hazardous Area
- Safety Zone
- Monitoring and Security Area
- Marine Exclusion Zone
- Assessment Zone

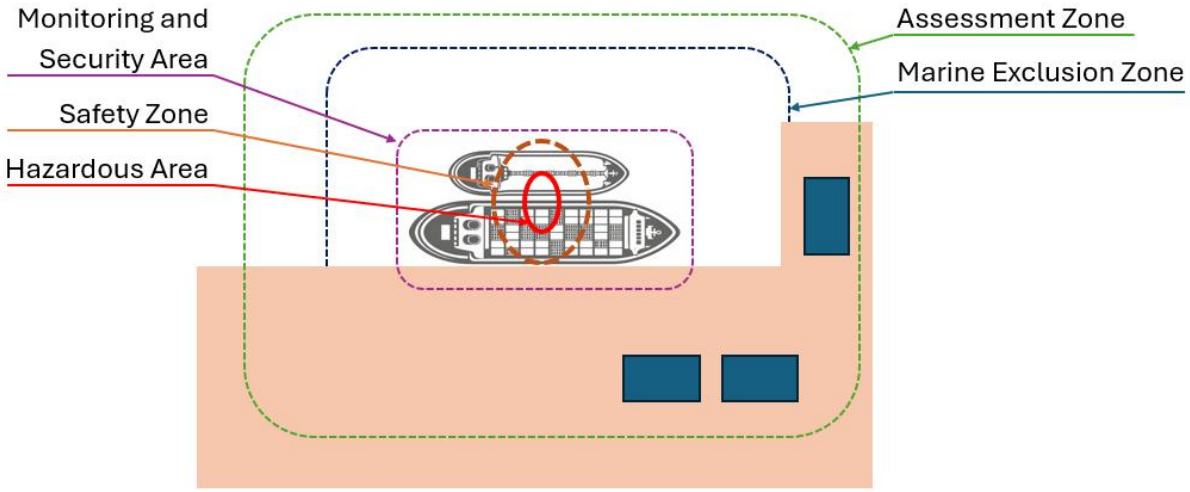

Figure2-3: Bunkering zones schematic

In addition, for fuels presenting significant health risks-particularly ammonia-a **Toxicity Area** may be defined to address potential exposure impacts beyond flammability-driven considerations.

These areas are closely linked to the management of simultaneous operations (SIMOPs) and should be considered together to ensure consistent control, communication, and enforcement during bunkering.

NOTE:

The following sections provide general information and background definitions related to Hazardous Areas, Toxic Areas, Safety Zones, and SIMOPs. It does not describe in detail how these areas are established, calculated, controlled, or monitored. For guidance on the assessment and determination of safety zones for methanol and ammonia, including methodology and practical application, please refer to Sections 4.3 and 4.4.

Hazardous area 2.6.1

The hazardous area is defined based on the potential presence of flammable atmospheres during normal operations or foreseeable abnormal conditions. For methanol bunkering, this relates primarily to the risk of vapour release and ignition. Hazardous areas are typically limited to the immediate vicinity of transfer equipment, manifolds, vents, and connection points.

For ammonia, while flammability is less dominant, hazardous areas may still be defined for equipment where specific conditions could lead to ignition but are more often influenced by toxic release considerations.

Port role:

- Understand the extent and implications of hazardous areas for port infrastructure and nearby activities.
- Ensure that ignition sources and incompatible activities are controlled within these areas.
- Confirm that hazardous-area definitions are reflected in port permits, procedures, and access rules.

Safety zone 2.6.2

The safety zone is established to protect people, assets, and port operations from the consequences of a potential incident. It is primarily driven by flammability-related hazards for methanol (e.g. jet fires, pool fires) and may be expanded for ammonia to account for toxic dispersion scenarios.

In addition to fuel-specific hazards, the definition and extent of the safety zone should also consider simultaneous operations (SIMOPs). Activities taking place within or adjacent to the bunkering location-such as cargo handling, passenger movements, maintenance work, or vessel traffic-may influence both the size of the safety zone and the operational controls required during bunkering.

The safety zone typically encompasses the hazardous area and extends beyond it to include a buffer where access is restricted and activities are controlled for the duration of the bunkering operation.

Port role:

- Review and approve the proposed safety zone as part of the risk assessment, including consideration of SIMOPs.
- Ensure the safety zone is compatible with port layout, berth use, traffic flows, and adjacent activities.
- Define and enforce access restrictions, activity limitations, and SIMOPs controls within the safety zone during bunkering.

Monitoring and security area 2.6.3

The monitoring and security area surrounds the safety zone and provides space for active supervision, detection, and response. Within this area, activities may continue but are subject to increased awareness and readiness.

Port role:

- Coordinate monitoring arrangements with terminal operators, VTS, and emergency services.
- Ensure clear communication and situational awareness during bunkering.
- Support rapid escalation if abnormal conditions are detected.

Marine exclusion zone 2.6.4

The marine exclusion zone is established on the water side to prevent unauthorised vessel movements near the bunkering operation. It reduces the risk of collision, wake effects, or interference that could compromise the safety of the transfer.

The size and shape of the marine exclusion zone depend on the bunkering scenario, vessel size, traffic density, and local navigational constraints.

Port role:

- Define and enforce marine exclusion zones, often in coordination with Vessel Traffic Services (VTS).
- Issue navigation warnings or traffic restrictions as required.
- Ensure pilots, tug operators, and other port users are informed.

Assessment zone 2.6.5

The assessment zone is a wider area considered during the risk assessment to evaluate the potential impact of worst-case scenarios, including fire escalation or toxic dispersion beyond the immediate bunkering location. Further guidance on assessment zone can be found in Section 4.3.3.

Port role:

- Use the assessment zone to understand potential off-site impacts on neighbouring terminals, public areas, and infrastructure.
- Inform land-use planning, emergency response planning, and stakeholder engagement.
- Ensure that societal risk considerations are addressed where required by national regulations.

Toxic area 2.6.6

A toxic area onboard of an ammonia fuel vessel is defined as an area in which ammonia is, or may reasonably be expected to be, present at concentrations that could pose a risk to human health. The concept of a toxic area has been introduced by the IMO through *MSC.1/Circ.1687 – Interim Guidelines for the Safety of Ships Using Ammonia as Fuel*.

The definition and application of toxic areas are specific to ships using ammonia as fuel under the remit of the IGF Code, where the interim guidelines set additional requirements to address ammonia's toxicity.

Under MSC.1/Circ.1687, the toxic area is defined using two complementary approaches:

1. **Prescriptive separation distances:** In accordance with paragraph 12bis.4.1, minimum distances are specified between ammonia fuel systems and:
   - life-saving appliances;

- emergency escape routes;
- air intakes, outlets, and other openings into accommodation spaces;
- service and machinery spaces;
- control stations; and
- other non-toxic spaces.

2. **Dispersion-based determination**: In accordance with paragraph 12bis.4.3, a gas dispersion analysis is required to determine the extent of the toxic area. The analysis should demonstrate that ammonia concentrations exceeding 220 ppm do not reach:
   - air intakes, outlets, and other openings into accommodation spaces;
   - service and machinery spaces;
   - control stations;
   - other non-toxic spaces on board; and
   - any additional areas specified by the Administration.

The toxic area determined through dispersion analysis may extend beyond the minimum prescriptive distances defined in paragraph 12bis.4.1, or may require the implementation of additional mitigation measures (such as ventilation, gas detection, shutdown systems, or operational controls) to ensure compliance.

It is important to note that the toxic area threshold specified by the IMO in *MSC.1/Circ.1687 – Interim Guidelines for the Safety of Ships Using Ammonia as Fuel*, is intended for design and safety-zone purposes, rather than time-based exposure assessment.

Given the critical safety implications of toxic areas for ammonia-fuelled vessels and their interface with port operations, this topic is addressed in further detail in Section 4.4.2.

SIMOPs integration 2.6.7

The definition of hazardous areas and zones is closely linked to the management of simultaneous operations (SIMOPs). Activities within or near these zones may need to be restricted, rescheduled, or subject to additional controls during bunkering.

Port role:

- Review SIMOPs assessments and approve permitted activities during bunkering.
- Coordinate restrictions across terminals, berths, and port services.
- Ensure SIMOPs arrangements are clearly communicated and enforced.

Bunkering Documentation 2.7

Safe methanol and ammonia bunkering relies on a structured set of documents that collectively define how bunkering is planned, authorised, prepared, and executed. These documents are typically brought together under a Methanol/Ammonia Bunkering Management Plan.

The Bunkering Management Plan is not a single document, but a documented framework that consolidates all information needed to demonstrate that bunkering can be carried out safely, in compliance with applicable regulations and port requirements. It is used to support risk assessment,

compatibility assessment, permitting, and operational control, and is commonly reviewed by the port authority acting as competent authority.

While the detailed content and format may vary depending on the bunkering scenario and local requirements, the Methanol/Ammonia Bunkering Management Plan should remain proportionate, practical, and non-duplicative, avoiding unnecessary bureaucracy while ensuring that all safety-critical elements are addressed.

Key considerations for ports:

The following considerations, based on established frameworks and lessons learned from LNG bunkering, should be taken into account when defining the bunkering documentation requirements:

1. **Documentation should support safe operations:** Bunkering documentation should be structured to actively support safe planning and execution of operations. It should not become a purely bureaucratic or "tick-box" exercise, nor impose unnecessary burden on operators or port staff.

2. **Documentation should evolve with operational maturity:** During early pilot phases, it is understandable that multiple iterative assessments, approvals, and documents may be required, often covering a single operation. As bunkering moves from pilot projects to business-as-usual, documentation should be streamlined, with a single framework covering multiple operations, vessels, or scenarios-provided these remain within the defined operational boundaries and assumptions.

3. **Documentation should be proportionate to risk:** The level of detail required should reflect the fuel, bunkering scenario, location, and operational complexity. Proportionality helps ensure that attention is focused on safety-critical issues rather than excessive documentation.

4. **Use existing industry documentation wherever possible:** Ports should refrain from creating new or bespoke bunkering documents where recognised industry guidance already exists. Established frameworks and templates are available, including:
    - SGMF guidelines for methanol and ammonia bunkering;
    - SGMF guidance for bunkering compatibility assessment;
    - IAPH Clean Marine Fuels Working Group bunkering checklists.

    Ports are therefore encouraged to reference and adopt existing industry documentation rather than modify or replace it. Where port-specific needs exist, these should be addressed through clearly defined additional requirements or conditions, complementing what is already in place rather than duplicating it.
    Experience from the early implementation of LNG bunkering demonstrated that the proliferation of port-specific documentation requirements was widely recognised as a barrier to operators, increasing complexity without commensurate safety benefit. Avoiding unnecessary divergence is particularly important in the early stages of methanol and ammonia bunkering to support consistency, efficiency, and safe uptake across ports.

5. **Role of the Joint Bunkering Plan (JBP / JPBO):** The Joint Bunkering Plan (JBP), also referred to as the Joint Plan of Bunkering Operation (JPBO), is a key document. It should be understood as an operational document, intended to support coordination, readiness, and execution of the bunkering operation. It should focus on essential operational and safety elements and should not be treated as a permitting document.

6. **The JBP/JPBO is not the same as a Joint Plan of Operation (JPO):** a JPO is used for ship-to-ship (STS) transfers under MARPOL Annex I. A JPO is a mandatory document for STS operations, typically applies to a single transfer only, and includes requirements that go beyond those normally included in a JBP. These documents should not be confused, and ports should be clear which document is required for which purpose.

Typical documents included in the bunkering management plan 2.7.1

A typical Bunkering Management Plan for methanol or ammonia bunkering may include the following key documents:

1. Bunkering Management Plan (core document)
   - Overview of the bunkering concept, systems, procedures, and safety measures.
   - Primary reference document submitted to the competent authority during the planning stage.

2. Bunkering Procedure
   - Step-by-step description of the bunkering operation, including roles, communications, and emergency actions.

3. Joint Bunkering Plan (JBP)
   - A concise, operation-specific summary of key information for a defined vessel, location, and supply scenario.
   - Often requested by port authorities as a practical overview for operational approval and oversight.

4. Bunkering Checklist
   - Mutual checklist used by supplier and receiver during preparation and operation to verify readiness and control execution.
   - Frequently based on the IAPH bunkering checklist framework.

5. Bunkering Compatibility Assessment / Report
   - Demonstrates that the physical, operational, and safety interfaces between supplier and receiver are compatible.
   - Includes recommendations to be reflected in procedures where necessary.

6. Risk Assessment Documentation
   - Hazard identification, risk evaluation, and definition of safety zones and SIMOPs, as applicable at port level.

7. Emergency Response and Contingency Information
   - Alignment between ship, supplier, terminal, and port emergency arrangements.

8. Training and Competence Records
   - Evidence that personnel involved have received appropriate training for methanol or ammonia bunkering.

Documentation - Port review and approval 2.7.2

Ports generally do not manage the bunkering operation but verify that it can be conducted safely within the port environment. Often the Bunkering Management Plan documents are sufficient for the licensing approval during the Design & Early Planning Stage while the JBP, is sufficient for operational approval.

Documentation requirements should be proportionate to risk, avoiding duplication while ensuring transparency and traceability.

Requirements may differ by bunkering scenario (STS, shore-to-ship, mobile-to-ship) and by fuel (methanol vs ammonia).

Once the bunkering operation is becoming an established practice in the port, the JBP is often the primary operational document for ports, supported by selected Bunkering Management Plan elements.

Appendix A: Bunkering Documentation for Ports provides a summary of the typical documentation required by ports during the different stages of the bunkering process and what actions are required.

Fuel Knowledge 3.

SCOPE AND INTENT:

This chapter provides **fuel-specific knowledge** for methanol and ammonia as marine fuels. It covers basic properties, safety aspects (fire, explosion, toxicity), use as cargo and fuel, and environmental impacts. This Part supports informed decision-making by ports and stakeholders and explains why certain risks, controls, and operational requirements differ between fuels. The content in this Part underpins the risk assessments, safety measures, and procedures discussed in later Parts.

Marine Fuels- Properties Summary 3.1

Table 3-1 provides an overview of the basic chemical and physical properties of the fuels considered, in order to support a comparative understanding of the hazards associated with each product relative to LNG, methanol, and marine gas oil (MGO). While the numerical values presented are generally consistent with commonly cited literature, it should be noted that individual values may vary slightly between publications depending on reference conditions and test methods applied. The data for MGO is subject to the highest degree of uncertainty, as MGO is not a single substance but a blend of numerous hydrocarbons with varying chain lengths and properties. Consequently, several parameters (e.g. boiling range, flash point, and vapour behaviour) are typically provided as ranges rather than as discrete values.

To ensure correct interpretation of table 3-1, the following definitions should be considered, as these terms are frequently misused or misinterpreted in practice:

- Boiling point: is the temperature at which a substance changes from liquid to gas at a defined pressure, typically 1 bar (atmospheric pressure). For liquefied gases such as LNG and ammonia, the boiling point explains the requirement for cryogenic or pressurised storage and the rapid phase change that occurs upon release to the atmosphere.
- Flash point: is the lowest temperature at which a liquid emits sufficient vapour to form an ignitable mixture with air at the liquid surface when exposed to an external ignition source. The flash point is only applicable to substances that are liquids under ambient conditions. It is therefore not a meaningful parameter for gases or liquefied gases such as LNG or ammonia. A low flash point indicates an increased likelihood of ignition during handling, transfer, and bunkering operations.
- Auto-ignition temperature: is the minimum temperature at which a substance will ignite spontaneously in air without the presence of an external ignition source. This parameter is independent of the flash point and is relevant for all fuels, including gases, as it characterises the inherent ignition resistance of the substance at elevated temperatures.

Table 3-1: Marine fuels - Properties comparison summary

Properties	Methanol	Ammonia	MGO	Methane (LNG)
Molar Mass	32.04 g/mol	17.03 g/mol	~250 g/mol	16.04 g/mol
Density	0.7918 kg/l @ 20°C	0.682 kg/l @ -33°C	0.860 kg/l @ 15°C	0.430 kg/l @ -160°C
Boiling Point	64.7°C	-33 °C	~250°C	-161.5°C
LFL	5.5%	15% vol	0.6%	5%
UFL	36%	28% vol	7.5%	15%
Flash Point	11°C	N / A	> 60°C	N / A
Autoignition Temperature	464°C	630 °C	~300°C	537°C
Water Solubility	Fully miscible	Highly soluble	Insoluble	Very low (sparingly soluble in water)
Energy content (LHV)	15.8 MJ/l	12.7 MJ/l	36.6 MJ/l	20.8 MJ/l
It shall be noted that different publications and sources reference present different figures due to different test conditions / standards and reference temperatures the tests are performed.				

Methanol Core knowledge 3.2

General & basic properties 3.2.1

Methanol (CH_3OH) is a simple, long-established chemical compound with a high carbon-to-hydrogen ratio, which makes it an attractive hydrogen-derived fuel despite not being carbon-free. 100 litres of methanol contain approximately 10 kg of chemically bound hydrogen, based on a liquid density of 0.792 kg/l and a hydrogen mass fraction of 12.6%.

Methanol is also known by its industrial names “methyl alcohol” or “wood alcohol / wood naphtha / wood spirit”, reflecting its historic production via wood distillation. It has been manufactured at scale for more than a century and remains a cornerstone feedstock in the global chemical industry. Major applications include the production of chemicals, polymers, plastics, adhesives, solvents, and intermediates for countless industrial processes. In the energy sector, methanol is increasingly used for fuel blending, alternative marine fuel pathways, and emerging e-fuel production concepts.

The methanol industry is one of the world's largest consumers of hydrogen, accounting for roughly 30% of global hydrogen demand, making it the second-largest hydrogen-consuming sector after ammonia.

Methanol has been transported safely by sea for over 50 years, supported by mature regulatory frameworks including the IMDG Code and IBC Code. In 2023, global production reached approximately 120 million tonnes per year and is projected to rise to 140 – 150 million tonnes per year by 2030, reflecting strong demand growth, particularly in Asia.

At ambient conditions, methanol is a colourless liquid with a faintly sweet, alcoholic odour. It is classified as a highly flammable liquid and has a flash point of approximately 11 °C. Methanol has a boiling point of approximately 65 °C, which is significantly lower than that of marine gas oil (MGO). However, unlike liquefied gases such as ammonia or LNG, methanol does not undergo an immediate phase change when released at ambient temperatures. Nevertheless, methanol vapour concentrations can increase to hazardous levels in confined or poorly ventilated spaces outside closed storage and fuel-handling systems.

Safety – Fire, explosion and toxicity 3.2.2

Methanol, due to its low ignition temperature combined with its toxicological properties, represents a distinct alternative marine fuel that requires dedicated safety measures and heightened operational awareness. Importantly, the concentration thresholds at which methanol poses toxic effects to personnel are significantly lower than its lower flammability limit (LFL/LEL). Based on modelling studies under typical atmospheric conditions indicate that methanol vapour concentrations reach the LFL on open spaces only under extreme spill scenarios, as methanol does not exhibit rapid or extensive volatilisation under ambient conditions. Nevertheless, the comparatively low toxicity thresholds necessitate particular attention, and appropriate exposure-control and mitigation measures should be implemented to protect personnel during normal and abnormal operating conditions.

At the same time, methanol exhibits a wide flammability range with 5.5–36% in air and cannot be disregarded, particularly in confined or poorly ventilated spaces, where the risk of forming a flammable atmosphere increases and requires appropriate hazardous-area classification, ventilation, gas detection, and procedural safeguards.

Toxicity exposure limits for hazardous substances vary across jurisdictions, reflecting differences in national regulatory frameworks. SGMF references the U.S. EPA Acute Exposure Guideline Levels (AEGL), which are widely applied in the maritime and offshore sectors to evaluate short-term public exposure risks from airborne chemicals. AEGL values define estimated concentration thresholds at which most individuals may begin to experience adverse health effects, based on defined exposure durations, as reflected in the table below. While AEGL-3 at 10 minutes exceeds 50% of the LFL (LEL), it is essential to emphasize that AEGL-3 conditions already represent emergency-level exposure scenarios that fall well outside safe or acceptable operational envelopes. For normal methanol fuel-handling, transfer, and bunkering operations, the AEGL-1 threshold should be treated as the governing operational limit, as it defines the highest airborne concentration considered tolerable for the general public without notable discomfort or health effects, and therefore sets the safety boundary for routine operations. Further details on AEGL limits are provided in section 4.2.1.

Despite the value of AEGL as a harmonized toxicological benchmark, applicable regulatory limits will still vary. Requirements issued by local port or shore authorities, flag state regulations governing IGF/IBC vessels, as well as company and industry standards, will consistently produce non-identical limit values due to differences in legal scope, protection goals, exposure assumptions, and regulatory methodology.

As cargo and as fuel 3.2.3

Methanol is transported by sea in accordance with the IMO IBC-Code using specialised chemical tankers, and by road in accordance with ADR regulations for tank-truck transport. The global methanol trade results in roughly 30 million tonnes per year being shipped by sea.

Under the IBC Code, specific construction and equipment requirements are limited, with the most relevant provisions relating to:

- Tank and cargo-system venting arrangements, and
- Pump-room design and configuration,

both of which are primarily driven by the toxicity and vapour-exposure risk of methanol, rather than its flammability.

From a maritime classification perspective, Methanol may be carried on IMO Type 3 chemical tankers, which represent the lowest hazard tier for ship design within the IBC Code. This reflects that Methanol, compared with many other bulk-liquid chemicals regulated under the Code, is considered a relatively low-hazard cargo with no requirement for high-integrity tank containment systems (such as Type 1 or 2).

Consequently, within the framework of the IBC Code, Methanol is generally regarded as a comparatively safe product from a design and containment perspective, which is in line with requirements of the ADR which does give any additional guidance as already stated above.

In addition to the above, OCIMF has published a guidance note specifically addressing the carriage of methanol in bulk onboard offshore supply vessels, titled “Carriage of Methanol in Bulk Onboard Offshore Vessels”, which should be read in conjunction with the OSV Chemical Code. The document includes guidance relevant to methanol transfer operations, including recommendations for truck-to-vessel transfer safety zones to support safe methanol transfer from shore-side supply chains.

It should be noted that methanol becomes corrosive to certain metals when mixed with water, particularly affecting materials such as copper, zinc, titanium, carbon steel, and some grades of stainless steel. In addition, methanol can be incompatible and degrading to O-rings, gaskets, and sealing materials made from specific elastomers, leading to swelling, embrittlement, or loss of integrity.

Methanol can be stored at ambient temperature and pressure and does not require pressure vessels or cryogenic/refrigerated storage for stability. As a liquid hydrogen derivative, methanol has a higher volumetric energy density than compressed hydrogen and a higher lower-heating value (LHV) than ammonia.

Methanol is produced in very large quantities and is safely handled in numerous industrial sectors worldwide, enabled by mature technologies and well-established global supply chains, including storage, transport, and distribution infrastructure.

Retrofitting existing marine engines to operate on methanol is generally less complex and less invasive compared to conversions for hydrogen, ammonia, or LNG, as it typically avoids the need for high-pressure, cryogenic fuel systems, extensive tank modifications, or gas-handling machinery.

Environmental impact GHG & Pollutants 3.2.4

Methanol contains no sulphur and therefore does not emit SO_x during combustion. However, as a carbon-based molecule, the presence of a carbon atom leads to CO_2 emissions when burned.

Methanol is completely miscible with water and, unlike oil-based products, does not form a surface film or visible sheen. When released into water, it is therefore considered a locally harmful and acutely toxic substance to the marine environment, causing temporary impact to aquatic organisms. However, methanol is readily and rapidly biodegradable, one of the fastest degrading liquid marine fuels, and demonstrates low long-term environmental persistence in seawater.

The combustion of methanol can be chemically described as follows:

$$2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$$

As noted above, the formation of CO_2 is unavoidable in this reaction. The equation reflects ideal combustion conditions, in which only CO_2 and water (H_2O) are produced. In real-world engine operation, combustion is not always ideal. Under incomplete or sub-optimal combustion conditions, by-products such as formaldehyde (CH_2O) may form and be emitted. This requires engine calibration, combustion optimization, and, where necessary, dedicated exhaust gas after-treatment systems to minimize environmental, health, and air-quality impacts. Formaldehyde is classified as a volatile organic compound (VOC) and is a relevant emission component in regulatory air-quality and occupational exposure assessments.

Ammonia Core knowledge 3.3

General & basic properties 3.3.1

Ammonia (NH_3) is a carbon-free, inorganic compound composed of one nitrogen atom and three hydrogen atoms. With 10.7 kg of hydrogen per 100 litres of ammonia, it serves as an effective and widely recognized hydrogen carrier. Ammonia has been produced via the Haber-Bosch process for more than 100 years, consuming approximately 40% of global hydrogen production, which also equates to around 60% of the world's total hydrogen demand.

Ammonia is a fundamental nitrogen source for both plants and animals. Around 80% of global ammonia production is used in agriculture, primarily as a feedstock for nitrogen-based fertilizers. These fertilizers support approximately 45% of the world's food crops, making ammonia-derived fertilizers critical to an estimated 45% of global food production.

Ammonia has been transported by sea for over 60 years and is among the most-produced chemicals in the world. Global production reached approximately 230 million tons in 2023 and is projected to grow to around 290 million tonnes by 2030.

At room temperature and atmospheric pressure, ammonia is a colourless gas with a sharp, pungent odour. It can be liquefied either by compression to roughly 8–10 bar, or by cooling to below −33 °C. Its odour detection threshold lies between 2–5 parts per million (ppm), making even small releases perceptible to the human nose.

Safety – Fire, explosion and toxicity 3.3.2

The low toxicity threshold and the exceptionally high ignition energy required to ignite ammonia set it apart from conventional maritime fuels such as methanol, LNG, and marine gasoil. Despite these inherent challenges, operators around the world have established mature, robust control frameworks and engineered safeguards that demonstrate ammonia can be managed safely when handled with appropriate risk controls and operational discipline.

Ammonia is classified as a non-flammable substance for maritime transport under both the IGC Code and the IMDG Code (noting that it may become flammable under certain concentration ranges and confinement conditions). The airborne concentration required to form a flammable atmosphere is substantially higher than that of conventional marine fuels. In addition, the minimum ignition energy (MIE) of ammonia is extremely high – roughly 10,000 times greater than that of hydrogen. It should be noted that the minimum ignition energy (MIE) differs significantly in the literature depending on the actual test setup. However, combined with a lower flammability limit (LFL) of approximately 16% by volume in air, ignition of an unconfined ammonia vapor cloud in open air is considered highly improbable. However, ammonia ignitions have been recorded in enclosed or confined spaces, where gas accumulation and localized ignition sources can create conditions capable of exceeding the LFL and overcoming the high ignition energy requirement. Therefore, the autoignition temperature is significantly higher than methanol or MGO.

Ammonia presents acute inhalation toxicity, with effects that are strongly concentration dependent. Compared to other established marine fuels, harmful concentrations occur at significantly lower levels, making toxicity the primary design driver when developing fuel supply and bunkering concepts.

Table 3-2: Ammonia concentration and effects

Concentration [ppm]	Effects
5 - 25	Odour perception
20 - 50	Mild discomfort
50 - 80 (2 hrs)	Perceptible eye and throat irritation
100 (2hrs)	Nuisance eye and throat irritation
140 (2hrs min)	Severe eye, nasal throat and chest irritation. Leave exposure area
300	No scape-impairing symptoms and no irreversible effect
500 (30 minutes)	Upper respiratory tract irritation, tearing of the eyes
700 – 1,700	Coughing, bronchospasm and chest pain with severe eye irritation and tearing
5,000 – 10,000	Rapidly lethal; chemical bronchitis and chemical burns of the skin
10,000	Promptly lethal

Table 3-2 has been compiled and refined by EMSA (European Maritime Safety Agency) following a structured review of publicly available safety data sheets and toxicological guidance. Key sources

include government agencies such as the Spanish Ministry of the Interior (Civil Protection), as well as health authorities including Public Health England and Public Health England successor guidance aligned with UK HSA frameworks, alongside industry input from chemical manufacturers' and sector associations such as CEFIC (European Chemical Industry Council) and CIAFA (Cámara de la Industria Argentina de Fertilizantes y Agroquímicos).

Exposure limits for hazardous substances differ across jurisdictions. SGMF references the U.S. Environmental Protection Agency (EPA) Acute Exposure Guideline Levels (AEGL), which are widely used to assess short-term public exposure risks from airborne chemicals. AEGL values define estimated concentration thresholds at which most individuals may begin to experience adverse health effects, based on a defined exposure duration as provided in the table below. Further details on AEGL limits are provided in section 4.4.2.

Despite the value of AEGL as a harmonized toxicological benchmark, applicable regulatory limits will still vary. Requirements issued by local port or shore authorities, flag state regulations governing IGF/IGC vessels, as well as company and industry standards, will consistently produce non-identical limit values due to differences in legal scope, protection goals, exposure assumptions, and regulatory methodology. In this respect it should be taken into account that ammonia vapor has a density ratio of 0.589 at 0°C relative to air, meaning that under ambient conditions ammonia gas is lighter than air and will tend to rise rather than settle in low areas.

However, the behaviour of ammonia following a release depends strongly on temperature, release phase, and meteorological conditions. In the case of a cold liquid release (e.g. refrigerated ammonia at approximately -33°C), the initial vapour cloud may be significantly colder and denser than the surrounding air. Under such conditions, the cloud can temporarily behave as a heavy gas, spreading laterally along the ground before warming and becoming buoyant. Similarly, aerosol releases consisting of fine liquid droplets entrained in vapour may exhibit heavier-than-air characteristics in the initial phase, particularly in low wind conditions.

As the released ammonia warms and mixes with ambient air, it will generally become lighter than air and rise. Therefore, dispersion assessments should consider the release phase (liquid, vapour, or aerosol), temperature, release rate, and local atmospheric conditions, rather than relying solely on the theoretical vapour density relative to air.

As cargo and as fuel 3.3.3

Ammonia is transported by ships, regulated under the IGC Code, and by trucks, regulated under the ADR (European Agreement concerning the International Carriage of Dangerous Goods by Road).

According to an infrastructure report by the Ammonia Energy Association, approximately 17 – 20 million tonnes of ammonia are safely transported internationally by sea each year. Marine transport is conducted using either fully refrigerated or pressurised cargo systems. The majority of global ammonia shipping is carried out under refrigerated conditions, typically on gas carriers with cargo capacities of up to 50,000 m³, while pressurised transport plays a smaller role. The largest share of this refrigerated transport is conducted on mid-size vessels with tank volumes up to 50,000 m³.

The IGC Code requirements for ammonia carriers place particular emphasis on the steel grades used for containment and cargo transfer systems, as ammonia can be corrosive to carbon-manganese and

nickel steels. This corrosion risk is accelerated by the presence of water and oxygen. To mitigate this, the IGC Code limits:

- Water content to 0.1% w/w, and
- Oxygen content to 2.5 ppm w/w.

Provided these limits are maintained, ammonia may also be transported on 2G-class gas tankers, which fall under the same IGC vessel classification used for LNG carriers (methane as defined under the IGC Code).

The ADR does not specify any additional technical requirements of relevance. However, trucks carrying these cargoes can only be parked under supervision, or may alternatively be parked without supervision in a secure depot or within secure factory premises.

Compared to other marine fuels, ammonia offers several distinct advantages. It can be stored in a liquefied state at atmospheric pressure at -33°C or in a fully pressurised state typically around 18 bar, and unlike LNG and hydrogen, it does not require cryogenic storage temperatures. Furthermore, ammonia is significantly more space-efficient than hydrogen due to its much higher volumetric energy density, which makes it easier to store and transport.

In addition, ammonia is produced in very large quantities and is safely handled across a wide range of industrial sectors, supported by mature technologies and established global supply chains.

However, the use of ammonia in internal combustion engines introduces new technical challenges and requires emerging fuel-specific technologies. Pilot and demonstration projects are currently underway worldwide to validate engine concepts, combustion behaviour, and supporting safety and handling frameworks.

Environmental impact GHG & pollutants 3.3.4

Ammonia contains no sulphur and therefore does not produce SO_x emissions. It also contains no carbon, meaning that no CO_2 is emitted during combustion – a key distinction compared to methanol. Furthermore, ammonia's lack of carbon represents a significant difference to methanol, particularly given methanol's inherent carbon content, even when derived from green or blue feedstocks.

Furthermore, ammonia is highly soluble in water, where it reacts to form ammonium hydroxide (aqueous ammonia). This dissolution process occurs under exothermic conditions, meaning that heat is released when ammonia dissolves in water. In addition, ammonia exhibits acute toxicity to aquatic life, particularly to fish, even at low concentrations. The principal environmental hazard is acute ammonia toxicity rather than long-term persistence, as ammonia does not bioaccumulate and is not considered environmentally persistent.

In theory, the ideal stoichiometric combustion of ammonia produces only nitrogen and water:

$$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$$

As ammonia-fuelled marine engines are still under development, real-world combustion at elevated temperatures can lead to the formation of undesirable by-products, including nitrogen oxides (NO_x) and nitrous oxide (N_2O). In particular, N_2O has a global warming potential over a 100-year horizon (GWP_{100}) approximately 273 times higher than that of CO_2, rendering its formation counterproductive to the IMO

greenhouse-gas reduction objectives. Effective mitigation of these emissions is therefore essential and is typically achieved through the application of Selective Catalytic Reduction (SCR) after-treatment systems.

Similar to LNG-fuelled engines, ammonia engines may also exhibit fuel slip, commonly referred to as ammonia slip, particularly in four-stroke engine configurations. Although ammonia itself is not classified as a greenhouse gas, local or regional environmental regulations may impose limits on ammonia emissions due to potential impacts on air quality and ecosystems. When appropriately designed and operated, SCR systems can reduce ammonia slip to trace concentrations in the low-parts-per-million (ppm) range.

Ammonia released through slip, together with NO_x compounds formed during combustion, may further react in the atmosphere to form secondary pollutants, including fine particulate matter such as ammonium nitrate (NH_4NO_3), contributing to $PM_{2.5}$ concentrations. Under certain atmospheric conditions, these reactions may also lead to the formation of additional N_2O.

Lifecycle Analysis for Methanol and Ammonia 3.4

Currently, less than 1% of global methanol production can be classified as blue or green, with the remaining share of ~99% produced as grey methanol (primarily from natural gas) or brown methanol (from coal). While comprehensive and standardised life-cycle assessments (LCAs) are not yet available for all methanol production pathways, it is evident that methanol derived from fossil feedstocks is unlikely to deliver greenhouse-gas (GHG) emission reductions when compared with LNG or MGO. Consequently, methanol produced via these pathways cannot be considered suitable for achieving GHG-reduction targets.

A similar situation applies to ammonia. To date, less than 1% of global ammonia production is classified as blue or green, with the vast majority, approximately 99%, still produced as grey ammonia from fossil feedstocks. Although comprehensive, standardised LCAs for ammonia are not yet fully established and reported emissions for grey ammonia vary depending on the specific production pathway, it is already apparent that the use of grey ammonia as a marine fuel would result in higher overall GHG emissions than conventional maritime fossil fuels. As such, grey ammonia is not considered suitable for its intended purpose of contributing to greenhouse-gas reduction in line with IMO targets.

Life-cycle assessments for methanol and ammonia as a marine fuel are likewise still under development, and robust, engine-specific emissions data remain limited. This is particularly the case for two-stroke marine engines, for which empirical data on the GHG-reduction performance of blue or green methanol and ammonia are not yet publicly available. The comparative overview provided by Bureau Veritas in its 2022 publication Outlook for Alternative Fuels therefore serves as a useful high-level reference but should be interpreted as indicative rather than definitive until more detailed and standardised LCA data become available as provided in figure 3-1.

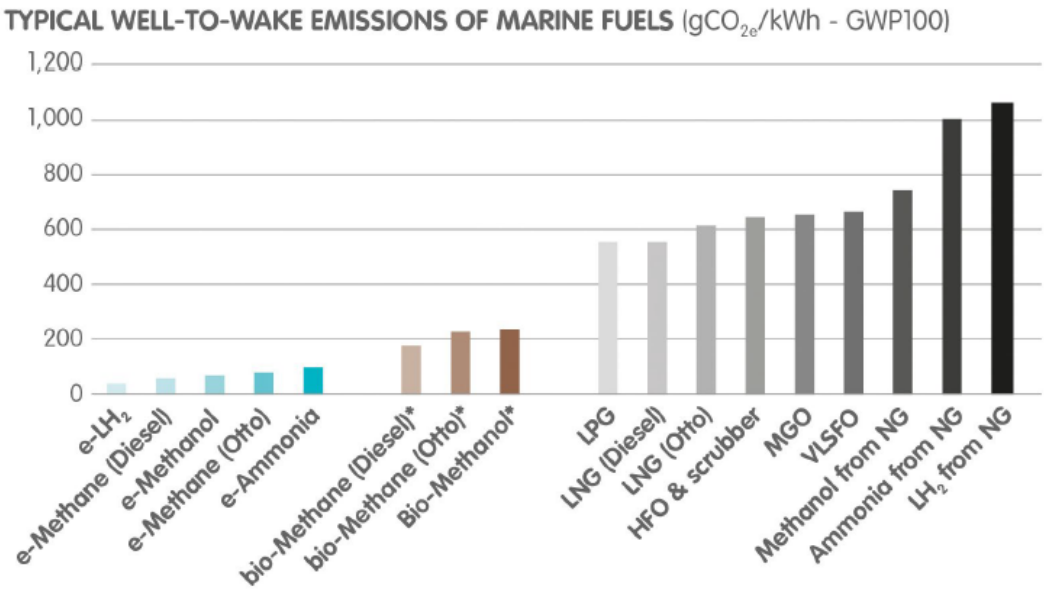

Figure 3-1: Typical fuel emission factors
Source: Bureau Veritas, Outlook for Alternative Fuels, 2022

Implementation Guidance 4.

SCOPE AND INTENT:

Chapter 4 brings together the practical elements that ports need to plan, authorise, control and oversee methanol and ammonia bunkering within their jurisdiction. Rather than describing a single linear process, the chapter is structured around the key decision areas and control functions that ports should address as bunkering moves from concept to routine operation.

How to read Chapter 4:

The chapter is organised in thematic blocks that broadly reflect how ports work in practice. The structure is designed to be practical and intuitive, allowing readers to focus on specific areas of responsibility.

The chapter complements and expands on the "Ports Roadmap to Bunkering" steps presented in Chapter 1. While Chapter 1 provides a high-level, step-by-step strategic pathway for ports to become bunkering-ready, Chapter 4 dives deeper into the operational, regulatory, safety and governance elements that underpin each of those steps.

In essence:

- Chapter 1 presents *what* needs to be done and in what sequence.
- Chapter 4 explains *how* those steps can be implemented in practice, across different port functions and stakeholder interfaces.

Chapter 4 thematic blocks:

1. **Governance and engagement** sections explain the role of the port authority across the four stages of bunkering development and how stakeholder responsibilities, communication and public engagement should be managed.
2. **Site selection and permitting** sections describe how ports identify suitable bunkering locations, integrate navigational and traffic considerations, and establish licensing and authorisation frameworks.
3. **Risk assessment and controlled areas** sections provide the analytical foundation used to define safety zones, assessment zones and SIMOPs controls, and to support consistent, defensible decision-making.
4. **Fuel-specific sections** address methanol and ammonia separately where their hazard profiles differ, particularly in relation to flammability, toxicity and dispersion behaviour.
5. **Operational control sections** describe the tools used to manage individual bunkering operations, including compatibility assessments, checklists, and emergency shutdown, and training and how ports maintain control during operations.
6. **Emergency preparedness,** sections explain how ports respond to incidents, and apply lessons learned.
7. **Special and non-routine cases,** sections address special and non-routine cases, supporting ports in managing infrequent or non-standard scenarios that fall outside business-as-usual operations but still require appropriate controls.

Readers do not need to read Chapter 4 sequentially from start to finish. Ports may focus first on the sections most relevant to their current Port Readiness Level, returning to other sections as their framework matures. Cross-references are provided throughout the chapter to support this modular approach.

Taken together, the sections in Chapter 4 are intended to support a structured yet flexible implementation pathway, allowing ports to progress from early planning and pilot operations to safe, repeatable, business-as-usual bunkering of methanol and ammonia.

Port governance, strategy and engagement 4.1

This section explains the role of the port authority across the four stages of bunkering development and how stakeholder responsibilities, communication and public engagement should be managed.

It includes guidance for:

- Role of ports across the four stages for vessel operators
- Link to the IAPH port readiness level framework
- Stakeholder engagement (internal and external)

Role of ports across the four stages for vessel operators 4.1.1

Ports play a critical role throughout all four stages (see section 2.4), often acting as, or supporting, the competent authority for the bunkering location.

Design Stage

Ports assess whether methanol or ammonia bunkering is feasible within the port environment. This includes:

- identifying suitable locations and interfaces with existing port activities,
- understanding high-level hazards and constraints, and
- engaging early with regulators, emergency services, and stakeholders.

Planning Stage

Ports focus on assurance and authorisation by:

- reviewing risk assessments, safety zones, and SIMOPs,
- assessing the Methanol/Ammonia Bunkering Management Plan, and
- establishing permit conditions and operational boundaries.

Preparation Stage

Ports verify readiness for a specific operation by:

- reviewing the Joint Bunkering Plan (JBP),
- confirming safety zones, traffic control, and communication arrangements, and
- ensuring emergency response and enforcement mechanisms are in place.

Operational Stage

Ports provide oversight and coordination by:

- enforcing approved conditions and access restrictions,
- coordinating with VTS, terminals, and emergency services, and
- responding to deviations, incidents, or abnormal situations.

Across all stages, ports ensure that bunkering is integrated safely into wider port operations.

Link to the IAPH port readiness level framework 4.1.2

The four-stage approach aligns closely with the IAPH Port Readiness Level for Marine Fuels (PRL-MF) framework.

- Design and early Planning Stages broadly correspond to PRL-MF 1–4, where ports develop foundational knowledge, assess feasibility, and establish governance and safety frameworks.
- Preparation and early Operational Stages align with PRL-MF 5–6, covering framework testing, training, and pilot-scale demonstrations.
- Repeated operations and business-as-usual bunkering align with PRL-MF 7–9, where processes are standardised, streamlined, and scaled.

This Guidebook is therefore particularly suited to supporting ports in the early to mid PRL-MF levels, while also providing a clear pathway toward mature, routine methanol and ammonia bunkering operations.

Stakeholder engagement (internal and external) 4.1.3

This section provides practical guidance for ports on identifying, engaging, and managing stakeholders involved in methanol and ammonia bunkering across the design, planning, preparation, and operational readiness stages. It focuses on port-level governance, coordination, and assurance and does not address operational roles during bunkering.

Stakeholder identification and maintenance 4.1.3.1

Ports should establish and maintain a formal stakeholder identification process covering all organisations that:

- have jurisdiction or regulatory authority over the bunkering location or activity;
- own, operate, or manage assets used for bunkering or located in proximity;
- provide emergency response, medical, or security services within the port area; or
- may be affected by bunkering activities within or adjacent to the port.

Stakeholder identification should be:

- completed at the outset of any new bunkering location or supply scenario;
- reviewed whenever there are changes to location, supply arrangement, facility design, or operating conditions; and
- documented in a stakeholder register that is updated as the project progresses.

Public and community engagement 4.1.3.2

Ports should address public engagement for methanol and ammonia bunkering through existing, well-established port communication and emergency-planning frameworks, recognising that ports form part of the wider local community.

Public engagement should:

- be proportionate to the assessed risk and potential off-site impact;
- be coordinated with local authorities and emergency services where required;
- use established channels already applied for other hazardous port activities; and
- avoid unnecessary alarm while providing clear, factual information.

Ports should consider public engagement where:

- emergency planning zones extend beyond port boundaries;
- bunkering occurs close to residential, commercial, or public-access areas; or
- national legislation requires consultation or notification.

Typical port actions may include:

- ensuring local emergency plans (including medical response and public health coordination) account for bunkering scenarios;
- aligning public information and warning arrangements with municipal emergency systems;
- designating a single port contact point for external communication; and
- supporting local authorities in responding to public enquiries, where appropriate.

Stakeholder engagement key considerations 4.1.3.3

Engagement aligned to development stage:

Ports should align stakeholder engagement with the stage of bunkering development, ensuring that the right organisations are involved at the right time.

1. Design and early planning
   - confirm applicable national and local legislation, standards, and acceptance criteria;
   - identify the competent authority or authorities for each stage;
   - agree expectations for risk assessment scope, modelling assumptions, and safety zone definitions; and
   - identify port-specific constraints, sensitivities, and interface risks.

2. Planning and preparation
   - review submitted risk assessments and safety concepts with relevant stakeholders;
   - confirm emergency response assumptions, including fire, medical, and evacuation considerations;
   - verify access routes for emergency vehicles, including ambulances; and
   - ensure communication and escalation arrangements are clear.

3. Transition to routine operations
   - formalise recurring engagement arrangements;
   - define triggers for re-engagement or re-assessment; and
   - ensure continuity where personnel or organisations change.

Clarification of roles and authority:

Ports should explicitly document:

- which organisation acts as the competent authority at each stage;
- how responsibilities are shared where multiple authorities apply; and
- how decisions, approvals, and enforcement actions are coordinated.

Where roles overlap, interfaces should be resolved before authorisation is granted.

Coordination with port users, neighbours, and emergency services:

Ports should implement proportionate engagement arrangements to:

- inform other port users of planned bunkering activities and any temporary restrictions;
- coordinate schedules and constraints where SIMOPs are present;
- consider neighbouring facilities where safety or assessment zones extend beyond the immediate bunkering area; and
- engage emergency services, including fire, police, and **medical services**, to confirm response roles, access routes, and casualty management arrangements.

Engagement should be scaled to the assessed risk and potential impact.

Documentation and traceability:

Ports should ensure that:

- stakeholder and public-authority inputs are recorded;
- agreed assumptions and constraints are traceable; and
- records are retained to support audits, regulatory review, and future re-assessments.

Review and continuous improvement:

Stakeholder and public engagement arrangements should be reviewed periodically and updated where:

- bunkering activities expand or change in nature;
- regulatory, security, or emergency-planning requirements evolve; or
- lessons learned indicate a need for earlier or clearer engagement.

Site selection, permitting and port planning tools 4.2

This section describes how ports identify suitable bunkering locations, integrate navigational and traffic considerations, and establish licensing and authorisation frameworks.

It includes guidance for:

- Site identification, design and risk assessment
- Port bunkering map
- Bunkering licensing process
- Nautical safety assessments
- Vessel traffic services and vessel traffic management

Site identification, design and risk assessment 4.2.1

The identification of suitable locations for methanol and ammonia bunkering within a port should follow a structured, risk-based approach led by the port authority, often acting as or supporting the competent authority. This process ensures that bunkering activities can be safely integrated into the port environment while remaining compatible with existing operations and local regulatory requirements.

Appendix B provides a practical, staged process that ports can apply to identify, approve, and operationalise bunkering locations for methanol and ammonia.

Site identification – What to consider 4.2.1.1

Site identification should be grounded in the port's existing safety framework, supplemented by the guidance provided in this Guidebook and any additional port-specific rules or by-laws.

Ports should define, at a strategic level:

- **which fuels** they intend to accommodate within the harbour or port area, informed by commercial considerations, fuel availability, and risk assessment;
- **which areas of the port** may be considered suitable for bunkering, taking into account existing port infrastructure, land availability, navigation constraints, and surrounding activities, and under what conditions bunkering may be permitted.
- **which areas are not currently suitable for bunkering but could be adapted or developed in the future**, for example through infrastructure upgrades, changes in land use, additional safety controls, or revised operational arrangements.

Identifying both current and potential future bunkering locations allows ports to plan proactively, manage expectations with stakeholders, and support phased implementation aligned with port development strategies and IAPH Port Readiness Levels.

This framework should establish clear principles, acceptance criteria, and assessment processes for identifying and approving bunkering locations. Once defined, it should be consistently applied across different fuels and bunkering scenarios, providing clarity to stakeholders and supporting efficient, defensible decision-making.

Port infrastructure and surrounding environment

The suitability of a bunkering site depends on its interaction with both port infrastructure and areas outside the port boundary. Key considerations include:

- proximity to buildings, roads, railways, terminals, and utilities;
- presence of public areas or sensitive receptors outside the port;
- availability of space to establish safety zones, marine exclusion zones, and access control;
- compatibility with existing berth layouts and quay structures.

Where neighbouring facilities or public areas may be affected, their presence should be considered within the risk assessment and reflected in site selection and mitigation measures.

Navigational considerations

Navigation and vessel traffic are critical elements of site selection. Ports should assess:

- access and manoeuvring requirements for receiving vessels and bunker vessels;
- proximity to fairways, turning basins, and pilot boarding areas;
- traffic density and the feasibility of establishing marine exclusion zones;
- interaction with Vessel Traffic Services (VTS) and pilotage requirements.

Locations where safe navigation cannot be assured during bunkering may require additional controls or may be deemed unsuitable.

Fuel-specific suitability

Not all locations within a port will be suitable for all fuels. Due to differences in hazard characteristics, a site acceptable for methanol bunkering may not be acceptable for ammonia, and vice versa. Ports should therefore assess site suitability on a fuel-specific basis, considering flammability, toxicity, dispersion behaviour, and emergency response implications.

This differentiation supports a pragmatic approach where ports may designate:

- areas suitable for multiple fuels;
- areas restricted to specific fuels; or
- areas excluded from bunkering activities altogether.

Port bunkering map 4.2.2

A port bunkering map is a planning and communication tool that visually identifies where and under what conditions bunkering of alternative fuels may be conducted within the port area. It provides a spatial representation of the port's strategic approach to bunkering, translating policy, risk assessment outcomes, and operational constraints into a clear, accessible format for both internal use and engagement with external stakeholders.

Ports are encouraged to develop and maintain a bunkering map identifying:

- approved or potential bunkering locations (berths, quays, anchorages);
- applicable bunkering supply scenarios;
- fuels permitted at each location;
- key constraints (e.g. maximum vessel size, operational limits).

Such a map supports transparency, consistent decision-making, and early engagement with stakeholders.

Licensing, permits and authorisation

Site identification and design should be closely linked to local licensing, permitting, and authorisation processes. Risk assessments conducted at the site level form the technical basis for these approvals and should demonstrate compliance with national legislation, port by-laws, and applicable international guidance.

Ports should ensure that permitting requirements are clearly defined and proportionate, with conditions reflecting the specific risks associated with the site, fuel, and bunkering scenario (See section 4.2.3).

Bunkering licensing process 4.2.3

Purpose of licensing 4.2.3.1

The licensing process should define the framework under which bunker suppliers and/or receiving vessels are permitted to conduct bunkering operations at designated locations within the port. This process may be referred to in other publications or by individual ports as permitting, authorisation, or equivalent terms.

For the purpose of this Guidebook, the term 'licensing' is used to cover permitting, authorisation, or equivalent regulatory approvals, unless explicitly stated otherwise.

The guidance provided below only marginally addresses stakeholders external to the port, such as permitting authorities or emergency response organisations as the requirements may significantly differ between various national jurisdictions. The port should establish a licensing process for bunker suppliers that is proportionate, transparent, and practicable, and which can be effectively managed with the resources and workforce available within the port organisation.

Clarification Note – Licensing versus Operation-Specific Approvals:

The underlying requirements remain essentially the same whether a port applies a one-off operational approval or a broader supplier licence. In both cases, the port must establish that the parties involved demonstrate the necessary expertise, technical capability and safety understanding.

Ports may decide to issue single-operation approvals based on specific circumstances, such as pilot projects, early-stage implementation or particular local constraints. For more routine or commercial operations, a general or standing bunker supplier licence - linked to defined locations, fuels and operational envelopes - is typically more efficient and scalable.

As a general principle, ports should regulate through standing licences where feasible, reserving operation-specific approvals for exceptional, non-routine or case-by-case situations.

Key Takeaways for Ports – Bunkering Licensing:

1. Licensing is a port-led control tool.
   Licensing (also referred to as permitting or authorisation) is the mechanism through which ports define where, how, and under what conditions methanol and ammonia bunkering may take place within the port area.

2. Start with national permits and legislation.
   Before establishing any bunkering licence, ports should confirm that bunkering activities are covered by existing national permits or identify where permit amendments are required. An early, structured gap analysis with regulators is essential.

3. HAZID underpins the licensing framework.
   Fuel-specific HAZID workshops are a critical foundation for licensing, informing safety zones, SIMOPs constraints, operational limits, emergency preparedness, and the definition of approved bunkering locations (e.g. port bunkering maps).

4. Use existing industry frameworks to avoid duplication.
   Ports are encouraged to rely on recognised schemes such as the IAPH bunker audit framework and industry guidelines, rather than creating parallel verification processes. This reduces administrative burden while maintaining assurance.

5. Be transparent and predictable.
   Licensing requirements, application steps, responsibilities, and approval conditions should be clearly documented and publicly available, ideally supported by digital application and tracking tools.

6. Ports remain the single coordination point.
   Even where national authorities impose additional conditions, the port authority should act as the primary interface for bunker suppliers, ensuring consistent coordination, compliance monitoring, and enforcement.

7. Licensing should evolve with maturity.
   As bunkering moves from pilot projects to business-as-usual, licensing frameworks should be streamlined, proportionate, and periodically reviewed to reflect operational experience and lessons learned.

Step 1: Review ports permit requirements 4.2.3.2

Ports operate under national permits that define the activities authorised, the conditions under which such activities may be carried out, and the associated monitoring and compliance requirements. Port operators should therefore engage with their competent regulatory authorities to determine whether bunkering operations or specific support services are covered by existing permits and to identify any additional requirements that should be fulfilled.

To support this process, the port and/or terminal should conduct an initial gap analysis to identify applicable requirements arising from national legislation, regulatory frameworks, and permitting conditions. These requirements are derived from binding national laws and permit obligations under which the port operates and are distinct from industry guidelines or voluntary best practices.

This initial gap analysis constitutes the first and most critical step in engaging with regulators and other external stakeholders. During an initial coordination meeting with the competent authority, the relevant regulators and stakeholders should be identified, and their respective roles and responsibilities clarified.

Subsequently, a detailed follow-up gap analysis, conducted jointly with all relevant national and local stakeholders, should be undertaken. This process should establish a common understanding of the applicable requirements and provide clarity on the technical, operational, and procedural measures that should be fulfilled prior to permitting and commencement of operations.

Only once the port permit has been amended, where required, and all applicable national requirements have been identified, may the licensing process for bunker suppliers be established.

Port HAZID workshop 4.2.3.3

To establish an effective licensing framework, the port should develop fuel-specific procedures based on the outcomes of HAZID workshops involving the stakeholders identified in section 2.2. These procedures should account for, at a minimum:

- Local legislation and permitting requirements
- Availability and capability of emergency-response facilities
- Designated bunker suppliers
- Designated bunker receivers
- Fuel-specific operational constraints
- Existing auditing results

It is strongly recommended that these HAZID workshops be facilitated by independent industry specialists, rather than being self-facilitated by the port authority. The HAZID outcomes should identify outstanding tasks, constraints, and limiting factors within the port area, including but not limited to:

- Licensing requirements for BSVs
- Manoeuvring and tug-assistance requirements for BSVs
- Transfer, draining, and purging requirements
- Maximum permitted transfer flow rates
- Venting requirements
- Safety and toxicity-based hazard zones
- Exclusion zones
- Reporting obligations
- Operational and pre-transfer checklist requirements
- Port heat map defining approved bunker locations
- SIMOPs requirements depending on the receiving-vessel type

As an example of established good practice, the Port of Rotterdam developed a port heat map at an early stage of LNG bunkering implementation. This heat map identifies locations where bunkering is permitted under a general licence, where additional restrictions apply, and where a case-by-case approval is required.

Such heat maps can only be developed through comprehensive HAZID workshops, defining which fuels may be supplied, at which locations, and via which transfer modes. This approach has since been adopted as good practice by several ports and allows bunker suppliers to readily assess where bunkering operations can be conducted.

Step 2: Establishing a bunker supplier licencing process 4.2.3.4

Ports may adopt different licensing concepts for bunkering operations, ranging from relatively simple to highly sophisticated. Depending on the port, these concepts may focus primarily on the bunker supplier, the receiving vessel, or a combination of both. Regardless of the chosen approach, a formal licensing process is essential to ensure compliance with national legislation and adherence to local port requirements and take the results of the conducted HAZID workshop into account.

Port and terminal operators should actively participate in the qualification and approval process of bunker suppliers. All licensing requirements should be clearly documented on the port's official website, including the designation of a responsible department within the port authority to manage such applications. The use of a digital platform for information exchange, application handling, and licensing is strongly recommended.

It should be noted that, in most cases, the bunker supplier and the technical manager of the bunker supply vessel are not the same legal entity. The license should therefore be applied for by the bunker supplier, with the technical manager acting on the supplier's behalf. Consequently, the license should be issued to the bunker supplier, with the technical manager being co-permitted. Any change of bunker supplier or technical manager should trigger a reapplication and reassessment of the licensing process. When utilizing road trucks, the bunker supplier might be the only applicant.

The International Association of Ports and Harbors (IAPH) has developed a model framework providing guidance on the qualification of bunker suppliers for licensing purposes. The IAPH audit tool outlines an eight-step process for obtaining such a license and serves as a recognized reference for ports implementing clean marine fuel bunkering operations.

In all cases, the national requirements set out in the port's national permit should be fully reflected in the bunker supplier licences, including any conditions, restrictions, or limitations.

IAPH bunker auditing process 4.2.3.5

The IAPH requires that an audit be conducted at the premises of the technical manager of the of the BSV including the bunker supplier. When providing licences for road trucks, the audit should be conducted at the bunker suppliers operational office.

Such audits should be carried out by suitably trained and qualified auditors. The applicable audit requirements should be clearly defined in documentation published on the port's official website and should incorporate relevant national legislation as well as specific port and/or terminal permitting requirements.

In this context, it is advisable for ports to rely on audits already performed under recognized IAPH frameworks, rather than implementing a parallel or standalone verification process. Leveraging existing IAPH member audits can reduce duplication of effort while maintaining a robust level of assurance.

In addition, it should be noted that the maritime industry applies its own established vetting and performance management systems for tankers, such as the Ship Inspection Report Programme (SIRE) and the Tanker Management and Self-Assessment (TMSA) schemes administered by Oil Companies International Marine Forum (OCIMF). These systems are widely enforced across the industry and provide detailed insight into the operational performance, safety management, and compliance standards of technical managers.

It is therefore recommended to consider SIRE and TMSA outputs as part of the bunker supplier verification and licensing process. As the majority of technical managers are already required to comply

with these frameworks, they offer a valuable and efficient means of assessment. Access to SIRE inspection reports can be formally requested through OCIMF.

Practical bunker licence considerations 4.2.3.6

As stated above, the port and terminal operator may impose requirements that should be fulfilled in addition to national regulatory obligations enforced by the relevant authorities. The port authority should remain the single point of contact for the bunker supplier for all matters related to permitting, coordination, and compliance.

It should be noted that certain publications and permitting approaches involve the receiving vessel directly in the permitting and verification process. This effectively creates an operation-based licensing scheme under which each individual bunkering operation requires separate approval following submission of the necessary documentation.

While such an approach may be appropriate under specific circumstances, it imposes a substantial administrative burden due to the need to review documentation for every single operation. Consequently, this model is generally only advisable in limited or exceptional cases where bunker location and setup is worth reviewing it on case to case basis instead of regulating it under a general bunker licence. Or where a licencing process is just being established.

The bunker licensing process should be visualised as a flowchart and made publicly available, either via the port's website or as a formal manual accessible to bunker suppliers and receiving vessels. The documentation should provide a clear overview of where, under what conditions, and for which fuels bunkering operations may be conducted within the port area.

Step 3: Licence application 4.2.3.7

Within the scope of the initial HAZID workshop, the documentation requirements for bunker suppliers should be assessed. As a minimum, the following documentation should be provided:

- General arrangement drawings
- Manoeuvring characteristics
- Hazardous area (Ex) zoning plans
- Drawings and descriptions of transfer systems (P&IDs, transfer hoses or equivalent systems, emergency release couplings, QCDCs or otherwise)
- Lifting appliances or derricks used for bunker transfer operations
- Transfer procedures, including draining, purging, and testing
- Applicable bunker checklists
- SIMOPs procedures and requirements
- IAPH audit results
- Location-specific risk assessments for bunker supply operations

The documentation should preferably be presented in person to the port authority, together with the bunker concept and the associated risk-management framework. Following the port's review and acceptance of the submitted documentation, a bunkering permit may be issued. Such a permit may include, but is not limited to, the following conditions:

- Permitted bunkering locations or reference to an approved bunker heat map
- Maximum permitted transfer flow rates
- Venting requirements
- Safety- and toxicity-based hazard zones

- Approved connection arrangements and purging requirements
- Exclusion zones
- Tug-assistance requirements for mooring and unmooring
- Reporting requirements to the relevant authorities
- Mandatory operational and pre-transfer checklists
- SIMOPs requirements depending on the receiving-vessel type

Licensing of receiving vessels is generally less favoured. Additional permits may only be issued for specific fuel-system-related operations, such as cool-down, gassing-up, or inerting activities, and should in all cases be subject to a dedicated, operation-specific risk assessment.

Cargo transfer 4.2.3.8

Furthermore, it should be noted that STS operations between a BSV and another IGC- or IBC-certified vessel, depending on the fuel involved, are generally not classified as bunkering under international legislation. Consequently, such operations may also fall outside the scope of existing port or terminal permits. This distinction should be carefully considered where STS operations are intended to be included within the permitted operational envelope additionally to bunkering.

Nautical safety assessments 4.2.4

General requirements 4.2.4.1

In preparation for the introduction of alternative fuels, nautical safety assessments may be required where risks are identified during the initial HAZID workshop. Such assessments should focus on navigational safety, traffic interaction, and operational constraints within the port area and should be proportionate to the fuel type, transfer method, and operational complexity.

At a minimum, the following aspects should be considered:

- Manoeuvring characteristics of BSVs
- Maximum vessel sizes routinely operating within the port
- Tug assistance requirements and potential exemptions based on propulsion and thruster capability
- Traffic density in different port areas and fairways
- Vessel-passing effects for STS configurations
- Collision and allision risk analysis

BSV manoeuvring characteristics 4.2.4.2

The manoeuvring characteristics of the BSV should be carefully reviewed as part of the nautical safety assessment. Although BSVs are typically not among the largest vessels operating within a port, exemptions from compulsory pilotage and/or tug assistance may be requested by bunker suppliers, particularly where vessels are equipped with enhanced propulsion and manoeuvring capabilities (e.g. azimuth thrusters, Becker rudders, DP capability, etc).

Where such exemptions are proposed, the bunker supplier should demonstrate, through documented evidence, that the vessel can be safely manoeuvred under all relevant environmental and traffic conditions. This demonstration may include:

- Manoeuvring data and stopping distances
- Thruster and propulsion redundancy

- Track records from comparable ports
- Bridge procedures and crew competence

If required by the port authority, these submissions should be supported by nautical simulations, particularly where exemptions from pilotage or reductions in tug usage deviate from existing port regulations.

STS and passing vessels 4.2.4.3

Where STS bunkering operations are introduced in ports where such operations are not routinely conducted, the effects of passing vessels should be specifically evaluated. This includes assessment of:

- Hydrodynamic interaction forces
- Surge, sway, and yaw motions of moored vessels
- Displacement of water in narrow channels

Initial screening may be undertaken using static calculations. However, where traffic density is high or manoeuvring margins are limited, dynamic analysis, including CFD simulations, may be required to adequately capture interaction effects.

As an outcome of the HAZID process, minimum passing distances and maximum passing speeds should need to be assessed and implemented through VTS procedures, port notices, or operational permits.

Traffic density 4.2.4.4

To support the identification of safe bunkering locations, it is considered good practice to develop traffic density plots using historical AIS data. These plots provide insight into traffic patterns, peak periods, crossing points, and high-utilisation fairways.

Based on these data sets, a collision and allision risk analysis may be performed to estimate incident frequency and risk levels. Such analyses typically consider:

- Vessel type and size distribution
- Traffic volume and routing
- Historical incident and near-miss data
- Operational constraints during bunkering

The results can be used to justify bunker location selection, define exclusion zones, support heat-map development, and determine whether additional control measures such as speed restrictions, traffic windows, or tug assistance are required.

Port role and expectations 4.2.4.5

All findings from the nautical safety assessment should be integrated into the port's overall risk management framework, including VTS procedures, SIMOPs requirements, emergency response planning, and bunker permitting conditions. Where exemptions or deviations from standard port rules are granted, these should be clearly documented, risk-based, and subject to periodic review.

Vessel traffic services and vessel traffic management 4.2.5

Vessel traffic management 4.2.5.1

Each port should operate a port-specific traffic management regime under the authority of the port operator and in close coordination with terminal operators. This regime should account for berth and jetty occupancy, vessel arrival and departure sequencing, cargo as well as bunker operations and any other operational constraints arising from activities at the jetty. Traffic management should also encompass land-side movements, including the controlled entry, routing, staging, and exit of road or train vehicles within the port area.

Vessel traffic services 4.2.5.2

Vessel Traffic Services (VTS), typically operated from a dedicated VTS centre, should be responsible for ensuring the safe and efficient navigation of vessels from the designated anchorages, pilot boarding ground to the assigned berth, jetty, or operational areas. This includes the assignment of anchorage positions for bunkering if this is considered as safe location during the licencing process.

The movements of BSVs operating without pilotage should be subject to enhanced monitoring and the VTS should observe the defined operational limits, including speed restrictions, routing constraints, and time-window limitations where appropriate.

Double-Banking configurations 4.2.5.3

For ship-to-ship (STS) bunkering operations, both vessel traffic management and VTS should explicitly address double-banking configurations. This includes assessment and control of:

- Reduced available manoeuvring space;
- Passing-vessel speeds and displaced water effects;
- Hydrodynamic interaction between vessels;
- Establishment and enforcement of marine exclusion and safety zones;
- Emergency response access and escape routes.

Onshore traffic management for road vehicles 4.2.5.4

Traffic management arrangements should further consider the movement and staging of road vehicles transporting dangerous goods, regulated under national legislation and the ADR framework. This should include:

- Designation of suitable waiting, holding, and marshalling areas for bunker trucks;
- Separation of toxic-goods traffic from general port traffic where practicable;
- Control of shore-side traffic in proximity to bunkering safety and exclusion zones;
- Coordination of truck movements with marine operations, particularly during STS bunkering and SIMOPs.

Port role and expectations 4.2.5.5

All traffic management measures, marine and shore-side, should be fully integrated into the port's SIMOPs framework, emergency response planning, and communication procedures. Clear lines of responsibility between the port authority, VTS, terminal operator, bunker supplier, and emergency services should be defined to ensure that simultaneous operations are conducted without compromising navigational safety, operational integrity, or environmental protection. In any case the vessel traffic service and the VTS should have the overview of the whole picture traffic situation in the port and are

essential to in the coordination of safe movements and interfaces in the port and play an essential role during emergencies.

All marine and shore-side traffic management conducted by vessel traffic services and VTS should be fully integrated into the port's traffic and SIMOPs framework, emergency response plans, and communication procedures. Clear lines of responsibility between the port authority, VTS, traffic management, terminal operator, bunker supplier, and emergency services should be established to ensure that safe bunker operations are conducted without compromising navigational safety, operational integrity, or environmental protection.

Traffic management and the VTS should maintain a comprehensive overview of the overall traffic situation within the port and its approaches and should play a central role in the coordination of vessel movements, operational interfaces, and traffic restrictions. During emergency situations, these functions should act as the primary coordination and information hub, supporting the effective implementation of response measures and ensuring the safe and orderly management of marine traffic throughout the port area.

Risk assessment framework and controlled areas 4.3

This section provides the analytical foundation used to define safety zones, assessment zones and SIMOPs controls, and to support consistent, defensible decision-making.

It includes guidance for:

- Risk assessment, controlled areas HAZOP and SIMOPs
- Vent mast releases and gas dispersion considerations
- Assessment Zone: Purpose, Implications and Relevance for Port

Risk assessment, controlled areas HAZOP and SIMOPs 4.3.1

The safe implementation of methanol and ammonia bunkering within a port requires a structured, risk-based approach that supports decision-making on site suitability, operational limits, controlled areas, and simultaneous operations (SIMOPs). From a port perspective, risk assessment is a planning and assurance tool, rather than a design exercise, and forms the technical basis for permitting, conditions of use, and enforcement.

Ports should ensure that risk assessments are proportionate, fuel-specific, site-specific, and aligned with the port's safety framework, while remaining consistent with recognised international standards and guidance.

Appendix D provides practical guidance to support ports, operators, and other stakeholders in preparing, reviewing, and applying HAZID, HAZOP, and SIMOPs assessments for methanol and ammonia bunkering operations.

Role of risk assessment in the port implementation process 4.3.1.1

Risk assessment supports ports in:

- determining where bunkering may be permitted and under what conditions;
- defining hazardous areas, safety zones, toxic areas (where applicable), and marine exclusion zones;
- assessing compatibility with port infrastructure, navigation, and neighbouring activities;
- managing SIMOPs and operational interfaces;
- establishing clear operational envelopes and permit conditions.

Risk assessments are normally prepared by operators and designers; however, ports-often acting as the competent authority-are responsible for reviewing, accepting, and applying their outcomes.

Types of risk assessment 4.3.1.2

Ports may encounter different forms of risk assessment at various stages of implementation. These should be viewed as complementary, rather than mutually exclusive.

Ports should also be aware that national or regional regulators may mandate the use of specific risk assessment methodologies. The selection and application of risk assessment types should therefore be informed not only by the characteristics of the bunkering operation, but also by applicable statutory and regulatory requirements.

Further information can be found Appendix section D.1

Qualitative Risk Assessment (QualRA) 4.3.1.3

Qualitative risk assessments are typically used in early stages of implementation to:

- identify hazards and credible scenarios;
- support site screening and feasibility decisions;
- inform stakeholder discussions.

QualRA is particularly useful when limited operational data are available, as is often the case for early methanol and ammonia projects.

Quantitative Consequence Assessment (QCA) 4.3.1.4

Quantitative consequence assessments focus on the physical effects of credible releases, such as:

- vapour dispersion (flammable or toxic);
- thermal radiation;
- impact distances.

QCA is commonly used to define:

- hazardous areas;
- safety zones;
- toxic areas (particularly relevant for ammonia);
- marine exclusion zones.

For ammonia, gas dispersion analysis is a critical component of QCA due to toxicity considerations. For methanol, dispersion and fire consequences are typically evaluated with flammability as the dominant hazard.

Quantitative Risk Assessment (QRA) 4.3.1.5

Where required by national regulations or port policy, a full QRA may be undertaken. This combines:

- likelihood of events; and
- severity of consequences,

to evaluate individual and, where applicable, societal risk. QRAs are more resource-intensive and are usually applied for:

- permanent infrastructure;
- complex port environments; or
- locations close to public receptors.

Ports should clearly state when QRA is expected and when qualitative or consequence-based approaches are sufficient.

Use of ISO/TS 18683 as a reference framework 4.3.1.6

Although developed for LNG, ISO/TS 18683:2021 – Guidelines for Safety and Risk Assessment of LNG Fuel Bunkering Operations provides a robust, structured methodology that can be adapted for methanol and ammonia bunkering.

From a port perspective, ISO/TS 18683 is useful because it:

- promotes a risk-based approach to system design and operation;
- explicitly considers SIMOPs and interfaces between parties;
- links risk assessment outcomes to controlled areas and operational restrictions.

While LNG differs significantly in properties, the methodological structure of ISO/TS 18683 can be applied to methanol and ammonia, provided that fuel-specific hazards-particularly toxicity for ammonia-are fully addressed.

Gas dispersion analysis and controlled areas 4.3.1.7

Gas dispersion modelling, as part of a consequence analysis, has been applied for several decades, particularly in air-quality assessment and major accident hazard studies. In recent years, the use of Computational Fluid Dynamics (CFD) has become increasingly feasible for complex geometries and site-specific conditions, including port environments.

A range of modelling tools is currently used within industry, including:

- PHAST (Process Hazard Analysis Tool) – developed by DNV;
- ALOHA (Areal Locations of Hazardous Atmospheres) – developed by the U.S. National Oceanic and Atmospheric Administration (NOAA);
- FLACS-CFD – developed by GexCon AS;
  among others.

From a port perspective, it is important that key elements are agreed and understood before dispersion modelling is undertaken, as modelling assumptions can significantly influence the resulting safety and toxic area definitions.

Gas dispersion quality and standards 4.3.1.8

At present, there is no fully consolidated or universally agreed industry approach for ammonia CFD modelling. The International Association of Classification Societies (IACS) is actively working toward developing harmonised guidance for gas dispersion analysis, and interim approaches may be found in classification guidance documents.

Until formal IACS guidance is published, different modelling providers may apply different assumptions and methodologies, potentially leading to different results for similar scenarios.

In this context, Lloyd's Register Guidance Note *LR-GN-057 – Guidance Notes on Gas Dispersion and Explosion Analysis for Alternative Fuelled Ships* provides a useful reference.

Link to risk assessments 4.3.1.9

Gas dispersion analysis should be undertaken as part of a broader risk assessment, with clear alignment to:

- defined credible release scenarios;
- transfer system configuration and operating conditions;
- emergency shutdown performance and response times.

Dispersion analysis should not be performed in isolation, but rather used to support decisions on controlled areas, SIMOPs limitations, and emergency planning.

Fuel considerations 4.3.1.10

For methanol:

- dispersion analysis typically supports flammability-driven safety zones and hazardous areas.

For ammonia:

- dispersion analysis can be used to determine toxic areas, commonly based on agreed concentration thresholds and exposure durations;
- both most-probable and maximum credible release scenarios should be considered.

HAZOP study 4.3.1.11

A Hazard and Operability Study (HAZOP) is a structured, systematic examination of a planned process or operation to identify potential deviations from the design intent, determine their causes and consequences, and verify that the system will perform safely under both normal and abnormal conditions.

The purpose of a HAZOP is to identify design weaknesses, operational vulnerabilities, and failure scenarios at an early stage, and to define additional safeguards or corrective actions where required. It supports the prevention of loss of containment, equipment damage, fire or toxic release, misoperation, and escalation scenarios.

HAZOP is typically performed at P&ID level and divides the system into logical "nodes" (e.g. storage tank, transfer line, vapour return system, emergency shutdown system). Each node is systematically reviewed using guidewords (e.g. *no flow, low flow, high flow, reverse flow, more pressure, less temperature*) combined with process parameters to explore all credible deviations from normal operating conditions.

For methanol and ammonia bunkering, a HAZOP study may focus on the bunker transfer system and associated interfaces, including but not limited:

- Storage and containment systems;
- Fuel transfer lines, hoses or loading arms;
- Vapour return systems;
- Emergency shutdown (ESD) integration between bunker supplier and receiving vessel;
- Drainage, purging, and inerting arrangements;
- Utility and support systems required for safe transfer.

A HAZOP does not re-perform the overall risk assessment but examines in detail how the engineered system behaves when deviations occur. It assesses whether existing safeguards are adequate and identifies where additional design measures, alarms, interlocks, procedures, or training are required.

From a port perspective, the HAZOP is normally conducted by the bunker supplier, vessel operator, terminal, or system designer. The port authority does not typically perform the HAZOP but should verify that:

- A HAZOP has been carried out by competent and independent facilitators;
- All relevant interfaces within port jurisdiction are included;
- Identified actions affecting port-controlled areas are clearly assigned and implemented;
- Findings are reflected in operating procedures, safety zones, and emergency planning.

HAZOP outputs should be documented and maintained as part of the Bunkering Management Plan and licensing documentation, and should be reviewed when significant changes occur, including modifications to transfer systems, changes in fuel type, new bunkering locations, or revised operational envelopes.

Further information can be found Appendix section D.2.

SIMOPs assessment 4.3.1.12

A SIMOPs study is required wherever bunkering takes place alongside other port activities. From a port perspective, SIMOPs assessment is critical to ensuring that bunkering does not introduce unacceptable combined risks.

Activities typically considered include:

- cargo handling;
- passenger movements;
- handling of dangerous goods;
- bunkering of other fuels;
- maintenance, construction, or testing activities;
- routine port and terminal operations;
- abnormal or unexpected events.

SIMOPs limitations should be derived from the risk assessment and dispersion analysis, and may include:

- prohibition of specific activities;
- sequencing or time separation;
- enhanced supervision or controls.

Ports should ensure that SIMOPs decisions are clearly documented, communicated, and enforceable during operations.

Further information can be found Appendix section D.3

Port role and expectations 4.3.1.13

Ports should ensure that:

- modelling assumptions reflect local weather conditions and site layout;
- results are used consistently to define safety zones, toxic areas, and SIMOPs limitations;
- controlled areas are operationally enforceable.

From an implementation perspective, ports are responsible for:

- defining expectations for risk assessment scope and quality;
- reviewing and approving outcomes relevant to port safety;
- translating technical results into permit conditions, controlled areas, and operational limits;
- coordinating SIMOPs controls across different port users;
- ensuring that risk assessments remain valid when conditions change.

Vent mast releases and gas dispersion considerations 4.3.2

In addition to releases associated directly with bunkering transfer operations, ports should consider gas dispersion arising from vent mast releases. Such releases may occur during bunkering activities or during normal or abnormal operation of the fuel system, and in some cases may result in dispersion distances greater than those associated with transfer-system failures. Vent mast releases therefore require explicit consideration within gas dispersion and explosion analyses, particularly in the port environment.

Typical vent release scenarios 4.3.2.1

A non-exhaustive list of scenarios that are commonly assessed within gas dispersion and explosion analyses includes:

- Venting of fuel storage tanks under worst-case relief conditions, such as thermal expansion or fire exposure scenarios.
- Venting due to credible failures, including pressure relief valve (PRV) passing, malfunction, or leakage.
- Ventilation-related releases, where flammable or toxic gas is discharged to atmosphere via enclosed-space ventilation or extraction systems (e.g. fuel preparation rooms, tank connection spaces).

These scenarios apply to both methanol and ammonia fuel systems, with the dominant hazard being flammability for methanol and toxicity for ammonia, although both aspects may be relevant depending on the configuration.

Key technical parameters influencing vent dispersion 4.3.2.2

For vent-related releases, the following parameters should be considered when defining release conditions at the vent tip:

- relief valve sizing and set pressure;
- expected flow rates under relief or passing conditions;
- upstream and downstream piping configuration, including pressure losses due to pipes and fittings;
- vent mast height and orientation;
- vent tip geometry and fittings, such as flame arrestors, rain ingress preventers, bird or debris protection grids, and deflectors.

These elements can significantly influence jet momentum, plume rise, dispersion direction, and dilution, and therefore the extent of hazardous, toxic, or safety zones.

Port operational considerations 4.3.2.3

From a port perspective, vent mast releases are particularly relevant because:

- vent outlets are often located at significant height, potentially affecting dispersion over a wider area;
- releases may occur independently of bunkering, meaning they can coincide with routine port operations;
- port activities such as overhead cranes, cargo-handling equipment, lighting towers, and elevated walkways may be located within the dispersion envelope of a vent release.

Ports should therefore ensure that vent mast dispersion scenarios are:

- included in site-level risk assessments and dispersion studies;
- considered when defining controlled areas, SIMOPs limitations, and access restrictions;
- reviewed in relation to activities involving personnel at height or moving equipment.

In some cases, dispersion distances from vent releases may exceed those from bunkering transfer failures and may therefore become the bounding scenario for defining safety or toxic areas.

Potential mitigation measures 4.3.3.4

Where vent dispersion presents a constraint, mitigation measures may be considered, subject to risk assessment and approval by the competent authority. These may include:

- Operational controls, such as restricting certain port activities (e.g. crane operations) during defined conditions;
- Enhanced monitoring and alarms to provide early awareness of abnormal venting;
- Procedural controls linking venting conditions to SIMOPs management.

Any mitigation intended to reduce controlled-area extents should be supported by updated dispersion analysis demonstrating an equivalent or improved level of safety.

Port role and expectations 4.3.3.5

Ports, often acting as the competent authority, should:

- ensure vent mast release scenarios are explicitly addressed in risk and dispersion analyses;
- understand how vent dispersion interacts with port infrastructure and operations;
- integrate vent-related hazards into SIMOPs planning and enforcement; and
- maintain awareness that vent releases, although less frequent, may represent a credible and potentially dominant hazard.

Assessment Zone: Purpose, Implications and Relevance for Port 4.3.3

Ports play a central role in ensuring that bunkering operations are conducted safely, not only for those directly involved in the operation but also for other port users and, where relevant, the surrounding community. In addition to the Hazardous and Safety Zones that address more frequent and localised events, ports should also consider the Assessment Zone.

The Assessment Zone is a planning and risk management concept. It is not intended to restrict routine port activities, nor does it imply that major accidents are likely. Instead, it provides a structured way for ports to consider very unlikely events with potentially wide consequences, and to confirm that appropriate preventive and emergency arrangements are in place.

Definition of the Assessment Zone 4.3.3.1

The Assessment Zone can be defined as:

The three-dimensional space within which very low-frequency, high-consequence events could, in extreme cases, have effects beyond the immediate bunkering area.

Key characteristics of the Assessment Zone are:

- it extends beyond the Safety Zone and may reach areas not under the direct control of the bunkering parties;
- it is associated with rare events, but with the potential to affect larger numbers of people, infrastructure or port operations;
- it is scenario-based, derived from credible worst-case assumptions rather than routine operational events;
- it supports planning and preparedness, rather than day-to-day operational control.

The Assessment Zone should always be understood as a three-dimensional space, taking into account height, terrain, structures, and confinement effects, not simply a horizontal distance.

Why ports need to consider the assessment zone 4.3.3.2

Considering the Assessment Zone helps ports to:

- demonstrate that bunkering activities have been assessed against societal risk expectations, not only occupational safety;
- ensure that port layout, neighbouring activities, and temporary land use (e.g. passenger areas or events) are compatible with bunkering operations;
- confirm that emergency response arrangements are proportionate to the scale of potential consequences, even if the likelihood is extremely low;

- provide confidence to regulators, stakeholders, and the public that risks are being managed responsibly and transparently.

Importantly, the Assessment Zone does not mean that bunkering is unsafe or unsuitable in ports. On the contrary, it reflects established international practice for managing rare but serious hazards in complex environments.

Port responsibilities and implications 4.3.3.3

From a port authority perspective, the Assessment Zone is primarily a strategic and regulatory tool. Typical port-level considerations include:

- reviewing and accepting the assumptions used to define the Assessment Zone as part of the bunkering risk assessment;
- understanding how the Assessment Zone interacts with port layout, access routes, nearby terminals, vessels, and public areas;
- identifying activities that may need coordination or restriction during bunkering (e.g. high-density passenger movements, SIMOPs);
- ensuring that emergency plans consider off-site or multi-agency response where relevant;
- embedding Assessment Zone considerations into port byelaws, licensing conditions, or approval processes, as appropriate.

The port is not expected to manage technical details of fuel systems. Instead, its role is to verify adequacy, ensure consistency with local conditions, and confirm that risks have been reduced to an acceptable level.

Mitigation and risk management approach 4.3.3.4

Risk management within the Assessment Zone follows the principle that:

- the likelihood of major events should be made very low, and
- the potential consequences should be mitigated as far as reasonably practicable.

This is typically achieved through a combination of:

- preventive measures that reduce the chance of initiating events;
- operational controls, including traffic management and coordination of activities;
- organisational and procedural barriers, such as competence, communication, and clear authority;
- emergency preparedness and response planning.

Ports are not required to eliminate risk entirely, but to be satisfied that risks are reduced to a level that is tolerable and broadly acceptable to society, in line with national and international practice.

Reassurance and proportionality 4.3.3.5

It is important to emphasise that Assessment Zone events are extremely unlikely. Their consideration does not imply a higher operational risk compared with conventional port activities involving any hazardous substances.

By addressing the Assessment Zone in a structured and proportionate manner, ports can:

- support the safe introduction of new fuels and technologies;
- maintain confidence among port users and authorities;
- avoid unnecessary conservatism while still meeting high safety expectations.

In this way, the Assessment Zone becomes a tool for informed decision-making, not a barrier to safe and efficient port operations.

Fuel-specific safety zone determination 4.4

This section addresses methanol and ammonia separately where their hazard profiles differ, particularly in relation to flammability, toxicity and dispersion behaviour.

It includes guidance for:

- Methanol: Determination and size of safety zones
- Ammonia: Determination and size of safety/toxic

Methanol: Determination and size of safety zones 4.4.1

The determination of safety zones for methanol bunkering is driven primarily by flammability-related hazards, with toxicity considerations addressed as secondary factors. Methanol is a low-flashpoint, volatile liquid that can form flammable vapour clouds when released. Although its flames may be less visible than those of conventional fuels, methanol fires can generate significant thermal radiation and escalation risk if not properly controlled.

Methanol is also toxic if ingested or inhaled at sufficient concentrations; however, under open-air bunkering conditions the concentrations associated with flammable vapour clouds are typically reached before acute toxic exposure thresholds become the dominant concern. Consequently, safety zones for methanol bunkering are generally defined on the basis of flammability and fire risk, rather than toxic exposure.

Appendix C provides a practical process that ports can apply to review and where requested approve a safety zone proposal from operators planning bunkering operations under their port jurisdiction.

Methanol flammability and toxicity levels 4.4.1.1

Figure 4-1 presents a simplified schematic illustrating relevant methanol concentration ranges for both flammability and toxicity, shown on a horizontal axis propagating outward from a hypothetical release source.

For clarity and consistency, concentrations are expressed in parts per million (ppm) throughout this section, including flammability thresholds.

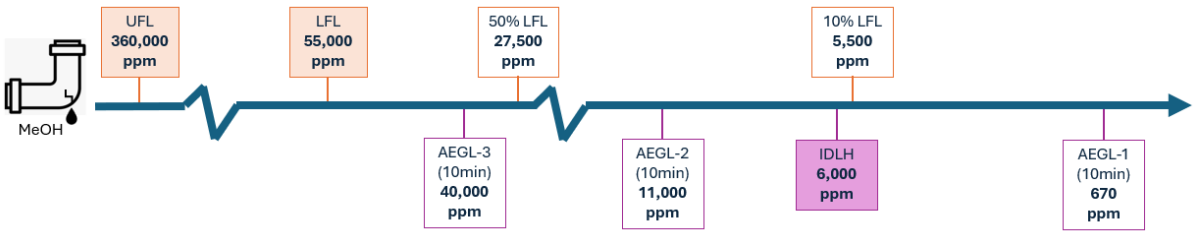

Figure 4-1: Methanol flammability and toxicity ppm levels of interest

Note: It should be recognised that safety zones are three-dimensional spaces, extending not only horizontally but also vertically, and therefore should take into account elevated structures, working at height, vent releases, crane operations, and multi-level access routes within the port environment.

Flammability limits:

- Methanol has a wide flammability range in air, approximately 5.5–36% by volume, equivalent to 55,000–360,000 ppm.
- In gas dispersion analyses, flammable hazard zones are commonly defined using a fraction of the Lower Flammable Limit (LFL). Typical practice applies 50% LFL as a conservative boundary for defining safety zones, although 10% LFL may be used in some contexts to provide additional margin.
- Methanol vapour is heavier than air and may accumulate near the ground or in low-lying areas, particularly under calm or obstructed conditions, increasing the likelihood of ignition if sources are present.

Toxicity exposure limits:

- Toxicity thresholds for methanol vary internationally, as different organisations and regulatory bodies apply different methodologies and exposure criteria.
- Human health impacts depend on both concentration and exposure time: the higher the concentration, the shorter the time a person can be safely exposed, and vice versa.
- Many national legislations define Occupational Exposure Limits (OELs) such as:
    - TWA (Time-Weighted Average) – the average concentration to which workers may be exposed over a typical 8-hour shift;
    - STEL (Short-Term Exposure Limit) – the maximum concentration permitted over a short reference period (typically 15 minutes).
- A useful reference for comparing exposure limits across countries, including EU Member States, is the IFA occupational exposure limit database (https://limitvalue.ifa.dguv.de/substances). However, ports are advised to confirm applicable limits with their national health and safety authority.
- In Figure 4-1, the following widely used toxicity reference levels are illustrated:
    - AEGL (Acute Exposure Guideline Levels) for 10 minutes exposure, developed by the U.S. Environmental Protection Agency (EPA), which define concentration thresholds for general public exposure during accidental releases, based on severity of health effects and short exposure durations (see Table 4-1 for definitions).
    - IDLH (Immediately Dangerous to Life or Health), defined by the U.S. National Institute for Occupational Safety and Health (NIOSH), representing a concentration that poses

an immediate threat to life or would impair the ability to escape. IDLH values are not linked to a specific exposure duration but represent a maximum escape threshold.

- While toxicity should not be disregarded, for open-air methanol bunkering operations flammability-based thresholds normally govern safety zone definition.

Table 4-1: Methanol acute exposure guideline levels (US EPA, 2016).

Methanol	10 min	30 min	60 min	4 hours	8 hours
AEGL 1	670 ppm	670 ppm	530 ppm	340 ppm	270 ppm
AEGL 2	11,000 ppm	4,000 ppm	2,100 ppm	730 ppm	520 ppm
AEGL 3	40,000 ppm	14,000 ppm	7,200 ppm	2,400 ppm	1,600 ppm
AEGL 1: Notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure. AEGL 2: Irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape. AEGL 3: Life-threatening health effects or death					

Methanol gas dispersion analysis considerations 4.4.1.2

CFD modelling for methanol dispersion can provide robust indication of the boundaries of a safety zone, nevertheless, results remain sensitive to how CFD are conducted and dispersion and release assumptions taken into account.

Exposure thresholds and regulatory context:

Before undertaking dispersion modelling for methanol bunkering, it is essential to agree the exposure thresholds and assessment criteria that will be applied. These thresholds are not globally harmonised, and different jurisdictions may apply different occupational health, fire safety, and environmental criteria.

While figure 4-1 provides indicative concentration levels, ports should recognise that:

- national legislation or guidance may impose specific exposure or safety thresholds;
- dispersion studies prepared for one jurisdiction may not be directly applicable in another if different criteria are applied;
- ports should be actively involved in agreeing the applicable thresholds, in coordination with national health and safety and fire authorities, to ensure regulatory alignment and enforceability.

Unlike ammonia, methanol dispersion modelling for bunkering is typically governed by flammability criteria rather than toxicity thresholds. Toxicity considerations remain relevant for occupational safety, but they do not usually define the extent of safety zones in open-air bunkering scenarios.

Note on a practical assessment approach for methanol:

In practice, a commonly adopted and conservative approach to define safety zones based on 10% of the Lower Flammable Limit (LFL) for dispersion analysis. This threshold is reached at concentrations that already encompass widely used acute exposure reference levels, including AEGL-2 and IDLH, under open-air conditions. As a result, applying a 10% LFL criterion can provide a pragmatic means of addressing both flammability and acute toxicity considerations simultaneously for open port environments, without the need to define separate toxicity-driven safety distances.

Ports should nevertheless confirm that this approach is acceptable under national regulatory frameworks and document its use clearly within the risk assessment and permitting process.

Methanol behaviour and implications for vapour cloud extent:

Methanol is a low-flashpoint, flammable liquid, stored and transferred at ambient temperature and pressure. At atmospheric pressure, methanol produces sufficient vapour to ignite at temperatures above approximately 12°C if an ignition source is present. However, its physical behaviour differs significantly from LNG and ammonia in ways that influence dispersion outcomes.

Methanol has a boiling point of approximately 64.7°C, which is substantially higher than that of LNG (approximately −162°C) and ammonia (−33°C). As a result:

- methanol does not flash-boil when released at ambient conditions;
- vapour generation is governed primarily by evaporation from a liquid pool, rather than rapid phase change;
- evaporation rates are influenced by ambient temperature, wind speed, surface area of the pool, and available heat input from the surroundings.

In the absence of an external heat source, methanol evaporation occurs more gradually than for LNG or ammonia.

The following implications should be also considered for safety zone definition:

- **Evaporation and pooling:** Methanol released as a liquid forms a pool that evaporates relatively slowly. However, vapour generation can continue for long time and as long as liquid remains present.
- **Spills on water:** Methanol is fully miscible with water. Releases onto water may disperse rapidly, reducing pool formation but potentially increasing vapour generation over a wider surface area.
- **Ignition and escalation:** Methanol burns with a low-luminosity flame, which can be difficult to detect visually. This characteristic increases the importance of ignition prevention, detection systems, and controlled access.
- **Storage condition:** Methanol is typically stored and transferred at ambient temperature and low pressure. Releases are therefore dominated by liquid pooling and evaporation, rather than high-momentum jets.

These characteristics should be explicitly reflected in dispersion modelling assumptions and the interpretation of results.

As a result of its physical properties and behaviour following a spill or release, methanol vapour plumes generated during credible bunkering scenarios are generally more limited in extent than those associated with LNG or ammonia, particularly in open and well-ventilated port environments.

This typically leads to:

- smaller and more localised vapour clouds;
- lower initial vapour momentum;
- shorter downwind dispersion distances under comparable conditions.

Credible release scenarios and hole size:

Defining credible release scenarios, including the assumed release or hole size, is one of the most influential aspects of dispersion modelling and often a subject of debate. The selected scenarios should be consistent with the risk assessment and reflect realistic failures of the transfer system.

As a reference, the most comprehensive industry work on representative release sizes has been undertaken by SGMF, particularly in its guidance "*Gas as a Marine Fuel – Recommendation of Controlled Zones during LNG Bunkering*". While developed for LNG, this work provides a useful methodological reference when defining credible release scenarios for ammonia, subject to appropriate fuel-specific considerations. In addition, the guidance proposes representative hole sizes for assessing safety zones arising from hose or fitting failures, ranging from 3 mm for a 2-inch transfer hose to 15 mm for a 10-inch transfer hose.

Port role in approval and enforcement 4.4.1.3

From a port perspective, the characteristics of methanol imply that:

- flammability-based safety zones for methanol are often smaller and more site-contained than those typically applied for ammonia or LNG;
- dispersion modelling should focus primarily on liquid pool formation, evaporation rates, and ignition prevention, rather than long-range toxic exposure;
- local conditions-such as deck materials, surface drainage, wind sheltering, and nearby structures-can have a significant influence on vapour behaviour;
- particular attention should be given to where liquid methanol may drain or collect, ensuring that runoff does not migrate into areas assumed to be safe or uncontrolled.

Ports, often acting as the competent authority, play a central role in:

- reviewing dispersion analyses and the assumptions used to define safety zones;
- ensuring that safety zones are compatible with port layout, access routes, and neighbouring activities;
- coordinating methanol safety zones with hazardous zones, SIMOPs arrangements, and marine exclusion zones;
- enforcing access control and operational restrictions during bunkering operations.

Evolution over time:

For simplicity and conservatism during early-stage implementation, LNG safety distances have in some cases been applied to methanol bunkering, providing a high level of inherent safety. However, this

approach may be overly conservative for certain port layouts or operational profiles and may unnecessarily constrain operations.

As experience is gained, ports may require methanol-specific gas dispersion analyses to refine safety zones. Any adjustment to safety distances should remain risk-based, transparent, and subject to approval by the competent authority, ensuring that the protection of people, infrastructure, and the port environment is not compromised.

Ammonia: Determination and size of safety/toxic zones 4.4.2

The determination of safety zone for ammonia bunkering is driven primarily by toxicity-related hazards, with flammability generally playing a secondary role. While ammonia is technically flammable, under typical open-air bunkering conditions the concentrations required for ignition are significantly higher than those that would already pose a severe toxic risk. In confined or enclosed spaces (e.g. machinery spaces), flammability considerations may become more relevant; however, for bunkering operations conducted in open port environments, toxicity is the prevailing hazard.

Ammonia is both toxic and corrosive, and even relatively small releases can result in harmful airborne concentrations extending over considerable distances, depending on release conditions and meteorology. As a result, the definition of safety zone for ammonia bunkering focuses primarily on limiting human exposure and protecting access to accommodation spaces, air intakes, and populated areas, rather than on ignition prevention.

Appendix C provides a practical process that ports can apply to review and where requested approve a safety zone proposal from operators planning bunkering operations under their port jurisdiction.

Ammonia flammability and toxicity levels 4.4.2.1

Figure 4-2 presents a simplified schematic illustrating relevant ammonia concentration ranges for both flammability and toxicity, shown on a horizontal axis propagating outward from a hypothetical release source.

For clarity and consistency, concentrations are expressed in parts per million (ppm) throughout this section, including flammability thresholds.

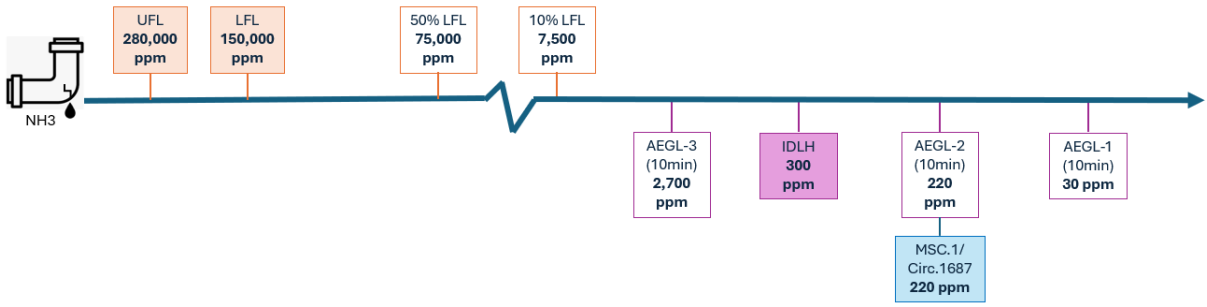

Figure 4-2: Ammonia flammability and toxicity ppm levels of interest

Note: It should be recognised that safety zone is a three-dimensional spaces, extending not only horizontally but also vertically, and therefore should take into account elevated structures, working at height, vent releases, crane operations, and multi-level access routes within the port environment.

Flammability limits:

- Ammonia has a relatively narrow flammability range in dry air, approximately 15–28% by volume, equivalent to 150,000–280,000 ppm.
- In gas dispersion analyses, flammable hazard zones are often defined using a fraction of the Lower Flammable Limit (LFL). Common practice may apply 50% LFL as a conservative boundary, although in some contexts 10% LFL is used for additional margin.
- For ammonia, these concentrations are typically well above levels that would already cause serious toxic effects, reinforcing why flammability is usually not the dominant driver for safety zone definition during bunkering.

Toxicity exposure limits:

- Toxicity thresholds for ammonia vary internationally, as different organisations and regulatory bodies apply different methodologies and exposure criteria.
- Human health impacts depend on both concentration and exposure time: the higher the concentration, the shorter the time a person can be safely exposed, and vice versa.
- Many national legislations define Occupational Exposure Limits (OELs) such as:
  - TWA (Time-Weighted Average) – the average concentration to which workers may be exposed over a typical 8-hour shift;
  - STEL (Short-Term Exposure Limit) – the maximum concentration permitted over a short reference period (typically 15 minutes).
- A useful reference for comparing exposure limits across countries, including EU Member States, is the IFA occupational exposure limit database (https://limitvalue.ifa.dguv.de/substances). However, ports are advised to confirm applicable limits with their national health and safety authority.

- In figure 4-2, the following widely used toxicity reference levels are illustrated:
  - AEGL (Acute Exposure Guideline Levels) for 10 minutes exposure, developed by the U.S. Environmental Protection Agency (EPA), which define concentration thresholds for general public exposure during accidental releases, based on severity of health effects and short exposure durations (see table 4-2 for definitions).
  - IDLH (Immediately Dangerous to Life or Health), defined by the U.S. National Institute for Occupational Safety and Health (NIOSH), representing a concentration that poses an immediate threat to life or would impair the ability to escape. IDLH values are not linked to a specific exposure duration but represent a maximum escape threshold.
  - The toxic area threshold specified by the IMO in MSC.1/Circ.1687 – Interim Guidelines for the Safety of Ships Using Ammonia as Fuel, which defines a fixed concentration limit intended for design and safety-zone purposes, rather than time-based exposure assessment.
- These toxicity thresholds form the basis for dispersion modelling and safety zone determination for ammonia bunkering, with ports applying them-together with national regulatory requirements-to define controlled areas, access restrictions, and SIMOPs limitations.

Table 4-2: Ammonia acute exposure guideline levels (US EPA, 2016).

Ammonia	10 min	30 min	60 min	4 hours	8 hours
AEGL 1	30 ppm	30 ppm	30 ppm	30 ppm	30 ppm
AEGL 2	220 ppm	220 ppm	160 ppm	110 ppm	110 ppm
AEGL 3	2700 ppm	1600 ppm	1100 ppm	550 ppm	390 ppm
AEGL 1: Notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure. AEGL 2: Irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape. AEGL 3: Life-threatening health effects or death					

Ammonia gas dispersion analysis considerations 4.4.2.2

Compared to LNG and methane, CFD modelling for ammonia dispersion remains more complex, due to ammonia's physical behaviour, phase change characteristics, and interaction with surfaces and water. In addition, there is currently less operational and experimental validation data available for ammonia compared to LNG. This situation is evolving as more studies, pilots, and experimental work are completed.

Exposure thresholds and regulatory context 4.4.2.3

It is essential to agree exposure thresholds and criteria before undertaking dispersion modelling. These thresholds are not globally harmonised, and different jurisdictions may apply different toxicity limits for ammonia.

While figure 4-2 provides informative concentration levels, ports should recognise that:

- national legislation or guidance may impose specific exposure limits;
- dispersion studies prepared for one region may not be directly applicable in another if different thresholds apply;
- ports should be involved in discussions on acceptable thresholds to ensure alignment with national health and safety requirements.

Credible release scenarios and hole size 4.2.2.4

Defining credible release scenarios, including the assumed release or hole size, is one of the most influential aspects of dispersion modelling and often a subject of debate. The selected scenarios should be consistent with the risk assessment and reflect realistic failures of the transfer system.

As a reference, the most comprehensive industry work on representative release sizes has been undertaken by SGMF, particularly in its guidance "*Gas as a Marine Fuel – Recommendation of Controlled Zones during LNG Bunkering*". While developed for LNG, this work provides a useful methodological reference when defining credible release scenarios for ammonia, subject to appropriate fuel-specific considerations. In addition, the guidance proposes representative hole sizes for assessing

safety zones arising from hose or fitting failures, ranging from 3 mm for a 2-inch transfer hose to 15 mm for a 10-inch transfer hose.

Behaviour of ammonia compared to LNG 4.4.2.5

Ammonia behaves significantly differently from LNG following a release, with important implications for safety and toxic area duration:

- **Evaporation and persistence:** Ammonia evaporates more slowly than LNG. As a result, safety or toxic areas may remain in place for a longer duration following a spill.
- **Liquid pooling on land:** When liquid ammonia is released, a fraction flashes immediately depending on release conditions (e.g. refrigerated or pressurised). The remainder forms a pool, which may take hours to fully evaporate, particularly in cold climates (note ammonia boiling point -33°C). Even small quantities can persist significantly longer than LNG pools, which typically evaporate within minutes.
- **Spills on water:** When ammonia is released onto water, approximately 50% may dissolve, releasing heat in the process. The total amount vaporised is generally lower than for land spills, but vapour may be generated more rapidly. In port environments, water currents can transport dissolved ammonia away from the release location, introducing additional considerations for emergency response and environmental protection. Firefighting water may similarly transport contamination and should be considered in mitigation planning.
- **Effect of storage condition:** Storage condition has a significant influence on dispersion:
    - **Refrigerated ammonia** typically drains under gravity with low initial velocity, forming a pool that evaporates over time.
    - **Pressurised ammonia** releases may form a jet with higher momentum and potentially larger dispersion distances, although mass flow rates may still be lower than for LNG.

These characteristics should be explicitly reflected in dispersion modelling assumptions and in the interpretation of results.

Ports should therefore focus on transparency and justification of assumptions, rather than expecting identical numerical results across studies.

Mitigation measures to reduce ammonia safety distances 4.4.2.6

Where site constraints limit the available space for safety or toxic areas, risk-reduction measures may be considered to reduce the extent of safety distances, provided that an equivalent or improved level of safety can be demonstrated through the risk assessment and dispersion analysis. The following mitigation measures are commonly discussed in relation to ammonia bunkering and may influence the size and duration of safety or toxic areas.

Flange guards and spray containment 4.4.2.7

Flange guards may be used to contain or deflect small leaks from flanged connections, reducing spray dispersion and the formation of airborne ammonia clouds. By limiting jet direction and momentum, flange guards can help reduce the horizontal spread of a release, particularly for minor failures. Their effectiveness should be assessed case by case, taking into account inspection, maintenance, and drainage arrangements.

Collection and downward direction of liquid releases 4.4.2.8

Design measures that collect released liquid and direct it downwards can significantly influence dispersion behaviour. By reducing aerosolization and horizontal jetting, liquid ammonia can be encouraged to form a pool rather than an airborne plume. Where feasible, liquid may be directed towards a safer area, such as a bunded zone or controlled drainage area, provided that secondary risks (e.g. prolonged evaporation, environmental contamination) are properly addressed.

Double-walled hoses or pipe-in-pipe systems 4.4.2.9

The use of double-walled hoses or pipe-in-pipe transfer systems may reduce the likelihood and severity of releases from the primary containment. Depending on design, monitoring, and failure detection arrangements, such systems may limit leak rates or provide early detection, thereby reducing the mass released before isolation. Any benefit to safety distances should be demonstrated through the risk assessment and supported by credible failure scenarios.

Reduction of ESD response time 4.4.2.10

Reducing the time to emergency shutdown (ESD) is one of the most effective measures for limiting release duration and total released inventory. Improvements may include faster detection, optimised control logic, or reduced valve closing times. Shorter ESD response times can directly reduce predicted toxic distances in dispersion modelling, provided that system reliability and spurious trip risks are adequately managed.

Port considerations 4.4.2.11

From a port perspective, the application of mitigation measures should be guided by the following principles:

- Mitigations should be risk-based and justified, not assumed.
- Any reduction in safety or toxic areas should be supported by updated dispersion modelling reflecting the mitigation measures.
- Mitigations should be robust, inspectable, and enforceable within the port environment.
- Secondary risks (e.g. prolonged pooling, environmental impact, contaminated runoff) should be explicitly assessed.
- Ports may accept mitigation-driven reductions in safety distances only where an equivalent level of safety is demonstrated and agreed.

Port role in approval and enforcement 4.4.2.12

Ports, often acting as the competent authority, play a central role in reviewing and approving safety/toxic areas for ammonia bunkering. This includes:

- verifying that safety zones are based on appropriate dispersion modelling and assumptions (exposure limits and hole size among others);
- ensuring that safety zones are compatible with port layout, access routes, and neighbouring activities;
- confirming that access control, monitoring, and enforcement arrangements are practical and effective;
- coordinating safety zones with marine exclusion zones, SIMOPs, and emergency response planning.

Because ammonia safety zones may extend further than those for methane/LNG early coordination with terminal operators, emergency services, and neighbouring facilities is particularly important.

Evolution over time 4.4.2.13

As ammonia bunkering progresses from pilot operations to routine activity, safety zones may be reviewed and optimised. Any changes should remain risk-based and subject to approval by the competent authority, ensuring that protection of people and the port environment is not compromised.

Core operational controls 4.5

This section describes the tools used to manage individual bunkering operations, including compatibility assessments, checklists, emergency shutdown, and training and how ports maintain control during operations.

It includes guidance for:

- Bunkering compatibility assessment
- Bunkering checklist
- Bunkering emergency shutdown (ESD)
- Communication protocols
- Enforcement protocols
- Training requirements and safety drills

Bunkering compatibility assessment 4.5.1

Compatibility assessment is a critical process to ensure that all elements of a bunkering operation can interface safely and effectively. While the compatibility assessment is normally prepared by the bunkering operator and receiving ship, ports play a key role in ensuring that compatibility has been systematically addressed before approving operations.

Purpose of compatibility assessment 4.5.1.1

A compatibility assessment confirms that:

- the bunkering supply system and receiving ship are technically compatible;
- operating parameters are aligned and understood;
- safety systems and procedures can function together as intended;
- the operation can be safely integrated into the port environment.

For methanol and ammonia, compatibility assessment is particularly important due to:

- low-flashpoint fuel characteristics;
- toxicity (ammonia);
- evolving regulatory frameworks and operational experience.

Typical elements of a compatibility assessment 4.5.1.2

While the detailed scope may vary, compatibility assessments typically address:

- fuel properties and operating conditions (temperature, pressure, phase);
- transfer system interfaces, including hoses, connectors, and manifolds;
- emergency shutdown (ESD) logic and response times;
- vapour return or venting arrangements, where applicable;
- communication protocols between supplier and receiver;

- procedural alignment, including checklists and emergency actions;
- training and competence of personnel involved.

A compatibility assessment is operation-specific, but it does not necessarily need to be repeated for every individual bunkering operation. Where a proposed operation is fully covered by an existing, approved compatibility assessment, a new assessment is not required. In such cases, the assessment should be validated or confirmed as still applicable, rather than re-performed in full.

Compatibility assessments may also be developed to cover a defined range of operational variations, such as different transfer rates, quantities, supply scenarios, or vessel types. Provided that the specific bunkering operation falls within the assessed operational envelope, the existing compatibility assessment may continue to be used. A new or updated assessment should be required only where material changes occur that fall outside the previously assessed conditions.

Port role in reviewing compatibility 4.5.1.3

From a port perspective, compatibility assessment supports confidence that:

- assumptions used in the risk assessment and safety zone definition remain valid;
- SIMOPs limitations are appropriate and enforceable;
- emergency response arrangements are realistic for the specific interfaces involved.

Ports should not duplicate the operator's technical assessment, but should:

- verify that a compatibility assessment process is in place and/or it has been completed;
- ensure that port-relevant interfaces (e.g. berth layout, access routes, neighbouring activities) are considered;
- confirm that outcomes are reflected in the bunkering management plan and joint bunkering plan;
- require reassessment where material changes occur.

Summary for ports 4.5.1.4

The compatibility assessment is a key input to the bunkering documentation framework described earlier in section 2.7 of this Guidebook. Its outcomes should be clearly reflected in the Bunkering Management Plan (BMP) and, where applicable, in the Joint Bunkering Plan (JBP/JPBO), operating procedures, and checklists.

From a port perspective, this linkage ensures that the technical compatibility conclusions are translated into practical operational controls, defined responsibilities, and enforceable conditions. Ports should therefore expect consistency between the compatibility assessment and the submitted bunkering documentation, and may use this alignment as part of their review and approval process.

Ports should:

- define when compatibility assessments are required (e.g. first operation, new vessel, new fuel, new site);
- ensure that compatibility outcomes are aligned with port procedures and permit conditions;
- recognise that compatibility is not a one-off exercise, but part of an ongoing assurance process as bunkering operations evolve.

Ports should be also aware that recognised industry guidance already exists for bunkering compatibility assessments. In particular, SGMF has published "LNG as a Marine Fuel – A Bunkering Compatibility Assessment Methodology", which provides standardised forms and structured questions.

Although developed for LNG, the methodology can be applied to methanol and ammonia bunkering, provided that fuel-specific risks are explicitly addressed. Ports are therefore encouraged to use established industry frameworks rather than develop bespoke compatibility formats, supporting consistency, completeness, and efficient review.

Bunkering checklist 4.5.2

The bunkering checklist is a core operational tool within the bunkering documentation framework as discussed in section 2.7 of this Guidebook. It provides a structured, step-by-step verification that all required technical, procedural, and safety conditions are in place before, during, and after bunkering. For methanol and ammonia bunkering, checklists are particularly important due to the involvement of low-flashpoint fuels, evolving operational experience, and multiple interacting stakeholders.

The IAPH Bunkering Checklists:

The IAPH Clean Marine Fuels Working Group has developed standardised bunkering checklists, available as a free download from the IAPH website.

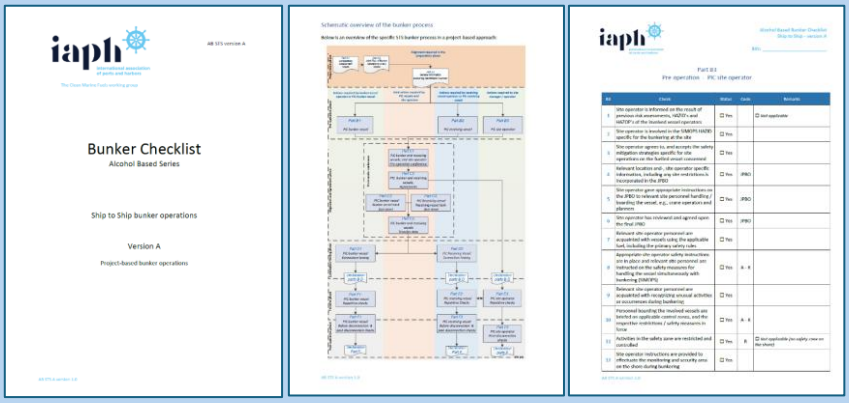

Figure 4-3: IAPH bunkering checklist
Source: https://www.iaphworldports.org/products/

These checklists are well established and widely used across the industry. They support the operationalisation of bunkering activities and are recommended for use rather than creating new ad hoc checklists.

IAPH updates these documents regularly. Users should always ensure they are working with the latest version.

The checklist is an on-site operational verification tool. It does not substitute pre-operational work such as HAZID, HAZOP, SIMOPS or the development of bunkering procedures.

During preparation and operations, the checklist is used by the supplier and receiving ship operator, typically through their respective Persons in Charge (PICs), to validate each step of the bunkering process.

Different checklists exist for various fuels and transfer scenarios (e.g. truck-to-ship, ship-to-ship). Users should select the correct version.

The checklist is structured in phases:

- Part A – Preparation phase
- Part B – Pre-operation phase
- Part C – Alignment and agreement phase
- Part D – Connection testing phase
- Part E – Transfer phase
- Part F – Post-operation phase

The checklists originated from LNG operations over 12 years ago and have since been expanded to cover multiple fuels, including liquid gases (e.g. LNG, liquefied biogas, liquid hydrogen), alcohol-based fuels (e.g. methanol, bio/e-methanol, ethanol) and ammonia, including refrigerated toxic gases.

Purpose of the bunkering checklist 4.5.2.1

The primary purpose of the bunkering checklist is to:

- confirm operational readiness of the supplier, receiving ship, and transfer system;
- ensure alignment and shared understanding between all parties involved;
- verify that critical safety controls are in place and functioning;
- provide a clear go / no-go decision point before transfer commences.

While the checklist itself is completed by the bunkering operator and receiving ship, it forms an important part of the assurance framework reviewed by ports.

Use of industry-standard checklists 4.5.2.2

Ports should be aware that industry-standard bunkering checklists are already available and widely used. In particular, the International Association of Ports and Harbors Clean Marine Fuels Working Group Bunker Checklists provide structured templates applicable to alternative fuels, including methanol and ammonia. These checklists are publicly available and designed to support consistent implementation across ports and regions.

From a port perspective, the use of recognised industry checklists is strongly recommended, and the development of bespoke or informal checklists should be discouraged unless clearly justified.

Typical content of a bunkering checklist 4.5.2.3

Although the exact format may vary, a bunkering checklist typically covers:

- confirmation of fuel type, quantity, and transfer method;
- verification of compatibility between supplier and receiving ship;
- readiness of transfer system, hoses, connectors, and ESD systems;

- confirmation of communication protocols and emergency signals;
- verification of controlled areas, access restrictions, and SIMOPs limitations;
- confirmation of weather, traffic, and operational conditions;
- readiness of emergency response equipment and personnel.

The checklist is normally divided into phases (pre-transfer, during transfer, post-transfer), with clear responsibility for each item.

Port role and expectations 4.5.2.4

Ports do not complete bunkering checklists themselves; however, they play an important role in:

- setting expectations that an approved, recognised checklist will be used;
- verifying that the checklist is consistent with the Bunkering Management Plan (BMP) and Joint Bunkering Plan;
- confirming that checklist items reflect port-specific requirements, including safety zones, SIMOPs controls, and emergency arrangements;
- requiring evidence that the checklist has been completed, where appropriate, as part of permitting or audit processes.

Ports may also specify minimum checklist elements or reference preferred industry templates (e.g. IAPH) within port by-laws or permitting conditions.

Summary for ports 4.5.2.5

- Require the use of recognised industry-standard bunkering checklists.
- Avoid bespoke formats unless clearly justified.
- Ensure checklist content reflects port-specific conditions and controls.
- Use the checklist as a practical assurance link between planning, permitting, and execution.

Bunkering emergency shutdown (ESD) 4.5.3

Emergency shutdown (ESD) is a safety-critical function of bunkering operations. It provides a controlled means to stop fuel transfer and, where necessary, to separate the transfer system from the receiving vessel in response to abnormal or emergency conditions.

From a port perspective, understanding the bunkering ESD concept, and in particular ESD-2, is important because:

- ESD activation can affect port traffic management, and SIMOPs;
- ESD-2 may be initiated if a vessel moves unexpectedly or is required to depart urgently, potentially leading to hose disconnection and spill risk;
- ESD-2 events often represent the point at which escalation from a contained event to a wider port emergency may occur; and
- port authorities may need to coordinate access control, emergency response, and post-event recovery following an ESD event.

Ports are not expected to manage the technical design of ESD systems. However, they should understand how ESD functions, what its implications are for port safety and emergency response, and how ESD scenarios are addressed within the bunkering risk assessment and procedures.

Overview of the bunkering ESD concept 4.5.3.1

The bunkering emergency shutdown process is initiated in response to defined emergency conditions to protect people, assets, and the environment. It is divided into two consecutive but independent stages:

- ESD-1: termination of the bunkering operation; and
- ESD-2: separation of the bunkering transfer system.

Although ESD-1 should normally be initiated before ESD-2, initiation of ESD-1 does not automatically imply that ESD-2 will follow.

The bunkering ESD system discussed in this guide relates specifically to bunkering transfer systems and should not be confused with ESD functions associated with machinery spaces under the IGF Code, which act on different equipment and systems.

ESD-1: termination of transfer 4.5.3.2

ESD-1 is the first stage of the bunkering emergency shutdown process. Its primary purpose is to stop the fuel transfer in a controlled manner.

For ports, ESD-1 is generally of limited direct interest, as it primarily affects:

- internal transfer systems;
- pressures and flow within hoses or transfer arms; and
- operational decision-making by the bunkering parties.

Nevertheless, ports should ensure that:

- ESD-1 initiation criteria are clearly defined in the bunkering risk assessment and procedures;
- ESD-1 events are reported to the port where required; and
- procedures address the management of trapped inventory and confirmation of system integrity before any resumption of operations.

ESD-2: separation of the transfer system 4.5.3.3

ESD-2 is the second stage of the bunkering emergency shutdown process and is of direct relevance to ports.

ESD-2 is intended to protect the transfer system, bunkering equipment, and ship manifolds if the vessel moves outside a predetermined operating envelope. Typical initiating conditions may include excessive drift, loss of moorings, or other scenarios where continued physical connection would create a greater hazard.

Activation of ESD-2:

- stops the transfer (if not already stopped); and
- activates an emergency release system (ERS), typically involving an emergency release coupling (ERC), to separate the transfer system from the receiving vessel.

ESD-2 may be initiated automatically by sensors or manually from the bunkering facility. It is not typically designed to be initiated from the receiving vessel.

Why ESD-2 matters for ports 4.5.3.4

From a port authority perspective, ESD-2 is critical because it may:

- occur during unexpected vessel movement or urgent departure scenarios;
- result in hoses or hose sections becoming suspended, partially submerged, or detached;
- create a potential spill or vapour release during or after disconnection;
- require immediate control of surrounding areas, traffic, and access; and
- it might trigger coordination with emergency services, including fire and medical response.

Ports should therefore ensure that ESD-2 scenarios are explicitly considered when:

- approving bunkering locations;
- reviewing safety zones and marine exclusion zones;
- assessing SIMOPs and traffic control measures; and
- validating emergency response and recovery arrangements.

Port expectations and implementation considerations 4.5.3.5

Ports should verify, through the risk assessment and supporting documentation, that the bunkering parties have:

- Clearly defined ESD-1 and ESD-2 scenarios, including initiating conditions and system responses.
- Documented procedures for managing ESD-1 and ESD-2 events, including:
  - control of trapped inventory on both sides of the transfer system;
  - management and recovery of hoses or transfer equipment following separation; and
  - criteria for declaring the operation safe or escalating to a port emergency.
- Arrangements for hose and equipment recovery, including:
  - minimising personnel exposure;
  - avoiding metal-to-metal contact that could cause sparks;
  - managing interaction with water, vessel movements, and port traffic.
- Clear communication and notification protocols, including when and how the port authority and emergency services are informed of an ESD-2 event.

Ports are not required to approve detailed ESD logic or system programming, but they should be satisfied that ESD-2 outcomes are compatible with port safety management and emergency response capabilities.

Spurious ESD and recovery considerations 4.5.3.6

Ports should be aware that ESD events may be triggered legitimately or spuriously. Any activation of a bunkering ESD should be:

- investigated;
- documented; and
- resolved before further transfer is authorised.

While specific ESD initiators may, under strict procedures, be overridden by the bunkering parties, ports should expect that:

- overall ESD system functionality remains intact;
- overrides are subject to risk assessment and clear authorisation; and
- recovery from ESD events, particularly ESD-2, may take longer than anticipated.

Port procedures and traffic management arrangements should allow for this potential extended recovery period.

Summary for ports 4.5.3.7

- ESD-1 primarily concerns the bunkering parties and transfer process.
- ESD-2 is of direct relevance to ports, as it may involve vessel movement, system separation, spill risk, and escalation to wider port emergency response.
- Ports should ensure that ESD-2 scenarios are explicitly addressed in risk assessments, safety zones, SIMOPs management, and emergency planning.
- Clear expectations, communication pathways, and recovery arrangements support safe and controlled management of ESD events within the port environment.

Communication protocols 4.5.4

Effective communication and information exchange are essential throughout the entire process. Communication requirements can be broadly divided into three distinct but interrelated areas, each involving partially different points of contact and responsibilities:

- Licensing and permitting communication
- Nautical and traffic-related communication
- Operational and emergency communication

Clear definition of interfaces and responsibilities is critical to ensure safe, efficient, and compliant operations.

Licensing and Permitting Communication 4.5.4.1

The licensing process should, wherever possible, be administered by a single entity. This may be the port authority itself or another designated competent body.

As outlined in section 4.2.3, a single point of contact should be established to ensure clarity, efficiency and consistency in the licensing process.

The harbour master's office (or equivalent) should coordinate and communicate with all relevant external authorities required to be involved in the initial licensing and permitting process. This may include environmental authorities, occupational safety authorities, fire services, and other competent bodies. Bunker suppliers and other applicants should interface exclusively with the designated single point of contact, thereby avoiding fragmented communication and ensuring consistent regulatory oversight.

Nautical and traffic-related communication 4.5.4.2

The approach, arrival, and departure of a BSV should be planned, coordinated, and authorised by VTS. While the vessels are in port and alongside, vessel operations hall be continuously monitored by vessel traffic management. This should include trucks supplying fuel from the shore side. The vessel traffic management monitor the following:

- The scheduled commencement of bunkering operations
- The completion of bunkering operations
- The specific fuel type being transferred (e.g. ammonia or methanol)
- Any deviations from the approved operational plan

Vessel Traffic Management should act as the primary operational point of contact for marine-related emergencies during bunkering operations, while the VTS should coordinate navigational matters, manage traffic conflicts, and ensure the safe and orderly movement of marine traffic.

Operational and emergency communication 4.5.4.3

During bunkering operations, the receiving vessel should maintain close coordination with the terminal operator, where applicable, and should comply with the terminal's emergency response and contingency plans.

Clear communication channels should be established between:

- The port authority
- The bunker supply vessel
- The receiving vessel
- The terminal operator
- Vessel traffic management and VTS
- Emergency services

In the event of an incident or emergency, predefined communication and escalation procedures should apply, ensuring that vessel traffic management is immediately informed and that the appropriate emergency response plans are activated without delay.

All communication interfaces and procedures should be clearly documented within the port's bunkering manual, SIMOPs procedures, and emergency response plans. Communication protocols should be tested periodically through exercises and drills, particularly for alternative fuels with elevated toxicity or flammability risks.

Enforcement protocols 4.5.5

The port authority, harbour master's office, or an equivalent competent authority of the port should ensure that all requirements stipulated in the bunker licence are effectively enforced. This enforcement should not be limited to the initial licensing phase but should also include random inspections, regular audits or the review of conducted audits by IAPH members independently of the formal licensing process.

Such oversight activities require adequate manpower, targeted training, and a sufficient level of technical competence, particularly with regard to fuel specific transfer and safety systems, risk assessments, and operational planning. The port authority (or equivalent) should ensure that inspectors are familiar with the specific hazards, safety concepts, and emergency procedures associated with the licensed bunkering operations.

Initial bunkering operations 4.5.5.1

It is recommended that the port authority (or equivalent) attends the first bunkering operation conducted under a newly issued licence. In addition, participation in the pre-transfer transfer meeting between the

BSV or road truck and the receiving vessel is advisable to verify that procedures, communication lines, and responsibilities are clearly understood and correctly implemented by all parties.

When planning physical inspections, it should be recognised that boarding or leaving the BSV during active bunkering operations may be restricted or prohibited due to established safety, exclusion, or toxic areas. Inspection concepts should therefore account for these limitations and may include alternative measures such as inspections prior to commencement of transfer or being conducted on the receiving vessel.

Training requirements and safety drills 4.5.6

Training is a critical enabler for the safe introduction and continued operation of methanol and ammonia bunkering in ports. Ports should ensure that all personnel involved in, supervising, authorising, or responding to bunkering operations are competent, trained, and familiar with:

- the specific fuels hazards,
- fuel handling procedures, and
- emergency actions associated with these fuels.

Training forms an integral part of the port's risk management, permitting, and SIMOPs framework and should be regarded as a prerequisite for authorising bunkering activities. Training requirements should be proportionate to role, exposure, and responsibility, and reviewed whenever bunkering locations, supply scenarios, fuels, or regulatory requirements change.

Port responsibilities for training 4.5.6.1

From a port perspective, training obligations extend beyond port staff alone. Ports should:

- define minimum training and competence expectations for all relevant stakeholders operating within the port area;
- verify that training requirements are met as part of licensing and permitting processes;
- ensure internal port personnel are trained to a level commensurate with their authority and responsibilities;
- coordinate training expectations with terminal operators, emergency services, and regulators.

Where training is not mandated by international or national regulation, ports should still set clear minimum requirements as a condition of authorisation.

Clarification Note – Training Responsibilities:

It should be noted that ports are responsible for training their own personnel to a level commensurate with their authority and operational responsibilities. Personnel employed by operators, suppliers, terminals or contractors remain the responsibility of their respective employers.

However, as part of the bunkering licensing and authorisation process, ports should verify that all parties involved demonstrate appropriate training and competence. Ports may define minimum training standards for stakeholders operating within their jurisdiction and require evidence of compliance during permitting.

Where training is not explicitly mandated by national or international regulation, ports may still establish minimum competence requirements as a condition of authorisation, ensuring safe and consistent operational practices.

Stakeholders, roles, and training scope 4.5.6.2

Training requirements vary depending on stakeholder role and degree of exposure. As a minimum, ports should consider the following groups:

- Bunkering personnel
- Port authority personnel
- Terminal operators
- Port workers (terminal personnel)
- Vessel Traffic Services (VTS) / Vessel Traffic Management
- Emergency response services
- External port stakeholders

Bunkering personnel

This includes personnel from the bunkering organisation (e.g. bunker supply vessel crew, truck operators, or terminal staff) and the receiving ship operator.

Training focus:

- Fuel-specific hazards of methanol and ammonia (flammability, toxicity, vapour behaviour);
- Transfer procedures, communication protocols, and ESD coordination;
- Use of PPE and gas detection equipment;
- Emergency response actions and initial mitigation measures.

For shipboard personnel, minimum competence requirements are governed by the STCW Convention and associated national regulations. Where bunkering is conducted ship-to-ship or shore-to-ship, additional national requirements may apply to bunker operators.

It should be noted that ongoing discussions at IMO include revisions to STCW to further address training needs related to alternative fuels, including methanol and ammonia.

Port authority personnel

Roles include acting as competent authority, leading licensing processes, enforcing conditions, and coordinating emergency preparedness.

Training focus:

- fuel-specific hazards for methanol and ammonia;
- interpretation of risk assessments, safety zones, toxic areas, and SIMOPs;
- bunkering documentation (Bunkering Management Plan, JBP, checklists);
- authority and procedures to suspend or stop unsafe operations;
- coordination with emergency services and other port users.

Key port personnel (e.g. safety officers, harbour masters, permit-issuing staff) should be trained by industry-qualified experts.

Terminal operators

Interface directly with bunkering operations at quays and berths.

Training focus:

- operational hazards and safety zones;
- interface management with bunkering vessels;
- emergency response actions and communication protocols.

Port workers (terminal personnel)

Work in areas where bunkering operations may occur.

Training focus:

- general understanding of methanol and ammonia properties and hazards;
- recognition of alarms, restricted areas, and emergency signals;
- basic response actions and evacuation procedures.

Vessel Traffic Services (VTS) / Vessel Traffic Management

Manage marine traffic during bunkering operations.

Training focus:

- awareness of fuel-specific hazards;
- understanding of marine exclusion zones and traffic restrictions;
- coordination during emergency scenarios.

Emergency response services

Fire, medical, police, and specialised response teams.

Training focus:

- ammonia and methanol properties and health effects;
- use of detection equipment and PPE;
- response to toxic dispersion, fires, and spills;
- coordination with ship, terminal, and port command structures.

External port stakeholders

Other port users operating nearby bunkering activities.

Training focus:

- general awareness of methanol and ammonia hazards;
- understanding of access restrictions and emergency instructions.

Training stages aligned with implementation 4.5.6.3

Training should evolve in line with the port's implementation stage and outcomes of the initial HAZID.

Initial training

- Conducted before formal engagement with national regulators.
- Aimed at preparing the port organisation for methanol and ammonia bunkering.
- Focus on regulatory context, high-level hazards, and implementation pathways.

Implementation phase training

- Conducted once regulatory requirements are clarified and permits amended.
- Provides detailed knowledge of bunkering systems, risk controls, and emergency procedures.
- Includes tabletop emergency exercises.

Operational phase training

- Ongoing and recurrent once bunkering becomes routine.
- Focuses on:
    - lessons learned from operations;
    - updates to standards and guidance;
    - refresher emergency response training and drills.

Core training content 4.5.6.4

Including port safety officers, harbour masters, enforcement officers, and permit-issuing staff.

Required competence:

- Understanding of methanol and ammonia properties, hazards, and risk drivers
- Interpretation of risk assessments, safety zones, toxic areas, and SIMOPs restrictions
- Familiarity with bunkering documentation (Bunkering Management Plan, JBP, checklists)
- Authority to suspend or stop operations under unsafe conditions
- Coordination with emergency services and other port users

Training programmes should, as a minimum, cover the following elements:

General (methanol and ammonia)

- Regulatory framework overview (IGF Code, interim IMO guidelines, port rules)
- Bunkering supply scenarios (STS, shore-to-ship, mobile-to-ship)
- Roles and responsibilities during bunkering
- Bunkering stages: design, planning, preparation, operation
- Hazardous areas, safety zones, marine exclusion zones, SIMOPs
- Human-factor considerations and communication protocols
- Incident reporting and lessons learned

Methanol-specific

- Flammability characteristics and ignition risks
- Toxicity thresholds and exposure control
- Vapour behaviour and confined-space risks

- Spill behaviour and environmental impact
- Methanol-compatible PPE and material considerations
- Fire-fighting principles for alcohol fires

Ammonia-specific

- Acute toxicity and health effects
- Odour threshold vs harmful concentration
- Gas dispersion behaviour and toxic area concept
- Use of gas detection and alarm systems
- Escape, evacuation, and sheltering principles
- Interaction with SCR systems and ammonia slip awareness

Operational rehearsals and system testing 4.5.6.5

As part of personnel training and operational readiness, ports may require structured operational rehearsals prior to first bunkering at a new location, when introducing a new fuel, or following significant modifications to the transfer system or procedures.

Such rehearsals may take the form of:

- Dry-runs (no product transfer), focusing on procedures and coordination; or
- Water-runs (wet rehearsals using water or another inert medium), focusing on system functionality;

The type of rehearsal required should depend on the circumstances, fuel type, complexity of the operation, and regulatory expectations.

Rehearsals may be used to test and validate:

- Roles and responsibilities;
- Communication protocols;
- Checklist execution;
- Permit and documentation flow;
- Emergency procedures and ESD logic coordination;
- Physical interfaces, including hoses, couplings, and connections.

Operational rehearsals are particularly useful prior to first-ever bunkering operations within a port. They help identify procedural gaps and interface mismatches before hazardous fuel is introduced. They can reduce the risk of aborted transfers, incidents, and operational delays, and build confidence among crews, regulators, emergency services, and port authorities.

Note:
Following a water-run, the transfer system should be thoroughly drained and, where necessary, cleaned and completely dried before introducing methanol or ammonia. Residual water may adversely affect fuel quality, increase corrosion risks, or create operational complications. Complete removal of water should therefore be verified in accordance with approved procedures.

Emergency drills and exercises 4.5.6.6

Ports should ensure that emergency drills are conducted at appropriate intervals and after significant changes to operations.

Drills should include:

- Methanol spill and fire scenarios
- Ammonia leak and toxic dispersion scenarios
- Emergency shutdown and evacuation
- Communication and coordination with emergency services
- Interface between ship, supplier, terminal, and port authority

The frequency and complexity of drills should be proportionate to:

- Fuel type
- Bunkering frequency
- Proximity to populated or sensitive areas
- National regulatory requirements

Documentation, records, and review 4.5.6.7

Ports should require and maintain evidence of training and competence, including:

- Training matrices by role
- Certificates or attendance records
- Drill reports and corrective actions
- Records of refresher training

Training requirements should be reviewed:

- following incidents or near misses;
- after operational or regulatory changes;
- as bunkering transitions from pilot activities to business-as-usual.

Emergency management and response 4.6

This section explains how ports respond to incidents, and apply lessons learned.

It includes guidance for:

- Emergency preparedness
- Incidents reporting and lesson learned

NOTE- Scope and Use of this Section:

This section provides high-level guidance on emergency preparedness considerations relevant to methanol and ammonia in port environments. It is intended to support ports in understanding key principles, typical response challenges, and areas requiring attention when integrating these fuels into their emergency planning frameworks.

Emergency preparedness measures described in this section apply both to bunkering operations and to the presence and operation of methanol- or ammonia-fuelled vessels within the port.

The content is not site-, or operation-specific, nor does it replace detailed emergency response plans, statutory requirements, or incident-specific procedures. Actual preparedness measures, response strategies, and resource requirements should always be defined through site-specific risk assessments, engagement with competent authorities, and alignment with national legislation, emergency services, and terminal operators.

Ports should use this section as a reference framework to inform further analysis and planning, recognising that emergency preparedness arrangements should be tailored to local layouts, bunkering scenarios, fuel characteristics, and the specific risk profile of each port location.

Emergency preparedness 4.6.1

The port authority and the respective terminal operators should be adequately prepared to manage incidents involving methanol and ammonia, taking into account their distinct physical, chemical, and toxicological properties. Furthermore, it should be pointed out that this does not only apply to bunkering operations but also to vessel using methanol or ammonia as fuel. Preparedness should, as a minimum, address the following:

- Accidental releases of methanol and ammonia, including the identification, modelling, and management of toxic exposure zones, with particular emphasis on ammonia vapour cloud dispersion and methanol inhalation and contact hazards;
- Leak detection, isolation, and mitigation measures, enabling a rapid response to product releases, including spill containment for methanol and vapour dispersion control for ammonia;
- Fire and emergency response capabilities, recognising methanol's high flammability and low flame visibility, and ammonia's limited flammability but significant toxic and corrosive effects;
- First-aid and medical response procedures, including immediate actions in the event of eye or skin contact, inhalation exposure, or chemical burns, supported by suitably located emergency showers, eyewash stations, and trained personnel.

Accidental release and leak detection of methanol and ammonia 4.6.1.1

Within the licensing process (see section 4.2.3), the outputs of the initial HAZID-including the underlying assumptions, identified hazards, and the resulting controlled areas / safety zones (see section 4.4) should be documented and made available to all relevant stakeholders, in particular those involved in emergency preparedness and response (terminal emergency teams, port emergency services, fire brigade, medical response, VTS/traffic management, and the bunker supplier's emergency organisation). This information should be incorporated into the port's emergency response framework to ensure that response actions, exclusion zones, muster points, and escalation triggers are aligned with the defined hazardous scenarios.

Furthermore, sufficient and fit-for-purpose gas detection equipment should be provided to support both routine operations and emergency response. As a minimum, detection capability should include:

- Ammonia toxic gas detection in ppm (low-range, resolution suitable for occupational exposure management and early warning), using equipment designed for toxic gas measurement performance in workplace atmospheres.
- Methanol vapour monitoring appropriate to the identified hazards, providing detection of methanol as a flammable vapour and enabling the monitoring of toxic exposure levels.

Due to the physical properties of methanol, elevated vapour concentrations are generally limited to the immediate vicinity of a spill and are only likely to form larger vapour clouds in the case of large-scale releases. Such scenarios are typically more localised and manageable when compared to ammonia releases, which can rapidly form larger vapour clouds that are toxic and corrosive, even at relatively low concentrations.

Methanol fire-fighting considerations 4.6.1.2

Methanol is a highly flammable liquid that burns with a nearly invisible flame, creating a significant hazard for emergency responders. Consequently, appropriate flame detection systems (e.g. IR/UV detectors) and thermal imaging equipment should be available where applicable to support early fire identification and safe response.

Extinguishing media and response strategy:

- Alcohol-resistant (AR) foam should be provided as the primary extinguishing medium for methanol pool and spill fires;
- Water spray or fog may be used for equipment cooling and vapour dispersion but should not be relied upon as the sole means of fire extinguishment;
- Dry chemical extinguishers may be used only for small, incipient fires;
- Fire-fighting strategies should prioritise fuel isolation and leak control, where safe to do so, while accounting for the limited visibility and low radiant heat of methanol flames.

Ammonia fire-fighting considerations 4.6.1.3

Ammonia is not readily flammable under normal ambient conditions; however, it poses a severe toxic and corrosive hazard. Fire-fighting strategies should therefore primarily focus on life safety, exposure control, vapour dispersion, and equipment cooling, rather than direct flame extinguishment.

In open areas, the likelihood of ignition of an ammonia vapour cloud is low. Ignition would generally require the presence of an external heat or ignition source in combination with a sustained high vaporisation rate, typically associated with a very large exposed liquid surface area. In the absence of

such conditions, vapour concentrations will not remain at or above the LFL, and sustained combustion is unlikely.

Key considerations include:

- Ammonia releases may form dense, toxic vapour clouds with significant downwind impact; life safety, evacuation, and access control should take precedence over fire suppression activities;
- In the event of an ammonia fire (typically under confined conditions or elevated concentrations), water spray or fog should be used to cool exposed equipment and structures and to support vapour dispersion;
- High-pressure water jets should not be applied directly to leaking liquid ammonia unless specifically required for vapour knock-down;
- The generation and management of contaminated firefighting runoff should be considered as part of the emergency response and environmental protection strategy.

Ammonia vapour suppression 4.6.1.4

The application of water as a response measure during an ammonia release should be evaluated on a case-by-case basis, with careful consideration of the potential consequences for personnel safety, environmental impact, and asset protection. The indiscriminate or automatic use of water may, under certain circumstances, aggravate the incident by increasing vapour generation or by spreading contamination.

In some scenarios, an ammonia release may disperse naturally into the atmosphere, limiting exposure. The application of water to suppress vapours can instead lead to the formation of ammonium hydroxide, resulting in contamination of soil, paved surfaces, or water bodies, with potentially greater impacts on responders, infrastructure, and the environment.

Emergency managers and response teams should understand the different release modes of ammonia including liquid releases, aerosols, and vapour releases and the distinct interactions that occur when water is applied to each.

Where water is used as part of the response strategy, the following should be considered:

- Direct application of water onto liquid ammonia should be avoided, as the interaction can significantly increase vaporisation and result in rapid and aggressive off-gassing;
- In confined or enclosed spaces, increased vapour generation may lead to elevated concentrations and, under certain conditions, may enter the flammable range, thereby increasing ignition risk;
- In open areas, while ignition is generally unlikely, the application of water may increase the density and extent of the vapour cloud and may intensify the effects of any associated fire;
- Aerosol releases may react less violently with water than liquid pools, but water application can still enhance vaporisation and produce effects similar to those observed with liquid releases;
- For vapour-phase releases, water curtains or sprays may absorb ammonia; however, depending on the release rate and water flow, a significant portion of the vapour cloud may pass through the water barrier, potentially exposing downwind personnel and receptors.
- Contaminated water runoff containing dissolved ammonia may travel beyond the immediate incident area, particularly via drainage systems, paved surfaces, or watercourses, and may continue to off-gas ammonia over distance and time, creating secondary exposure risks for responders, port personnel, and adjacent areas.

Response strategies involving water should therefore be carefully planned, risk-based, and aligned with the specific release scenario, taking into account atmospheric conditions, site layout, and the availability of alternative control measures.

Methanol first aid considerations 4.6.1.5

Methanol is a toxic substance that can be absorbed by inhalation, skin contact, or ingestion. Due to the risk of delayed and systemic effects, all suspected exposures should be treated seriously and followed by appropriate medical evaluation.

Methanol vapour inhalation, the affected person should be removed immediately to fresh air and kept warm, calm, and at rest. Breathing, level of consciousness, and general condition should be continuously monitored. Even if symptoms appear mild or absent initially, urgent medical assessment is required, as methanol exposure may result in delayed effects such as headache, dizziness, visual disturbances, or metabolic acidosis.

In the event of skin or eye contact with methanol, contaminated clothing, footwear, and contact lenses should be removed immediately. The affected skin or eyes should be flushed thoroughly with water for at least 15 minutes. Medical advice should be sought in cases of persistent irritation, significant exposure, or suspected systemic absorption, recognising that methanol can be absorbed through the skin. In cases of eye contact immediate medical support should be provided.

Ammonia first aid considerations 4.6.1.6

Due to the toxic and corrosive nature of ammonia, any suspected exposure whether to vapour or liquid should be treated as a medical emergency, and immediate first-aid measures should be initiated.

Affected skin or eyes should be rinsed promptly with copious amounts of water at low pressure. In cases involving inhalation exposure, supplemental oxygen should be administered where available, taking into account the severity and duration of respiratory exposure.

The extent of ammonia exposure may be difficult to assess initially, as symptoms can appear mild at first and subsequently worsen rapidly. Individuals who appear to recover following initial treatment may still experience delayed respiratory effects. For this reason, medical evaluation and continued observation for several hours are essential following any ammonia exposure. Access to specialist medical care should be arranged as early as practicable.

Decontamination of exposed personnel should be completed prior to transport into enclosed spaces, such as ambulances or rescue craft. Off-gassing from contaminated clothing or skin in confined environments can hinder medical treatment and pose additional risks to responders, even if concentrations are not immediately life-threatening.

Where clothing or personal protective equipment has been contaminated by cold liquid ammonia, removal should be undertaken with caution. Items should be thoroughly flushed with water before removal to prevent adhesion to the skin and further injury.

Methanol & Ammonia PPE requirements 4.6.1.7

It is essential to assess the potential exposure risk in order to define the appropriate personal protective equipment (PPE). As a minimum, standard PPE should be worn at all times, including long-sleeved coveralls, safety helmet, safety footwear, and protective gloves.

Based on the assessed exposure level, additional PPE requirements should apply as follows:

- Low exposure risk: Additional face shield should be worn. For ammonia an escape device should be considered.

- High exposure risk: Chemical-resistant protective suits with a full-face mask should be worn.
- Emergency responders: Fully encapsulating chemical protective suits in combination with self-contained breathing apparatus (SCBA) should be required.

Incidents reporting and lessons learned 4.6.2

Incident reporting is a key mechanism for ports to maintain oversight of bunkering safety and to support continuous improvement. For methanol and ammonia bunkering, ports should ensure that incidents, near-misses, and abnormal events are reported, reviewed, and used to inform future decisions on site suitability, operational controls, and permitting conditions.

This section addresses incident reporting from the port authority perspective, rather than internal company reporting systems.

What should be reported to the port 4.6.2.1

Ports should define clear reporting expectations covering, as a minimum:

- loss of containment, spills, or releases (liquid or vapour);
- activation of emergency systems, including ESD-1, ESD-2, or ERC;
- unexpected vessel movement, mooring failure, or drift outside the approved operational envelope;
- unplanned interruptions, aborted operations, or spurious shutdowns with safety relevance;
- SIMOPs conflicts or breaches of operational controls; and
- near-misses with credible potential for escalation.

Reporting thresholds and timescales should be proportionate to the severity of the event and aligned with existing port and national reporting requirements.

Immediate notification and escalation 4.6.2.2

Ports should require prompt notification of incidents that:

- affect safety zones, marine exclusion zones, or access control;
- may require emergency services involvement; or
- could have off-site or community impacts.

Clear escalation pathways should be established so that the port can:

- activate internal response arrangements;
- coordinate with emergency services, VTS, and other stakeholders; and
- implement temporary operational restrictions if required.

Investigation and follow-up 4.6.2.3

Ports should expect that:

- incidents are investigated by the responsible parties in line with their management systems; and
- findings relevant to port safety and operations are shared with the port authority.

For significant events, ports may:

- request a formal incident report;

- require corrective actions before further bunkering is authorised; and
- review whether site approvals, operational envelopes, or permit conditions remain appropriate.

The focus should be on causal understanding and risk reduction, rather than attribution of fault.

Lessons learned and continuous improvement 4.6.2.4

Ports should establish a mechanism to capture and apply lessons learned from:

- incidents and near-misses within the port;
- comparable events at other ports, where information is available; and
- relevant industry guidance and experience.

Lessons learned may inform:

- updates to port procedures, by-laws, or guidance;
- changes to site suitability or operational constraints;
- additional training or competence requirements; and
- engagement with stakeholders, including emergency services and neighbouring facilities.

Where appropriate, ports may share anonymised lessons learned with operators to promote consistency and learning across the port community.

Integration with permitting and governance 4.6.2.5

Incident reporting and lessons learned should be integrated into the port's governance framework, including:

- permitting and authorisation processes;
- periodic review of approved bunkering sites;
- renewal or modification of conditions for repeat operations.

This ensures that experience gained from operations is systematically fed back into decision-making, supporting safe and controlled development of methanol and ammonia bunkering within the port.

Special and non-routine cases 4.7

This section addresses special and non-routine cases, supporting ports in managing infrequent or non-standard scenarios that fall outside business-as-usual operations but still require appropriate controls.

It includes guidance for:

- Methanol or ammonia as fuel at ports without a bunkering framework
- Quantity and quality of fuel
- Support services, e.g. maintenance and gas freeing
- Debunkering

Methanol or ammonia as fuel at ports without a bunkering framework 4.7.1

Ports may receive vessels that use methanol or ammonia as fuel even where the port does not permit, support, or intend to develop bunkering for these fuels. This may occur during routine port calls, cargo operations, layovers, or when a vessel requests access as a port of refuge.

In such cases, the presence of a vessel using methanol or ammonia does not in itself constitute a bunkering activity. However, it introduces specific considerations for ports related to safety, emergency preparedness, and coordination.

This section provides guidance for ports on how to manage such situations without establishing or implying acceptance of bunkering operations.

Key principle for ports 4.7.1.1

A port that does not have a bunkering framework in place:

- is not required to permit bunkering or debunkering of methanol or ammonia; and
- may still safely accept vessels using these fuels, provided that appropriate precautions and awareness measures are in place.

The focus for the port is on safe presence and contingency readiness, not fuel transfer.

Routine port calls (no bunkering) 4.7.1.2

When a methanol- or ammonia-fuelled vessel calls at a port for purposes other than bunkering, ports should consider the following.

1. Awareness of fuel type
   - Confirm the fuel type used by the vessel as part of normal port call information.
   - Ensure relevant port departments (marine operations, safety, emergency response) are informed.

2. No-fuel-transfer condition
   - Clearly state that bunkering and debunkering are not permitted unless a specific framework and authorisation are in place.
   - Ensure this condition is reflected in port instructions or permits for the call.

3. Emergency preparedness
   - Confirm that port emergency plans can address credible scenarios involving the vessel's fuel (e.g. leak, fire, toxic release).
   - Ensure emergency services are aware that the vessel carries methanol or ammonia fuel, even if no transfer is planned.

4. Interface with port activities
   - Consider proximity to passenger areas, other vessels, or sensitive operations.
   - Apply additional controls only where justified by risk (e.g. access control during alongside stay).

Port of refuge situations 4.7.1.3

Where a methanol- or ammonia-fuelled vessel requests access as a port of refuge, additional considerations apply.

Ports should assess:

- the nature of the casualty and whether fuel systems are involved;
- whether remaining at sea presents a greater risk than controlled access to port waters;
- the dominant hazard (toxicity for ammonia; flammability for methanol); and
- the port's ability to establish temporary safety measures and coordinate emergency response.

Granting refuge does not imply approval for bunkering or debunkering. Any fuel-related intervention beyond stabilisation (e.g. fuel removal) should be subject to separate, explicit authorisation.

Emergency actions without a bunkering framework 4.7.1.4

Even where no bunkering framework exists, ports should be prepared for fuel-related emergencies involving visiting vessels. This includes:

- isolating areas and managing access if required;
- coordinating with fire, medical, and hazardous-materials responders;
- supporting the vessel in making the situation safe, without engaging in fuel transfer unless specifically authorised; and
- escalating to national or regional authorities where required.

Ports should avoid ad-hoc technical decisions and instead rely on existing emergency governance structures.

Communication and documentation 4.7.1.5

Ports should:

- document decisions taken when accepting methanol- or ammonia-fuelled vessels without a bunkering framework;
- clearly communicate any limitations or conditions imposed on the vessel; and
- ensure that lessons learned are captured to inform future preparedness.

Summary for ports 4.7.1.6

In summary:

- ports may safely receive methanol- or ammonia-fuelled vessels without permitting bunkering;
- the presence of such vessels requires awareness and emergency preparedness, not a full bunkering framework;
- port-of-refuge decisions should be risk-based and case-specific; and
- any fuel transfer remains a separate decision requiring explicit authorisation.

This approach allows ports to fulfil their safety and refuge responsibilities while maintaining clear boundaries on permitted activities.

Quantity and quality of fuel 4.7.2

The management of fuel quantity and fuel quality is an essential element of safe and reliable methanol and ammonia bunkering. While responsibility for fuel supply, custody transfer, and quality assurance primarily rests with suppliers and ship operators, ports have an important oversight and coordination role, particularly where fuel characteristics may affect safety, environmental protection, or port operations.

Methanol 4.7.2.1

For methanol used as a marine fuel, an international fuel specification is available. International Organization for Standardization ISO 6583:2024 – Methanol as a fuel for marine applications: General requirements and specifications defines key quality parameters, including purity, allowable contaminants, and test methods.

From a port perspective, this provides a clear reference baseline when reviewing bunkering documentation and compatibility assessments. Ports should be aware that deviations in methanol composition (e.g. water content, impurities) may:

- affect combustion performance and emissions;
- influence corrosion or material compatibility;
- increase operational or safety risks during storage and transfer.

Ports are not expected to verify fuel quality themselves but may reasonably expect operators to declare compliance with ISO 6583 or an equivalent agreed specification.

Ammonia 4.7.2.2

At present, there is no dedicated international marine fuel quality standard for ammonia as a marine fuel equivalent to ISO 6583 for methanol. Ammonia quality requirements are therefore typically defined through:

- project-specific specifications;
- supplier–operator agreements.

From a port perspective, the absence of a harmonised standard increases the importance of:

- clarity in declared fuel composition and purity;
- awareness of potential contaminants (e.g. water, oil, other nitrogen compounds) that may influence safety, corrosion, or release behaviour.

Ports should ensure that fuel quality assumptions used in risk assessments and dispersion modelling are consistent with the declared ammonia specification.

Fuel quantity and measurement 4.7.2.3

Accurate measurement of fuel quantity is important for:

- custody transfer;
- verification of transferred volumes / masses;
- post-incident investigation, if required.

Fuel quantity measurement may be achieved using:

- tank level measurements before and after bunkering;
- mass flow measurement systems.

In any case, standardized calculation methods for density and energy content are well established across the industry and are routinely applied when methanol and ammonia are shipped as cargo. In addition, local customs requirements should be evaluated to determine the units in which these products are to be declared. While this forms part of the bunker supplier's due-diligence obligations, the port can and should support the establishment of the initial framework for these fuels.

Summary for ports 4.7.2.4

Ports are not responsible for commercial custody transfer, but clarity on quantity measurement supports transparent risk management and emergency planning.

- the measurement method should be clearly defined in the bunkering documentation;
- assumptions on transferred quantity should be consistent with those used in risk assessment, particularly when defining worst-case or credible release scenarios;
- ports may wish to ensure that measurement systems are suitable for the fuel and operating conditions, especially where bunkering is conducted regularly.

Ports should:

- understand which fuel quality specification applies to each bunkering operation;
- ensure consistency between declared fuel properties and those assumed in risk and dispersion studies;
- confirm that fuel quantity measurement arrangements are clearly documented;
- recognise that changes in fuel composition or operating conditions may trigger the need for review of safety zones or compatibility assessments.

Support services, e.g. maintenance and gas freeing 4.7.3

General support services 4.7.3.1

Support services required for gas-freeing, gassing-up, cool-down, or debunkering operations typically necessitate additional technical assessments and, in many cases, a dedicated review of port permitting conditions and national regulatory requirements. These services may be provided by bunker suppliers, shipyards, or specialised repair and service facilities operating within the port area.

While the majority of such services are commonly offered by bunker suppliers, they introduce specific operational, environmental, and safety implications that should be addressed in advance. These activities may include, but are not limited to:

- Venting of inert or process gases
- Cool-down of bunker tanks (ammonia)
- Flaring or the use of portable gas combustion units (GCUs) during gas-freeing or cool-down operations, where applicable
- Debunkering or removal of fuel from bunker tanks

Venting operations 4.7.3.2

This section addresses planned, operational venting only, such as venting associated with inertisation, gas-freeing, purging, or other foreseeable and controlled operational activities. It does not cover emergency venting, which is considered an abnormal event and should be managed under the port's emergency response framework.

Any emergency venting, including venting required to protect life, vessel integrity, or prevent escalation of an incident, falls outside the scope of this section. Such events should be treated as emergencies, immediately reported to the port authority, and managed in accordance with the port's emergency response and incident reporting procedures.

National legislation, environmental permitting conditions, and port-specific operational limits should be carefully reviewed to determine which gases may be vented, which are prohibited from venting, and under what conditions venting is permitted. This assessment should explicitly consider both safety and environmental protection requirements, including air-quality limits, occupational exposure thresholds, odour nuisance, greenhouse gas emissions, and potential off-site impacts.

Venting of toxic, flammable, or environmentally harmful gases should not be considered normal or acceptable practice. In many jurisdictions, such venting is explicitly restricted or prohibited under environmental or occupational health legislation. Where venting is permitted, it should be minimised, justified, and subject to clear controls.

This is particularly relevant during inertisation, gas-freeing, or purging of bunker tanks and transfer systems, where vented streams may include nitrogen or other inert gases, as well as residual methanol or ammonia vapours. Ports should ensure that venting of residual fuel vapours is not undertaken unless explicitly authorised, appropriately controlled, and limited to designated locations.

Venting requirements should address:

- Permitted gas types and compositions
- Maximum allowable flow rates and durations
- Dispersion and exposure considerations
- Meteorological limitations

- Notification and reporting obligations to authorities

Flaring and GCUs 4.7.3.3

Where flaring is proposed, a site-specific assessment should be conducted to verify the suitability of the intended flare location. This assessment should typically include:

- Heat radiation calculations
- Assessment of safe distances to personnel, vessels, structures, and equipment
- Evaluation of ignition and escalation risks
- Notification and coordination with the local fire brigade and emergency services
- Compliance with environmental and emission limits

As an alternative, the use of portable gas combustion units (GCUs) is generally preferred, as these systems operate without open flames and therefore reduce ignition risks. However, GCUs may generate significant noise levels, which should be assessed against local noise regulations and port operational limits. Where required, additional mitigation measures or operational time restrictions may need to be implemented.

Summary for ports 4.7.3.4

All support-service activities related to gas-freeing, gassing-up, cool-down, flaring, GCU operation should be integrated into the port's permitting framework, SIMOPS procedures, and emergency response planning. Clear roles and responsibilities between the port authority, service provider, bunker supplier, terminal operator, and emergency services should be defined to ensure that these non-routine operations are conducted safely and in compliance with applicable legislation.

Debunkering 4.7.4

Debunkering is the removal of fuel from a vessel's fuel tanks, typically by transferring it to a receiving facility or temporary storage. It is considered a non-routine operation and is distinct from normal bunkering.

From a port perspective, debunkering may occur only in special circumstances, such as:

- urgent or unplanned maintenance;
- preparation for dry-docking or repair;
- damage to fuel systems; or
- other exceptional or emergency situations.

Debunkering is not normally part of routine port operations and is not expected to occur frequently. Debunkering operations may also require separate permitting or authority notification, particularly where hazardous or toxic fuels are involved.

Why debunkering is relevant for ports 4.7.4.1

Ports need to consider debunkering because, compared with bunkering, it may:

- take significantly longer to complete;
- involve reverse flow through transfer systems;
- it might generate higher quantities of vapour;
- require temporary storage or onward transfer of removed fuel; and
- introduce additional safety, environmental, and security considerations.

Debunkering may also interact with port traffic, berth availability, emergency planning, and environmental controls over an extended period.

Port approach to authorisation:

Debunkering is typically not automatically permitted in ports. Instead, ports may:

- allow debunkering only on a case-by-case basis;
- restrict it to clearly defined emergency or exceptional situations; and
- apply additional conditions compared with normal bunkering.

Ports should clearly define whether debunkering:

- is allowed within the port jurisdiction;
- is limited to emergency or maintenance-related scenarios; and
- requires specific authorisation from the port authority and, where applicable, national regulators.

Vessel procedures and port requirements:

Vessels intending to carry out debunkering should have specific, debunkering procedures in place, supported by a risk assessment.

Where debunkering is proposed, ports should request and review the vessel's debunkering procedures as part of the authorisation process. These procedures should demonstrate that:

- the operation can be carried out safely with the available equipment;
- vapour management and emissions are controlled as far as practicable;
- emergency shutdown and disconnection arrangements are addressed; and
- responsibilities between the vessel, receiving facility, and port are clearly defined.

Ports should avoid authorising debunkering where suitable procedures are not available or where risks cannot be adequately managed.

Handling of debunkered fuel 4.7.4.2

Ports should ensure that arrangements for debunkered fuel are clearly defined before authorisation is granted. This includes:

- identifying the receiving facility or storage location;
- confirming compatibility of transfer systems and reverse-flow arrangements;
- ensuring that environmental controls are in place to manage spills, and vapour release; and
- confirming responsibility for the fuel once it is removed from the vessel.

Ports should avoid authorising debunkering unless a safe and compliant destination for the removed fuel has been confirmed.

Safety and environmental considerations:

Ports should expect debunkering proposals to address:

- safety zones and access control for the full duration of the operation;
- management of vapour generation and venting, including minimisation of emissions where practicable;
- extended exposure of personnel and port users to the operation; and

- emergency response arrangements, including escalation pathways if conditions change.

Where debunkering is proposed as part of an emergency response, ports should recognise that normal controls may need to be adapted, while still aiming to minimise environmental impact and risk to people.

Summary for ports 4.7.4.3

In summary:

- debunkering is a non-routine, exceptional operation;
- ports may choose to permit it only under defined conditions, often limited to emergencies or essential maintenance;
- the destination and handling of debunkered fuel should be clearly defined and agreed in advance; and
- safety, environmental protection, and prolonged operational impacts should be explicitly considered before authorisation;
- Impose additional permitting requirements for the port

References

EMSA - Safety of ammonia for use in ships

IAPH - Port Readiness Level for Marine Fuels (PRL-MF) assessment tool for bunker ports

IMO - Interim guidelines for ships using ammonia as fuel - MSC.1/Circ.1687

IMO - Interim guidelines for ships using methyl/ethyl alcohol as fuel - MSC.1/Circ.1621

IMO - IGF Code, International Code of Safety for Ships using Gases or other Low-flashpoint Fuels

IMO - IGC Code, International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk

IMO - IBC Code, International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk

ISO 6583:2024 - Methanol as a fuel for marine applications: General requirements and specifications.

ISO 20519:2021 - Specification for bunkering of liquefied natural gas fuelled vessels

ISO/TS 16901:2022 - Guidance on performing risk assessment in the design of onshore LNG installations including the ship/shore interface

ISO/TS 18683 - Guidelines for safety and risk assessment of LNG fuel bunkering operations

OCIMF - International Safety Guide for Oil Tankers and Terminals (ISGOTT 6)

SGMF - GD-A033_Methanol as a Marine Fuel – An Introduction

SGMF - GD-A032_Ammonia as a Marine Fuel – An Introduction

SGMF - FP25-01_Accidental Release Preparedness and Response

SGMF - FP22-01_Methanol As Marine Fuel – Safety and Operational Guidelines – Bunkering

SGMF - FP23-01_Ammonia – Safety and Operational Guidelines – Bunkering

SGMF - FP02-01_Recommendations of Controlled Zones During LNG Bunkering

Appendix A: Bunkering Documentation for Ports

Port Documents Review Matrix A.1

Summary of typical key bunkering documents and actions required by ports:

1. Actual requirements may vary by port, bunkering scenario, and national regulation.
2. Ports typically focus on assurance and oversight, not operational control.

Table A-1: Port Documents Review Matrix

	Bunkering Stages				
Document	**Design / Early Planning**	**Planning & Permitting**	**Preparation (Operation-specific)**	**Operational Oversight**	**Typical Port Role**
Bunkering Management Plan	Review (draft)	Review for license approval	Reference	---	Primary assurance document
Design package / equipment technical specification	---	Reference	---	---	Vessel and equipment codes and regulatory compliance assurance
Risk assessment (incl. HAZID)	Review	Review -> approve	Confirm applicability	---	Verify risk acceptability
Safety zones & hazardous areas	Review (concept)	Review -> approve	Confirm implementation	Enforce	Assure safe port operations

	Bunkering Stages				
Document	**Design / Early Planning**	**Planning & Permitting**	**Preparation (Operation-specific)**	**Operational Oversight**	**Typical Port Role**
SIMOPs assessment	Review (concept)	Review -> approve	Confirm implementation	Enforce	Coordinate port activities
Emergency response arrangements	Review	Review -> approve	Confirm emergency preparedness	Coordinate	Assure port emergency readiness
Training & competence records	---	Review (framework)	Confirm availability	---	Verify preparedness
Quality and quantity agreement	---	Reference	Reference	---	Awareness / emergency input
Bunkering procedure	---	Acknowledge	Reference	---	Operator responsibility
Bunkering checklist	---	Acknowledge format	Confirm completeness	---	Execution tool (operators)
Compatibility assessment / report	---	Acknowledge format	Confirm completeness	---	Interface assurance (operators)
Joint Bunkering Plan (JBP)	---	Review (framework)	Review -> acknowledge or approve (if required)	Reference	Key short operational summary

Documentation Expectations by Operation Maturity Level A.2

Table A-2: Documentation Expectations by Operation Maturity Level

	Early-Stage Ports (Pilot / First-of-a-Kind Operations)	**Business-as-Usual Ports (Established Operations)**
Aspect	**Typical Expectation**	**Typical Expectation**
Documentation depth	More detailed and conservative	Proportionate and streamlined
Bunkering Management Plan	Full submission typically required	Referenced master document
Risk assessment	Site-specific, conservative assumptions	Updated only when conditions change
Safety zones	Larger, precautionary zones	Optimised based on experience
SIMOPs assessment	Restrictive controls	Standardised procedures
Emergency planning	Extensive coordination and drills	Integrated into port systems
Training evidence	Detailed and fuel-specific	Periodic verification
Bunkering checklist	Detailed and operation specific	Standardised procedures
Compatibility assessment	Detailed and operation specific	Standardised procedures
Joint Bunkering Plan (JBP)	Mandatory and closely reviewed	Primary approval document
Port involvement	High (frequent reviews, inspections)	Oversight and enforcement
Objective:	**Build confidence, manage uncertainty, and capture lessons learned.**	**Enable efficient operations while maintaining safety and compliance.**

Documentation Expectations Aligned with IAPH PRLs A.3

The IAPH Port Readiness Level for Marine Fuels (PRL-MF) framework defines nine progressive levels covering research, development, deployment, and market maturity for bunkering a specific marine fuel.

Documentation requirements for methanol and ammonia bunkering should evolve in line with these levels and remain proportionate to port maturity and operational experience.

Key alignment principles:

1. Documentation depth decreases as PRL-MF increases, but never disappears.
2. Early PRL-MF levels emphasise learning, analysis and framework design.
3. Middle levels focus on testing, pilots and validation.
4. Higher levels prioritise standardisation, efficiency and market growth.
5. The Bunkering Management Plan and Joint Plan of Bunkering Operation are central tools throughout, with their role evolving rather than expanding.

Note on Port Readiness Level (PRL) applicability

This Guidebook is designed primarily to support ports at Port Readiness Levels (PRL-MF) 1 to 4, where ports are developing foundational knowledge, assessing feasibility, and establishing the frameworks required for methanol and ammonia bunkering. It provides practical guidance to help ports progress through these early readiness stages and prepare for implementation.

At the same time, the Guidebook supports ports in transitioning from pilot and project-based operations to business-as-usual bunkering, corresponding to PRL-MF 5 to 9. As ports gain experience, the guidance can be used to refine procedures, streamline documentation, and support the safe scaling-up of methanol and ammonia bunkering operations.

PRL-MF 1 – Foundational Background Information

Objective (IAPH): establish baseline understanding of the target fuel.

Documentation expectations

- High-level overview of methanol or ammonia properties and hazards
- Initial regulatory scan (IMO, ISO, EU, national)
- Preliminary stakeholder mapping
- Reference material (IAPH, EMSA, SGMF, class guidance)

Port authority focus

- Awareness building
- Internal capacity development
- No operational approvals

PRL-MF 2 – Stakeholder Interest and Feasibility Assessment

Objective: assess stakeholder interest and feasibility of bunkering.

Documentation expectations

- Preliminary feasibility and safety considerations
- Initial identification of bunkering scenarios
- Early engagement records with regulators and emergency services

Port authority focus

- Understanding feasibility and constraints
- Identifying regulatory and safety gaps

PRL-MF 3 – Detailed Research, Analysis and Conclusions

Objective: support an informed decision on whether to proceed.

Documentation expectations

- Gap analysis against regulatory and safety requirements
- Preliminary risk assessment (high-level)
- Initial safety-zone concepts
- Identification of required services (e.g. emergency response, debunkering)

Port authority focus

- Decision point: proceed or halt
- Early definition of competent-authority roles

PRL-MF 4 – Framework Drafted, Roadmap and Timeline Developed

Objective: define how bunkering could be implemented.

Documentation expectations

- Draft port-level bunkering framework
- Draft permitting and approval process
- Draft SIMOPs and emergency-response concepts
- Communication and stakeholder-engagement plan

Port authority focus

- Acting as framework owner
- Ensuring alignment with national legislation

PRL-MF 5 – Framework Implementation, Testing and Training

Objective: test and validate the framework.

Documentation expectations

- Bunkering Management Plan submitted for review
- Detailed risk assessment (incl. safety zones and SIMOPs)
- Compatibility assessment methodology
- Training plans and competence requirements
- Emergency response plans aligned with port systems
- Draft JBPtemplates

Port authority focus

- Acting clearly as competent authority
- Approving framework and readiness to pilot

PRL-MF 6 – Pilot-Scale Demonstration

Objective: conduct controlled pilot bunkering operations.

Documentation expectations

- Operation-specific JBP
- Confirmed Bunkering Management Plan
- Final risk assessment for pilot
- Emergency drills and exercise records
- Incident and lessons-learned reporting

Port authority focus

- Close operational oversight
- Conservative safety zones and controls
- Feedback into framework refinement

PRL-MF 7 – Project-Based Bunkering Established

Objective: repeat operations on a project basis.

Documentation expectations

- Bunkering Management Plan maintained as a living document
- JBP for each operation
- Updated risk assessments where conditions change
- Standardised checklists and procedures

Port authority focus

- Oversight and enforcement
- Refinement of SIMOPs and traffic management

PRL-MF 8 – Full Capabilities for Bunkering Established

Objective: enable routine bunkering operations.

Documentation expectations

- Bunkering Management Plan referenced rather than resubmitted
- JBP as primary approval document
- Risk assessments updated only for material changes
- Integrated emergency and Vessel Traffic Services (VTS) procedures
- Periodic training verification

Port authority focus

- System-level governance
- Reduced case-by-case intervention

PRL-MF 9 – Market Penetration and Growth

Objective: support mature, competitive bunkering market.

Documentation expectations

- Standardised documentation processes
- Continuous-improvement and performance monitoring
- Periodic framework reviews

Port authority focus

- Strategic oversight
- Market facilitation while maintaining safety

Appendix B: Bunkering Site Identification Process

This appendix provides a practical, staged process that ports can apply to identify, approve, and operationalise bunkering locations for methanol and ammonia.

It complements section 4.2 by expanding on implementation-level considerations, with a particular focus on port activities.

Note: The bunkering site identification process described in this appendix is indicative and non-prescriptive. It is intended to provide a practical reference framework for ports, rather than a mandatory sequence of steps.

Depending on national legislation, port governance structures, regulatory arrangements, and local practice:

- some steps may be undertaken in a different order;
- certain steps may be combined or iterated;
- responsibilities may sit with different organisations; and
- additional steps or decision gates may be required.

Ports are therefore encouraged to apply this process flexibly, adapting it to their local regulatory and organisational context, while ensuring that all key considerations described in this appendix are addressed before bunkering operations are authorised.

Establish governance and ownership

- Assign clear internal ownership and decision authority for alternative fuel bunkering.
- Define competent authority roles and escalation paths across port and national bodies.
- Agree risk acceptance criteria and documentation expectations upfront.

Identify candidate bunkering locations

- Proactively shortlist suitable berths, terminals, and anchorages.
- Assess space for safety zones, access control, and emergency response.
- Exclude locations that are clearly unsuitable at an early stage.

Define applicable bunkering supply scenarios

- Identify feasible supply modes (STS, shore-to-ship, mobile-to-ship) per location.
- Check physical and interface constraints (manifolds, hoses, access, infrastructure).
- Base later risk assessments on realistic, achievable configurations.

Screen fuel suitability by location

- Assess dominant hazards (flammability or toxicity) for each fuel.
- Evaluate impacts on people, infrastructure, and neighbouring areas.
- Exclude locations where fuel-specific risks cannot be reasonably managed.

Undertake site-level risk assessment

- Define safety zones, exclusion areas, and navigational controls.
- Assess SIMOPs restrictions and emergency access arrangements.
- Document assumptions, credible scenarios, and required controls.

Define operational envelopes and constraints

- Translate risk outcomes into clear operational limits.
- Set constraints for inventory, weather, SIMOPs, and traffic management.
- Adjust transfer parameters where space is constrained, not safety distances.

Engage external stakeholders

- Review sites and envelopes with regulators, terminals, VTS, and emergency services.
- Confirm alignment with legislation and emergency response requirements.
- Identify additional conditions early to avoid late objections.

Develop the bunkering map and site register

- Consolidate approved and conditional bunkering locations.
- Define permitted fuels, supply scenarios, and operating limits per site.
- Use the register to support transparency and consistent decision-making.

Integrate into permitting and port procedures

- Embed site decisions into by-laws, permits, and port rules.
- Align document submission and review workflows.
- Enable efficient, consistent assessment of future bunkering requests.

Establish governance and ownership B.1

Ports should begin by establishing clear governance arrangements for alternative fuel bunkering. This includes assigning internal responsibility and defining how decisions will be made and approved.

Key actions include:

- Appointing port leads responsible for alternative fuel bunkering, typically involving safety, marine operations, environment, and permitting functions.
- Clearly defining decision authority, including when the port acts as the competent authority and when responsibilities sit with national administrations, regulators, or other bodies.
- Establishing how decisions are escalated and documented, particularly where multiple authorities are involved at different stages.
- Agreeing an internal risk acceptance approach, including high-level criteria for what constitutes acceptable risk for methanol and ammonia bunkering.
- Defining documentation expectations, including the level of detail required at site, planning, and operation stages (e.g. BMP, JBP, risk assessments).

Early clarity on governance avoids uncertainty later and supports consistent, defensible decision-making.

Identify candidate bunkering locations B.2

Ports should proactively identify and shortlist potential bunkering locations rather than assessing requests on an ad-hoc basis.

This typically includes:

- Reviewing existing berths, quays, terminals, anchorages, and lay-by areas.
- Considering physical space available for safety zones, access control, and emergency response.
- Assessing proximity to neighbouring terminals, public areas, buildings, roads, railways, and utilities, including outside the port boundary.
- Evaluating whether emergency services can reach and operate safely at the location.
- Identifying locations where bunkering is clearly unsuitable and excluding them early.

The outcome should be a shortlist of candidate locations suitable for further assessment.

Define applicable bunkering supply scenarios B.3

For each candidate location, ports should identify which bunkering supply scenarios are feasible.

This includes:

- Assessing suitability for ship-to-ship (STS), shore-to-ship, and mobile-to-ship operations.
- Identifying interface constraints such as:
    - hose or transfer arm reach;
    - manifold height and orientation;
    - availability of fixed infrastructure;
    - road access and turning space for trucks or portable tanks.
- Recognising that some locations may support only one scenario, while others may support multiple.

This step ensures that later risk assessments are based on realistic and achievable configurations.

Screen fuel suitability by location B.4

Ports should apply an early fuel-specific screening to determine whether a location is suitable for methanol, ammonia, or both.

This screening should consider:

- Dominant hazard drivers (flammability for methanol, toxicity for ammonia).
- Potential impact on people, infrastructure, and neighbouring areas.
- Ability to establish and enforce safety zones and marine exclusion zones.
- Compatibility with emergency response capabilities.

Locations where the fuel-specific risks cannot be reasonably managed should be excluded at this stage, even if they are suitable for other fuels.

Undertake site-level risk assessment B.5

For each shortlisted location and fuel, a baseline site-level risk assessment should be performed.

This assessment should address:

- Definition of hazardous areas, safety zones, and toxic areas (as applicable).
- Identification of required marine exclusion zones and navigational controls.
- Assessment of SIMOPs, including which activities may need to be restricted or prohibited during bunkering.
- Evaluation of emergency access, escape routes, and escalation pathways.

The assessment should clearly document:

- assumptions and limitations;
- credible release scenarios;
- operational boundaries;
- required mitigation and control measures.

Define operational envelopes and constraints B.6

Risk assessment outputs should be translated into practical, enforceable operational limits, often referred to as the operational envelope.

This may include:

- Maximum inventory involved in a single operation.
- Weather and visibility limits.
- SIMOPs restrictions and traffic management measures.
- Minimum competence, training, and staffing requirements.

Where physical space is constrained, ports should require adjustment of transfer parameters and operational limits so that safety zone remain achievable and enforceable, rather than arbitrarily reducing safety distances.

Engage external stakeholders B.7

Early and structured engagement with external stakeholders is essential.

Ports should:

- Review proposed sites and operational envelopes with national regulators, terminal operators, VTS/pilotage services, and emergency services.
- Confirm alignment with national legislation, emergency planning requirements, and response capabilities.
- Identify any additional conditions or constraints required by external authorities.

This step reduces the risk of late objections or conflicting requirements.

Develop the bunkering map and site register B.8

Ports should consolidate outcomes into a bunkering map and site register, which may be internal or partially public.

The map/register should identify:

- approved and conditionally approved bunkering locations;
- fuels permitted at each location;
- permitted bunkering supply scenarios;
- key operational envelopes and constraints.

Integrate into permitting and port procedures B.9

Finally, the site framework should be embedded into port governance and processes, including:

- port by-laws and local rules;
- permitting and authorisation workflows;
- document submission requirements (e.g. BMP, JBP);
- review and approval timelines.

This ensures that future bunkering requests can be assessed efficiently and consistently against an established framework.

WHY EARLY SITE IDENTIFICATION IS USEFUL:

Conducting site identification and risk-based location assessment in advance allows ports to move from reactive decision-making to a planned, consistent approach. This is particularly important for methanol and ammonia because early operations often involve uncertainty, multiple stakeholders, and evolving regulatory expectations.

Early work enables the port to:

- **Reduce lead time** when a vessel or supplier requests bunkering, avoiding ad-hoc approvals under time pressure.
- **Provide clarity to the market** by indicating where and under what conditions bunkering may be accepted.
- **Apply consistent risk acceptance criteria** across different requests, improving transparency and defensibility.
- **Identify infrastructure or capability gaps** (space for safety zones, access control, emergency response resources) and address them before operations begin.
- **Coordinate stakeholders early** (regulators, terminals, emergency services, VTS, neighbours), reducing late-stage changes and misalignment.
- **Support permitting and authorisation** with pre-established site-level assessments, rather than repeating foundational work for each operation.

Apepndix C: Port checklist: reviewing a proposed safety zone

This appendix complements section 4.4 and it provides a practical process that ports can apply to review and where requested approve a safety zone proposal from operators planning bunkering operations under their port jurisdiction.

When a bunkering operator proposes safety zone for a methanol or ammonia bunkering operation, the port authority-often acting as, or supporting, the competent authority-should verify that the proposal is risk-based, site-specific, and operationally enforceable.

1. Basis and methodology

   - Confirm that the safety zone is derived from a documented risk assessment, using recognised methodologies appropriate to the fuel and bunkering scenario.
   - Verify that credible release scenarios have been identified for the actual transfer system configuration (e.g. hoses, transfer arms, connectors, ERCs, valves, manifolds).
   - Check that the hazard driver used to define the safety zone is clearly justified (e.g. flammability for methanol, toxicity for ammonia, or a combination where relevant).

2. Assumptions and key drivers

   - Review the main assumptions that influence safety zone size, including:
     - transfer pressure and flow rate;
     - storage and transfer conditions (temperature, phase);
     - detection and isolation time (ESD performance);
     - static inventory involved;
     - local meteorological conditions and dispersion assumptions;
     - physical layout, obstructions, and ventilation.
     - appropriate and compliant flammability and toxicity threshold levels have been selected
   - Confirm that assumptions reflect local port conditions and are not generic or overly optimistic.

3. Control, access and enforceability

   - Ensure that the proposed safety zone lies within a space where effective control can be exercised during bunkering.
   - Verify that access restrictions, exclusion measures, and control of ignition sources or personnel exposure can be implemented and enforced in practice.
   - Check that the safety zone is clearly defined, communicated, and compatible with port security and access arrangements.

4. Interface with port operations and SIMOPs

   - Confirm that the safety zone has been assessed against simultaneous operations (SIMOPs), including cargo handling, passenger movements, maintenance activities, and vessel traffic.

- Verify that any required restrictions, suspensions, or sequencing of activities are clearly identified and acceptable from a port operations perspective.
- Ensure alignment with marine exclusion zones and vessel traffic management measures, where applicable.

5. Emergency preparedness and escalation

- Check that emergency response arrangements are consistent with the assumptions used to define the safety zone.
- Verify coordination with port emergency plans, emergency services, and neighbouring facilities, where relevant.
- Confirm that escalation procedures are defined should conditions change or an abnormal situation occur.

Additional considerations for ports C.1

1. **Safety zone sizing is fuel-specific.** Although safety zones for LNG and methanol are both influenced by flammability-related hazards, the flammability characteristics and dispersion behaviour of the two fuels differ significantly. For ammonia, the dominant driver for safety zone definition is typically toxicity and exposure, rather than flammability. As a result, LNG safety distances and zone definitions should not be directly reused for methanol or ammonia without a fuel-specific risk assessment and appropriate modelling.
    a. **National toxicity thresholds for ammonia and methanol may differ** across countries and national legislations. Ports should therefore confirm the applicable national exposure limits and emergency planning criteria and ensure that dispersion modelling assumptions, safety zone definitions, PPE requirements, and emergency procedures are aligned with those national requirements.

2. **Safety zones are operation-specific and should be reviewed for each bunkering operation,** taking into account the actual vessel, location, transfer system, and conditions. This does not necessarily require recalculation of the safety zone, but confirmation that the assumptions and conditions on which they were based remain valid and applicable.

3. **Use of generic or envelope safety zones.** Where appropriate, ports may agree on a generic or envelope safety zone that covers a defined range of operational profiles (e.g. different vessels or transfer rates), provided this is supported by a conservative risk assessment.

4. **Applicability limits should be explicit.** Any safety zone intended to cover multiple operational profiles should clearly define its assumptions, limits, and applicability, and identify when a re-assessment is required.

5. **Adjusting transfer parameters to match physical constraints.** Safety zone for a specific location and bunkering scenario are normally defined based on the bunkering risk assessment and the associated transfer parameters (e.g. flow rate, pressure, inventory, duration). However where physical layout limitations-such as buildings, roads, rail lines, quays, or other fixed infrastructure-constrain the available space, ports may agree to adjust the bunkering transfer parameters so that the resulting safety zones fit within the space available.

    a. In such cases, the safety zone should not be arbitrarily reduced. Instead, the risk assessment should demonstrate that the modified transfer parameters (e.g. reduced

flow rate or pressure, staged transfer, reduced inventory, or shorter transfer duration) lead to a corresponding reduction in the extent of the safety zone.

b. Additional operational controls-such as enhanced monitoring, stricter access control, tighter weather limits, or increased supervision-may also be required to ensure that an equivalent level of safety is maintained.

6. **Onshore inventory limits and land-based permitting considerations.** For shore-to-ship and mobile-to-ship arrangements, ports should consider whether national or regional legislation places inventory limits on the quantity of hazardous or toxic substances permitted on land, even when held temporarily (e.g. within a terminal boundary, in temporary storage, or in mobile units). Such limits may influence:

    a. allowable transfer quantity;
    b. siting and separation distances for temporary equipment;
    c. permitting routes, notifications and competent authority involvement; and
    d. emergency planning assumptions for onshore populations and neighbouring facilities.

    Where such constraints apply, they should be addressed explicitly in the authorisation process and reflected in operational controls.

7. **Security-related restrictions for toxic substances.** Some national legislation may impose additional restrictions for toxic substances on security grounds (e.g. due to misuse potential). These requirements may apply to both land and waterside activities and may include enhanced access control, escorting, surveillance, restricted areas, movement controls, and additional verification of personnel and contractors. Ports should:

    a. confirm applicable security requirements early in the planning stage;
    b. integrate them with existing port security arrangements (e.g. ISPS and local security plans); and
    c. ensure roles and responsibilities are clear between port, terminal, supplier and ship.

8. **Safety zones should remain temporary and dynamic**, applied only for the duration of bunkering and adjusted or withdrawn once operations are complete.

9. **Change management.** Changes to the operation (e.g. different supply scenario, equipment, weather limits, or SIMOPs) should trigger a review of the safety zone.

10. **Optimisation over time.** As ports gain experience and move toward business-as-usual operations, safety zone may be optimised, but only where supported by updated risk assessments and competent-authority approval.

Appendix D: Further considerations on HAZID, HAZOP and SIMOPs

This Appendix provides practical guidance to support ports, operators, and other stakeholders in preparing, reviewing, and applying HAZID, HAZOP, and SIMOPs assessments for methanol and ammonia bunkering operations.

It complements sections 4.3 by expanding on implementation-level considerations, with a particular focus on port environments and interfaces.

Hazard Identification (HAZID) D.1

HAZID is a systematic hazard identification exercise, typically applied at an early stage of development or prior to first or pilot operations. From a port perspective, HAZID is particularly valuable to:

- identify hazards at the ship–shore–port interface;
- support site screening and selection;
- identify constraints affecting controlled areas and SIMOPs;
- inform permit conditions and operational envelopes.

HAZID workshops should involve representatives from the bunkering supplier, receiving ship, port authority, terminal operator, and emergency services, as appropriate.

Typical operational nodes for HAZID:

The following list may be used to structure a HAZID exercise for methanol and ammonia bunkering. These nodes define the extent of the system being analysed and should be considered for all operations that will take place:

- preparation (compatibility checks, testing, mooring);
- connection of transfer system;
- inerting or purging of relevant pipe sections;
- transfer start;
- transfer at nominal flow;
- transfer stop, including topping-up;
- draining and purging;
- inerting (post-transfer);
- disconnection;
- commissioning or return to service;
- security and access control;
- local factors (e.g. weather, visibility);
- generic and port-specific issues.

Ports should ensure that port-side activities and interfaces are explicitly included, not only shipboard systems.

HAZID guidewords:

To guide and structure the HAZID workshop, the following guidewords may be applied. The list is not exhaustive and should be adapted to the fuel and scenario:

- toxicity (particularly critical for ammonia);
- leakage;
- rupture;
- corrosion;
- impact (e.g. ship, vehicle, dropped objects);
- fire/explosion;
- structural integrity;
- mechanical failure;
- control or electrical failure;
- human error;
- manufacturing defects;
- material selection;
- flange or connector failure;
- vapour management;
- ESD valve control failure;
- ERC failure;
- loss of containment (piping, valves);
- liquid leaks;
- hose damage;
- major structural damage;
- vapour dispersion;
- vapour entering air intakes;
- excessive transfer rate;
- hydraulic power unit failure;
- communication failure;
- blackout;
- relative motion of vessels;
- SIMOPs;
- vent unexpectedly not closing;
- harsh weather.

For ammonia, toxicity-related consequences and dispersion should be explicitly addressed at each node. For methanol, flammability, ignition sources, and fire escalation require particular attention.

Hazard and Operability Study (HAZOP) D.2

HAZOP is a detailed, structured analysis, typically applied once system design and operating philosophy are defined. It focuses on how the system behaves under deviations from intended operation.

From a port perspective, HAZOP is relevant where:

- fixed or semi-permanent infrastructure is involved;

- complex interfaces exist between ship, shore, and port systems;
- deviations could affect controlled areas or SIMOPs.

Ports are not expected to lead HAZOPs but should review outcomes that affect port safety, operability, and emergency response.

Operational modes to be considered:

HAZOP should address the full range of operational modes, including:

- start-up;
- normal operations;
- normal shutdown;
- emergency shutdown.

Typical HAZOP nodes:

HAZOP is normally conducted at P&ID level. Typical nodes include:

- storage tank;
- fuel transfer system;
- vapour return system;
- fuel supply to consumers;
- utility systems supporting operations;
- emergency and supporting systems (e.g. venting, detection).

Guidewords and deviations:

Each node should be examined using guidewords such as:

- no flow;
- low flow;
- high flow;
- reverse flow;
- overpressure;
- underpressure;
- wrong composition;
- loss of containment.

Practical considerations for ports:

When reviewing HAZOP outcomes, ports should focus on:

- joining and coordination of ESD systems between ship, shore, and transfer system;
- emergency shutdown and quick-release protocols;
- emergency unmooring scenarios;
- loss of power (ship and shore, including changeover);
- emergency venting of fuel or vapour;
- need for external assistance (e.g. tugs);
- implications for controlled areas and marine exclusion zones;

- human-factor issues, including fatigue, stress, and workload during bunkering.

SIMOPs (Simultaneous Operations) Assessment D.3

SIMOPs assessments address combined risks arising when bunkering occurs alongside other activities. From a port perspective, SIMOPs management is critical, as ports are responsible for coordinating multiple users and activities within a shared environment.

The risk level for each SIMOP should be acceptable and consistent with the port's risk tolerance, as defined by the competent authority, and agreed by all parties involved.

Activities requiring SIMOPs assessment:

SIMOPs assessment should consider, as a minimum:

- cargo handling;
- ballasting operations;
- passenger embarking/disembarking;
- vehicles embarking/disembarking;
- dangerous goods loading/unloading;
- loading or unloading of stores and provisions;
- handling of chemical products, including toxic cargoes;
- handling of other low-flashpoint products;
- bunkering of fuels other than methanol or ammonia;
- maintenance, construction, testing, and inspection activities;
- hot work or any activity that could generate sparks;
- any external activities that may pose a hazard during bunkering;
- activities that may distract the bunkering crew;
- shipboard operations affecting vessel stability or power systems.

Minimum considerations for SIMOPs risk assessment

SIMOPs risk assessment should take into account, at a minimum:

- size and location of the bunkering Safety Zone, Monitoring and Security Area, and any Toxic Area;
- interaction between safety zones introduced by bunkering and those associated with other activities;
- credible failure and impact scenarios;
- access, egress, and escape/evacuation routes;
- transfer scenario (ship-to-ship, shore-to-ship, mobile-to-ship);
- largest credible spill or release;
- transfer flow rate and duration;
- type of cargo or passenger operation;
- safeguards to control passenger and cargo movements;
- dropped-object risks;
- vent mast positions, air intakes, and exhausts;
- restrictions related to hazardous cargo handling.

Port expectations:

Ports should ensure that:

- SIMOPs decisions are clearly documented and reflected in permits and operational plans;
- prohibited or restricted activities are unambiguous and enforceable;
- SIMOPs arrangements are communicated to all relevant port users;
- SIMOPs assessments are reviewed whenever operational conditions change.

Appendix E: Ports Roadmap Checklist

Ports Roadmap to Bunkering

CHECKLIST for steps and decision gates for alternative fuels bunkering

The ports roadmap is structured into 15 implementation steps, grouped into four development phases, and punctuated by four decision gates.

Phase A – Strategic foundation *(Steps 1–4 | Gate 1)*

Step 1 – Assess the business case and strategic rationale

Clarify why alternative fuel bunkering is relevant to the port, which fuels are in scope, and over what timeframe.

Strategic drivers

☐ Market demand from shipping lines, bunker suppliers, or other interests has been assessed.
☐ Alignment with national or regional decarbonisation policy has been reviewed.
☐ Competitive positioning relative to neighbouring ports has been considered.
☐ Existing cargo flows and/or fuel handling experience have been analysed.
☐ Strategic positioning (e.g. fuel hub, early mover, follower) has been discussed at leadership level.

Strategic clarity

☐ Fuels in scope have been identified (fuel-agnostic approach applied).
☐ Indicative time horizon has been defined (near-term pilots / medium-term deployment / long-term).
☐ The intended port role has been clarified (facilitator, regulator, competent authority, landlord, operator).
☐ Internal strategic risks and opportunities have been documented.

Deliverable

☐ A documented internal position paper or briefing note.

Step 2 – Build internal knowledge and assign ownership

Establish baseline fuel knowledge and assign clear internal responsibility across safety, marine, environment, and permitting functions.

Organisational ownership

☐ A named internal lead or cross-functional team has been appointed.
☐ Reporting lines and accountability are defined.
☐ Responsibilities across, safety, marine, environment, permitting, legal, and communications are mapped.

Technical baseline knowledge

☐ Basic properties and hazards of relevant alternative fuels are understood.
☐ Operational implications for navigation, cargo handling, SIMOPs, and emergency response are reviewed.

Institutional capability

☐ Key knowledge gaps have been identified.
☐ External advisory or technical support needs have been assessed

Deliverable

☐ Internal briefing materials or knowledge pack prepared.

Step 3 – Establish governance and competent authority roles

Define decision authority, escalation paths, and internal risk acceptance principles.

Authority and legal position

☐ The role of the port authority has been clarified (full or partial competent authority).
☐ Interfaces with national regulators and administrations are mapped.
☐ Legal basis for port decision-making has been reviewed.

Decision-making framework

☐ Decision responsibilities are formally assigned.
☐ Escalation pathways are defined.
☐ Cross-department coordination mechanisms are agreed.

Risk governance

☐ High-level risk acceptance principles are defined.
☐ Alignment with national risk criteria (where applicable) has been considered.

Deliverable

☐ Governance and authority structure documented and approved internally.

Ports Roadmap to Bunkering

CHECKLIST for steps and decision gates for alternative fuels bunkering

The ports roadmap is structured into 15 implementation steps, grouped into four development phases, and punctuated by four decision gates.

Step 4 – Understand the regulatory and standards landscape

Identify applicable national and international regulations, standards, and guidance, and where early regulator engagement is needed.

Regulatory mapping

☐ National legislation relevant to bunkering has been identified.
☐ Port permit conditions and local by-laws have been reviewed.
☐ Applicable international conventions and IMO instruments are identified.
☐ Relevant ISO standards and recognised industry guidance are identified.

Gap and interface analysis

☐ Areas requiring clarification or interpretation are identified.
☐ Potential regulatory gaps are documented.
☐ Early regulator engagement needs are identified.

Principle confirmation

☐ No attempt has been made to create new port-specific rules prematurely.
☐ The approach is based on adapting and applying existing instruments where possible.

Deliverable

☐ Regulatory landscape summary prepared and approved internally.

Gate 1 – Strategic Readiness and Internal Alignment

Decision focus: Is there a clear strategic case and sufficient internal alignment to proceed?

Confirms that:

☐ A strategic rationale and indicative timeline are defined
☐ Internal ownership and governance are clear
☐ Regulatory context is understood at a high level
☐ No fundamental barriers are evident

Phase B – Feasibility and alignment *(Steps 5–8 | Gate 2)*

Step 5 – Wider stakeholder and public engagement

Engage regulators, terminals, emergency services, port users, and - where relevant - local authorities and the public

Stakeholder identification

☐ National regulators identified and mapped.
☐ Local regulators and authorities identified.
☐ Terminal operators and berth owners identified.
☐ Shipowners and bunker suppliers identified.
☐ Emergency services identified (fire, medical, coastguard, etc.).
☐ Neighbouring industries and port users identified.
☐ Local authorities and public stakeholders identified where relevant.

Engagement strategy

☐ Engagement objectives defined (information, consultation, alignment).
☐ Communication channels agreed (meetings, workshops, briefings).
☐ Engagement responsibilities assigned internally.

Risk and perception management

☐ Key stakeholder concerns identified and documented.
☐ Public perception risks assessed (particularly for higher-consequence fuels).
☐ Alignment with emergency services initiated.
☐ Clear explanation of port role and authority communicated.

Deliverables

☐ Stakeholder engagement log created and maintained.
☐ Summary of stakeholder feedback documented.
☐ Issues register created with mitigation actions.

Ports Roadmap to Bunkering

CHECKLIST for steps and decision gates for alternative fuels bunkering

The ports roadmap is structured into 15 implementation steps, grouped into four development phases, and punctuated by four decision gates.

Step 6 – Identify potential bunkering locations

Proactively screen and shortlist candidate locations based on navigational, spatial, and emergency response considerations.

Physical screening

☐ Berths, quays, anchorages, and interfaces reviewed.
☐ Manoeuvring and navigation constraints assessed.
☐ Traffic density and SIMOPs complexity considered.
☐ Access routes for supply modes reviewed (marine and/or road).

Spatial and sensitivity review

☐ Proximity to people, buildings, and sensitive receptors assessed.
☐ Interaction with neighbouring industrial activities reviewed.
☐ Emergency access and egress routes assessed.
☐ Compatibility with existing port zoning evaluated.

Fuel-agnostic suitability assessment

☐ Recognition that suitability may vary by fuel type.
☐ Preliminary constraints documented for each candidate location.

Location classification

☐ Preliminary locations classified as been assigned

Deliverables

☐ Draft port bunkering map prepared.
☐ Location screening rationale documented.

Step 7 – Define bunkering scenarios and fuel suitability

Identify feasible supply modes and fuel-specific constraints for each candidate location.

Supply mode definition

☐ Feasible supply modes identified (ship-to-ship, shore-to-ship, mobile-to-ship).
☐ Compatibility with port layout confirmed.
☐ Frequency and scale assumptions defined.

Physical and operational constraints

☐ Hose reach and manifold access reviewed.
☐ Mooring and positioning constraints assessed.
☐ Road access and traffic impacts considered.
☐ SIMOPs implications identified.

Fuel-specific considerations

☐ Key hazard characteristics considered (flammability, toxicity, cryogenic risks, etc.).
☐ Operational limitations documented.
☐ Differences between fuels reflected in scenario assumptions.

Deliverables

☐ Scenario definition document for each candidate location.
☐ Assumptions clearly recorded for use in risk assessment.

Ports Roadmap to Bunkering

CHECKLIST for steps and decision gates for alternative fuels bunkering

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Step 8 – Undertake risk assessments and define controlled areas

Review risk assessments to define safety zones, toxic areas (where applicable), SIMOPs constraints, and operational limits.

Risk assessment framework

☐ Type(s) of risk assessment agreed with competent authority.
☐ Applicable risk acceptance criteria identified.
☐ Applicable exposure thresholds (where relevant) confirmed.

Analytical studies

☐ Qualitative and/or quantitative risk assessments reviewed.
☐ Consequence and dispersion analyses reviewed (where applicable).
☐ HAZID / HAZOP studies reviewed.
☐ SIMOPs studies reviewed.

Assumption validation

☐ Credible release scenarios agreed.
☐ Representative release sizes defined.
☐ Operational frequency assumptions validated.
☐ Environmental and meteorological assumptions confirmed.

Controlled areas definition

☐ Hazardous areas defined.
☐ Safety zones defined.
☐ Toxic areas defined where applicable.
☐ Marine exclusion zones identified.
☐ Assessment zone boundaries documented.

Operational boundary review

☐ Compatibility with port layout confirmed.
☐ Conflicts with neighbouring activities identified.
☐ Navigational safety implications assessed.

Documentation and defensibility

☐ Risk assessment review findings documented.
☐ Decision rationale recorded.

Deliverables

☐ Approved risk assessment framework.
☐ Preliminary controlled area definitions.
☐ Updated port bunkering map reflecting constraints.

Gate 2 – Strategic feasibility and stakeholder alignment check

Decision focus: Can bunkering be supported in principle within the port's operational, regulatory, and social context?

Confirms that:

☐ Stakeholders and regulators are broadly aligned
☐ Feasible locations and bunkering scenarios are identified
☐ Risks can be managed within agreed criteria
☐ No prohibitive constraints remain

Ports Roadmap to Bunkering

CHECKLIST for steps and decision gates for alternative fuels bunkering

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Phase C – Implementation and authorisation *(Steps 9–13 | Gate 3)*

Step 9 – Infrastructure development

Address any physical, spatial, or access constraints needed to support controlled bunkering.

Physical infrastructure assessment

☐ Berth and quay strength and load-bearing capacity assessed.
☐ Layout and spatial constraints evaluated.
☐ Adequate space exists to establish and enforce safety and segregation zones.
☐ Marine access for bunker supply vessels or barges assessed.
☐ Road access for mobile supply units assessed (where applicable).

Utilities and support systems

☐ Power, lighting, and communications availability confirmed.
☐ Drainage and containment arrangements reviewed.
☐ Monitoring systems evaluated where required.
☐ Traffic management and access control arrangements assessed.

Emergency access

☐ Emergency vehicle access routes confirmed.
☐ Evacuation routes reviewed.
☐ Interface with neighbouring operations assessed.

Development planning

☐ Locations classified as fully suitable or conditionally suitable with defined constraints.
☐ Required upgrades identified (fixed or temporary).
☐ Phased or scalable infrastructure approach documented.

Deliverables

☐ Infrastructure assessment report.
☐ Updated bunkering map reflecting physical constraints.
☐ Implementation plan for required upgrades.

Step 10 – Licensing, permitting, and authorisation processes

Establish proportionate licensing and approval processes aligned with national requirements.

Framework alignment

☐ Licensing approach aligned with national permits and legislation.
☐ Legal authority to issue conditions confirmed.

Requirements definition

☐ Clear documentation requirements defined for applicants.
☐ Conditions of operation linked to risk assessment outcomes.
☐ Approval criteria documented and transparent.

Proportionality and consistency

☐ Use of recognised frameworks where appropriate.
☐ Administrative burden proportionate to risk and scale.

Compliance and oversight

☐ Compliance monitoring procedures defined.
☐ Enforcement mechanisms clarified.
☐ Record-keeping and audit processes established.

Deliverables

☐ Published licensing and authorisation framework.
☐ Standard application and review process defined.

Ports Roadmap to Bunkering

CHECKLIST for steps and decision gates for alternative fuels bunkering

The ports roadmap is structured into 15 implementation steps, grouped into four development phases, and punctuated by four decision gates.

Step 11 – Documentation and operational controls

Define documentation requirements to support safe operations and oversight.

Documentation requirements

☐ Bunkering Management Plan required.
☐ Compatibility assessment required.
☐ Joint Plan of Bunkering Operation required.
☐ Bunkering checklists defined.
☐ Any fuel-specific supporting documents identified.

Port role clarification

☐ Port role limited to specifying, reviewing, and verifying documentation.
☐ Operators retain responsibility for preparing operational documents.
☐ Review and approval responsibilities internally assigned.

Review and control processes

☐ Review / approval criteria documented.
☐ Clear linkage between documentation and licence conditions confirmed.

Deliverables

☐ Published documentation requirements.

Step 12 – Training and competence

Ensure port personnel, terminals, contractors, and emergency services are trained and prepared.

Key port personnel

☐ Harbour master and marine staff trained.
☐ Safety and enforcement officers trained.
☐ VTS personnel trained.
☐ Communications staff briefed on fuel-specific considerations.

Stakeholder verification

☐ Minimum competence standards defined where not mandated by regulation.
☐ Operators and suppliers competence confirmed.
☐ Terminal staff competence confirmed.
☐ Contractors' competence confirmed.

Drills and exercises

☐ Joint drills conducted or scheduled.
☐ Fuel-specific scenarios included.
☐ Lessons from exercises documented.

Competence management

☐ Training records maintained.
☐ Refresher intervals defined.
☐ Training scaled to frequency and complexity of operations.

Deliverables

☐ Training matrix and competence framework.
☐ Verification process integrated into licensing.

Ports Roadmap to Bunkering

CHECKLIST for steps and decision gates for alternative fuels bunkering

The ports roadmap is structured into 15 implementation steps, grouped into four development phases, and punctuated by four decision gates.

Step 13 – Emergency preparedness and response

Integrate fuel-specific scenarios into port emergency planning and conduct joint exercises.

Planning and integration

☐ Fuel-specific emergency scenarios incorporated into port emergency plan.
☐ Spill, fire, toxic release, and escalation pathways defined.
☐ Clear command and control structure documented.

External coordination

☐ Fire, medical, coastguard, and other responders engaged.
☐ Mutual aid arrangements reviewed.
☐ Interface protocols tested.

Communication and escalation

☐ Notification procedures defined.
☐ Communication lines rehearsed.
☐ Public communication strategy considered.

Validation

☐ Emergency response drills conducted.
☐ Lessons learned incorporated.
☐ Alignment with risk assessment assumptions confirmed.

Deliverables

☐ Updated emergency response plan.
☐ Drill and exercise reports.

Gate 3 – Operational authorisation decision

Decision focus: Can the port authorise first or pilot bunkering operations under controlled conditions?

Confirms that:

☐ Infrastructure, procedures, and controls are in place
☐ Roles and responsibilities are clear
☐ Personnel and responders are trained
☐ Emergency arrangements are tested

Phase D – Operation and scale-up

(Steps 14–15 | Gate 4)

Step 14 – Pilot operations and controlled introduction

Conduct first or pilot operations with enhanced oversight to validate assumptions and controls.

Pilot bunkering controls

☐ Operation-specific approvals issued.
☐ Additional constraints defined where necessary.
☐ Enhanced monitoring requirements implemented.

Validation

☐ Risk assessment assumptions tested.
☐ Safety zones validated in practice.
☐ SIMOPs controls evaluated.
☐ Emergency response tested under realistic conditions.

Continuous improvement

☐ Lessons learned captured.
☐ Gaps identified and documented.
☐ Corrective actions defined.

Deliverables

☐ Pilot bunkering evaluation report.
☐ Updated risk and operational documentation.

Ports Roadmap to Bunkering

CHECKLIST for steps and decision gates for alternative fuels bunkering

The ports roadmap is structured into 15 implementation steps, grouped into four development phases, and punctuated by four decision gates.

	Gate 4 – Pilot validation and scale-up decision
	Decision focus: Can operations transition beyond pilots?
	Confirms that:
	☐ Pilot operations have validated assumptions
	☐ Procedures and controls work in practice
	☐ Lessons learned are embedded
	Step 15 – Transition to business-as-usual operations
	Progressively integrate bunkering into routine port operations, maintaining a risk-based approach.
	Operational consolidation
	☐ Documentation streamlined and consolidated.
	☐ Administrative processes optimised.
	☐ Transition from operation-specific to standing licences where appropriate.
	Expansion
	☐ Additional locations assessed and approved where justified.
	☐ Additional bunkering scenarios authorised where justified.
	Ongoing governance
	☐ Risk-based review process maintained.
	☐ Periodic reassessment of operational envelope conducted.
	☐ Continuous improvement mechanism active.
	Deliverables
	☐ Standard licensing / authorisation framework in place.
	☐ Updated bunkering map reflecting expanded capability.
	☐ Periodic review schedule defined.

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Q&A Baltic Ports Bunkering Guidebook

Methanol and Ammonia as Marine Fuels

Authors

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H2Deri@BSP - A cooperation project to develop proof-of concepts for the uptake of H2 derivative fuels!

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Introduction

This Q&A document compiles key questions and responses arising from the Interreg project *H² Derivatives @ Baltic Sea Ports* partner calls, meetings and review exchanges concerning the *Baltic Ports Bunkering Guidebook – Methanol and Ammonia as Marine Fuels*.

The inputs reflected in this document originate from the following calls, meetings and review processes:

Date	Note
28.01.2026 to 12.02.2026	All partners document review
18.02.26	Project management team document review call
…	…
…	…

Q&A:

Q: Why does the Guidebook use a Roadmap approach?

The Roadmap structure is used to provide ports and stakeholders with a clear, staged and logical sequence for implementing alternative fuel bunkering. Introducing fuels such as methanol and ammonia involves multiple actors, regulatory interfaces and safety considerations. A Roadmap helps organise this complexity into defined steps and decision gates.

The approach ensures that critical elements, such as regulatory mapping, stakeholder coordination, risk assessment (HAZID, HAZOP, SIMOPS), safety zone definition, licensing, procedures and emergency preparedness, are addressed in the correct order. It also allows ports to pause, reassess or adjust before progressing to the next stage.

The Roadmap is process-driven and risk-based. It does not prescribe technical solutions but ensures that the necessary assessments and governance steps are completed in a structured manner.

For practical purposes, a checklist aligned with the Roadmap steps is also provided as a reference tool. This checklist is intended to help ports track progress and verify completion of key actions. However, it does not replace or reduce the requirement for formal risk assessments, technical studies or regulatory approvals. It serves only as a tracking and verification aid

Q: What is the role and responsibility of ports in alternative fuel bunkering?

The roles and responsibilities must first be clearly mapped and assigned among stakeholders, as they vary significantly across jurisdictions.

The term “port” in this Guidebook is used in a functional sense, referring to the entity or combination of entities that hold responsibility and accountability for authorising, overseeing and enforcing bunkering activities within port limits.

Ports operate within a broader maritime ecosystem that includes terminal operators, bunker suppliers, ship operators, maritime administrations, environmental authorities and occupational health and safety regulators. Each stakeholder holds distinct responsibilities. Technical design, fuel supply and transfer execution typically sit with commercial operators, while statutory oversight and enforcement may lie with national or regional authorities.

The port’s role is therefore primarily one of coordination, regulatory interface and assurance. As bunkering activities occur within its jurisdiction, the port must ensure that appropriate risk assessments, authorisations and safety measures are in place, irrespective of which party performs the operational functions. The exact allocation of duties depends on the applicable legal and institutional framework.

Q: What is a bunkering checklist?

A bunkering checklist is an operationalisation tool used in the field to verify that all agreed conditions, procedures and safety measures are in place before and during a bunkering operation.

It does not replace the underlying planning work, such as HAZID, HAZOP, SIMOPS, risk assessments or the development of bunkering procedures. Instead, it translates those agreed outcomes into a structured, step-by-step verification process carried out by the responsible Persons in Charge (PICs).

The checklist is used during preparation, connection, transfer and post-operation phases to confirm readiness, alignment and compliance. Its purpose is practical verification and coordination on site, ensuring that the safeguards identified during the planning stage are effectively implemented during execution.

Q: Ammonia and methanol are very different fuels. Why does the Guidebook use one common framework for bunkering?

While ammonia and methanol have different physical, chemical and toxicological properties, the overall governance and implementation framework for bunkering does not fundamentally change.

The Roadmap presented in the Guidebook reflects the general stages required to introduce any new marine fuel at port level. These stages, strategic alignment, regulatory mapping, stakeholder engagement, risk assessment, definition of safety zones, licensing, operational procedures and emergency preparedness, are process-driven and consistent with established regulatory practice. They are structured around risk assessment as the central decision-making mechanism.

The differences between fuels are addressed within that framework through fuel-specific risk assessments (e.g. HAZID, HAZOP, SIMOPS) and technical evaluations. It is through these assessments that fuel characteristics, such as toxicity (ammonia), flammability (methanol), vapour behaviour, dispersion, ignition potential and environmental impact, are analysed and translated into appropriate mitigation measures.

In other words, the framework remains constant; the risk profile and resulting controls are fuel-specific. This approach avoids creating parallel governance models for each fuel while ensuring that their distinct hazards are properly managed.

Q: Are Ship-to-Ship (STS) and Mobile/Truck-to-Ship (MTS) bunkering fundamentally different?

STS and MTS bunkering differ in their operational environment and interface, but not in their fundamental safety principles.

The core transfer process, equipment philosophy and safety objectives remain the same. In both cases, bunkering involves controlled fuel transfer between two systems, governed by risk assessment, agreed procedures and defined safety zones.

The differences arise in implementation. STS operations take place within the marine environment and must consider navigational safety, vessel movements and marine SIMOPS. MTS operations involve a land–sea interface and must also address road transport regulations, vehicle access, traffic management and terrestrial emergency response.

These environmental differences influence the magnitude of certain risks and the mitigation measures required. However, the overarching framework, risk-based approach and governance structure remain consistent for both scenarios.

Q: Who is responsible for training, and what is the role of the port?

Responsibility for training primarily rests with the employer of the personnel involved. Bunker suppliers, terminal operators and ship operators are responsible for ensuring that their respective staff are properly trained, competent and certified in accordance with applicable regulations and operational requirements.

The port's responsibility relates to its own personnel and to oversight within its jurisdiction. Ports must ensure that their staff are trained to a level commensurate with their authority and responsibilities. In addition, as part of the licensing or authorisation process, ports should verify that all parties involved in bunkering operations can demonstrate appropriate training and competence.

In some jurisdictions, ports may also define minimum training standards as a condition of authorisation. The port's role is therefore not to train all operational personnel, but to ensure that adequate training frameworks are in place and that competence is verified before operations are permitted.