



MAGPIE

SMART GREEN PORTS

Ammonia Bunkering Demonstration Report





AMMONIA BUNKERING DEMONSTRATION REPORT D5.1

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AUTHORS	<p>Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping</p> <p>Boon, Cees - Port of Rotterdam Harbour Master Division</p> <p>Brink, Françoise van den - Port of Rotterdam Harbour Master Division</p> <p>jc.boon@portofrotterdam.com</p> <p>f.brink@portofrotterdam.com</p> <p>Martin.Eriksen@zerocarbonshipping.com</p>

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NAME	ROLE	DATE
Martin Eriksen	Work Package (WP) Leader	17-04-2026
Larissa Van Der Lugt	Peer reviewer	12-01-2026
Peter Mollema	Peer reviewer	15-02-2026
Maarten Flikkema	Scientific Coordinator	13-05-2026
Arne-Jan Polman	Project Coordinator	13-05-2026

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Executive Summary

Purpose and Scope

The MAGPIE consortium, a collaboration of European ports, research institutions, and private companies, aims to accelerate the transition to sustainable, smart, and multimodal transport systems. As part of this initiative, the Port of Rotterdam (PoR) and its partners conducted a ship-to-ship (STS) ammonia bunkering pilot on 12th April 2025, marking a significant milestone in the development of green maritime fuel infrastructure in ports.

This pilot, designated as Demo 4 under Work Package 5 of the MAGPIE project, was designed to simulate an ammonia bunkering operation within the Port of Rotterdam. It focused on demonstrating and validating operational feasibility, safety protocols, and stakeholder coordination (the port safety framework) required for future ammonia bunkering.

Key Achievements

- **Operational execution:** A successful in-port simulation of an ammonia bunkering was performed by conducting a ship-to-ship transfer of refrigerated ammonia at a terminal adhering to stringent safety and environmental protocols.
- **Governance and team structure:** Seven specialized teams managed various aspects of the pilot, including tactical operations, enforcement, stakeholder communication, incident response preparedness, and validation and reporting.
- **Safety and risk management:** Comprehensive risk assessments, including Quantitative Risk Assessment (QRA) and gas dispersion studies, informed the establishment of control zones and emergency response plans.
- **Permit and regulatory compliance:** The operation was conducted under specific exemptions and permits aligned with the Port of Rotterdam's port bylaws and national safety legislation.
- **Technical validation:** Equipment such as Emergency Shut Down (ESD) systems, cryogenic hoses, and purging mechanisms were tested and validated. The operation adhered to Oil Companies International Marine Forum (OCIMF)/International Chamber of Shipping (ICS) guidelines and International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) training standards.
- **Stakeholder engagement:** Extensive communication efforts ensured transparency and preparedness among local authorities, businesses, and the public.

General Findings

- **Coordination challenges:** Notwithstanding the significant work done ahead of securing vessels for the pilot, due to the short interval between the vessels nomination and the execution of the pilot, limited preparation times highlighted the need for improved inter-team communication and internal organizational readiness.
- **Environmental factors:** An ammonia bunkering operation within a port must be structured to fully comply with all applicable in-port operational requirements. The

surrounding environment must be appropriately configured to mitigate the inherent risks of such activities.

- **Operational insights:** The pilot revealed technical complexities in purging and leak testing, emphasizing the importance of detailed planning and equipment certification.
- **Governance framework:** The pilot validated the Port of Rotterdam's ammonia bunkering safety framework, which will guide future operations and licensing.

Outlook

The pilot lays the groundwork for the next stage of ammonia bunkering in the Port of Rotterdam, with operations to be governed by the validated safety framework, licensing system, and the "Ammonia Bunker Map" defining suitable locations. Continuous monitoring and evaluation mechanisms will be implemented by Port of Rotterdam to further refine best practices and ensure safe, scalable deployment of ammonia as a marine fuel.

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1. Introduction

The MAGPIE consortium is a unique collaboration consisting of 4 ports (Lighthouse Port of Rotterdam, Fellow ports DeltaPort (inland Germany), Port of Sines, and HAROPA), 9 research institutes and universities, 32 private companies, and 4 other institutes. It addresses the missing link between green energy supply and green energy use in port-related transport, and supports the implementation of digitization, automation, and autonomy to increase transport efficiency. MAGPIE aims to accelerate the introduction of green energy carriers (batteries, hydrogen, ammonia, bio-methane, and methanol) combined with the realization of logistics optimization in ports through automation and autonomous operations.

The MAGPIE project consists of several workstreams, and this Bunker Pilot is part of MAGPIE Project Work Package 5, described in the MAGPIE project agreements as Demo 4. Appendix 4 is an extract from section 1.3.3 WT Work package descriptions of Grant Agreement number 101036594-MAGPIE-H2020-LC-GD-2020 detailing Work package number WP5. This report represents deliverable D5.1, Ammonia bunkering demonstration report.

Described in the objectives for Demo 4, a concept design of a scalable green ammonia storage terminal with cracking capabilities will be developed. This concept design has not been developed and consequentially, details will not be included in this report.

After extensive preparatory work, on 12th April 2025, the Port of Rotterdam Harbour Master Division and Port of Rotterdam Sustainability Programme together with their partners successfully completed a simulation of a ship-to-ship ammonia bunkering operation within the port.

The report is arranged to help readers find the main consolidated bunker demonstration information in the core report, while further detailed project-specific insights and pilot learnings from implementation are available in the appendices.



2. Demo 4 Development Summary

The expected scope of work for Demo 4 defined in the MAGPIE project agreements was based on two assumptions: that an inland waterways pressurized-ammonia carrier could be easily modified and equipped to serve as an ammonia bunker barge, and that ammonia-fueled ships would be available. Unfortunately, although some proof-of-concept ammonia-fueled ships have been developed, commercially available, mainstream ammonia engines have only been recently introduced to the market and the first dual-fuel ammonia-capable ships will only start sailing in 2026.

For the inland waterways pressurized-ammonia carrier conversion, early safety studies and current industry opinion suggests that the handling of pressurized ammonia is less safe than the handling of refrigerated ammonia. Standards and guides have now been written to favor the bunkering of refrigerated ammonia. An aspiration for zero ammonia emissions has also been universally adopted and therefore, the conversion of the candidate barge was considered to be far more complex than first expected and deemed not commercially feasible at this stage of the ammonia marine fuel pathway.

Given this context, the most reasonable and achievable simulation of a ship-to-ship ammonia bunkering operation was considered to be a ship-to-ship transfer of refrigerated ammonia between two LPG carriers and this became the project goal.

3. Project Organization

Figure 1 and 2 below outline the organisational relationship in the project consortium and the relationship between Demo 4 project partners.

Figure 1: MAGPIE organization and where Demo 4 fits.

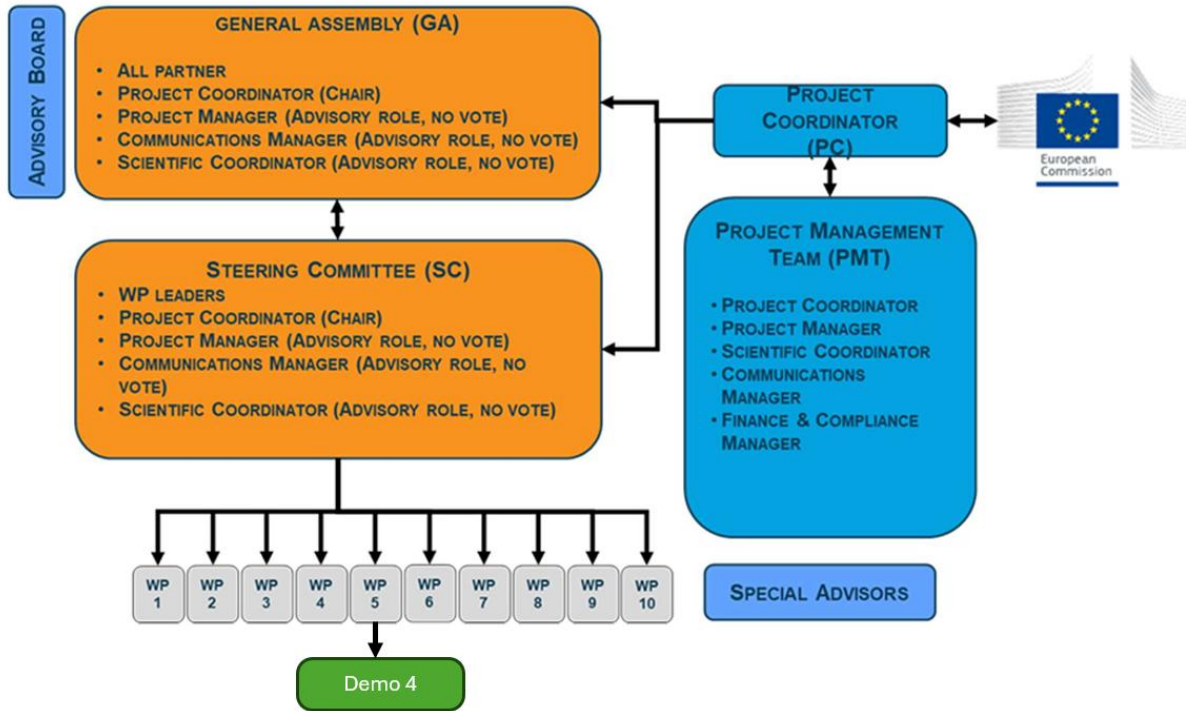
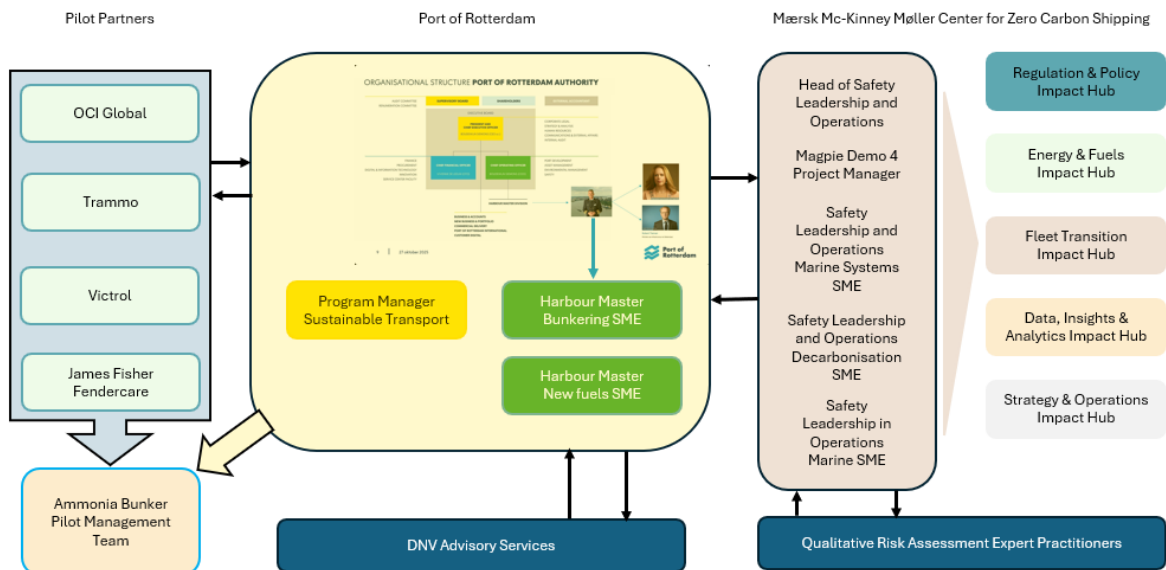


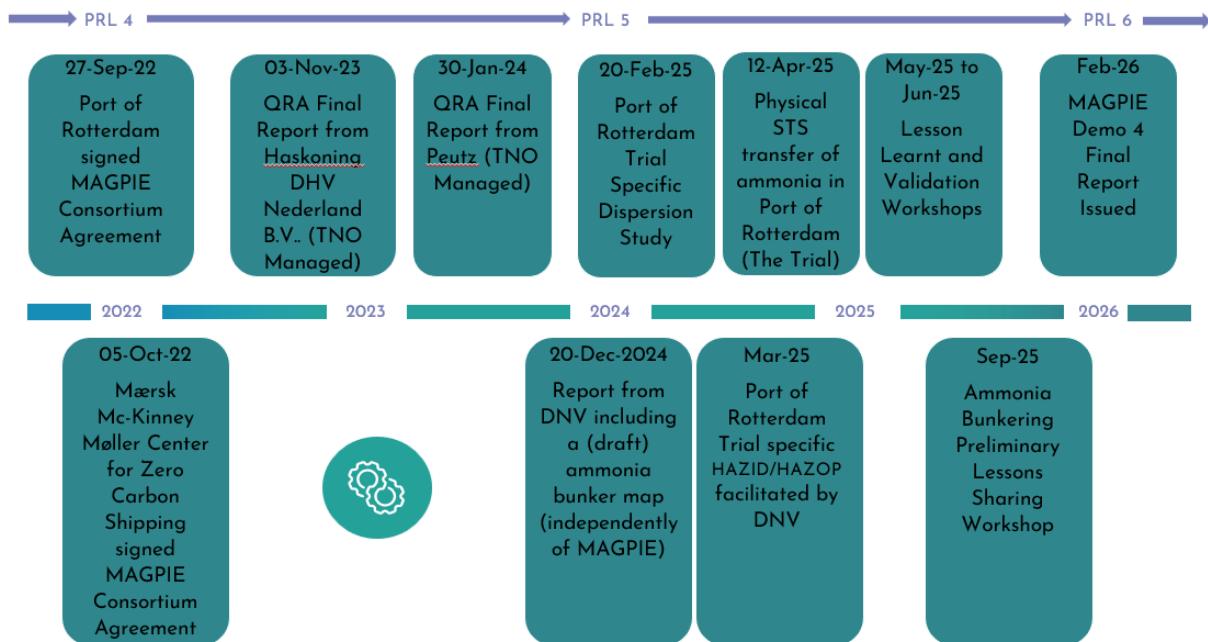
Figure 2: Demo 4 organization



4. Chronology of Events

Figure 3 outline the chronology of key activities leading to this bunker demonstration report. Additionally, they visualize the port readiness level development during the project.

Figure 3: Chronology of Events



5. Ammonia Fuel Pathway: Why Ammonia?

Ammonia is considered a viable alternative marine fuel due to its scalability, feedstock availability, and chemical properties that can support the maritime sector's reductions in greenhouse gas (GHG) emissions. While ammonia is handled and shipped globally as a commodity today, the innovation is using it as a fuel. Ammonia has great potential as an alternative fuel because its volumetric energy density, its slow combustion rate that aligns well with marine engines, and the absence of carbon, resulting in carbon-free combustion at the point of use^{1,2}.

Beyond its combustion properties, the viability of ammonia as a marine fuel also depends on its production pathway, which determines its lifecycle emissions, and in turn, emission factors. There are two production pathways to scalable, low GHG-intensity ammonia: blue-ammonia and e-ammonia.

In blue ammonia, nitrogen from air reacts with the hydrogen from reforming of natural gas, complete with carbon capture and permanent storage. Blue ammonia with carbon capture and permanent storage is a low-cost near-term solution to aid in low-emissions fuel

¹ [Ammonia will become one of the key green marine fuels](#)

² [Everllence 2-stroke engine: now available](#)

pathway as the supply of renewable energy for fuels is scaled³. Blue ammonia is produced in regions with abundant natural gas and existing infrastructure. Its climate performance depends on minimizing fugitive methane emissions from the natural gas supply chain and ensuring permanent carbon storage⁴.

In e-ammonia, nitrogen from air is combined with hydrogen (separated from water via electrolysis, powered by low-emission electricity). In the long term, e-ammonia can be produced using low-emission electricity, water, and air as renewable feedstocks. Additional sustainability and safety requirements include safety guidelines to limit personnel exposure to ammonia’s toxicity, strong environmental and biodiversity safeguards, and a clear assessment of land-use change, water usage, and low-emissions electricity required for sustainable production.

For an overview of the latest assessment from the MMMCZCS concerning feedstock availability; fuel production; fuel storage; logistics and bunkering; onboard energy storage and fuel conversion; onboard safety and operations; vessel emissions; and regulations and certification, please refer to our Fuel Pathway shown in Figure 4.

Figure 4: The MMMCZCS’s view on Fuel Pathways which maps the level of maturity: mature (green), solutions identified (yellow), and major challenges remain (red) based on several critical criteria⁵.



6. Benefits of the Pilot

The main benefit of the pilot is to test the Port of Rotterdam bunkering safety framework and to validate the International Association of Ports and Harbours (IAPH) Port Readiness Tool. The safety framework has already been successfully used in the introduction of LNG and methanol bunkering in the port, but this is the first time the Port Readiness Tool has

³ [Fuel for thought: Ammonia](#)

⁴ [Hydrogen decarbonization pathways A life-cycle assessment](#)

⁵ [Fuel Pathways](#)

been used to prepare for ammonia bunkering. The pilot also demonstrates to the wider industry and local stakeholders that the ship-to-ship transfer of ammonia within a port can be done safely and without any emissions.

A further benefit was to validate, where possible, all relevant international standards, guides, and recently developed best practice. And to put into practice any recommended improvements from similar, recently conducted trials.

7. Initial HAZID and QRAs

To assess the feasibility of bunkering ammonia in the Port of Rotterdam a Hazard Identification (HAZID) Risk Assessment and two Qualitative Risk Assessments (QRA) were carried out. A summary report of these assessments and detailed reports of the QRAs are included in Appendix 2.

The HAZID assessed the risk to the individuals directly involved in the bunkering operation while the QRAs assessed the risk to the local community of regular ammonia bunkering operations in the port.

Both QRAs were based on the same assumptions and were done in accordance with the Dutch National Regulations. They considered leak scenarios from a bunker hose with a failure rate of 4×10^{-6} per annum and calculated 10^{-6} local risk factor contours relative to the leak sources. Any scenario involving a ship collision was not considered in the assessments as measures are already in place to ensure ship collisions are an extremely unlikely event in the port.

The initial HAZID & QRAs formed the basis for the comprehensive risk management activities undertaken to prepare for the pilot. As preparations and operational details matured, pilot specific HAZID was commissioned and completed. Risk insights are further outlined in the section "VS 02" in appendix 1.

8. Port Readiness

The Port of Rotterdam used the recommended steps in the IAPH Port Readiness Level for Marine Fuels Tool to prepare for ammonia bunkering in their port. The port helped develop the tool based on their experience preparing for LNG bunkering and early drafts of the tool were used to prepare for methanol bunkering. An in-depth description of the IAPH Port Readiness Level for Marine Fuels assessment framework and its application by the Port of Rotterdam at the different port readiness levels are described in detail in appendix 1.

Many of the recommended steps to prepare for a new marine fuel are similar regardless of fuel type. The Port of Rotterdam used an optimized approach based on their experience with other fuels and from the port's many years of experience hosting the OCI ammonia terminal. The Port of Rotterdam is an established industrial zone with agreements in place that define a port activity risk line to guide where high-risk activities can be performed. Reference to this line proved valuable in the feasibility study for using ammonia as a marine fuel.

At the beginning of 2021, ammonia bunkering was confirmed feasible, business drivers and port aspirations were established, and work had begun to address some regulation, code, standard, and technology gaps. At this point, the Port of Rotterdam considered itself at

readiness level 3 and started to prepare for a pilot ammonia bunkering operation expecting to reach readiness level 6 on completion.

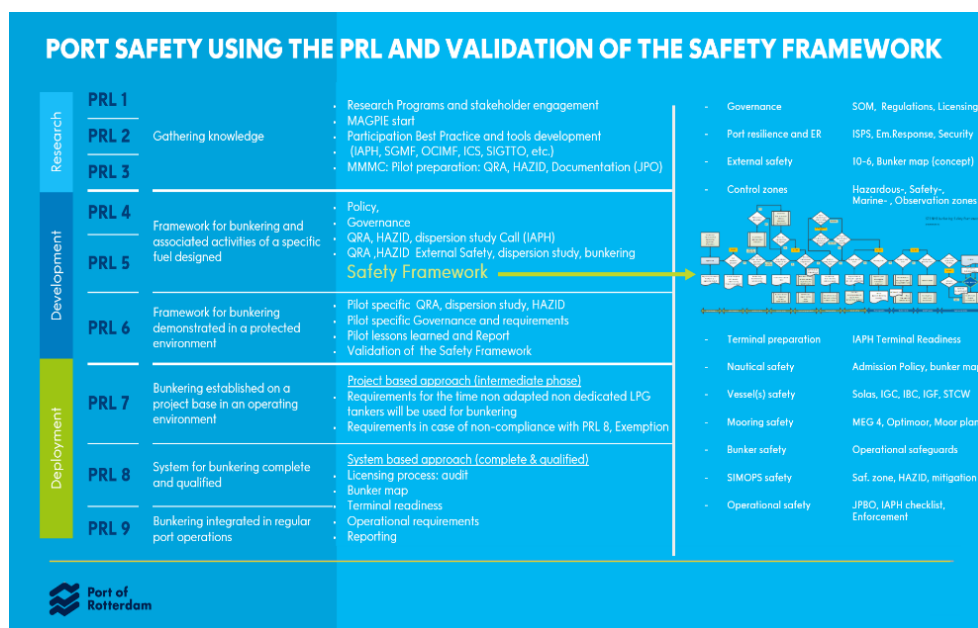
9. Port of Rotterdam Safety Framework Description

To achieve Port Readiness level 5 for ammonia as a marine fuel, the port required to establish a safety framework for ammonia bunkering. The safety framework for ammonia bunkering developed by the Port of Rotterdam in 2023 is based on the safety framework for LNG bunkering. The framework headings remain the same as the LNG framework but the detail under each heading has been adapted to account for ammonia's specific properties. The safety framework for bunkering in Rotterdam consists of eleven topics, and each topic includes several conditions that must be satisfied to permit ammonia bunkering in the port.

The topics of the safety framework are:

1. Governance
2. Port resilience and emergency response
3. External safety
4. Control zones
5. Terminal preparation
6. Nautical safety
7. Vessel(s) safety
8. Mooring safety
9. Bunker safety
10. SIMOPS safety
11. Operational safety

Figure 5: The nine port readiness levels used by the Port of Rotterdam to validate safety.



Details of pilot specific safety framework assurance activities are described in section 10.4 below.

10. Pilot Preparation and Execution

The Port of Rotterdam Harbour Master personnel managed the overall setup of the pilot and coordinated all activities to ensure it was a success. Aspects coordinated by the Harbour Master personnel include the following:

- Technical concept development
- Communication between the port environmental agency and the emergency responders
- Communication with external stakeholders
- Nautical safety authorities within the port and traffic management
- Terminal authorities
- Control zone enforcement authorities
- External safety
- The use of the Global Centre for Maritime Decarbonisation (GCMD) Pilbara trial lessons

10.1. Pilot Organization

For managing the ammonia bunker pilot project, eight teams were established, all with separate tasks and responsibilities.

- *Pilot management team:*

Development of the operational agreement to take care of commercial issues such as partnership, liability, costs, and management of all the working groups

- *Operational tactical Team:*

Focus on a safe operation: conduct compatibility checks, approved the Joint Plan of Bunkering Operations (JPBO), completed checklists, maintain safeguards during connection, transfer, purging and disconnection.

- *Enforcement team:*

A team of PoR enforcement officers and safety specialists from the Harbour Master division supervising safe and compliant working arrangements and conforming compliance with applicable regulations, agreed procedures, and JPBO.

- *Governance team*

A team of Rotterdam authorities (EPA, ERO, and incident response officers) looking into the pilot specific incident response and communication plans for the Rotterdam incident response organization.

- *Strategic stakeholder management and communication team:*

This team implemented the communication plan to reach out to all stakeholders in the pilot area, including the general public in the small villages and local neighborhood.

An “ammonia pilot information sheet” was developed and distributed to all relevant stakeholders.

- *Vicinity team*

The vicinity team was established to reach out to companies in the inner control zones to help them prepare for a possible ammonia spill that may impact their operations.

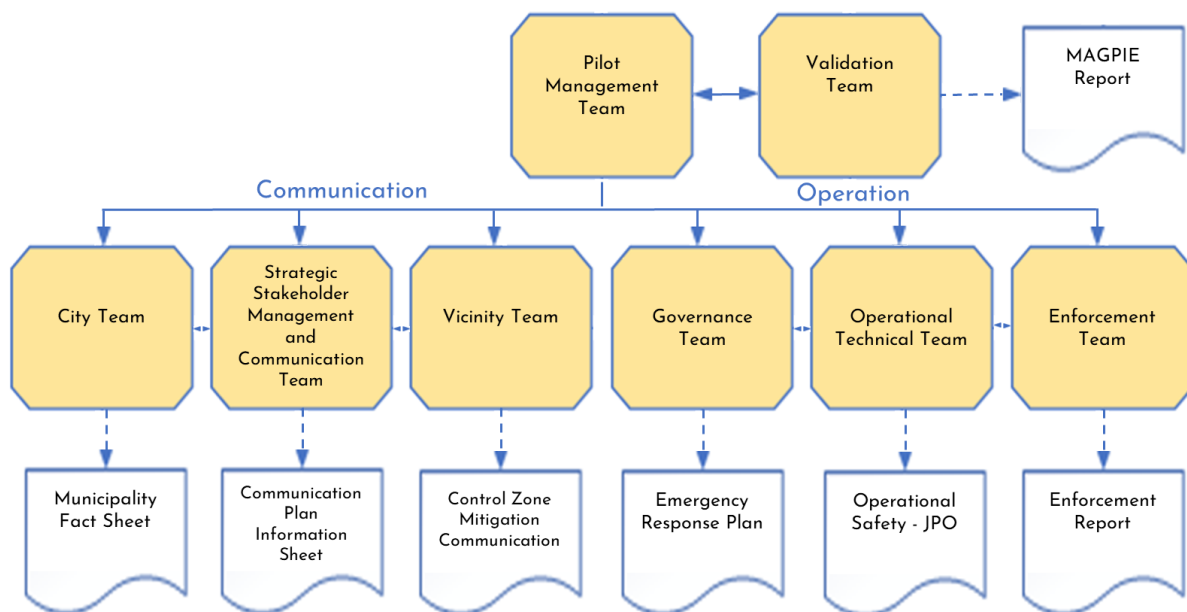
- *City team:*

The city team arranged the communication with the city administration and the cabinet of the Mayor and Aldermen of Rotterdam.

- *Validation team*

The validation team was responsible for the evaluation and validation of the Rotterdam safety framework after the event and MAGPIE reporting.

Figure 6: The organization of the eight teams managing the ammonia bunker pilot project.



10.2. Stakeholder Engagement and Communication

The Port of Rotterdam has a large community of stakeholders and neighbors and operates based on open, transparent, and constructive communication. For the pilot, the Strategic Stakeholder Management and Communication Team (SOMCOM) identified stakeholders and neighbors that could be affected by an ammonia release during the pilot and developed a plan to inform and collaborate with them. This included the local community within a 10 km radius. Additionally, a specific city and vicinity team were established.

Effective communication was critical to address issues proactively and avoid misunderstandings. The Port worked on aligning expectations, communicating the purpose, benefits, and impact of the pilot, including details of the port development in support of the global energy transition.

A pilot communication pack was developed on the basis of an exchange of information with The Municipality of Rotterdam, the safety region (VRR), and the Environmental agency (DCMR) throughout 2024.

As a first step, a factsheet was developed to inform the administrative and political levels of the municipality. A first version of the fact sheet was shared in September 2024, followed by a second version in February 2025 specifically for the Aldermen of Rotterdam. Also, input was given for a specific Aldermen's briefing letter. The ammonia information sheet, developed for and distributed to, all relevant public and private stakeholders in the area was also shared with the Aldermen.

For the companies with premises close to the pilot and the general public, information was shared via email, phone calls, and an ammonia pilot information sheet (see "VS 01" in appendix 1). Questions and concerns were addressed by providing details of the safety studies conducted in preparation for the pilot including details of risk assessments and dispersion studies.

To complete the communication plan, direct discussions were held with the companies located within meters of the pilot such as the companies involved in the construction of the new terminal where the pilot was planned to take place. In addition to the information shared with the general public, guidance was also given with respect to what to do if ammonia was accidentally released and how they would be informed of such an event.

10.3. Volunteer Ships and Partner Involvement

The search for volunteer ships to take part in the pilot and an ammonia cargo was not straight forward. The Port of Rotterdam business development team and the Harbour Master personnel worked for several months in discussion with multiple companies to find willing partners for the pilot. There were a number of problems to solve including commercial aspects, availability of cargo and suitability of ships or barges.

10.4. Pilot-Specific Port Safety Framework Assurance Activities

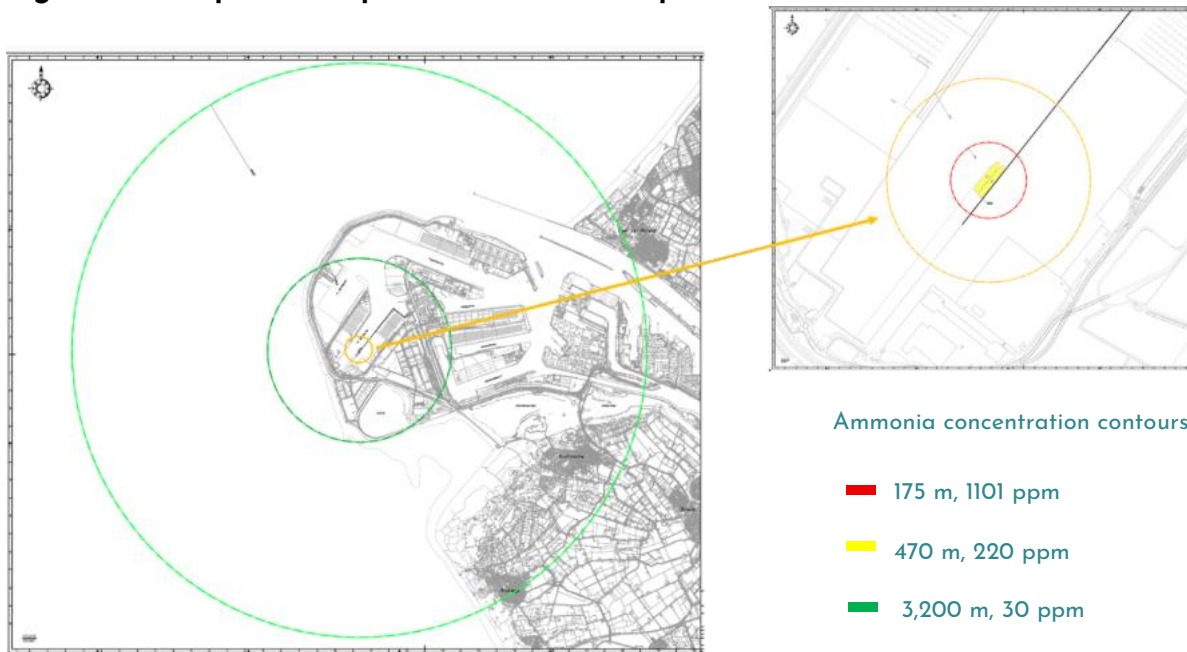
- **Governance** - The Port Harbour Master Division lead the Governance Team and provided high level guidance and coordinated all pilot preparations including permitting. They managed stakeholder communications and ensured the pilot-specific incident response plan was in place and fit for purpose.
- **External safety** - Dutch national regulations require a quantitative risk assessment to assure the risk of operations with dangerous goods is below maximum risk levels for vulnerable objects such as residential areas, schools, hospitals, etc. To comply with these regulations, port operations should not impose a risk of a fatality within a vulnerable object of greater than 1×10^{-6} . Considering a transfer of $450 \text{ m}^3/\text{h}$ for 3 hours, the 1×10^{-6} fatality contour was calculated to be less than 320 meters from the pilot location. The nearest vulnerable object to the pilot location was at least 6 kilometers away.
- **Control zones** - A gas dispersion study was performed which considered a leak from the liquid hose used for the pilot transfer either by complete rupture of the hose or due to a small but sustained leak from a hole in the hose (in accordance

with Dutch national regulations). Worst case ammonia gas concentration contours relative to the leak source were calculated and control zones around the pilot were defined up to 175 meters, 470 meters, and 3200 meters from the ship's manifolds corresponding to minimum predicted concentrations of 1101 ppm for 1 hour, 220 ppm for half an hour, and 30 ppm for an hour at their extremities, respectively. These zone boundaries were in addition to the zone boundaries described for nautical safety and were primarily used to establish personnel control measures such as access rights and minimum required Personal Protective Equipment (PPE).

- **Terminal preparedness** - To prepare the terminal for the pilot, the Health, Safety Environment, and Quality (HSEQ) department of the terminal was included in the vicinity team mentioned above and the terminal representative was actively involved in the overall pilot preparations. Although the location for the pilot was a part of the terminal under construction and not yet a working terminal, the working procedures for LNG and methanol bunkering from the adjacent working terminal were referenced and used to inform the personnel and construction workers likely to be in close proximity to the operation. It was agreed that terminal operations personnel or terminal construction personnel would not be required to help with responding to an emergency event during the pilot however (see section 10.7). Their role in terms of response would be to follow their emergency procedures and evacuate the area and take shelter when prompted to do so via the agreed emergency alarm signals. The timing of the pilot was planned to minimize the amount of terminal personnel (if any) and construction workers close to the pilot location.
- **Nautical safety** - Both ships followed normal port regulations for ships carrying dangerous goods. The usual 50-meter exclusion zone was setup, however, further pilot-specific restrictions were applied. A no passing vessel zone was setup at 100 meters from the ships while ammonia was being transferred. This zone was communicated to other ships in the vicinity by the Port of Rotterdam Vessel Traffic Service and enforced by a Port Patrol Vessel appropriately positioned during the pilot.
- **Vessel safety** - Both ships follow international regulations for trading sea-going ships. Compliance was confirmed by port enforcement officers.
- **Mooring safety** - Verified during the compatibility check by JF Fendercare via Optimoor study.
- **Bunker safety** - A pilot-specific HAZID was conducted, and findings were included in the pilot's Joint Plan of Operations (JPO). Control zones were established for personnel and passing traffic control, and the pilot's location and timing were selected to minimize impact to any external stakeholders. Bunkering equipment was selected based on industry best practice including shut down and emergency release provisions. If pressure rises due to transfer and boil off, it can be controlled by the vessels equipment. A vapour return line may be connected, though not opened, as a secondary safeguard. An overriding principle was set to have zero ammonia emissions, even during hose purging and a deck tank was reserved to receive purge gas.
- **SIMOPS** - No SIMOPS were permitted during the pilot as to allow SIMOPS would introduce unnecessary risk and distraction.
- **Operational safety and enforcement** - The Port of Rotterdam enforcement officers confirmed both ships' officers and crews were competent and experienced in the handling of ammonia as a cargo. The pilot transfer operations were adequately described in a pilot specific JPO and JF Fendercare was contracted to provide equipment and supervision personnel. JF Fendercare have had very recent

experience supervising and supporting similar operations successfully conducted elsewhere. A pre-operations meeting was convened to make sure all ship personnel were aware of all relevant aspects of the pilot and the entire operation was supervised by the Port of Rotterdam enforcement officers. An incident response plan was in place and incident responders were put on standby.

Figure 7: Example of the pilot control zone map



10.5. Permitting

The fuel bunkering in the Port of Rotterdam is governed by Rotterdam's municipal executive, and the terms under which bunkering can or cannot be performed are defined in the port's bylaws. For ammonia bunkering, a permit is required and Article 1 of the "Designation decree for fuels and energy sources that may be bunkered with a permit only, 2021" refers.

Since two LPG tankers carrying ammonia were used for the pilot, and from a juridical perspective, the operation was an STS transfer of gas outside a "Petrol Harbour Regime," three exemptions were required to allow the bunkering trial to proceed. Article 5.4 restricts the berthing of a tanker carrying dangerous substances to a petroleum haven only (2 exemptions, 1 per ship), and Article 6.4 prohibits the transshipment of gas within the port (1 exemption for the operation).

Application was via a Harbour Master adopted form supported by an operation risk assessment, and other evidence demonstrating that the operation was well planned and could be safely executed.

All exemptions and a bunkering permit were obtained subject to the following additional conditions:

- Both vessels moor with their bows in the direction of departure (bow out);
- The ship-to-ship transfer will take place from 12 April 18:00 to 13 April 07:00;

- During the ship-to-ship transfer, no activities other than the transfer where the exemption applies can take place;
- A specific JPO has been drawn up for ship-to-ship transfers and the plan dated 11-04-2025 forms part of the exemption.
- The ship-to-ship transfers and other operations shall be carried out in accordance with the JPO mentioned above and the OCIMF-ICS Ship-to-Ship Transfer Guide for Petroleum, Chemicals, and Liquefied Gases.
- The ship-to-ship transfer will take place under the supervision of a competent and physically present STS superintendent.
- The exemptions and permits will expire upon completion of this specific operation. Other proposed ammonia ship-to-ship transfers or bunkering operations are subject to separate application or licensing requirements as specified or determined by the port authorities.

During the pilot, a Port of Rotterdam supervisor was on board to supervise and confirm compliance with the above, including the completion of the recommended OCIMF-ICS checklists. The port supervisor was the designated onboard competent authority responsible for assessing and authorizing, or prohibiting, any deviations from these requirements.

10.6. Pilot-Specific Risk Assessments

Pilot-specific risk assessments were conducted during the planning stage. A HAZID facilitated by DNV was conducted in March 2025 and JF Fendercare followed their usual Hazard Identification and Risk Assessment (HIRA) process and sought operator input on risk mitigation during pre-operations meetings and as the operation was in progress.

JF Fendercare emphasized that they expect and empower all personnel to stop work if any unsafe act or condition occurs. Risk mitigation recommendations from the risk assessments were addressed by amending or adding to the JPO.

Pilot-specific HAZID by DNV and JF Fendercare HIRA is further described in “VS 02” in appendix 1. For more information on pilot specific studies reach out to Port of Rotterdam.

10.7. Incident Response Preparedness

As is usual in the port for incidents involving ships, the first response will always be performed by the ship’s crew. Regulations dictate that international seagoing ships are equipped and their crews are trained in first response. No change to this arrangement was made for the trial.

The JPO included details of what the ship’s crew must do to notify the authorities of an incident and when they require support. Namely, the contact details of the port’s emergency response organization.

The second party in an incident response is the terminal. The terminal was not expected to respond to any emergencies during the pilot other than reacting to any alarm by evacuating and seeking shelter, as discussed under terminal preparedness below.

The third party involved will be the Port’s Emergency and Incident Response Organization (ERO). This organization in the Port of Rotterdam is trained and equipped for incidents with ammonia, and includes the Joint Fire Brigade Rotterdam (GB), a unique public-private

fire service organization responsible for fire safety and incident response in the Rotterdam port and industrial area.

A specific incident response plan was developed for the pilot based on the following leak scenarios:

- Hose rupture with total loss of hose contents
- Hose leak from a small hole in accordance with Dutch legislation

Both scenarios were subject to gas dispersion modelling to determine ammonia gas concentration contours relative to the source. The response plan is further described “VS F010” in appendix 1.

During the pilot, the lines of communication in case of an incident were assured by the presence of a Port of Rotterdam Representative.

10.8. Communication message when an incident takes place

For an ammonia incident requiring a multidisciplinary response, communication is the responsibility of the VRR. They are responsible for coordinating the communication, if necessary, between other parties such as DCMR and Divisie Havenmeester Rotterdam (DHMR), Harbour Master Division of the Port of Rotterdam. Three communication messages (see “VS I” appendix 1) were prepared, each to reach people in different incident affected areas and for transmission via existing emergency communication protocols.

10.9. Joint Plan of Operations (JPO)

The JPO developed and used during the ammonia bunker pilot was made in line with the STS transfer guide of OCIMF-ICS and was created by the ship-to-ship service provider, JF Fendercare.

The following items were included in the JPO (see “VS D” in appendix 1).

Nautical topics:

- Vessel particulars
- Approach parameters
- Local nautical and berth particulars
- Optimoor study
- Mooring plan
- Fendering plan
- Communications
- Weather operating limits

Transfer topics:

- International Ship and Port Facility Security (ISPS) Code security level (1)
- Contingency plans in event of an emergency
- Emergency response plans
- Means of escape

- Man overboard rescue and recovery arrangements
- External emergency response (independent of the vessels)
- Odor nuisance
- Contact information
- Personnel transfer methods
- Supplied equipment (arrived with a barge)
- Vessel separation detector (including calculated length of the cables)
- STS transfer plan
- Dressing up and rigging up
- Pressure leak test
- Emergency shutdown test of the ESD pendants
- ESD closing time (25-28 sec)
- Cooldown cargo line
- Transfer parameter
- Vapor and tank pressure management
- Notices for cargo transfer
- Completion
- Draining, hot gassing, and purging
- Hose disconnection
- PPE
- Schematic manifold drawing
- Hose envelope
- Un-mooring plan
- Agreed vessel parameters

The JPO was approved by the operational tactical team including the representative of the Rotterdam Port Authority. Its primary purpose was to ensure safe operation on board both vessels and included the required risk mitigation measures to be applied within the inner control zone (threshold used: 1101 ppm/0,5h).

The required risk mitigations for the other control zones were established by the vicinity team, governance team, and the strategic stakeholder management and communication team which included the external incident response plan, the external communication plan and the terminal preparations. This is reflected in the JPO.

10.10. Compatibility

JF Fendercare performed their usual ship-to-ship transfer compatibility check. Items considered during the check included the following:

- Each ship's overall length
- Each ship's freeboard
- Each ship's manifold arrangement
- Each ship's mooring equipment and safe working loads
- Each ship's hose handling crane, outreach, and safe working load
- Required safe fender arrangements

- Required safe transfer hose length
- Allowable maximum safe rolling angle
- Recommended mooring arrangement supported by Optimoor mooring calculations
- Recommended vessel separation device settings

From the compatibility assessment performed the following items were included in the JPO

- Agreed wind operating limits (As recommended by port pilots and verified by Optimoor study)
- Fendering plan
- Mooring lan
- Vessel separation device cable lengths
- Manifold, saddle, and hose setup arrangements

10.11. Pre-Arrival Preparations

Both ships and JF Fendercare exchanged information prior to both ships arrival and mooring and completed the usual ship-to-ship checklist to confirm everything was ready to moor the ships and start the operations. Checklist 1 to 3 of the OCIMF Ship to Ship Transfer Guide (Liquefied Gas) were completed and are included in appendix 6.

10.12. Pre-Operation Meeting

A pre-operations meeting was held between 20:20 and 22:00 on 12th April via Very High Frequency radio (VHF) between the two ships. The meeting was chaired by the JF Fendercare STS Superintendent (POAC) and the agenda and attendees (described further in "VS E" in appendix 1).

The meeting was conducted via VHF as moving participants between ships was considered a risky operation and better to be avoided. The VHF connection was interrupted at times during the meeting which resulted in some misunderstandings that required further clarification.

The purpose of the **pre-operation meeting** was to ensure that all participants understood the procedures, risks, and emergency measures to be used and considered during the operation, thereby significantly reducing the likelihood of an incident.

The main document discussed during the meeting was the JPO.

Other key points discussed during the pre-operation meeting included:

- Review of the JPO
- Roles and responsibilities of each party
- Step-by-step bunkering procedure
- Agreed safety and emergency protocols
- Toxicity and safety measures
- Personal protective equipment (PPE) requirements
- Operational planning

- Bunkering start and end times
- Transfer rates and total volume
- Connections
- Equipment readiness and compatibility
- Weather and wind direction monitoring
- Means of escape
- Communication protocols
- Reporting intervals and confirmation steps
- Completion of safety checklists and logs
- Hot gassing temperature and measuring
- Quantity
- Max pumping rate

The JPO was amended following the meeting to capture any agreed change.

Details of control zones, external safety, incident response preparedness, external communication, etc. were not covered in the pre-operations meeting, see above.

The OCIMF Ship to Ship Transfer Safety Checklist 4 was completed by Port of Rotterdam representative during the pre-operation meeting and is included in appendix 3.

11. Lessons Learnt

Shortly after completing the pilot, the Port of Rotterdam Harbour Master convened several Pilot Lesson Learning events where operational actual performance was compared with operational planned performance. Positive and negative lessons were captured and in total more than 30 lessons and 50 recommendations were recorded. Details are included in appendix 1.

For reference, lessons cover the following topics:

- Structured information exchange between team members and within partner organizations is important.
- Ammonia cargo transfer equipment is relatively straightforward. However, ammonia bunkering equipment is expected to be more elaborate and include more safety features. Ammonia-specific bunkering equipment meeting the standards expected is not currently available.
- If pressure rises due to transfer and boil off, it can be controlled by the vessels equipment. A vapour return line may be connected, though not opened, as a secondary safeguard.
- Ammonia detection device requirements are not defined for ammonia transfer operations and particularly for determining line content concentrations.
- Hot gassing removal of ammonia from transfer hoses can be challenging.
- The Port of Rotterdam's safety framework is a validated governance structure to manage the introduction of new fuels to European ports and beyond.

12. Results and Conclusions

This report is intended to represent deliverable D5.1 of the MAGPIE Project. It describes the steps taken by the Port of Rotterdam to prepare themselves for bunkering ammonia in their port and the work done by them to organize and have the regulatory aspect in place to permit a trial ammonia bunkering operation, the Bunker Pilot. It also describes the key lessons learnt during the process and includes validation fact sheets in the appendices that were produced as part of the Port's normal process to validate and assess what had been done.

In this case, the Port took advantage of their previous experience permitting LNG and methanol bunkering in the port and used the same process, the port's safety framework. They also used the IAPH Port Readiness Tool to demonstrate to key stakeholders that they had performed appropriate due diligence. The use of the Port's safety framework and the IAPH Port Readiness Tool has confirmed that they are both fit for purpose instruments for any port to use when considering new fuels.

As a result of the above and after several months of preparation, the simulation of a ship-to-ship ammonia bunkering operation within the port of Rotterdam was successfully completed without incident. In addition, the risk mitigation measures put in place as part of the contingency planning were not invoked. Port of Rotterdam are now able to declare that they have achieved PRL 6 and can look towards working with industry to develop ammonia bunkering on a project basis and move to PRL 7.

On completion of the Bunker Pilot, and from the beginning of May until mid-July, several workshops were arranged with everyone associated with the pilot to capture lessons and validate the work done in preparation and execution of the pilot. All validation (fact) sheets detailing the work done to date and expected next steps are included in appendix 1. They confirm that all actions were appropriate.

Three notable learnings from the Pilot that require further consideration are as follows:

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1. The transfer equipment used was 'borrowed' from LNG ship-to-ship operations and are considered cumbersome for use with ammonia. Ammonia specific equipment is required for future operations.
 2. At the end of the operation, the clearing of ammonia from the transfer hoses proved problematic. The options around clearing of hoses of ammonia require to be thoroughly considered and tested if this approach is to be universally adopted.
 3. Ammonia bunkering using a seagoing bulk ammonia carrier instead of a purpose-built or adapted bunker barge is considered more complex. Purpose-built or adapted ammonia bunker barges are preferred and will offer an optimized, more efficient operation with fewer variables.
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13. Post Pilot: PoR Requirements for Ammonia Bunkering

Having now achieved PRL 6 for ammonia as a marine fuel, PoR are now focused on progressing further, keeping pace with industry and making sure that they are fully prepared and ready for ammonia fueled ships in their port when they arrive. Validation sheets included in appendix 1 include details of PoR expected next steps. They also include a list of recommendations based on lessons learnt for future bunkering operations within PoR during the final stages of the port readiness framework, stages 7, 8 and 9.

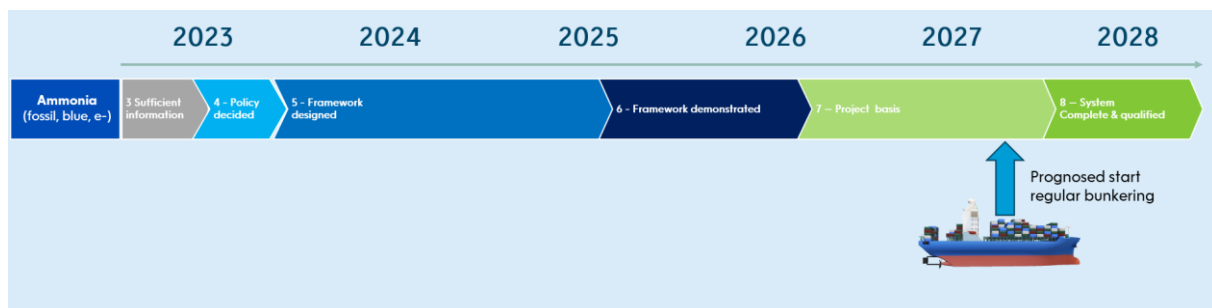
13.1. Safety policy for ammonia bunkering in the port of Rotterdam

The entire process to establish the safety policy for ammonia bunkering in the Port of Rotterdam is based on the IAPH Port Readiness Level (PRL) methodology introduced above.

On a strategic level, the ambition of the Harbour Master of Rotterdam is for the PoR to be fully prepared once ammonia bunkering is a regular operation in the port. This requires the Harbour Master organization to monitor and align progress using the PRL methodology.

The Port PRL should be in at least level 7 when ammonia-fueled vessels start visiting the port regularly, expressed in figure 8:

Figure 8: When ammonia fuelled vessels visit the port regularly, the Port PRL should be in at least level 7.



13.2. Validation of the safety framework

An important task in PRL 6 is the validation of the safety framework.

Ammonia bunkering is only considered to be safe if all ammonia bunker operations can be performed with a sufficient level of safety, expressed by fulfilling all 11 topics of the safety framework.

During the preparation and execution of the pilot in PRL 6, the 11 safety framework topics were adequately fulfilled. The knowledge and lessons learned from the pilot has been used to improve and validate the safety framework and its topics.

The safety framework addresses the requirements and licensing for future ammonia bunkering in Rotterdam. For every ammonia bunkering in the future the 11 safety framework topics should be fulfilled and achieved.

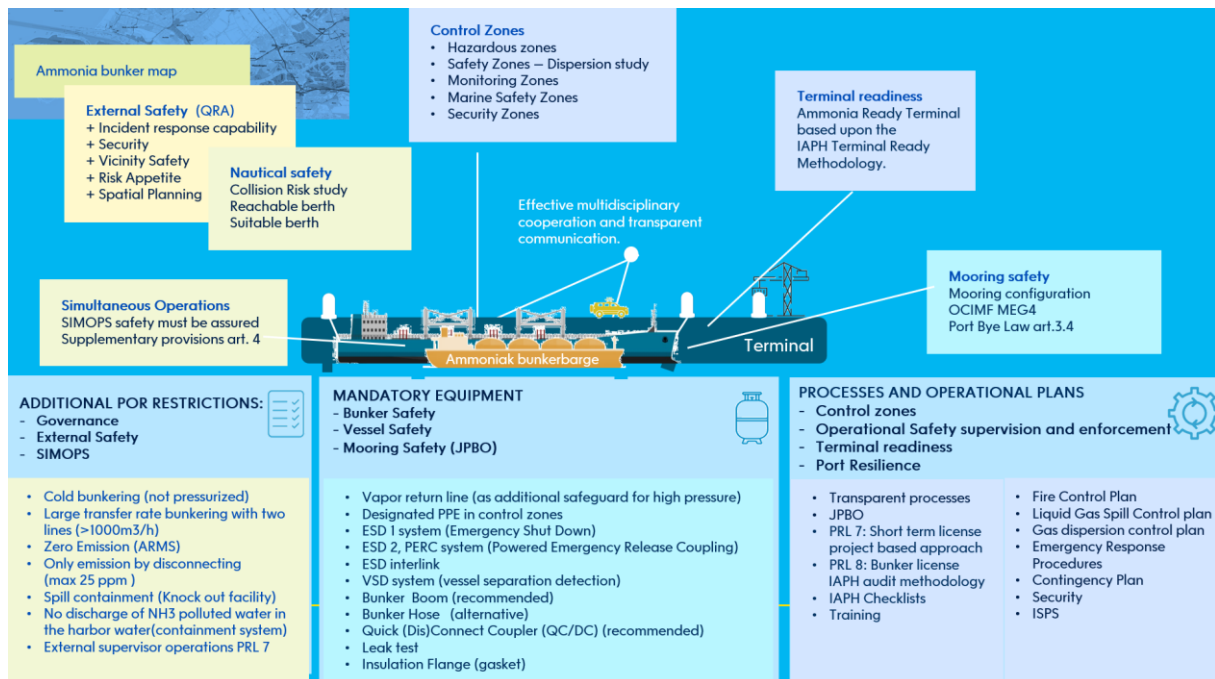
The conditions and restrictions for future ammonia bunkering operations are presented per topic in the validation sheets (FO01 to FO11) in appendix 1.

13.3. From adequate preparation to safe ammonia bunker execution

The lessons learned from the MAGPIE ammonia bunkering pilot and the validation of the safety framework, will be the basis for the safety requirements for future ammonia bunkering in the Port of Rotterdam.

This infographic, expressed in figure 9, provides a summary and more info can be read in the validation sheets found in appendix 1.

Figure 9: Ammonia port safety infographic



There are 23 validation sheets in appendix 1, where most are structured with a general section, the report on the pilot, the recommendations based on the lessons learned from the pilot and the requirements for future safe bunkering in PRL 7, 8 and 9.

Different stakeholders within the supply and bunker value chain have contributed to establishing safe ammonia handling. Port specific safety conditions for ammonia bunkering

are established by a cooperation between these stakeholders and the port safety community of Rotterdam.

Abbreviations list

Acronym	Definition
DCMR	Dienst Centraal Milieubeheer Rijnmond
DHMR	Divisie Havenmeester Rotterdam
DNV	Det Norske Veritas
EPA	Environmental Protection Agency
ERO	Emergency and Incident Response Organization
ESD	Emergency Shut Down
GB	Joint Fire Brigade Rotterdam
GCMD	Global Centre for Maritime Decarbonization
GHG	Greenhouse gas
HAZID	Hazard Identification
HIRA	Hazard Identification and Risk Assessment
HSEQ	Health, Safety Environment, and Quality
IAPH	International Association of Ports and Harbours
ICS	International Chamber of Shipping
ISPS	International Ship and Port Facility Security
JPBO	Joint Plan of Bunkering Operations
JPO	Joint Plan of Operations
LNG	Liquefied natural gas
MAGPIE	sMArt Green Ports as Integrated Efficient multimodal hubs
MMMCZCS	Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping
OCI	
OCIMF	Oil Companies International Marine Forum
PoR	Port of Rotterdam
PPE	Personal protective equipment
PRL	Port Readiness Level
QRA	Quantitative Risk Assessment
SGMF	Society for Gas as a Marine Fuel
SIMOPS	Simultaneous operations
SOMCOM	Strategic Stakeholder Management and Communication Team
STCW	International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers
STS	Ship-to-ship
VHF	Very high frequency
VRR	Rotterdam-Rijnmond safety region

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Appendix 1: Validation Sheets

The Validation sheets are structured with a general section, the report on the pilot, the recommendations based on the lessons learned from the pilot and the requirements for future safe bunkering in PRL 7, 8 and 9.

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- VS 00 Lessons learned
 - VS 01 Safety system, PRL and safety framework
 - VS 02 Pre operation management (PRL 1-5)
 - VS A Bunker scenarios
 - VS B Regulatory framework and licensing
 - VS C Bunker compatibility assessment
 - VS D Joint plan of (bunker) operations JP(B)O
 - VS E Pre operation meeting
 - VS F: Safety framework topics:
 - o VS F 001 Governance
 - o VS F 002 External safety
 - o VS F 003 Control zones
 - o VS F 004 Terminal preparation
 - o VS F 005 Nautical safety
 - o VS F 006 Vessel safety
 - o VS F 007 Mooring safety
 - o VS F 008 Bunker safety
 - o VS F 009 Simultaneous operations SIMOPS
 - o VS F 010 Operational safety, supervision and enforcement
 - o VS F011 Port resilience and emergency response preparedness
 - VS G Checklists (IAPH)
 - VS H The call of an ammonia fueled vessel
 - VS I Strategic stakeholder management and communication

Appendix 2: Initial HAZID and QRA Reports



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report Risks of amm

Appendix 3: Completed OCIMF Ship to Ship Transfer Guide (Liquified Gas) Checksheets, 1 to 4

(Available through ocimf.org/document-library/1044-ship-to-ship-safety-checklist/file)

Appendix 4: MAGPIE Grant Agreement Work Plan 5 Details



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This deliverable is still awaiting final approval from the European Commission.