Together in Safety

Future Fuels Risk Assessment

Contents

About Together in Safety 3
Summary 4
Introduction 6
Overview of fuels 8
Methodology 10
What if scenarios 13
Recommendations 16
Conclusions 17
Contact Us 18

About Together in Safety

'Together in Safety' is a non-regulatory shipping industry safety coalition that was established with the principal objective to protect seafarer lives, and also to deliver improved business efficiency and commercial effectiveness. The focus is strongly on collaboration with the emphasis to deliver solutions that will improve the safety performance in shipping.

'Together in Safety' comprises all of the shipping industry groups including the International Chamber of Shipping, BIMCO, OCIMF, Intertanko, Intercargo, Interferry, Cruise Liners International, World Shipping Council, in addition to major shipping companies, Classification Societies, P&I insurance, and country representatives.

Summary

As shipping moves to transition from existing energy sources, the timescale of this change shall mean that learning from experience shall be limited.

Fuel oil use today is relatively safe in its storage and use and the industry over time has learnt to mitigate any risks that arose. It is widely acknowledged that the fuels of the future shall bring additional risks to seafarers. If not dealt with correctly the consequences both on the ship and on land could be catastrophic. Such an event could have an impact on the energy transition. It is therefore imperative that industry comes together to bring collective experience to pro-actively place measures and safeguards to reduce the likelihood and consequence of any incidents.

'Together in Safety' has carried out a series of hazard identification workshops with the purpose of identify and prioritising recommendations to the industry to ensure the safe deployment of future fuels. The fuels considered were LNG, Methanol, Ammonia and Hydrogen with the assumption that these are likely fuels to be used. The sustainability of the fuels in their well-to-wake factor, availability and cost were not in scope. The workshops were based on a tanker design using LNG as a fuel.

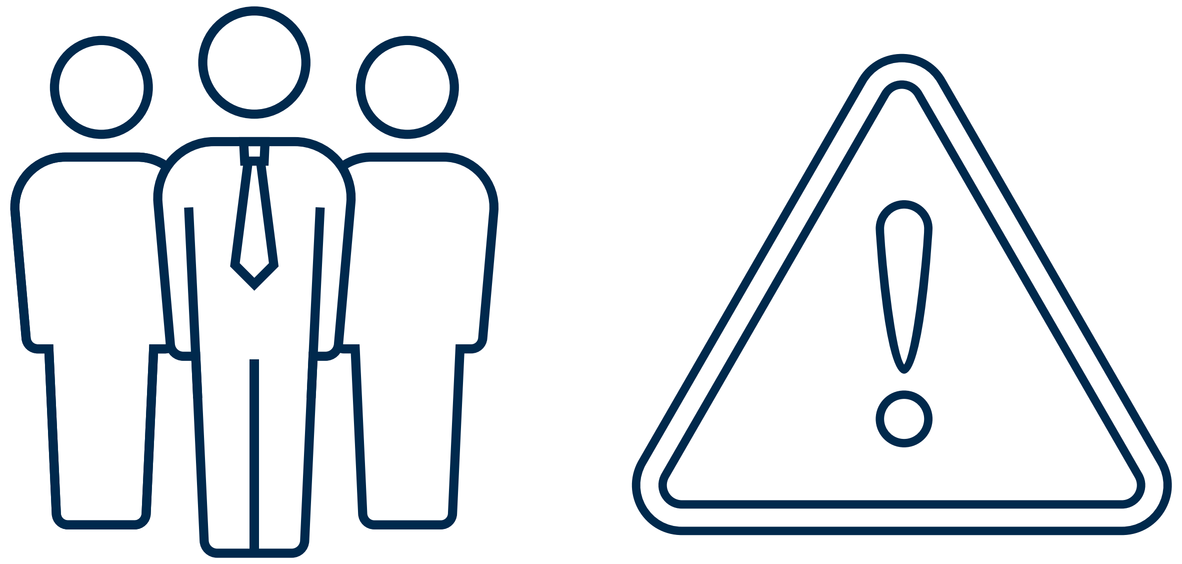
The working group consisted of representatives from the following companies: APM Terminals, Carnival Corporation, Chevron, Euronav, Lloyd's Register, Mærsk, MSC Ship Management, OCIMF and Shell.

Out of scope were in-depth technical discussions on design specific items, i.e. the lifting pressure and re-closure times for pressure relief valves. Similarly, it was assumed that no simultaneous operations would take place during the bunkering process, for this requires a system, location and ship specific HAZID to be conducted. As is generally the case, criminal and terrorist actives were also considered outside the scope of these risk assessments, noting that these are the prerogative of Port States.

In the full understanding that:

- the HAZID results presented were based on generic vessel design considerations and typical ship procedures,
- the associated risk rankings might not be conservative,
- actual risk rankings will depend heavily on specific designs and integrated safety measures,

it remained indicative to make a side-by-side comparison of the future fuels to appreciate their associated risks.



If one assumes that the higher the risk rankings are correlated to the effort required for implementing the fuel compared to the HFO baseline, then it follows that methanol would require the least effort with regards to additional safety measures, followed by LNG, hydrogen and ammonia being the most demanding, but with all requiring inherently safer designs for implementation.

The recommendations from this report can be defined in areas of responsibility between design, operator, regulators and ports.

Introduction

The world needs to take urgent action to tackle climate change. The Paris Agreement set a goal to limit global warming to well below 2°C compared to pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C.

Global seaborne trade is forecast to more than double by 2050. The shipping industry, which transports ~80% of the world's traded goods and is responsible for 2.9% of global CO_2, must choose a pathway, supported by regulation, that is sustainably viable to reach a net-zero emissions future by 2050. To achieve this goal the industry must collectively do more to accelerate change.

As the sector focuses on the pathways to achieving net-zero the advancement of zero carbon fuels will be required. These fuels will demand significant changes to ship designs, port infrastructure, and supply chain operations. We can anticipate these fuels being available, at scale for deep sea shipping applications, within the early 2030's. Given the impact change in a short period of time, action is required now to ensure we, as an industry, are ready for their safe introduction.

Zero Carbon fuels are currently in their infancy and whilst high level feasibility is being assessed by several industry bodies, the practical application of these fuels onboard ships has largely yet to be considered or factored into any development programmes.

Objective

For this study the following fuels were considered:

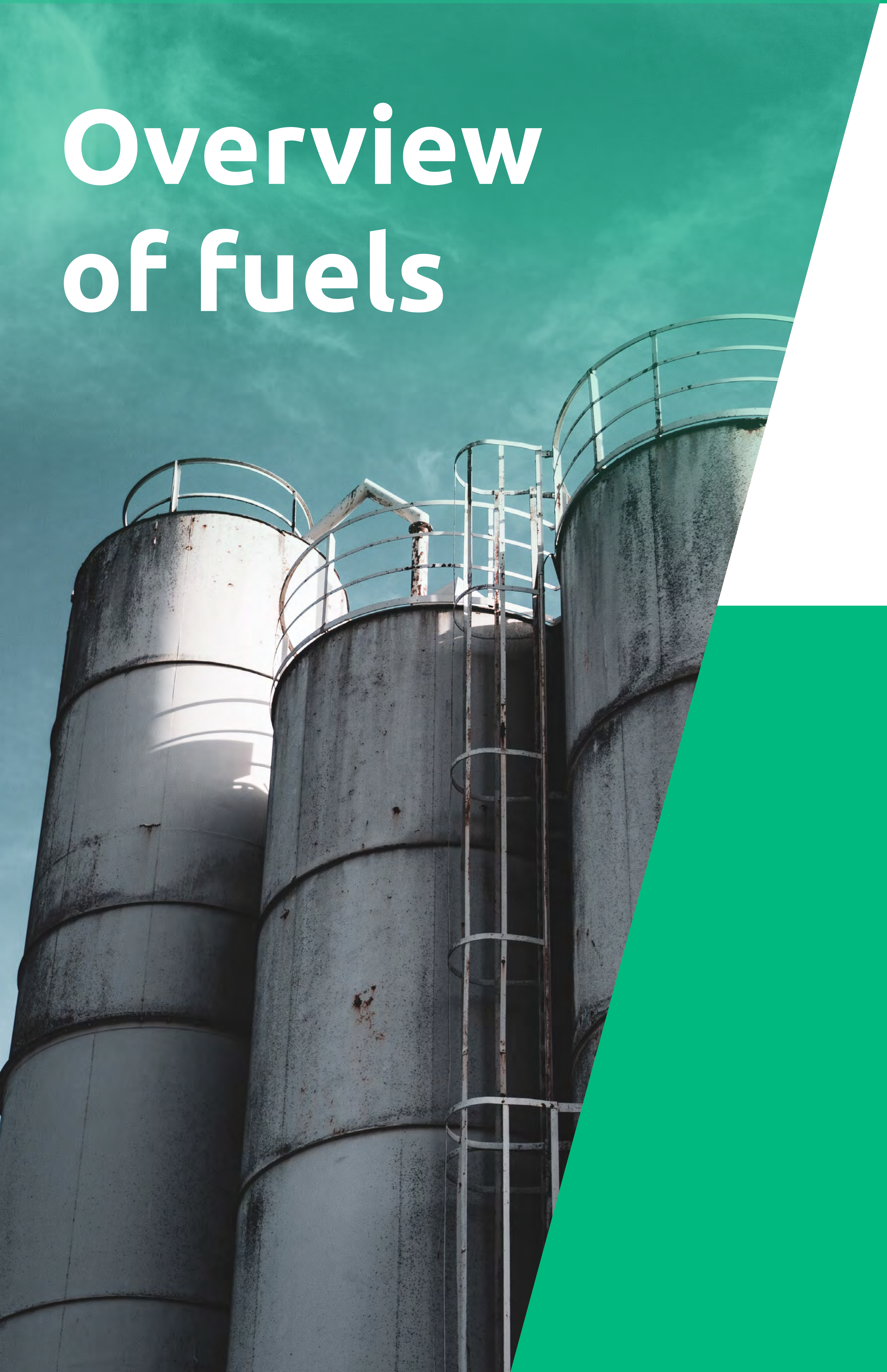
- Liquified Natural Gas
- Hydrogen
- Methanol
- Ammonia

The objective is to enhance and further the common understanding associated with future fuels by:

- identifying hazards, in particular how they can be realised (what can go wrong, and how?). This considered all applicable risks, as well as unplanned and emergency scenarios related to the construction, installation, commissioning and operation of the relevant equipment and systems
- understand reasonably foreseeable consequences of these hazards, including the identification of loss of containment events and assess the level of risk
- review system safeguards and control measures to ensure suitability and understand what additional measures could be taken to eliminate or reduce the level of risk further, following ALARP principles, the detection and control of potential issues as well as suitable emergency response
- recording actions and recommendations for further supplementary work

Together in Safety

Overview of fuels



LNG

Part A-1 of the IGF code sets out specific requirements for the use of LNG as fuel onboard ships. These regulations formalise, amongst others, the best design practices in terms of arrangement, containment, fire and explosion prevention and control and monitoring systems.

The goal-based nature of the code encourages designers to adopt a risk-based design approach that fulfils its functional requirements. The working group therefore foresees that the same design philosophy and rationale will be applied to other future fuel systems.

Hydrogen

To meet the demand onboard ships and the associated energy densities, hydrogen will either be stored in very high-pressure vessels (typical in excess of 300 barg) or as a cryogenic liquid (–253 °C) at atmospheric pressure. Unlike LNG and Methanol, no international regulations and guidance are available for the use of hydrogen as fuel in the marine environment for either storage type. In order to have a reasonably generic HAZID discussion, the HAZID team decided to only consider cryogenic liquid hydrogen, for it permitted the regulated LNG design rationale and concepts to be used as a reasonable proxy. The HAZID team fully acknowledges that a one-to-one comparison with LNG and Hydrogen systems is not possible.

Ammonia

Similar to hydrogen, there is no existing framework of regulations, rules and guidelines regarding the use of ammonia as fuel. The HAZID team acknowledges that liquid ammonia has been carried in bulk onboard ships as a cargo and that the lessons learned from this industry should be considered.

Ammonia is liquified either by low to medium pressure or cooling down to -34°C forming a non-cryogenic liquid.

Methanol

Well established international regulation and Class rules are in place for the use of methanol as fuel onboard ships. In contrast to LNG, hydrogen and ammonia, methanol is a liquid fuel under ambient temperature and pressure. It differs from conventional fuels in that its flash point is well below 60°C, meaning that additional fire prevention measures need to be taken when storing and handling it.

Typically, methanol tanks are surrounded by cofferdams and have an inert gas in the vapour space above the fuel. Indicative to the risks associated with methanol is that the IMO MSC.1621 circular permits methanol fuel tanks against the side shell, provided the tank is situated below the lowest possible waterline.

Methodology

The HAZID study followed a Structured What-If? (SWIFT) and checklist technique, based upon experience with guidance from the following sources:

- **BS ISO 31000**: 2009, Risk Management – Principles and Guidelines
- **BS ISO 31010:** 2010, Risk Management – Risk Assessment Techniques

The HAZID workshops were facilitated by an experienced Risk Specialist.

HAZID prompts and 'What if?' scenarios prepared prior to the workshops were applied, initiating and encouraging discussions on possible events that may lead to an unplanned event. These prompts were based upon previous experience and indicated the types of hazards that were thought to be applicable.

Identification of hazards and causes

Possible hazards were identified by applying the checklist guidewords. When a credible potential event was identified the HAZID team considered the possible causes that may lead to this.

Evaluation of consequences

The consequences of each cause were analysed by the HAZID team and a discussion followed on the potential consequences.

Evaluation of safeguards and design recommendations

To obtain a coherent list of design recommendations, the HAZID team made a distinction between safeguards required by Rules and Regulations and commonly applied measures in the industry that are effectively design choices. The latter were included in the design recommendations and assumed to be implemented in the assignment of the risk ranking.

Together in Safety

Risk Ranking

To facilitate an understanding of the level of risk associated with a particular hazard, a consequence and likelihood were assigned and compared to the risk matrix in **Table 1**. ▼

The chosen risk acceptance criterion reflects 'good practice' in major hazard industries regulated by governments and is recognised by the UK Health and Safety Executive (HSE) as a good basis for use.

The matrix identifies three risk zones:

High Risk (Unacceptable) - This level of risk cannot be justified and the hazard should be eliminated, substituted or controls implemented to reduce the risk to tolerable levels.

Medium Risk (Tolerable) – This level of risk can only be tolerated where it has been demonstrated to be As Low As is Reasonably Practicable (ALARP). This can be demonstrated by analysis to assess whether the implementation of risk mitigation measures is proportionate to the reduction in risk they would achieve.

Low Risk (Acceptable) – This level of risk does not need to demonstrate ALARP, however, it is good practice to implement measures to further reduce the risk where possible. The risks should be periodically reviewed to ensure they remain in this region.

To demonstrate ALARP, the High and Medium risks prompted further discussions on whether existing safeguards and the design recommendations were sufficient; or additional layers of protection needed to be identified.

Table 1: Risk acceptance criteria

- Intolerable risk
- Tolerable risk - ALARP
- Broadly acceptable

				Consequence				
				C1 Minor Injury	**C2** Minor Injury	**C3** One fatality or multiple major injuries	**C4** 2-10 Fatalities	**C4** 11+ Fatalities
Likelihood	**L7**	Extremely Likely	≤100 to 10^{-1}					
	L6	Very Likely	≤10^{-1} to 10^{-2}					
	L5	Likely	≤10^{-2} to 10^{-3}					
	L4	Unlikely	≤10^{-3} to 10^{-4}					
	L3	Very Unlikely	≤10^{-4} to 10^{-5}					
	L2	Extremely Unlikely	≤10^{-5} to 10^{-6}					
	L1	Remote	≤10^{-6}					

Together in Safety

What if scenarios

The working group considered the below scenarios that may occur on the vessel. These scenarios are not comprehensive, but covered the daily operations of a vessel and situations that may arise.

The scenarios did not cover day to day tasks such as maintenance which would be expected to be covered in the Safety Management System.

In using the **'What if'** approach, a list of potential causes was produced and then examined to determine the consequences and safeguards.

The following scenarios were considered:

What if-

- there is loss of manoeuvrability at sea?
- there are excessive motions at sea?
- there is a black-out at sea?
- an excessive trim / list develops at sea or in port?
- there is a requirement for tug support / 3rd party vessel attendance at sea or in port?
- there is a ship grounding in way of the future fuel tanks and system?
- the vessel needs to be abandoned?
- there is a ship collision in way of the fuel tank?
- cargo operations are required in way of the future fuel tanks and system components?
- there is a crew change?
- there is a completely new crew after vessel handover?
- onboard access is required by personnel not managed by the ship's operator?
- there is a misalignment of the bunkering stations?
- there are excessive motions during bunkering?

Together in Safety

Considerations, assumptions and discussion

In the full understanding that:

- the HAZID results presented in the previous chapters were based on generic vessel design considerations and typical ship procedures,
- the associated risk rankings might not be conservative,
- actual risk rankings will depend heavily on specific designs and integrated safety measures,

it remained indicative to make a side-by-side comparison of the fuels to appreciate their associated risks.

Indicative comparison

Table 2 ▼ the risk rankings for each HAZID prompt are provided for LNG, hydrogen, ammonia and methanol.

During the HAZID workshop no particular tank sizes, types or locations were excluded from the discussion. It's duly noted that the associated risk ranking could therefore be non-conservative and could vary substantially from vessel to vessel.

The assigned rankings should therefore be interpreted as purely indicative. The risk rankings point to typical areas of focus during the design stage and follow-on risk studies of a fuel system. Their objective is to encourage designers to implement preventative measures as early on as possible in the design cycle, for it is typically easier and leads to better overall designs.

Together in Safety

Table 2: Indicative comparison of HAZID risk rankings

Intolerable risk | Tolerable risk - ALARP | Broadly acceptable

Node	What If Questions	Causes	Consequences	LNG	H2	Ammonia	Methanol
1. Navigation	**What if there is loss of manoeuvrability at sea?**	1. Propulsion failure	1. Grounding	C1-L4	C1-L4	C1-L4	C1-L4
			2. Collision	C1-L4	C1-L4	C1-L4	C1-L4
			3. Build-up of tank pressure	C1-L5	C1-L5	C3-L3	C1-L1
			4. Excess motions	C1-L5	C1-L5	C1-L5	C1-L1
	What if there are excessive motions at sea?	1. Loss of fin stabilisers	1. Excess motions	C1-L5	C1-L5	C1-L5	C1-L1
	What if there is a black-out at sea?	1. Engine / generator failures	1. Boil-off management affected that could lead to build-up in tank pressure	C1-L2	C1-L2	C3-L2	C1-L1
	What if an excessive trim / list develops at sea or in port?	1. Loading / Ballasting error	1. Potential for gas pocket formation	C1-L2	C1-L2	C3-L2	C1-L1
		2. Grounding	1. Large heel / trim angles that could lead to liquid fuel coming from vent mast	C1-L3	C1-L3	C5-L3	C1-L1
		3. Collision leading to hull breach	1. Large heel / trim angles that could lead to liquid fuel coming from vent mast	C1-L3	C1-L3	C5-L3	C1-L1
	What if there is a requirement for tug support / 3rd party vessel attendance at sea or in port?	1. Fuel / Bunker / Supply up lift	1. Potential source of ignition	C3-L2	C3-L3	C1-L1	C3-L2
			2. Damage to pipe work (hard landing / hard contact by tug)	C1-L2	C1-L2	C1-L2	C1-L2
			3. Potential of exposure to toxic fumes	-	-	C3-L2	-
	What if there is a ship grounding in way of the future fuel tanks and system?	1. Propulsion / Steering gear / Human failure	1. Tank breach	C5-L1	C5-L1	C5-L1	C2-L3
	What if the vessel needs to be abandoned?	1. Loss of LNG tank pressure control / LNG tank breach / Loss of propulsion in high seas that pose risk to crew	1. Liquid / vapour release / Tank pressure build up	C1-L1	C3-L2	C1-L1	C1-L1
2. External events	**What if there is a ship collision in way of the fuel tanks?**	1. Hull breach	1. Loss of containment	C5-L1	C5-L1	C5-L1	C2-L3
			2. Build-up of tank pressure	C1-L2	C1-L2	C1-L2	
			3. Potential ignition sources in hazardous areas (from colliding vessel)	C3-L2	C3-L2	C3-L2	C3-L2
	Potential of ignition	1. Oil spill / pipe breach / vehicle fire / lightning strike / etc.	1. Build-up of tank pressure	C1-L2	C2-L3	C3-L2	C1-L1
3. Ship operations other than bunkering	**What if cargo operations are required in way of the future fuel tanks and system components?**	1. Operational requirements	1. Damage to equipment / Vent mast	C1-L5	C1-L5	C3-L5	C1-L4
		2. Crane reach	1. Inadvertent ignition source in hazardous area		C2-L4		
	What if there is a crew change?	1. Operational requirements	1. Potential for un/under-informed personnel taking over control	C1-L1	C1-L1	C1-L1	C1-L1
	What if there is a completely new crew after vessel handover?	1. Crew unfamiliar with the vessel	1. Potential for un/under-informed personnel taking over control	C1-L5	C2-L5	C2-L5	C1-L2
	What if onboard access is required by personnel not managed by the ship's operator?	1. Electronic equipment carried inadvertently in hazardous areas	1. Potential source of ignition	C2-L4	C2-L4	C2-L4	C2-L4
		2. Persons inadvertently being exposed to toxic atmosphere	1. Toxic exposure			C3-L4	C2-L4
4. Bunkering	**What if there is a misalignment of the bunkering stations?**	1. Mooring Control	1. Tension on hoses and couplings, manifolds	C1-L4	C1-L4	C2-L4	C1-L3
		2. Mooring line tension	1. Tension on hoses and couplings	C1-L4	C1-L4	C2-L4	C1-L3
	What if there are excessive motions?	1. Passing ships / weather	1. Tension on hoses and couplings	C1-L4	C1-L4	C2-L4	C1-L3
		2. Asymmetric filling of tanks	1. Heel angles exceeding limits for bunkering	C1-L4	C1-L4	C2-L4	C1-L3
	What if there is a loss of control?	1. Filling rate	1. Leakage / Overfilling	C2-L3	C2-L3	C5-L3	C2-L2
		2. Incorrect level readings	1. Leakage / Overfilling	C2-L3	C2-L3	C5-L3	C2-L2
		3. BOG management	1. Venting	C1-L3	C1-L3	C3-L2	
		4. Roll over	1. Venting	C1-L3	C1-L3		
	What if there is a leak / loss of containment?	1. Overfilling	1. Loss of containment	C2-L3	C2-L3	C5-L3	C2-L2
		2. Joints leakages	1. Loss of containment	C2-L3	C2-L3	C3-L3	C2-L2
		3. Incompatible flange types	1. Damage to equipment / Vent mast	C2-L3	C2-L3	C3-L3	C2-L2
		4. Insufficient pre-cooling of bunkering lines	1. Damage to equipment / Vent mast	C2-L2	C2-L2	C2-L2	
5. Fuel preparation, use and monitoring	**What if there is a loss of control?**	1. Power outages	1. Automated shut-down	C1-L4	C1-L4	C1-L4	C1-L1
		2. Sensor and system failures	1. Automated shut-down	C1-L4	C1-L4	C1-L4	C1-L1
6. End of life	**What if the vessel is scrapped?**	1. Vessel age	1. Potential for residual gas in tank	C3-L2	C4-L1	C3-L2	C3-L2

Recommendations

A risk rating was assigned against the consequences for each cause, along with safeguards and recommendations for the industry to take forward. An overview of the recommendations is given in the table below, along with the related risk rating they are addressing.

The recommendations can be defined in areas of responsibility between design, operator, regulators and ports.

Node	Mitigation measures	Current Risk without Mitigation			
		LNG	LH2	NH3	CH3OH
Navigation	Following collision or grounding, crew to anticipate performing additional checks for leakages in areas not necessarily assigned as hazardous areas (pipe work, void spaces, etc.) with intrinsically safe (EX-) equipment. This should be included in the ship's SMS				
	Dedicated boil-off management training to be provided to the crew for LNG, Ammonia and Hydrogen				
	Seafarer training in all hazards associated with the fuel system				
	The tank type selection to consider the vessel's trading routes and the associated expected recovery duration in case of propulsion failure				
	Crew training on the effects of trim and list on the fuel storage system				
	Trim/ Heel Alarms to be provided for seafarers if there is a risk of gas pocket formation				
	Dedicated emergency training for crew on handling large heel/trim angles, due to loading errors, collision and grounding, on vessel with installations where gas pockets could form				
	Salvage operators to have portable gas detection equipment capable of measuring the airborne concentration, escape sets and appropriate skin covering to ensure salvagers' safety and safe exposure limits				
	Where possible and safe from a cyber-security perspective, consider remote tank status monitoring (i.e. pressure and temperature), potentially only activated upon abandoning ship				
	Dedicated design guidelines to be developed on how to engineer out credible liquid release scenarios resulting from large sustained heel angles				
	Crew awareness training of the presence of inert gas in the tanks and that this gas could potentially spill into the adjacent void spaces if there is a leak				
External	Crew emergency response training dedicated to spills / leaks				
	Tank design to consider water ingress in surrounding space, where applicable, and how this impacts the boil-off rate.				
	Bridge team to communicate with other vessel to stay clear of collision area if this is in way of the ammonia fuel system.				
	Ship emergency response plan to consider collision scenario with overlap in hazardous zones				
	Vessels to have a communication protocol requesting colliding vessel to de-energise area of collision to ensure affected areas are isolated on both vessels				
	Crew training on the impact of radiated heat on the vessel's fuel system				
Ship Operations other than bunkering	Crew training on the requirements for EX-rated equipment within the hazardous zones				
	Training for harbour personnel with regards to fuel system safety devices and how to recognise them				
	Crew training on how to handle damage to the fuel system scenarios caused by dropped objects or structural (crane) interactions				
	The fuel system to be designed such that it is adequately protected against normal vessel operations, like cargoes and supply lifting operations				
	Vessel to have a Contractor/Visitor control management plan that ensures that people boarding are made aware of additional dangers and control measures associated with the fuel system				
	Crew to be appropriately trained and accredited for the fuel used before being permitted to board the vessel				
	Company SMS needs to account for specific fuelled vessel. This should include crew handover procedures and time allotments				
	Fuel system Subject Matter Expert should have sufficient time and rest for effective handover, which typically requires more time than handing over other crew tasks				
	Formalisation of handover procedure of future fuel systems, allowing sufficient time for crew (SME) familiarisation with system operational parameters				
	Crew awareness training regarding the potential lack of knowledge that visitors have about the onboard safety systems and future fuel risks				
	Crew training in effective knowledge transfer of safety critical information to visitors				
	International bodies to ensure uniformity of alarms associated with fuels in ports and vessels				
Fuel Preparation & Monitoring	Crew training on impacts of fuel density differences when bunkering				
	Fuel overfill control plan needs to be in place and part of the ship's emergency response plan				
	Bunkering systems to be designed with sufficient safeguards against and during loss of control				
	Crew training on how to detect methanol fires				
	Companies to consider having on-board testing of toxic exposure levels				
	A Quantitative Risk Assessment to be conducted for the bunkering operation, in which the consequences of credible leakage scenarios are assessed				

Conclusions

As the shipping industry migrates through the energy transition there shall be inherent risks that need to be mitigated. Out of the fuels reviewed, methanol poses the least risk, followed by LNG, hydrogen and ammonia risk ratings increasing.

A number of risks for ammonia as a fuel are classified as High (Intolerable), and as such the hazards should be eliminated, substituted or sufficient controls put in place to significantly reduce the risk to with medium or a low risk rating.

Across all the fuels there are a number of medium risk rating, whilst these may be accepted tolerable, every effort must be demonstrated that the risks have been reduced to be As Low As Reasonably Practicable (ALARP).

The recommendations can be defined in areas of responsibility between design, operator, regulators and ports. This report is produced to enable those stakeholders to ensure the risks raised and identified are dealt with in further projects, and further risk fed back to 'Together in Safety' to incorporate into future updates.

Regardless of the vessels fuel, there are scenarios where vessels shall come across another vessel operating on a different fuel, and thereby having potentially a different and unknown risk category. This could be through port operations, collision, rescue or grounding. It is the intention of 'Together in Safety' to work collectively within the industry to address this challenge.

Get in touch with us
to find out more about joining
Together in Safety:

www.togetherinsafety.info/contact-us