Webinar:
Ammonia as a shipping fuel

Safety **concept** of the M/S NoGAPS vessel design

December 12, 2022

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for Zero Carbon Shipping

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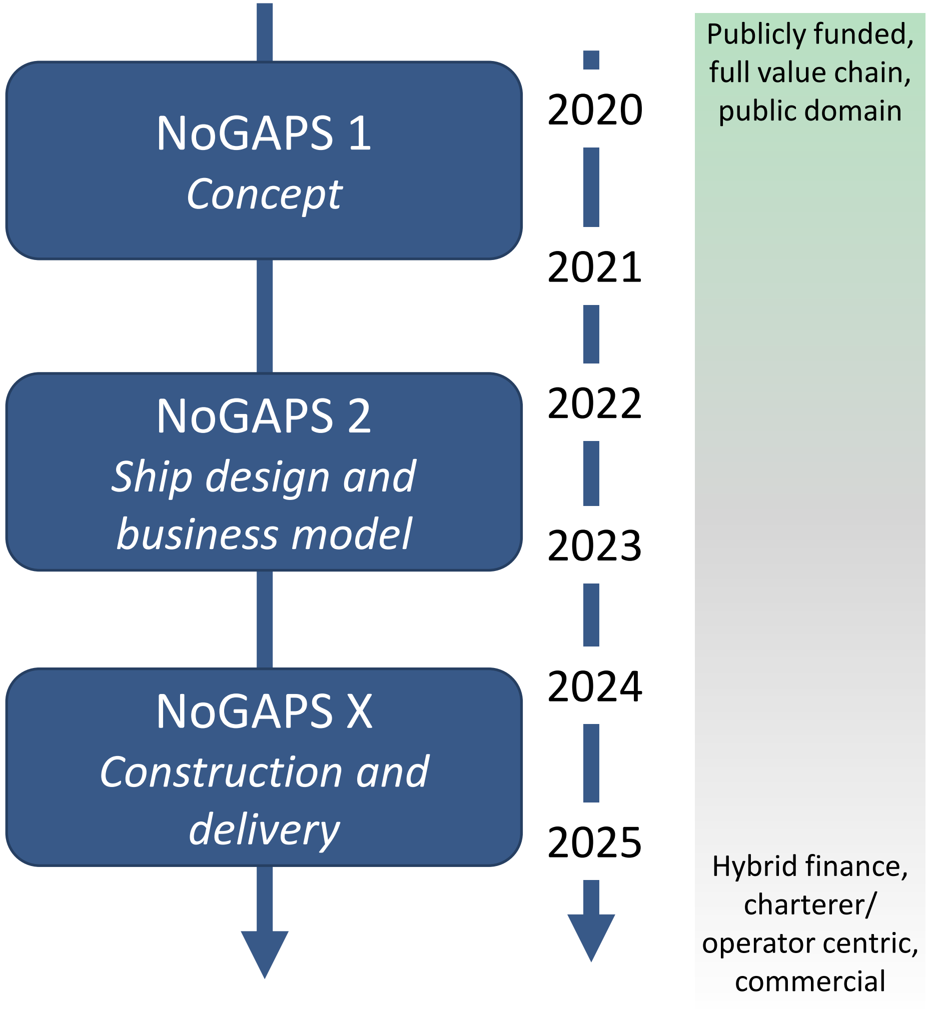
NoGAPS ammonia-fueled gas carrier – from concept to reality



- The NoGAPS journey has completed a first step, agreeing on a shared overall concept and identifying key issues to be addressed when developing specific solutions
- NoGAPS2 sees some narrowing of focus toward the vessel and its design, operation, and economics, but a broader interaction with the ecosystem is still important to build support for the model and exchange knowledge
- Following phases will involve some ‘public’ component (e.g., in financing) but will primarily be defined by commercial agreements

Initial project conclusions inform our ship design objectives: confirmation of no major obstacles and demonstration of risk and cost reduction

In line with the pillars of zero-emission shipping, the consortium investigated the vessel, the fuel and the fueling options, as well as the business and financing considerations. The major conclusions were clear:

1. The potential of ammonia-powered shipping to contribute to the decarbonization of the maritime sector is significant, and ammonia carriers present a logical starting point for demonstrating this potential.
2. Neither the technical considerations nor the associated regulatory approval for an ammonia-powered vessel present major obstacles to putting the M/S NoGAPS on the water.
3. Ammonia synthesized from green hydrogen represents a credible long-term, zero-emission fuel.
4. The most important challenge to be overcome is to develop and demonstrate a business model that is credible in the eyes of investors and operators. Both the vessel design and the fuel sourcing strategy offer opportunities to reduce risks and costs in meaningful ways.
5. Government support and public finance can both accelerate the short-term timetable for investment in demonstration and improve the outlook for long-term deployment of ammonia as a shipping fuel.

Objective 1:
Confirm no major technical or regulatory obstacles are present to putting a vessel on the water

Objective 2:
Demonstrate a credible business model through meaningful risk and cost reductions

Fuel pathway maturity map

MATURE
Solutions are available, and none or marginal barriers are identified..

SOLUTIONS IDENTIFIED
Solutions exist, but some challenges on e.g. maturity and availability are identified.

MAJOR CHALLENGES
Solutions are not developed or lack specification.

Agenda

- **Quantifying the risks, designing intelligent safeguards**
  Claus Rud Hansen, Secondee, Onboard Vessel Solutions, MMMCZCS
- **Introducing M/S NoGAPS and its safety concept**
  Jun Ito, Ship Design Secondee, MMMCZCS
- **M/S NoGAPS HAZID outcomes**
  Thomas McKenney, Ship Design Manager, MMMCZCS
- **Panel discussion with Q&A**
  - Dorthe Marie Sveistrup Jacobsen, Principal Research Engineer, Fuel & Emissions, Engine Process Development, MAN Energy Solutions
  - Fredrik Lindfors, Project Manager Sustainable Fuels and Decarbonization, Wärtsilä
  - Sven Rolfsen, Naval Architect, Breeze Ship Design
  - Mayank Bhatt, Fleet Manager (HSE & Compliance), BW Epic Kosan

Ammonia as marine fuel

Quantifying the risks

Designing intelligent safeguards

Claus Rud Hansen, Secondee, Onboard Vessel Solutions

Ammonia as a shipping fuel – Safety concept of the NoGAPS vessel design

The work discussed is a collaboration between

Lloyd's Register

Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping

Partners to the project include - Phase 1 and Phase 2

MAERSK, MAN Energy Solutions, MITSUBISHI HEAVY INDUSTRIES, LTD., NYK LINE NIPPON YUSEN KAISHA, TotalEnergies

Partners to the project include - Phase 2

ABS, bp, Cargill, Stolt Tankers, V.Group

The Ammonia pathway will remain constrained until safety concerns are addressed – proper risk management is thus a key transition enabler

Phase 1
Quantitative Risk Assessment
QRA – Risk of fatality

3 selected vessel segments →

1. **Location Specific Individual Risk (LSIR)**
2. **Individual Risk per Annum (IRPA)**

Ammonia containment and fuel systems has been applied to existing vessel design

- Ammonia Tanks, type, size and location
- Fuel supply system, location and components. P&I diagrams made
- Fuel consumers, Main Engine, Aux Engine and Boiler
- Pipe routing, with pipe dimensions, ammonia flow rate, temp and pressure.
- Volume of spaces with ammonia equipment calculated

Phase 2
Deep dive on identified risk areas

→

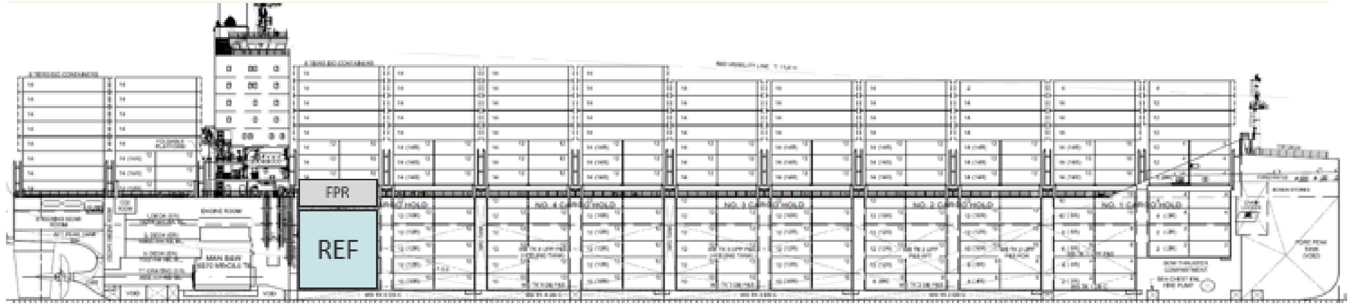
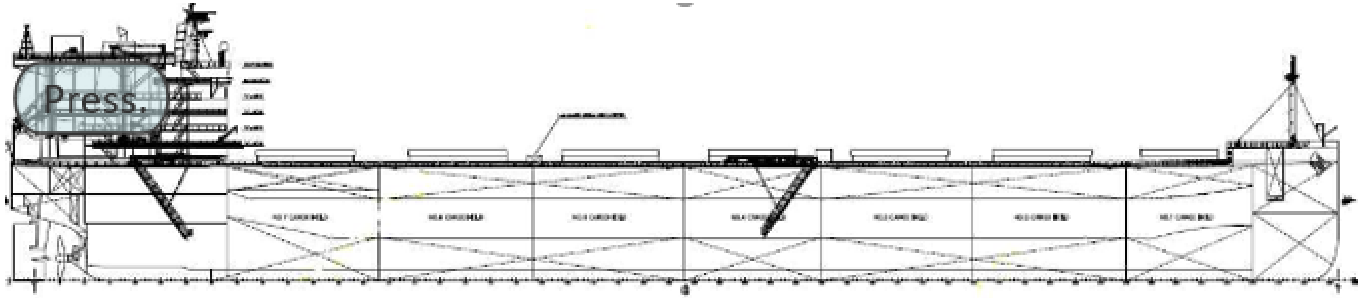
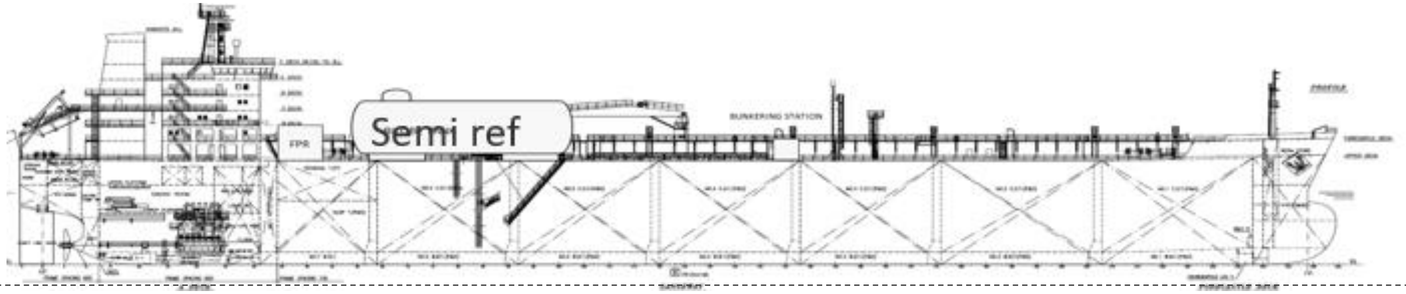
Risk mitigation, technical

1. Further risk analysis
2. Re-engineer base design (ALARP)

Risk mitigation, Human factor

1. Risk identification
2. Competence, training and safety system requirements

Three different vessel design cases

Container 3500 TEU		• Fully refrigerated tank system • Liquid ammonia at atm. pressure. -33 C°
Bulker 80-10.000 DWT		• Fully Pressurized tank system • Liquid ammonia at ambient temperature. Designed for 18 Bar
MR Tanker 50.000 DWT		• Semi refrigerated tank system • Liquid ammonia at 4 bar

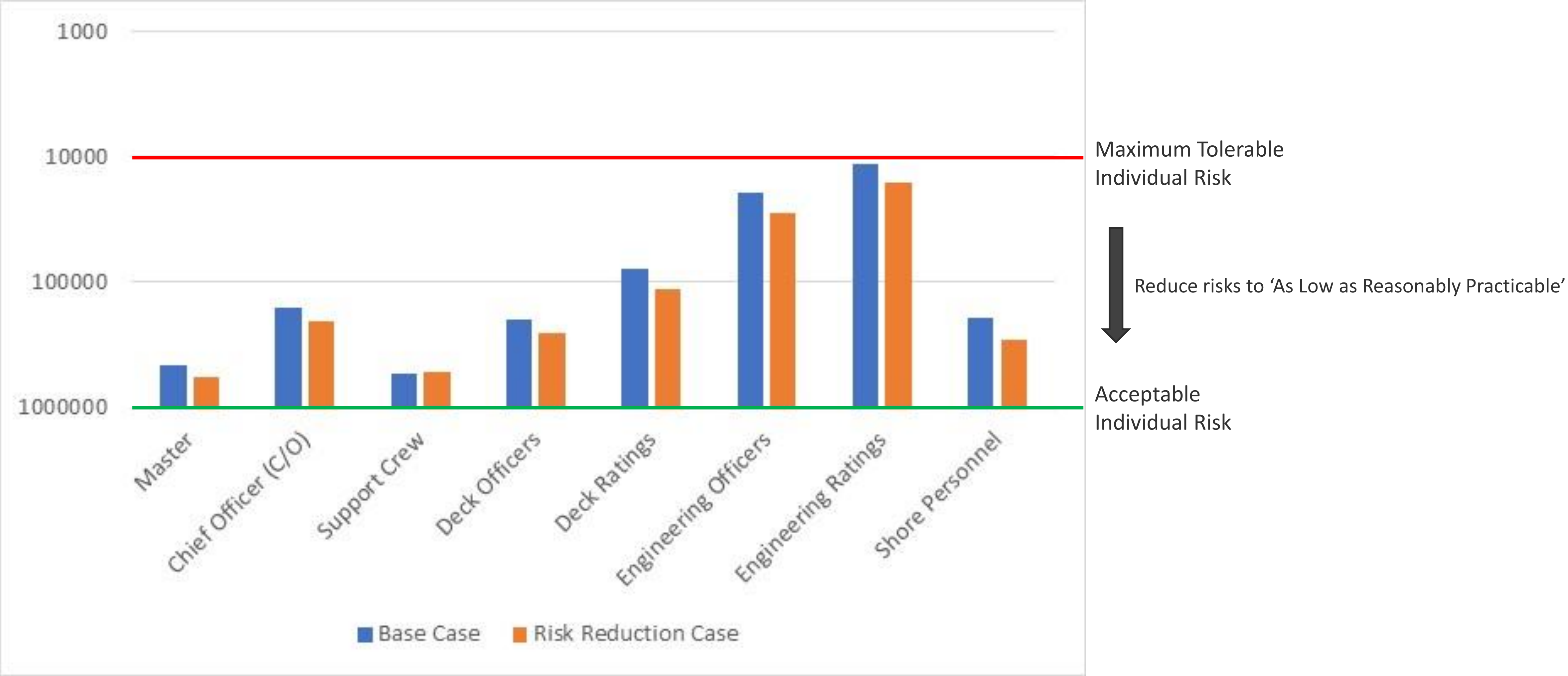
Vessel and system design has variation in the risk level for the different locations onboard. (LSIR), necessitating dedicated further work

The Location Specific Individual Risk (LSIR) reflects the risk of fatality with permanent occupation in selected locations.

The Highest risk areas across all segments: (1) Fuel preparation room, (2) Tank connection space, all with ammonia containing equipment.

Vessel location / Vessel segment	Container	Tanker	Bulker
Fuel preparation room			
Tank connection space			
Engine room			
Tank area on deck, Tanker and bulker	N/A		
Deck Forward		due to tank location	
Cargo Hold		N/A	
Bunker Station			
Deck Aft			
Accommodation			due to tank location
Engineering Control Room			

Individual risk to crew (IRPA)



NOTE: Results are preliminary

The QRA findings for the 3500 TEU Container case pinpoint concrete key risk drivers and mitigation actions based on the LSIR and IRPAs.

Key observations

- Risks of ammonia as marine fuel are manageable with proper safeguards in design and operations.
- The level of risk exposure is close to the Maximum Tolerable level, in some cases, indicating need for risk mitigation.
- Crew training and competence is equally important to engineered design solutions.

Key identified risk drivers and mitigations

<u>Key risk drivers in QRA calculations</u>

- Number of leak sources
- Flow, pressure and volume of ammonia in equipment
- Chance of escape

<u>Key risk mitigations</u>

- Ventilation of room
- Restriction of access to location.
- Separation of bunker station from accommodation
- Water curtain at bunker station
- Recirculation of ventilation in accommodation
- Double walled piping in ER and other places outside FPR

Presentation: Introducing M/S NoGAPS and its safety concept

Jun Ito, Ship Design Secondee, MMMCZCS

Design requirements

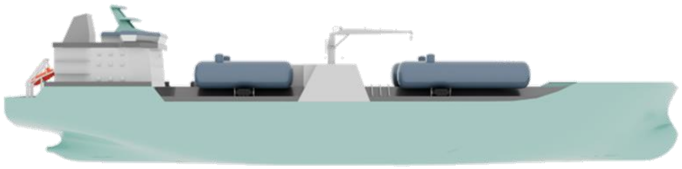
- 22,000 m^3 gas carrier
- Semi-refrigerated cargo tanks, 5.3 bar
- Multi-gas, but main intended cargo commodity is ammonia →
- Range on ammonia: 12,000 nm

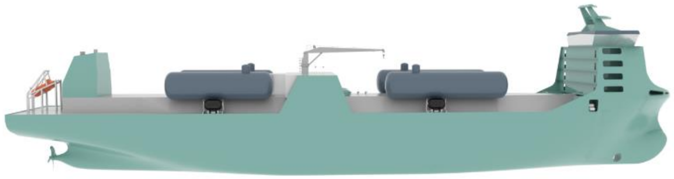
- Semi-refrigerated fuel tanks, 8 bar, -33.2C
- Ammonia bunkering capability
  - Extra manifold
  - Manoeuvring requirements
  - Fenders

- Intended route: Gulf of Mexico to Norway
- Range on ammonia: 12,000 nm
- Class notation: 1A Tanker for liquefied Gas, Shiptype 2G (-48C, 700kg/m3, 5.3bar) GF NH3, Clean design, E0, NAUT(OC), BMON, BIS, TMON, BWM (T), Recyclable, DNV Ice Class 1A

- Anhydrous ammonia (normally contains maximum 0.5% moisture)
- 1,3-Butadiene
- Butane (ISO and normal)
- Butane/propane mixtures
- n-Butane/i-Butane mixture
- C4 mixture
- Butylene
- Propane Commercial propane (maximum 2.5 mole % ethane in the liquid phase)
- Propylene
- Vinyl chloride monomer
- Isoprene monomer

Accommodation location

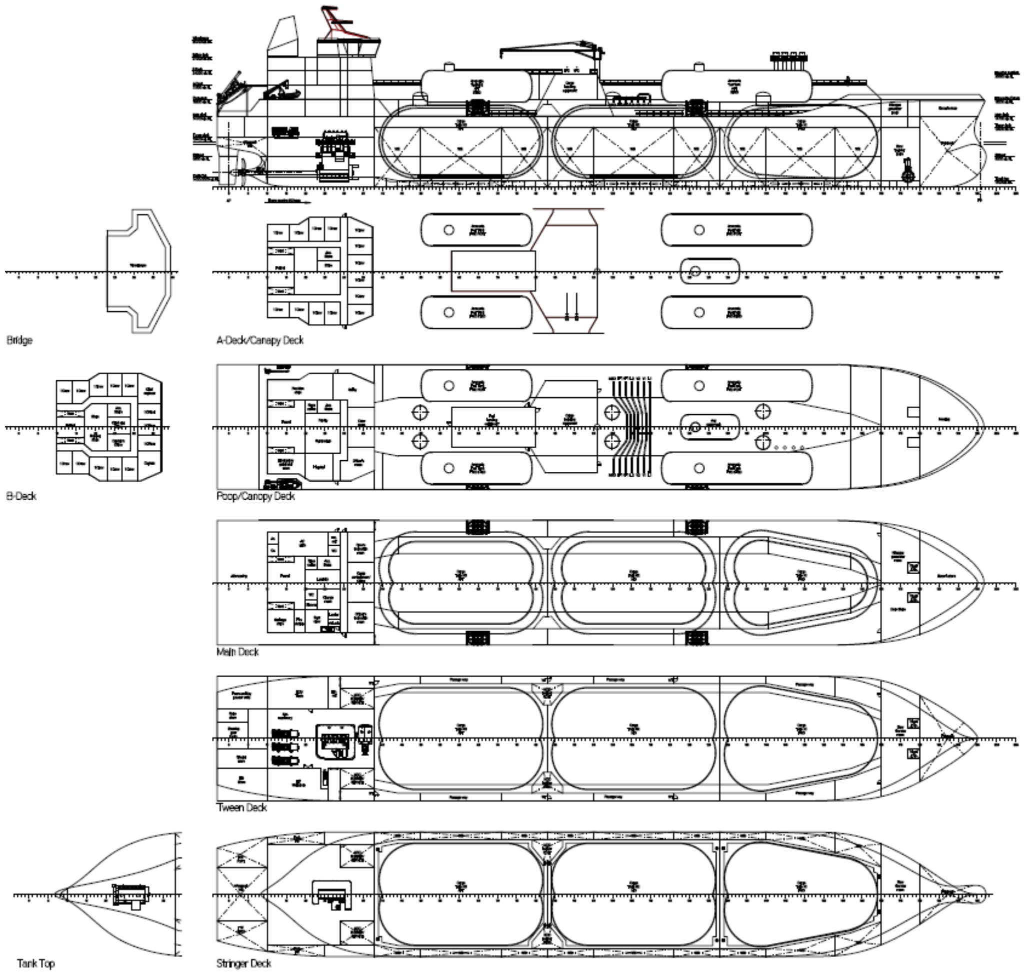


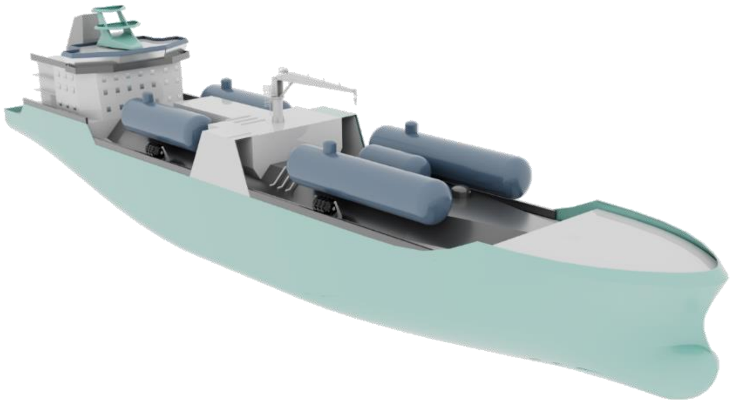


Consideration		AFT	FWD
Cost		-	More expensive
Performance		Average noise and vibrations	Higher motions require speed reduction in higher sea states
Safety & Operations	Lifesaving	-	Long distance to aft lifeboat in case of mustering/emergency
	Engine room	-	Longer time to mobilize for fires or alarms
	Ammonia exposure	Higher risk at sea	Higher risk in port during cargo operations
Commercial Availability		-	More limited experience, but not significant
Design Complexity		-	More complex

Selected

NoGAPS arrangement and main characteristics





MAIN DIMENSIONS

Length over all .... 160.00 m
Length PP .... 156.60 m
Breadth moulded .... 26.00 m
Depth moulded .... 14.70 m
Draught, design .... 9.00 m
Draught max .... 9.50 m
Deadweight, des. draught.......... 17 960 t
Deadweight, max. draught......... 19 820 t

SPEED & ENDURANCE

Service speed, ... 15.0 kn
Max. speed .... 16.0 kn

Endurance (service speed)... 12 800 nm

CAPACITIES (100%)

Cargo tanks .... 21 844 m³
MDO .... 1 035 m³
BW .... 9 617 m³
FW .... 260 m³

CARGO EQUIPMENT

Segregations .... 2 (3 cargo tanks)
Cargo pumps (submerged) 6 x 400 m³/h
Cargo pumps type .....Deep-well, electric
Discharge rate (6 simult.).......2 400 m³/h

NH_3 FUEL TANKS

NH_3 ....3 450 m³
Pressure ....8.0 barg

FUEL CONSUMPTION

(service speed, design draft, 15% SM)

Fuel consumption, NH_3 .... 51.5 t/d
Fuel consumption, MDO (pilot) .... 1.8 t/d

ACCOMMODATION

- 27 + 6 Suez Crew all in single cabins

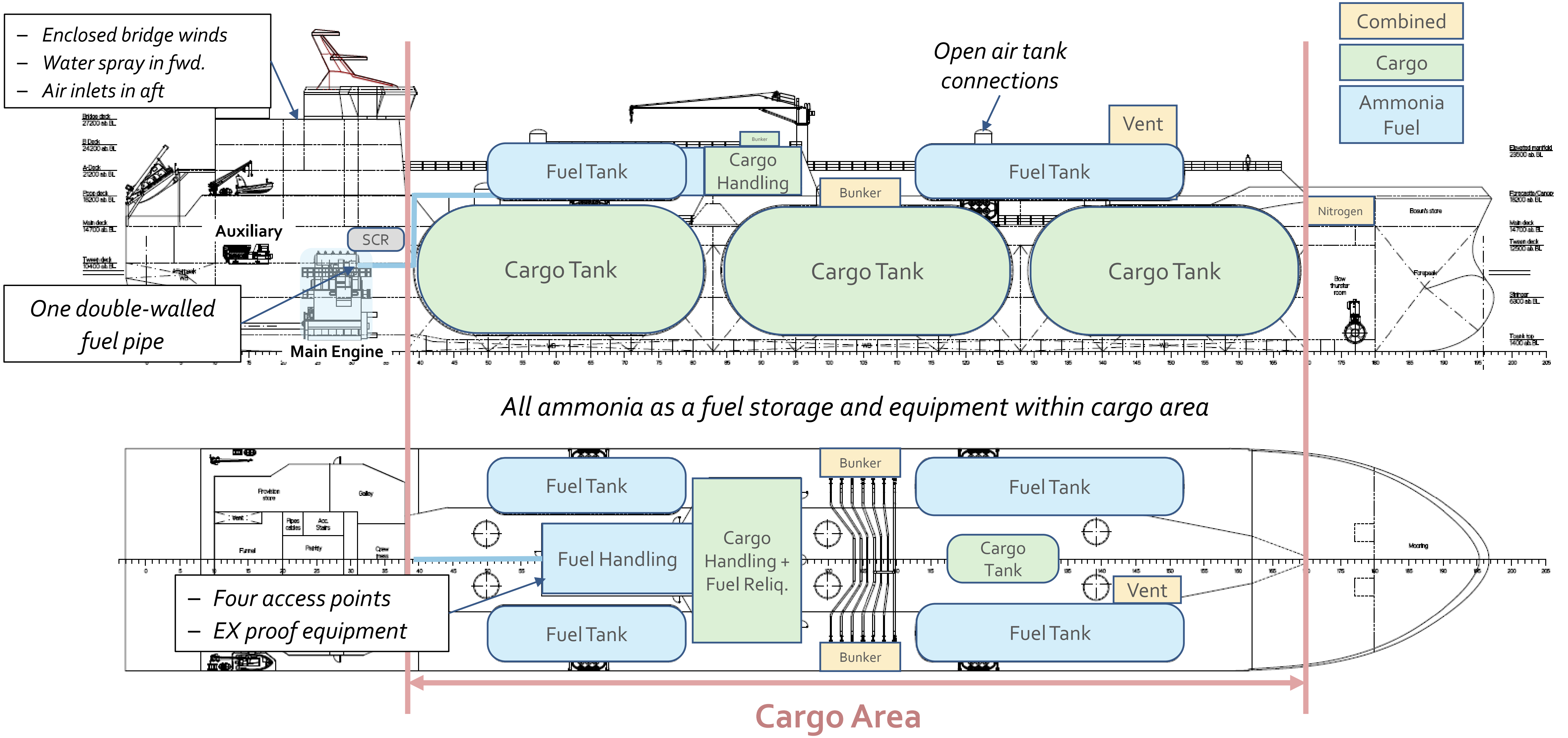
PROPULSION / MACHINERY

- 2-stroke 6G50ME-C9.6-Ammonia HL main engine
  1 x 7,200 kW at 93.0 r/min
- 4 stroke Wärtsilä Generating sets
  3 x 1,255 kWe 6L20
- Shaft generator (PTO) 1,000 kWe
- 1 CP Propeller, dia. 5.8 m
- 1 x Emergency diesel generator
- 1 x Bow thruster 1000 kW

CLASSIFICATION

1A Tanker for liquefied Gas, Ship type 2G (-48C, 700kg/m3, 5.3bar) GF NH3, Clean design, E0, NAUT(OC), BMON, BIS, TMON, BWM (T), Recyclable, DNV Ice Class 1A

Preliminary safety concept

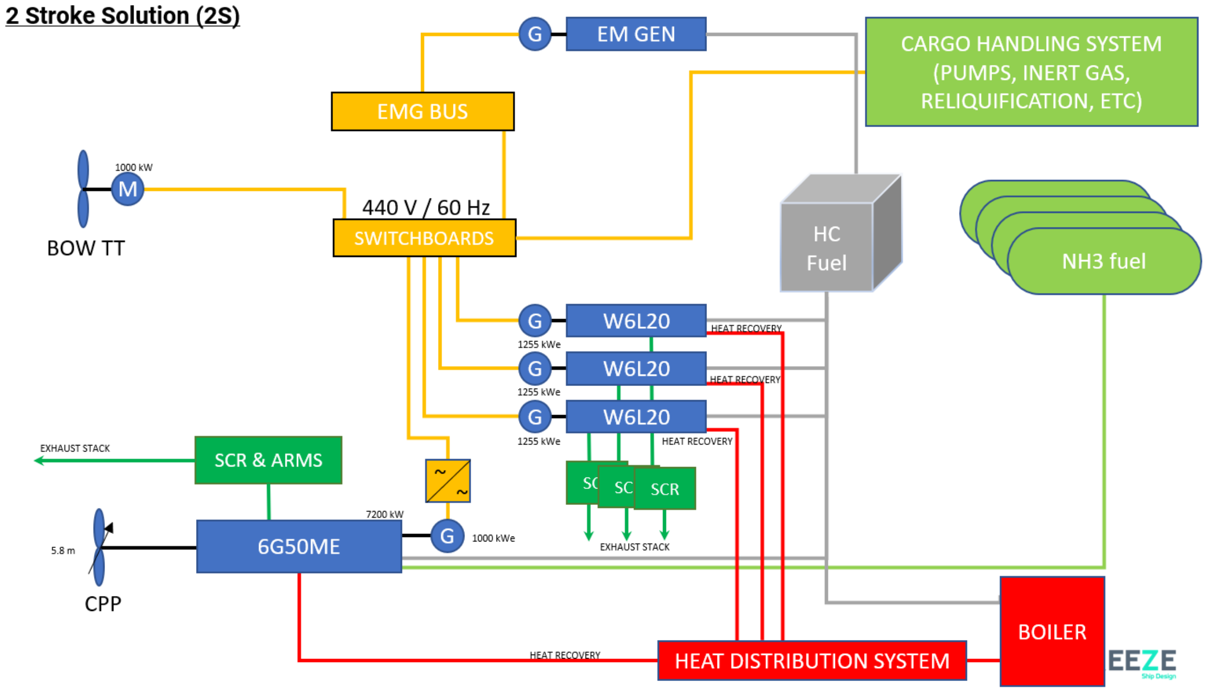


Reducing risk and cost: auxiliary engines and boiler

Auxiliary engines and boiler to use conventional and biofuels (not ammonia)[1]

- Two-stroke configuration has expected low pilot fuel amounts
- Use of a biofuel or shore power can reduce emissions to net-zero
- Additional safety risks to be mitigated with three more ammonia consumers on the two-stroke configuration
- Design cost and complexity increases with only novel engine technologies onboard
- Ammonia-fueled boiler still under evaluation

Selected machinery arrangement



[1] To reduce safety risks (fewer ammonia consumers) and costs for limited emission benefits

Properly managing ammonia emissions onboard

Multiple emission reduction technologies planned onboard

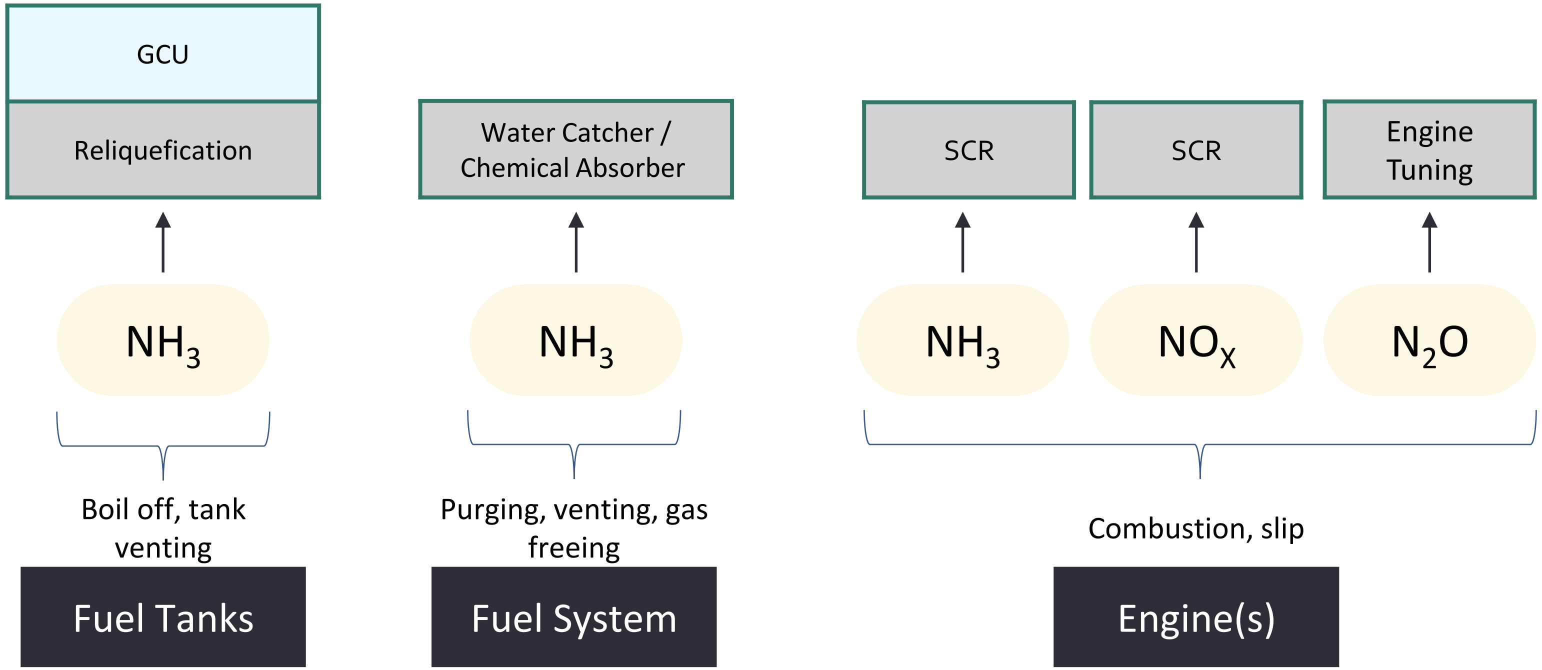
Ammonia combustion

- High-pressure SCR installed to reduce NO_X emissions
- Assume minimum N_2O emissions managed by engine tuning
- Ammonia slip is utilized in SCR as reducing agent

Fuel storage and supply

- Boil-off managed using fully redundant reliquification plants
- Water catcher/chemical absorber part of fuel supply system
- Management of tank venting using GCU under discussion

Planned emission reduction technologies

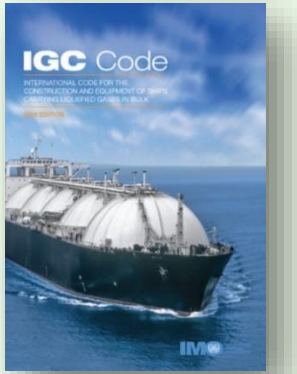


Presentation:
M/S NoGAPS HAZID outcomes

Thomas McKenney, Naval Architect, MMMCZCS

Regulatory approach

IGC Code and DNV Rules as a basis



- Ch.16 of the IGC Code covers cargo as fuel
- IGC Code is mainly written for methane (LNG) cargo as fuel, but §16.9 in the IGC Code allows for alternative fuel products
- Unlike IGF Code, IGC Code prohibits toxic products as fuel
- DNV Rules for Liquified Gas Carriers can accept use of ammonia subject to agreement with flag administration

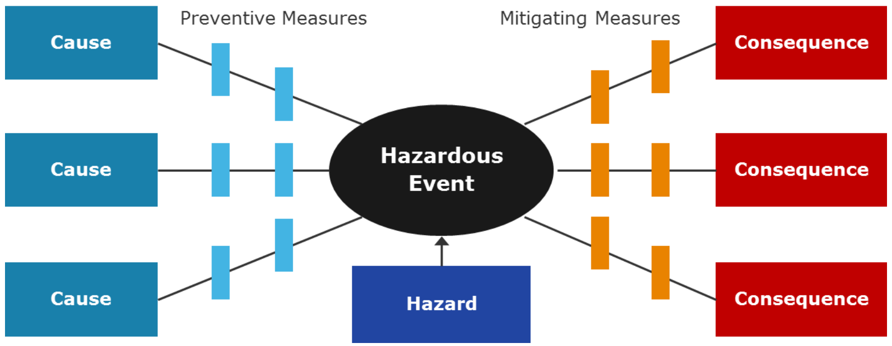
Equivalent safety as methane (LNG) cargo as a fuel

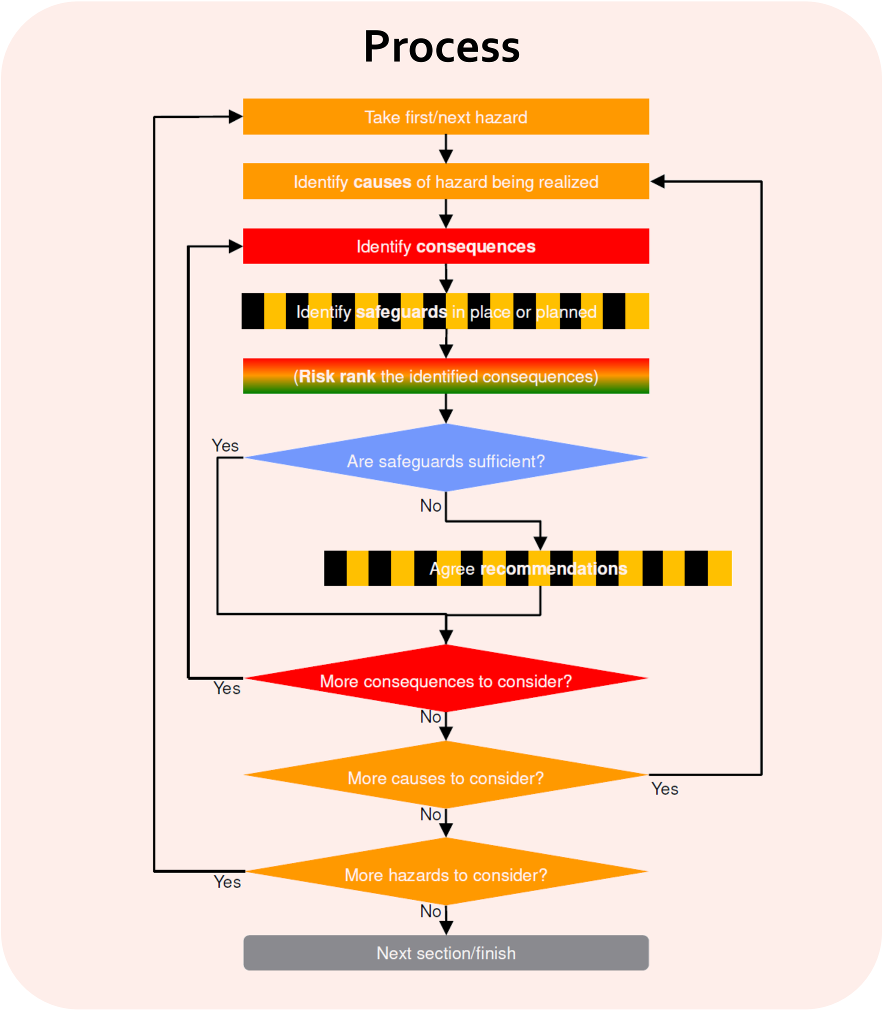
- NoGAPS project and planned AIP is only a high-level review of relevant early design documentation
- A hazard-based on ALARP principle is found to be appropriate level to document similar safety for NH_3 as fuel compared to Methane (LNG)
- When potential vessel is made, then full compliance with rules must be done

DNV

HAZID methodology

- **HAZID** is a structured team-based review technique to identify hazards associated with a particular concept, design, operation or activity
- **HAZID** is one of the most effective approaches to identify major accident hazards with the expertise and knowledge of a competent and experienced workshop team represented by people from design, construction and operation





DNV

HAZID results and top risks

Frequency		Severity: 1 None	2 Minor	3 Significant	4 Severe	5 Catastrophic
5	Frequently					
4	Very likely					
3	Likely	1.3, 1.6, 3.8	1.2	1.4, 3.1, 3.3	6.1	
2	Unlikely		1.1, 1.5, 2.1, 2.3, 3.5, 3.6	2.2, 3.10, 6.[illegible]	3.2, 3.9	2.6, 4.1
1	Extremely remote					2.4, 2.5

Top Risks

- Fuel tanks: Loss of primary containment due to fire (2.4), explosion (2.5), impact or dropped object (2.6), connection failure
- Fuel handling room: leakage in valves/flanges (3.1), pipe rupture (3.2), heater/cooler leakage (3.3), trapped liquid (3.9)
- Rupture of high-pressure fuel piping on deck (6.1)
- Pipe rupture in engine room (4.1)

Ongoing investigations and further mitigation measures

Fuel Handling Room

- Automated ventilation design
- Fire fighting equipment
- Division into smaller spaces
- Minimize crew time in fuel handling room

Ammonia releases/emissions

- Automated accommodation ventilation design with gas detection
- Water catcher/chemical absorber in fuel supply system and resulting ammonia water solution
- Ammonia slip from engines

Engine Room

- Length and routing of high-pressure fuel supply to engine
- Minimized amount of ammonia if pipe rupture occurs

Emission Reduction

- NO_X and N_2O
- Pilot fuel: minimize amount and prepare for biofuel

Energy Efficiency

- Fuel cells, batteries, wind assisted propulsion, hullform optimization, ...

Panel discussion: NoGAPS Partners

- **Dorthe Marie Sveistrup Jacobsen,** Principal Research Engineer, Fuel & Emissions, Engine Process Development, MAN Energy Solutions
- **Fredrik Lindfors**, Project Manager Sustainable Fuels and Decarbonization, Wärtsilä
- **Sven Rolfsen**, Naval Architect, Breeze Ship Design
- **Mayank Bhatt**, Fleet Manager (HSE & Compliance), BW Epic Kosan

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Next steps

Thank you for listening!

Questions about M/S NoGAPS?
Please contact Anna Rosenberg at aro@globalmaritimeforum.org