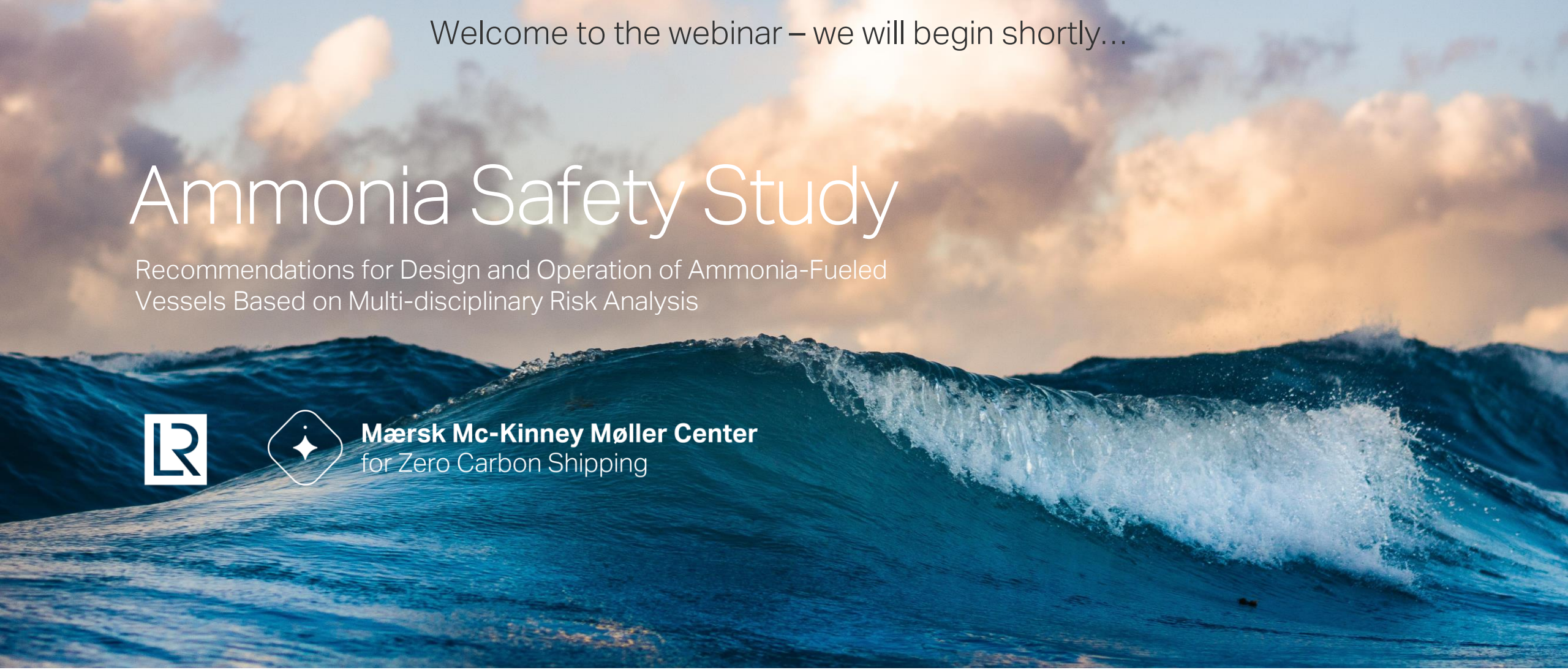
Welcome to the webinar – we will begin shortly…

Ammonia Safety Study

Recommendations for Design and Operation of Ammonia-Fueled Vessels Based on Multi-disciplinary Risk Analysis



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On today’s agenda:

01 Introduction

02 Ammonia - a potential fuel pathway for the maritime

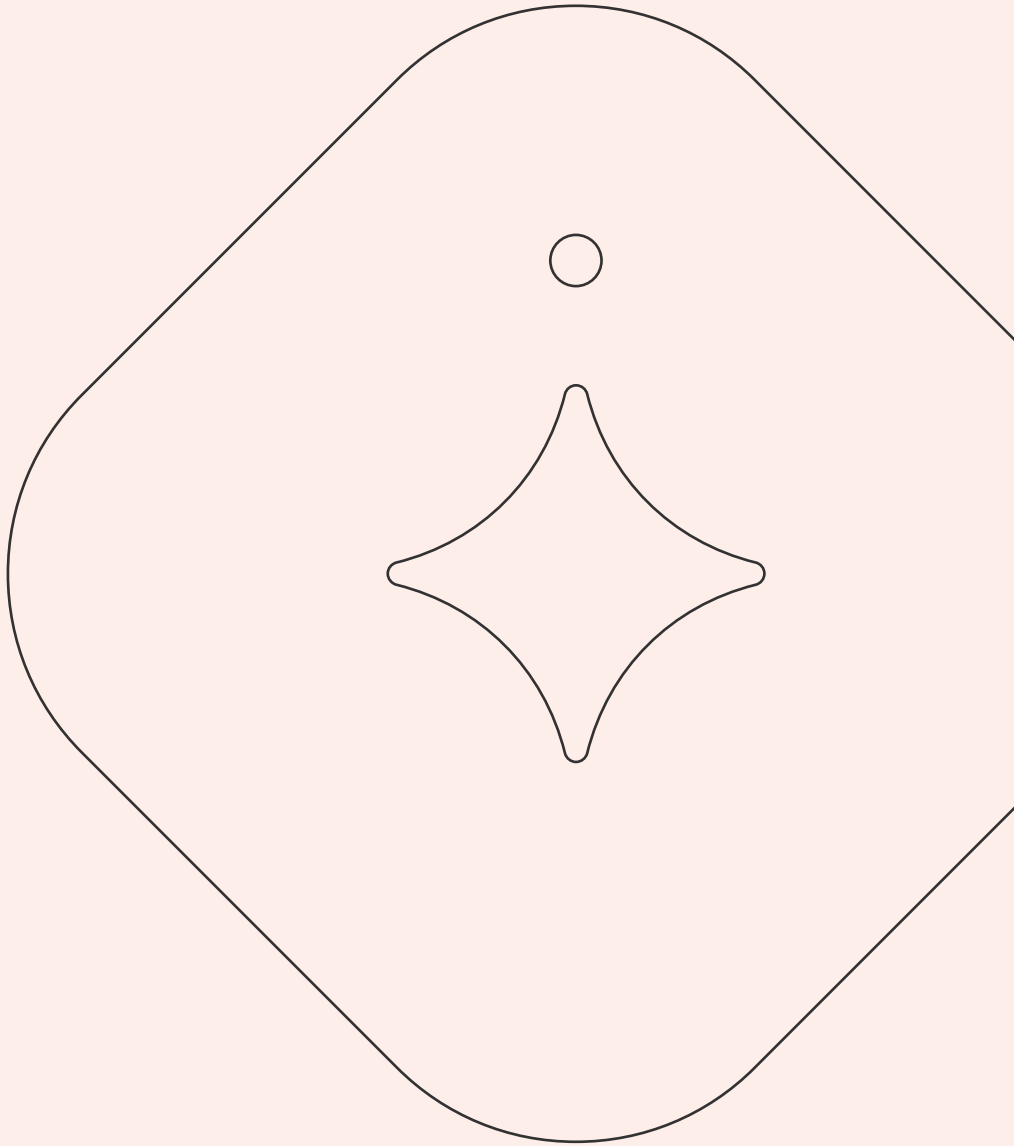
03 Quantitative risk assessment & criteria framework

04 Reducing risks to crew to below project targets

05 Human Factors

06 Summary

07 Panel discussion and Q&A



On today's webinar panel

Andrew Franks

Project Manager

Lloyds Register – Maritime Decarbonisation Hub

Claus Rud Hansen

Project Manager

Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping - Secondee from Maersk

Martin Eriksen

Head of Safety Leadership & Operations

Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping

Matt Dunlop

Project Team Member

Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping - Secondee from V.Group

Peter Herena

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Thomas McKenney

Moderator

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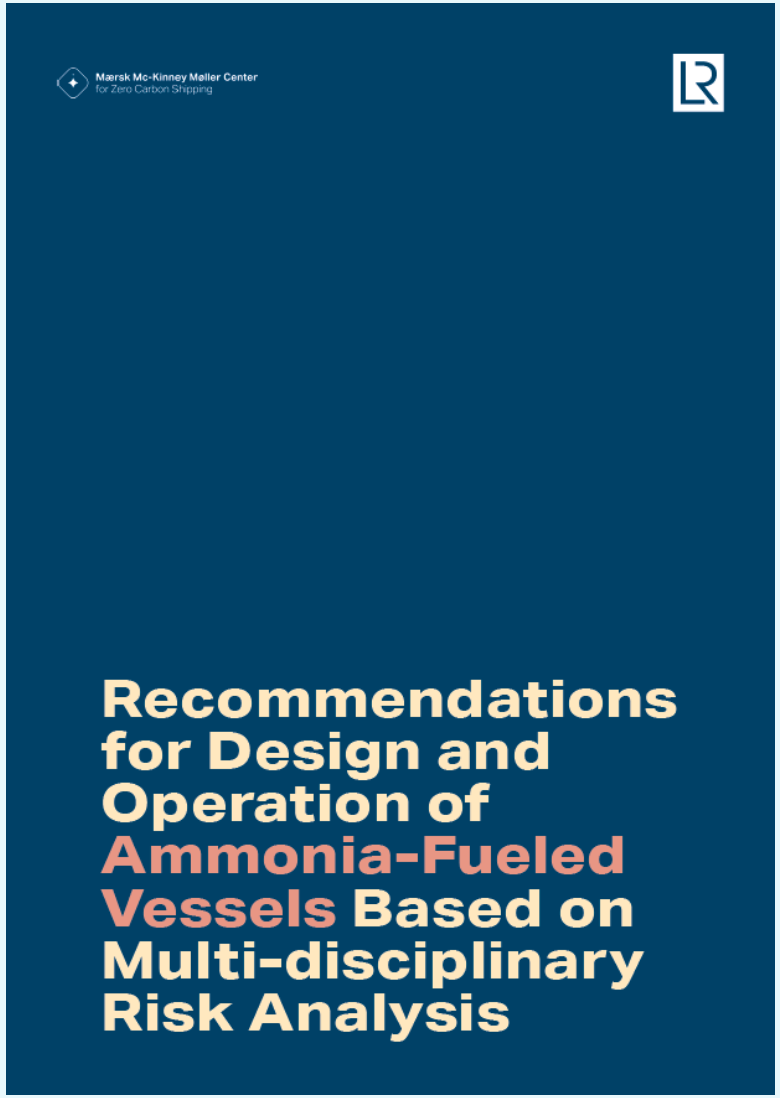
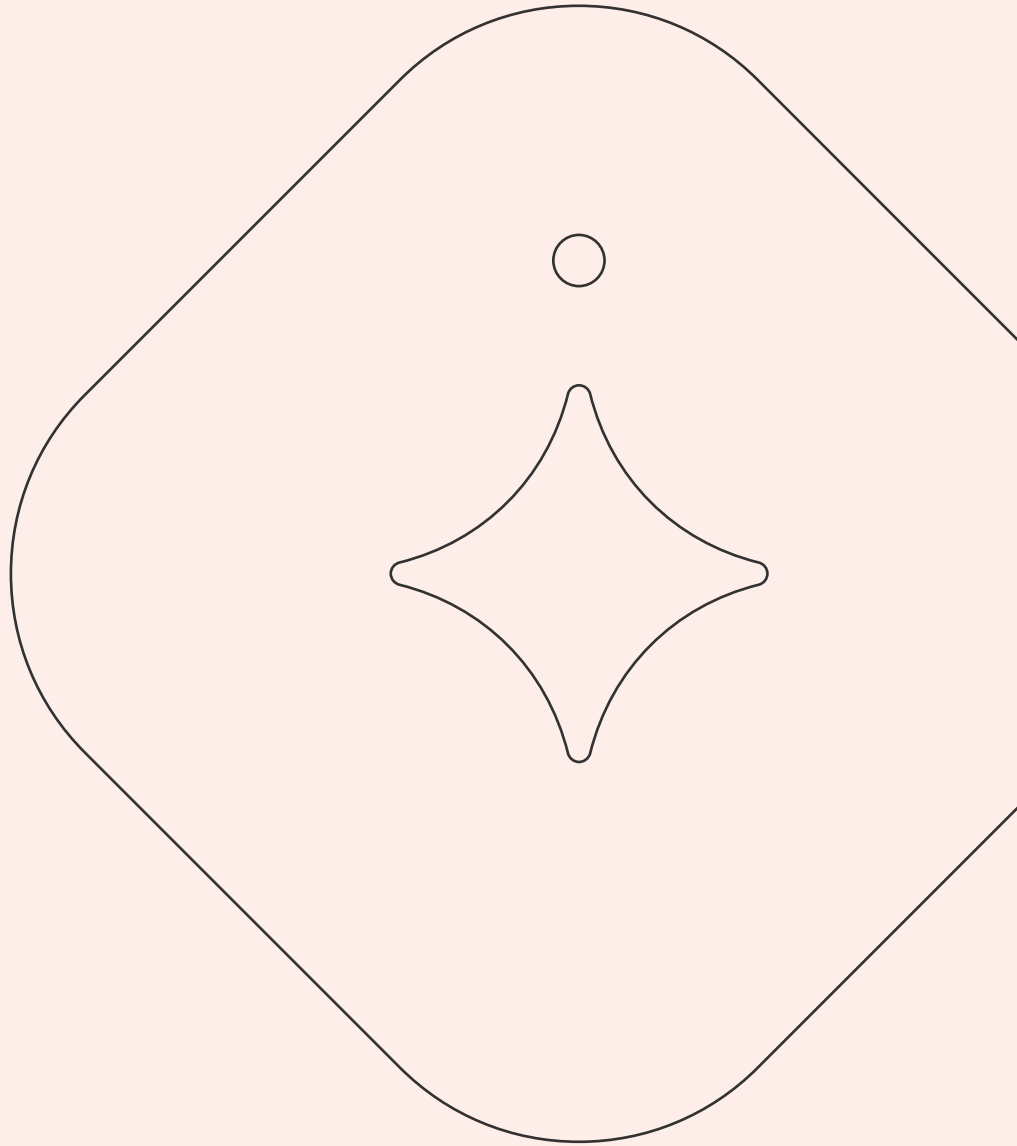
LR & MMMCZCS recently published the report "Recommendations for Design and Operation of Ammonia-Fueled Vessels.

- Quantitative Risk Assessment (QRA) analysis - applied to three reference ships designs fueled by ammonia
- Human Factors analysis



Download the report and many other publications on www.zerocarbonshipping.com

Ammonia - a potential fuel pathway for the maritime



Industry is on a path to decarbonize - ammonia being a promising marine fuel pathway

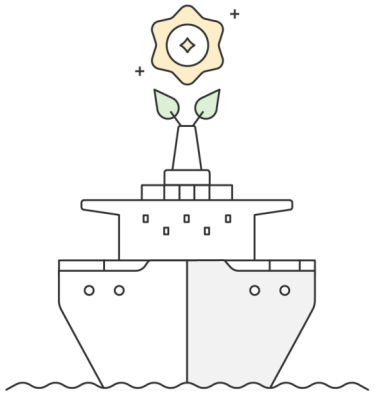
- Ammonia offers a viable and scalable low-emission pathway early in the industry transition.
- Ammonia can be combusted with limited carbon dioxide emissions.
- Novel fuel system technologies (i.e., engines) and ship designs are rapidly developing.
- Maritime industry has experience with gas as fuels and carrying ammonia as cargo.
- Onshore industries possess significant experience in safely handling, transferring, and storing ammonia.

Critical challenges to onboard safety and operations

Ammonias toxic properties

Absence of harmonized international rules

Ammonia dispersion properties



Development of novel system technologies (i.e., engines and fuel supply systems)

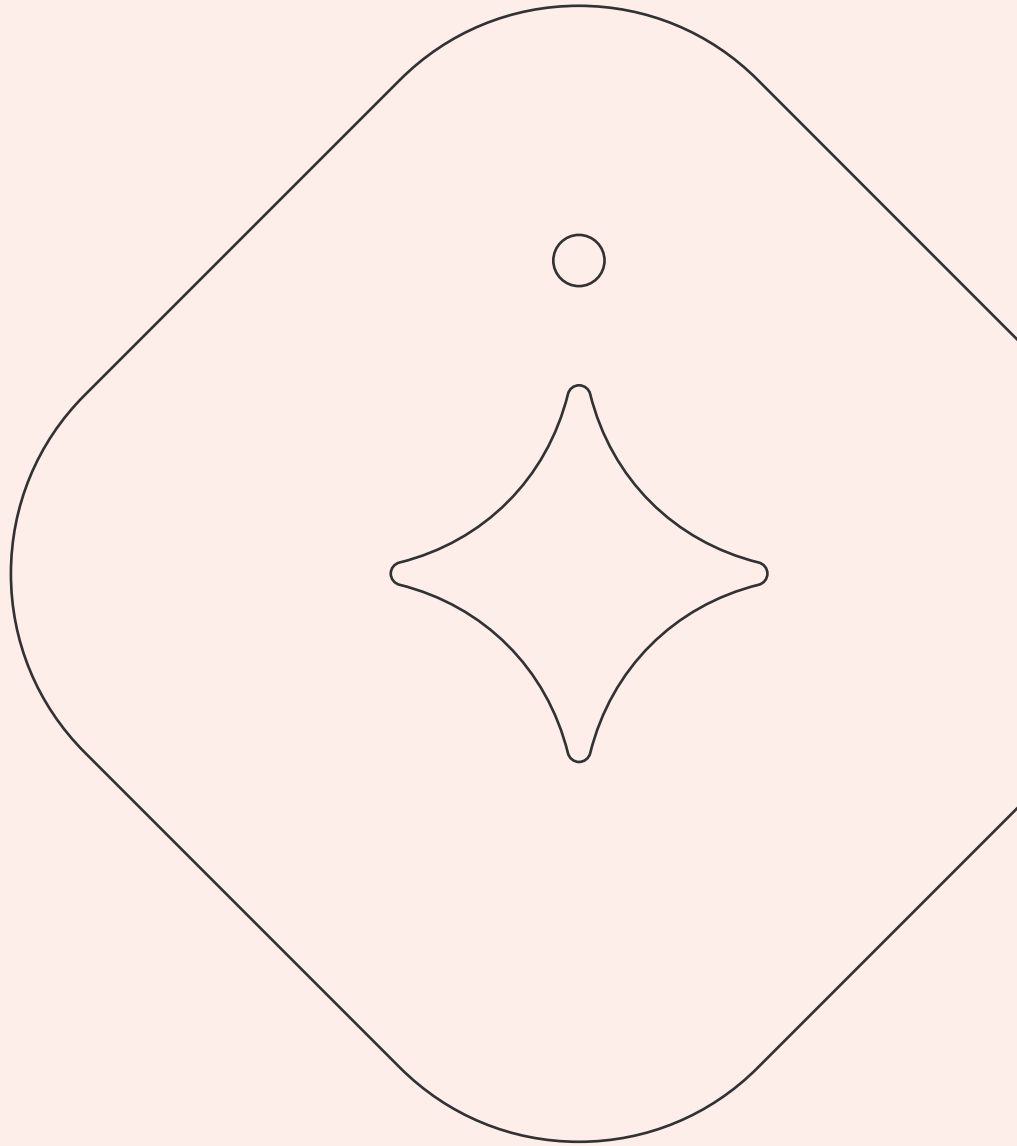
Obtaining a deeper understanding of the onboard risks to crew

Significant upskilling needed

Reducing risks to crew to be “as low as reasonably practicable”. (ALARP)

Andrew Franks,
Senior Decarbonisation Risk Specialist,
LR Maritime Decarbonisation Hub

Quantitative risk assessment & criteria framework



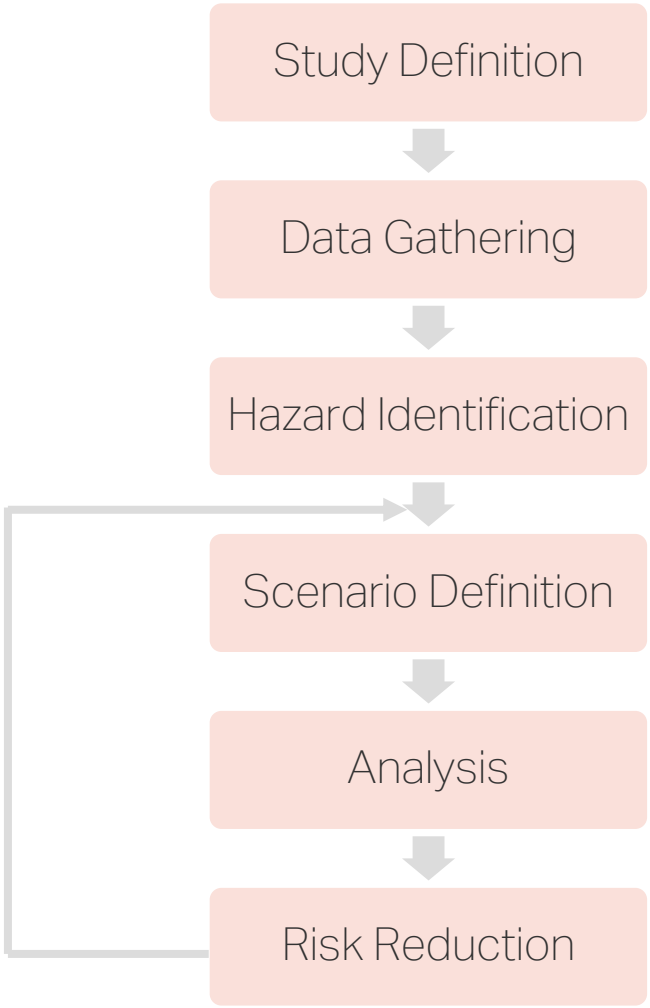
What are the risks to crew in using ammonia as a marine fuel?

Are those risks tolerable?

What safety measures can be implemented to reduce these risks?

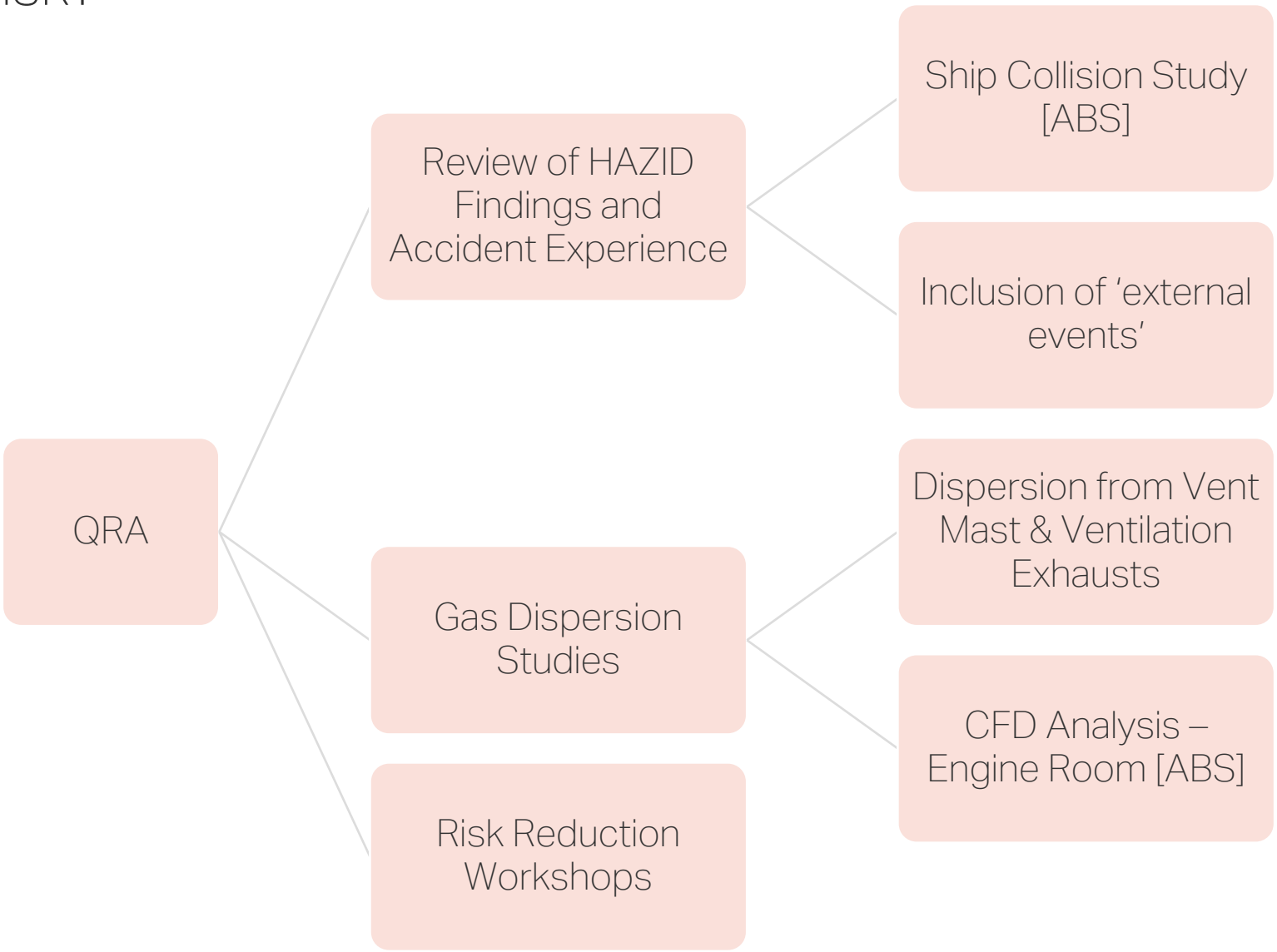
Fundamental questions that we wanted to address.
Ammonia Safety Study, Phase 1 & 2, 2021-2023

What is the risk?

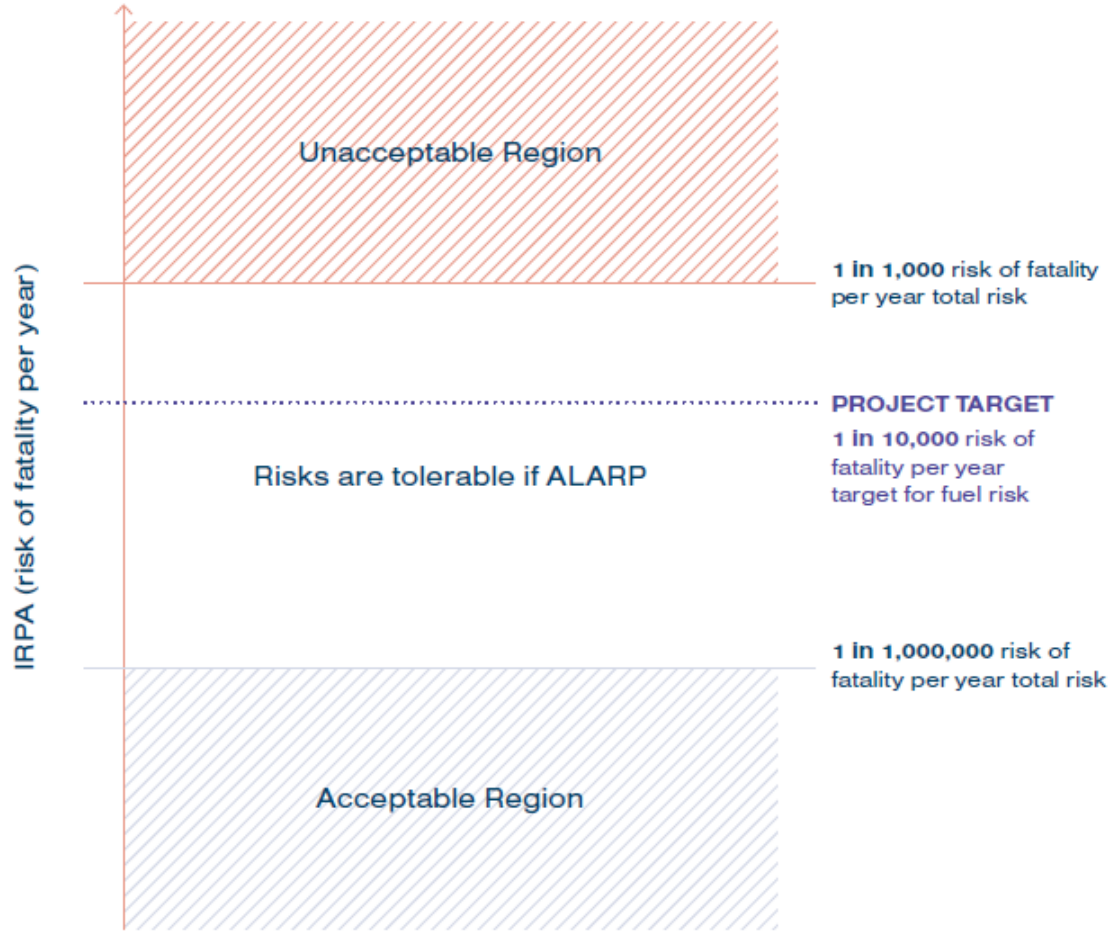


- We used Quantitative Risk Assessment (QRA) to get numerical estimates of risk to crew
- QRA has been used for a long time in the offshore oil & gas and onshore process industries but its use in marine is relatively new
- It is very detailed and can give useful insights into the main factors driving the risk

What is the risk?



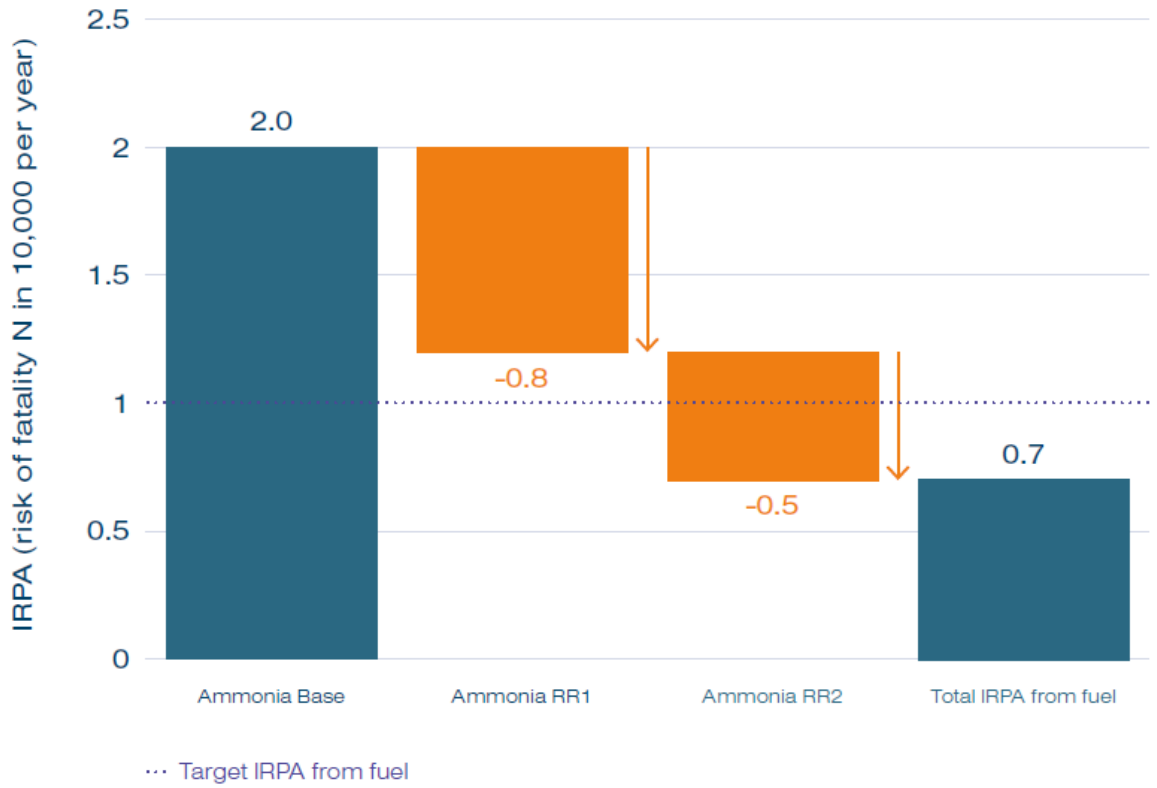
Quantitative Risk Assessment – risk criteria framework



IRPA criteria framework and project target.

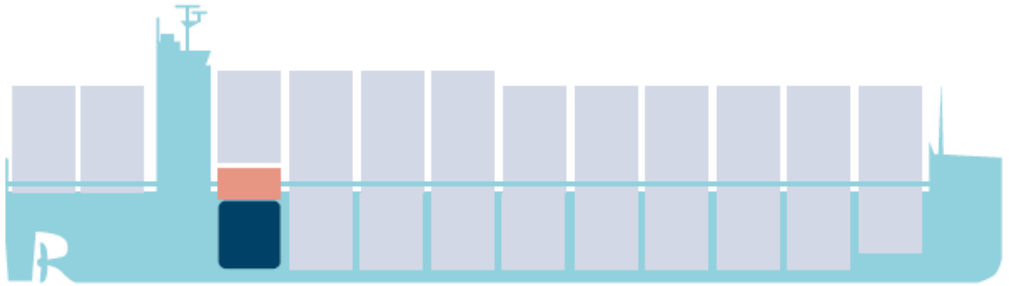
- How safe is safe enough?
- We used well-established, internationally recognised risk criteria as a framework for judgement
- To this we added a more stringent project target
- 'As Low As Reasonably Practicable': risk mitigation is applied until the cost of doing more would become very large compared to the benefit you would get

Risk reduction process



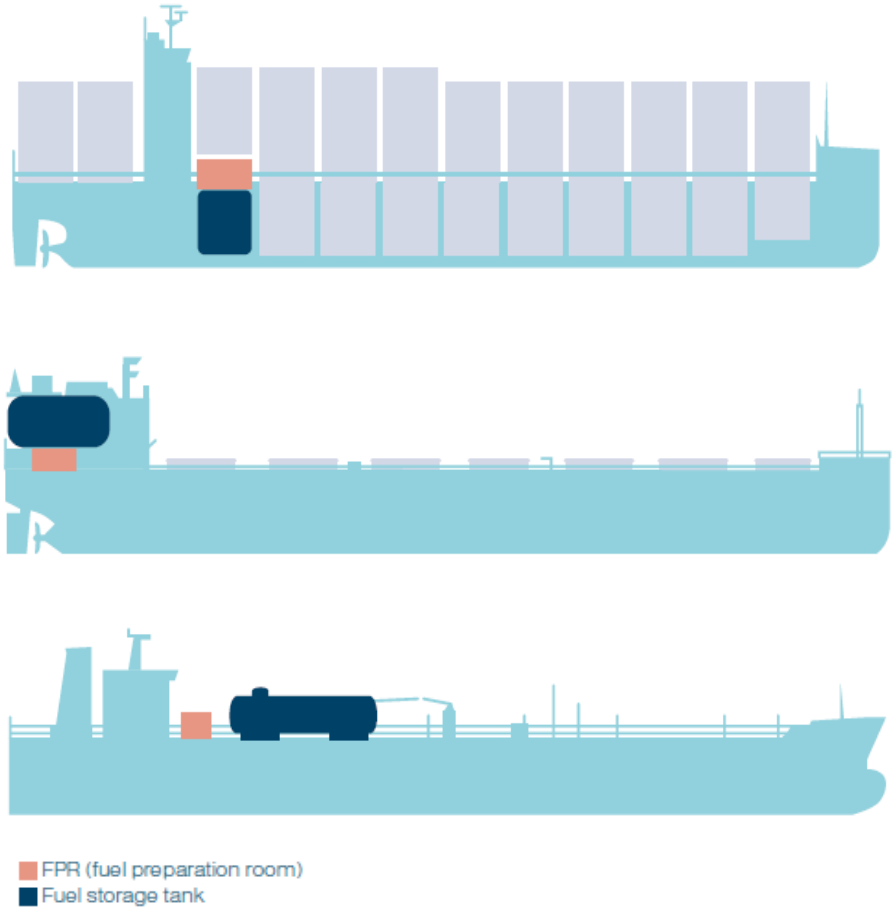
- Take a design, analyse it
- Look at the results to find the highest risks and what's driving them
- Propose measures to mitigate risks, focussing on the risk drivers
- Incorporate into the design and re-analyse

Three different vessel design cases applied to develop the Quantative Risk Assessment model

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

FPR (fuel preparation room)
Fuel storage tank

What safeguards can be applied?



Reduce the impact of a leak

- Store at a lower temperature (tends to give lower risk / less risk mitigation effort required)

Reduce exposure to leak sources

- Divide the fuel preparation room into two or more separate rooms containing different groups of equipment

Reduce the time of exposure

- Access to and length of time spent in spaces containing ammonia equipment should be minimised, monitored and controlled

Safe by location

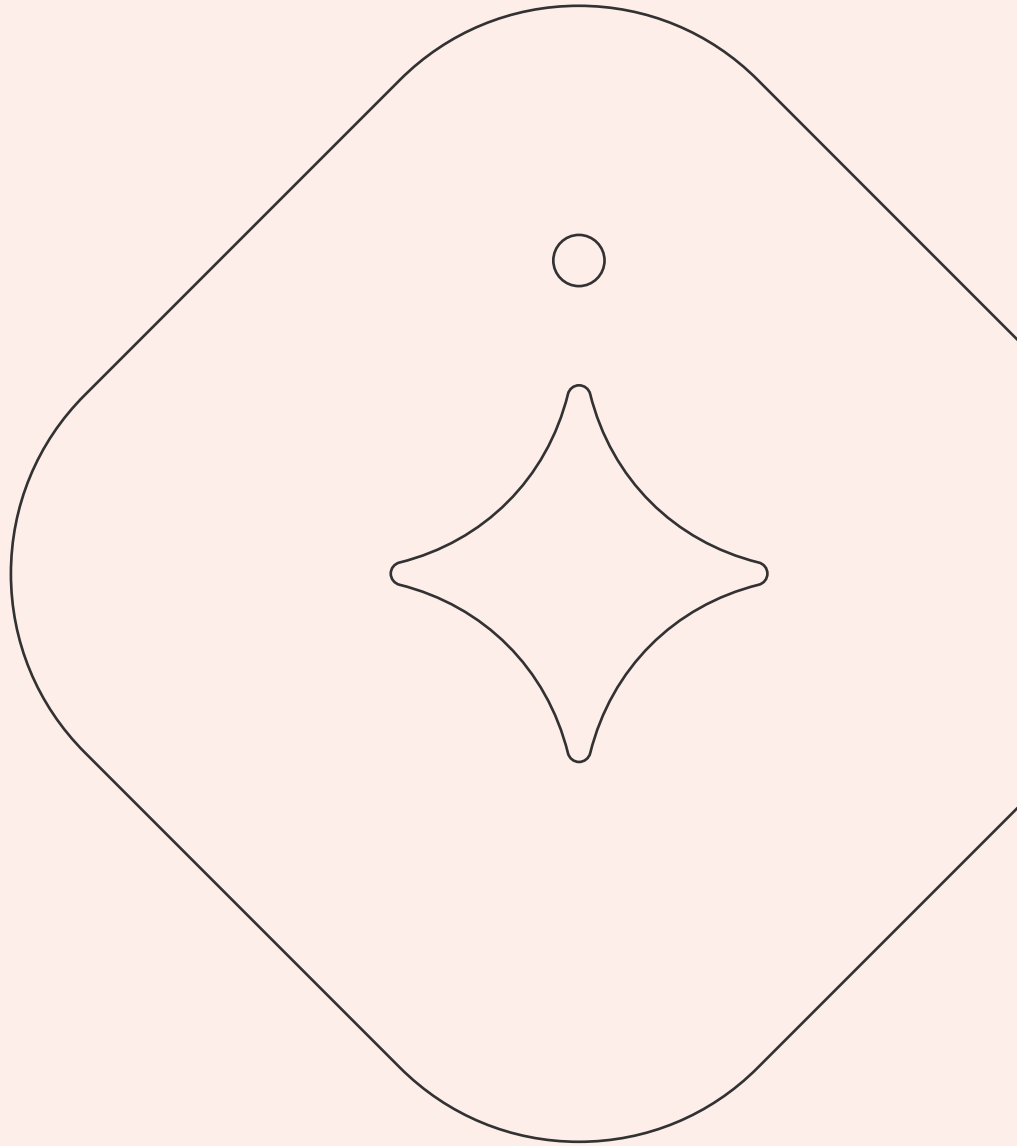
- Ventilation outlets from spaces containing ammonia equipment should be placed in a safe location adequately separated from areas accessed by crew

Rapid, reliable leak detection and isolation

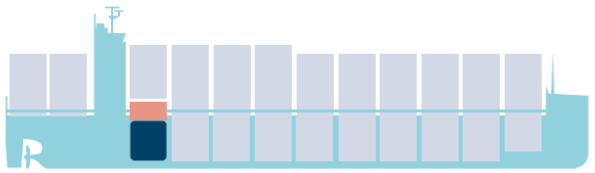
- Multiple sensors of different types to detect ammonia leaks should be installed

Claus Rud Hansen,
Senior Technology Manager,
Maersk and Secondee to MMCZCS

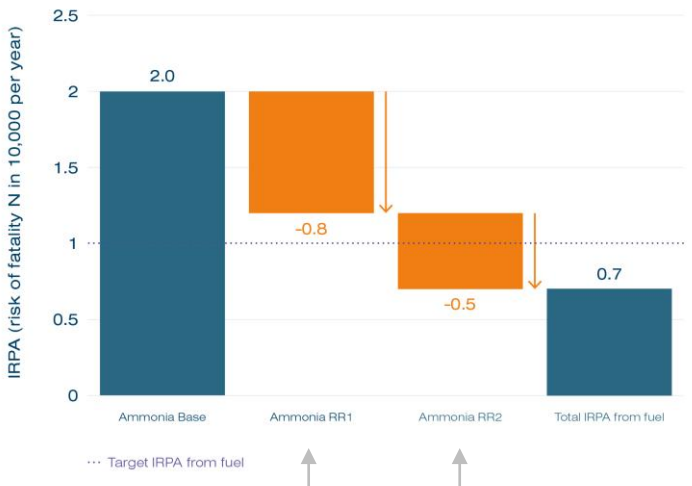
Reducing risks to crew to below project targets



Crew risk can be substantially reduced through stepwise mitigation



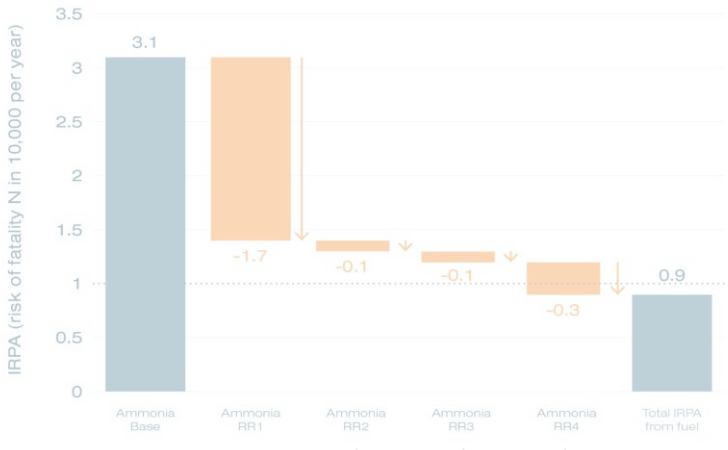
Container ship/fully refrigerated storage



Split FPR

Ventilation increase in FPR

Semi-Refrigerated Storage / Tanker



Split FPR

Vent. increase in FPR

Accommodation vent shutdown

Separate filter room

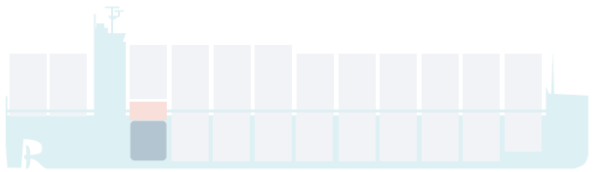
Pressurized Storage / Bulk Carrier

Switch to semi ref. storage

Scrubber in front of ventilation intake

Refine FSS design

Crew risk can be substantially reduced through stepwise mitigation



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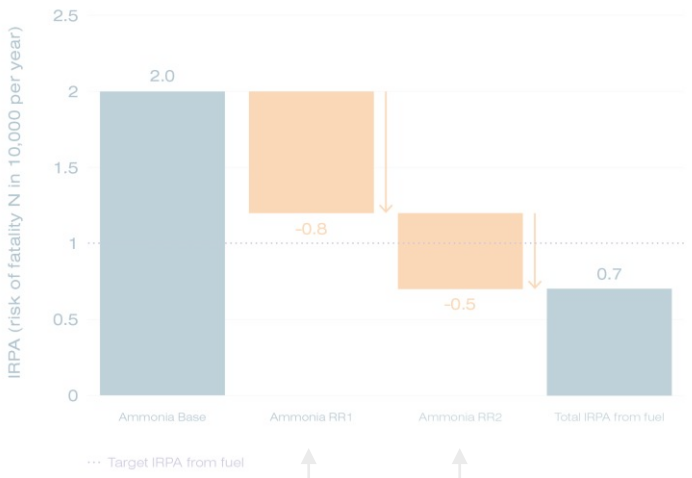

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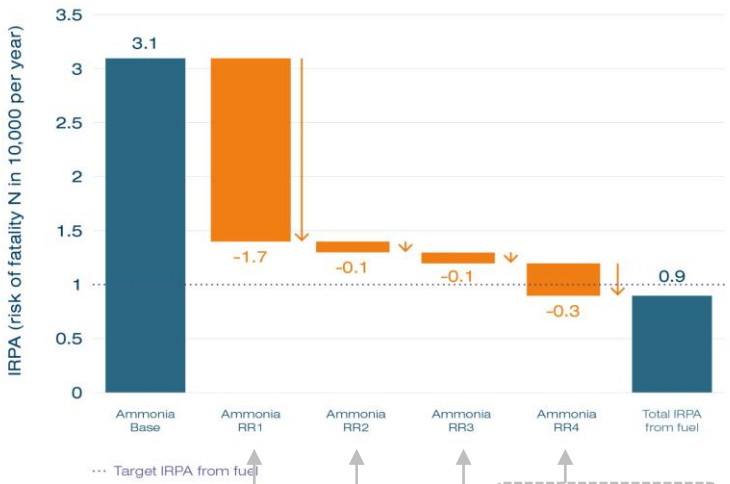

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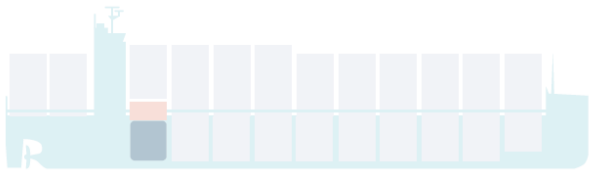

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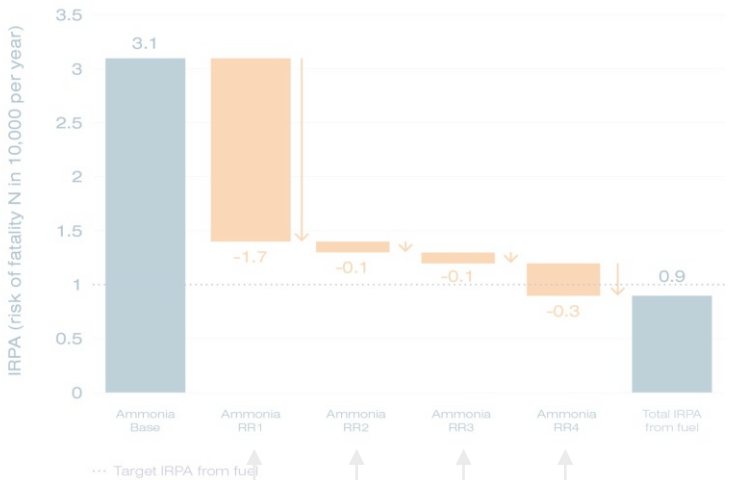

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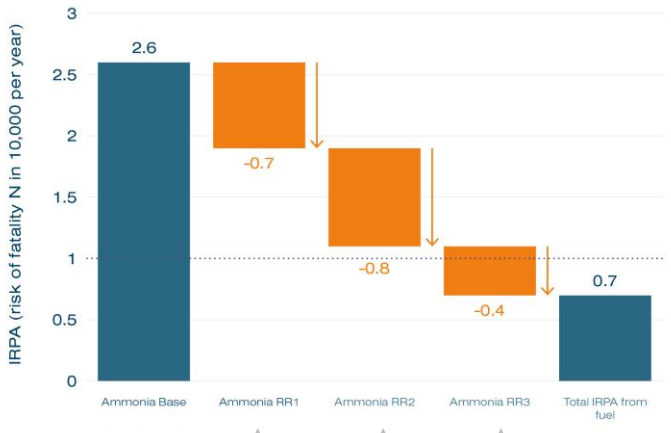


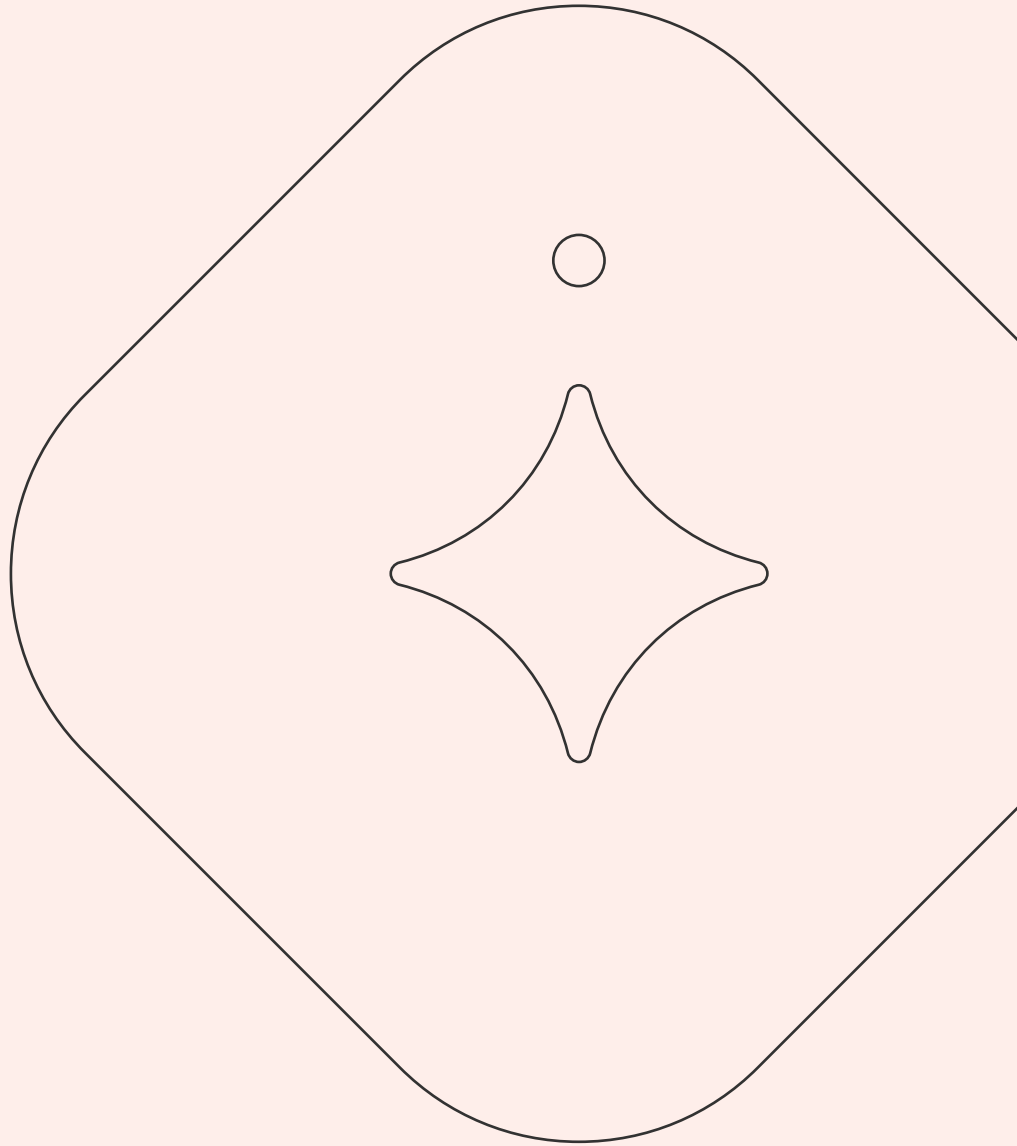
Switch to semi ref. storage

Scrubber in front of ventilation intake

Refine FSS design

Martin Eriksen,
Head of Safety Leadership &
Operations, MMMCZCS

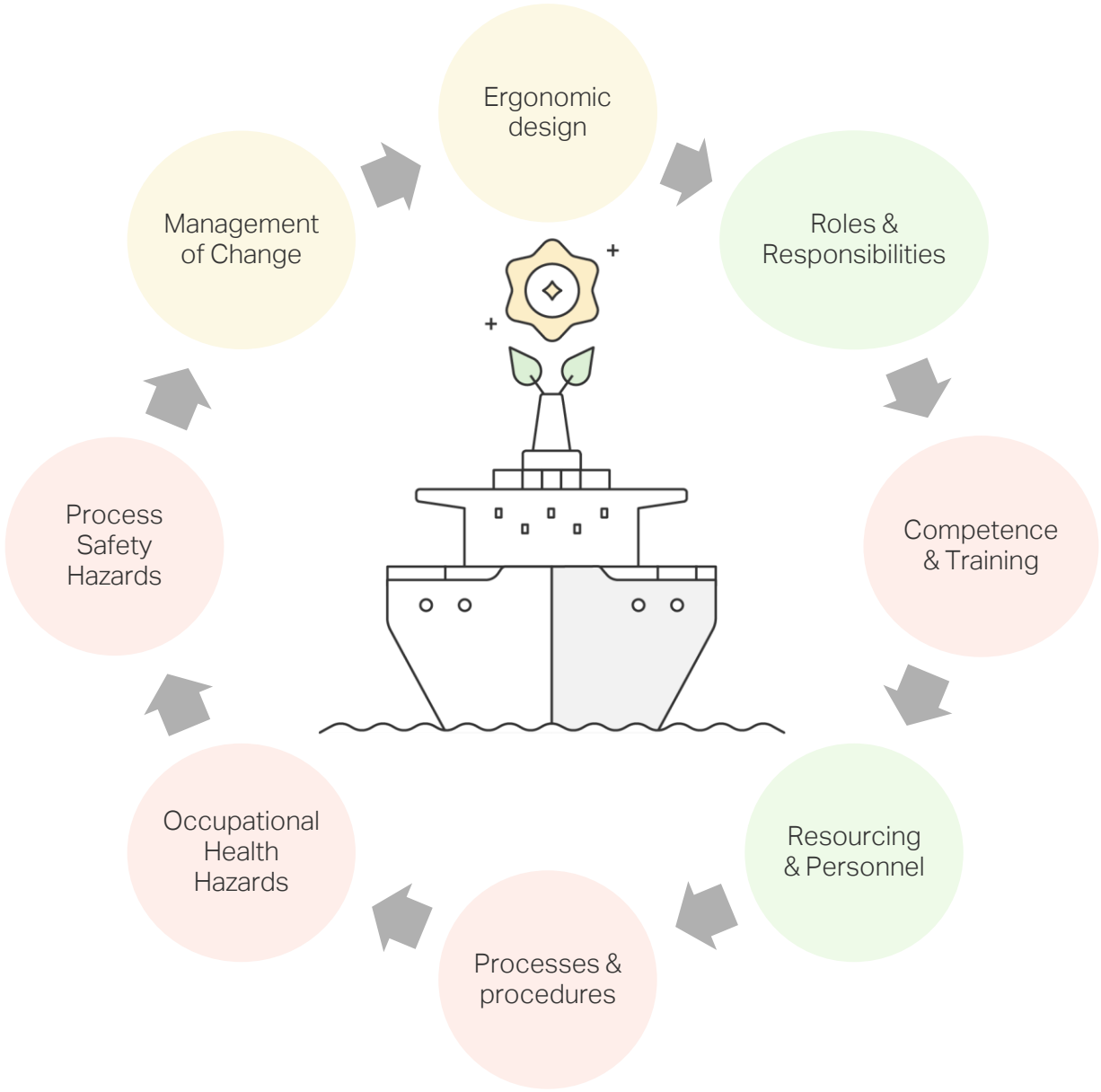
Human Factors



Why Human Factors

" The scientific discipline concerned with the **understanding of interactions among humans and other elements of a system**, and the profession that applies theory, principles, data, and methods to **design in order to optimize human well-being and overall system performance** "

Human Factors - analysis outcome

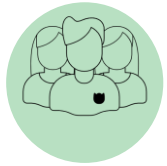


Impact criteria

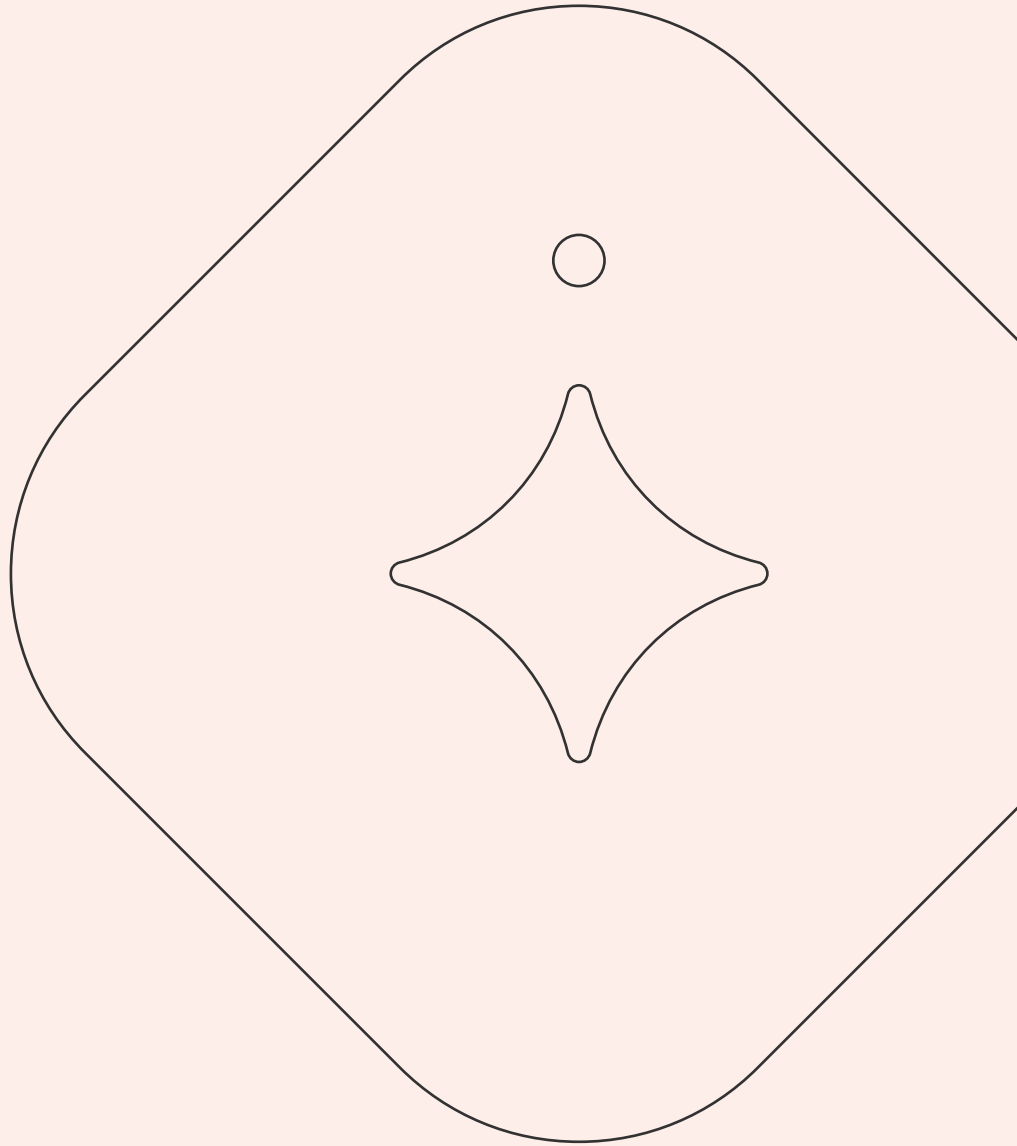
- Low – Minor Changes
- Medium - Changes
- High – Significant Changes

- If we are to **reach consensus on the safe implementation of ammonia** as an alternative fuel, the industry will need further detail on the high-impact human factors areas identified in the report.
- **We call for** specific Human Factor studies to **address implications of high impact considerations.**

Focus - high impact themes

	Description	Anticipated to impact the following areas:
 Competence & Training	• Technical and non-technical skills, knowledge, understanding and application	• New technical skills for specific operations and maintenance • General ammonia risk awareness across crew
 Process Safety Hazards & Management	• Human involvement in the contribution, exacerbation, and recovery of a major accident	• Changes to and management of ammonia system parameters such as those associated with tanks and fuel handling system including level, temperature, and pressure.
 Occupational Health Hazards	• Exposure to toxicity, fire, noise, musculoskeletal risks, trips and falls, etc.	• Materials / substance hazards (e.g., toxicity) • Mechanical (energy of components of a mechanical system e.g., crushing, motion, falling) • Thermal (e.g., hot surface, flames, cold stress)
 Processes and procedures	• Documented processes and work practices	• New ammonia-specific policies, procedures, and processes. • Updates to operational and maintenance work practices, procedures, and plans • Review and, where necessary, change of emergency response processes

Summary



Safety risks of ammonia fuel can be kept within tolerable limits, if...

Safeguards

Suitable and sufficient **technical barriers and administrative safeguards are implemented** to protect the crew against various ammonia risks

Human Factors

Human factors considerations, such as those outlined in the study, are **addressed**

Apply industry learnings

The maritime industry **build upon existing maritime industry experience** with gas as fuels and cargo and **carry over learnings from other industries with considerable experience** in safely handling, transferring, and storing ammonia

Phase 3

Recommendations identified in this study is further investigated and **developed into tangible guidance and actions** for the industry.

Detailed guidance and regulatory frameworks addressing the technical, engineering, and human factors aspects is **needed to mature the ammonia fuel pathway**.

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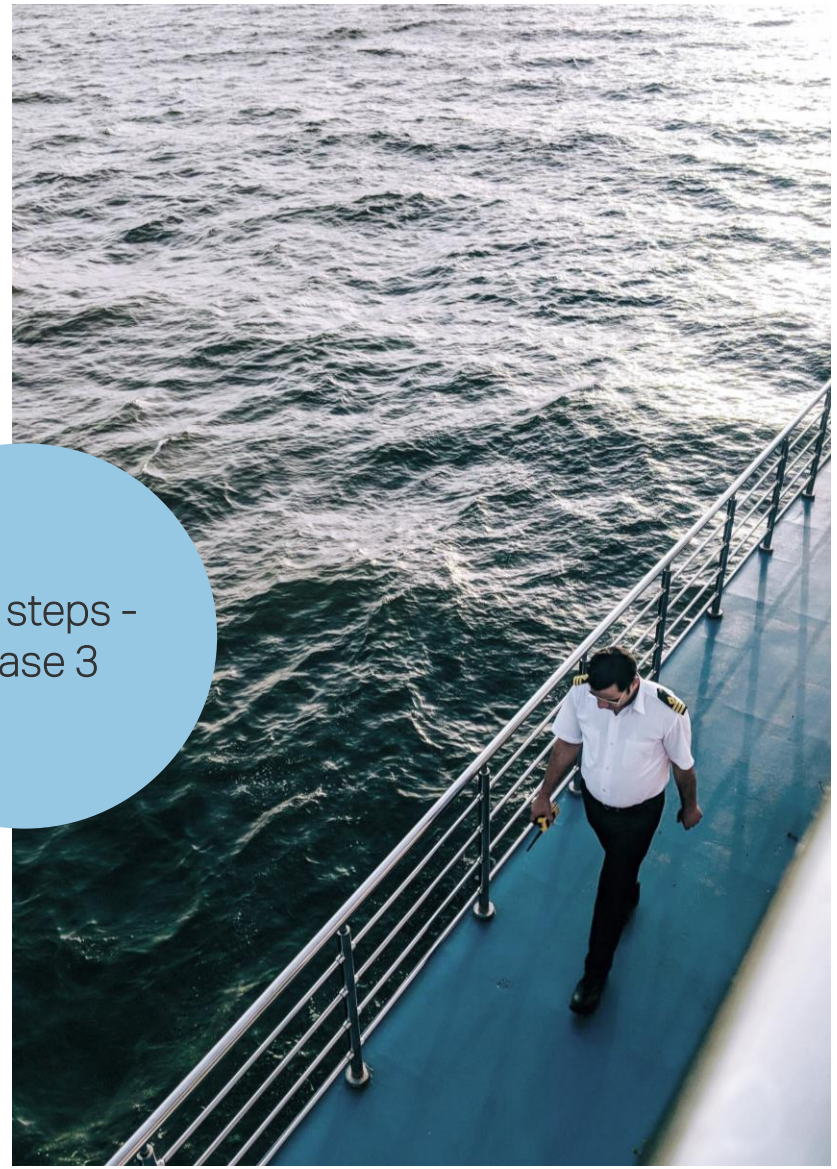
Wrap up

Safeguards

Human Factors

Apply industry learnings

Next steps - Phase 3



Thank you for joining!

The recording & presentations will be shared with all participants shortly.

Let's stay in touch

Visit our website www.zerocarbonshipping.com or LR's Maritime Decarbonisation Hub website at www.lr.org/en/expertise/maritime-energy-transition/maritime-decarbonisation-hub and make sure to follow us on LinkedIn to stay up to date with the latest news and events.

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Related Projects

→ Nordic Green Ammonia Powered Ships
One of the first ammonia-fueled vessel designs

→ MAGPIE
Demonstrating ammonia bunkering in Rotterdam