



IUMI webinar
27 November 2025

Ammonia, hydrogen, methanol: Alternative fuels and their risks – an update on Project METAFUEL





METAFUEL – MARINE ALTERNATIVE FUELS

Risk-Based Safety Framework for Methanol, Ammonia & Hydrogen

Leonard Sang Tuei – Project Leader, DBI



WHY METAFUEL?

- Safety guidance needed for green fuels
- METAFUEL links fuel properties → hazards → safety functions → compliant design

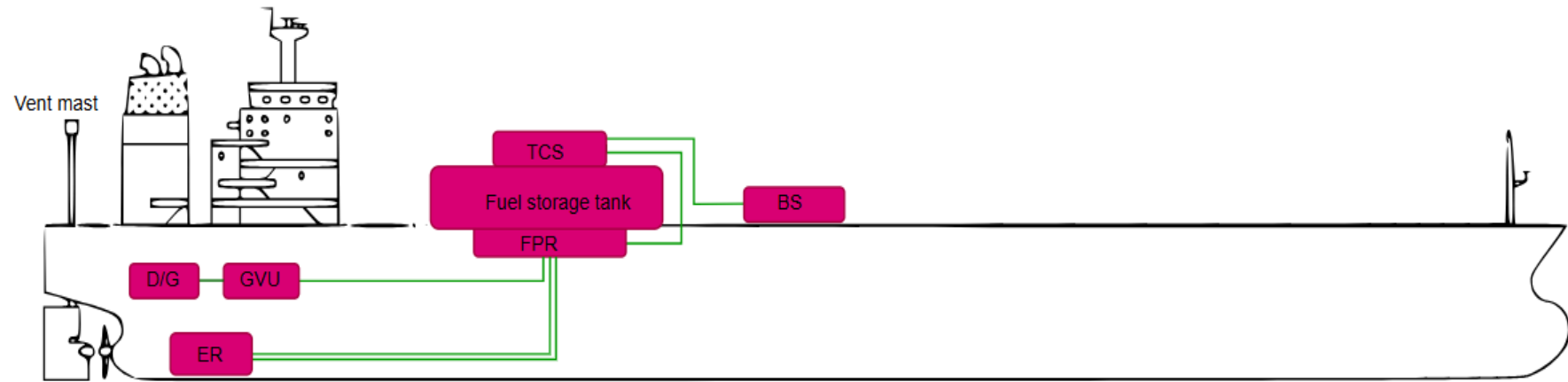
FUEL PROPERTIES & HAZARDS

Fuel	Storage mode on-board a ship	Main Hazards
Methanol	Liquid (ambient)	Flammable (Flash Point ~11 °C) Toxic by ingestion/inhalation Invisible flame
Ammonia	Pressurized or Refrigerated	Highly toxic & corrosive Mildly flammable (15–28%) Dense vapor cloud when cold
Hydrogen	Compressed (CH_2) or Cryogenic (LH_2)	Extremely flammable (4–75%) Very low ignition energy Cryogenic (LH_2 : –253 °C)

SHIP FUEL HANDLING ARCHITECTURE

CROSS-CUTTING SYSTEMS:

- Ventilation
- Segregation
- Hazardous Area Classification
- Detection & alarms
- ESD & Isolation
- Fire fighting strategy
- Material selection



BS= Bunker station, TCS = Tank connection space, FPR = Fuel preparation room, ER= Engine room, GVU= Gas valve unit, D/G= Diesel generator

— Fuel transfer line

DESIGN RISK MANAGEMENT

RISK ASSESSMENT TOOLS:

QUALITATIVE RISK ASSESSMENT

- HAZID (Hazard Identification) — e.g., identify fire, explosion, or toxic release hazards in FPR.

QUANTITATIVE RISK ASSESSMENT (QRA)

- Consequence Modelling: e.g., dispersion of ammonia vapor, methanol pool fire, hydrogen jet flame.

Bowtie Analysis - Risk-visualization method → Link fuel properties to safety functions



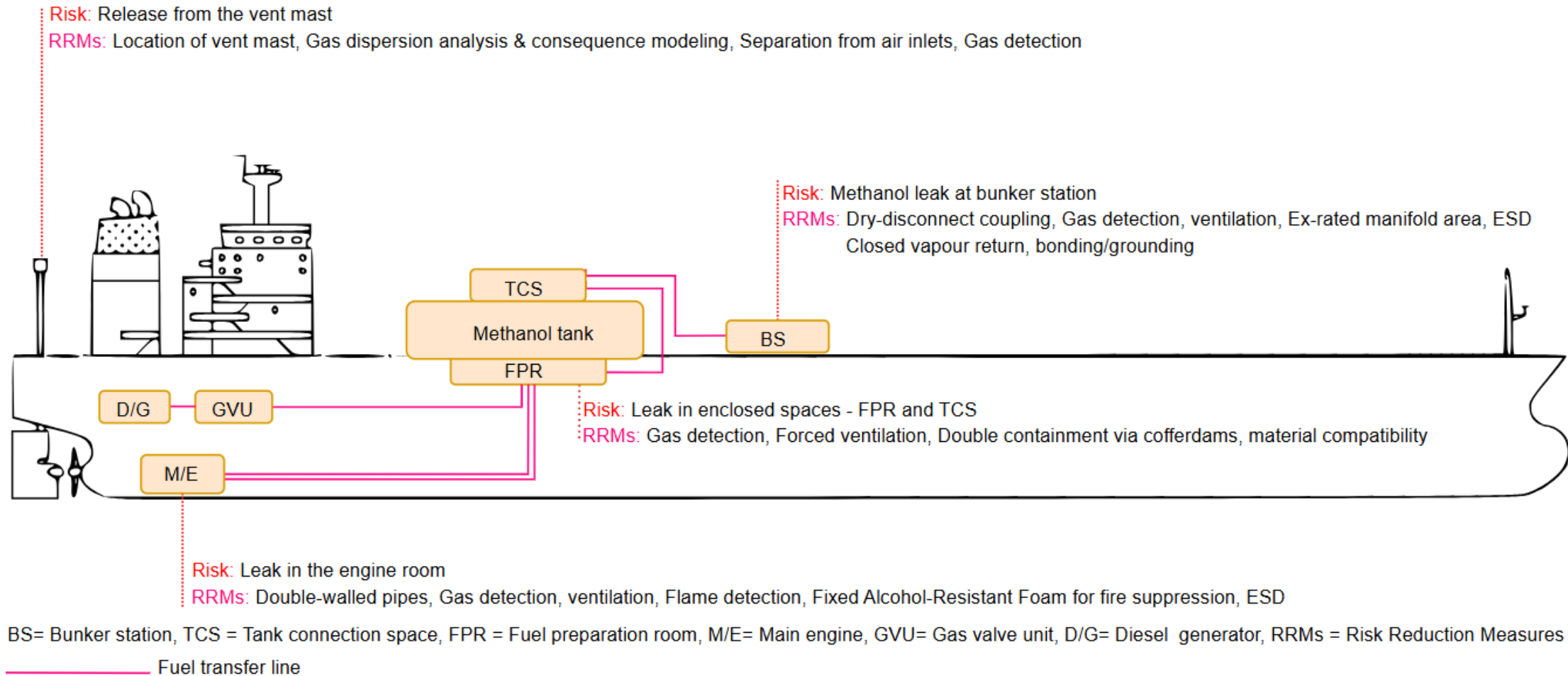
HUMAN FACTORS ENGINEERING (HFE)

KEY FOCUS AREAS

- Crew Interface & Ergonomics – clear alarms, intuitive control layouts, simplified emergency actions
- Situational Awareness – visibility of leaks, clear flame indicators, gas detection feedback
- Procedural Design – bunkering, venting, isolation, and maintenance steps designed to minimize human error
- Emergency Response & Escape – evacuation routes, PPE access, and training aligned with fuel hazards
- Training & Competence – fuel-specific handling knowledge (toxicity for NH_3 , flammability for methanol/Hydrogen)

Impact: Reduce human error–related incidents, Enhances crew confidence and operational safety, Supports regulatory acceptance and risk-based design

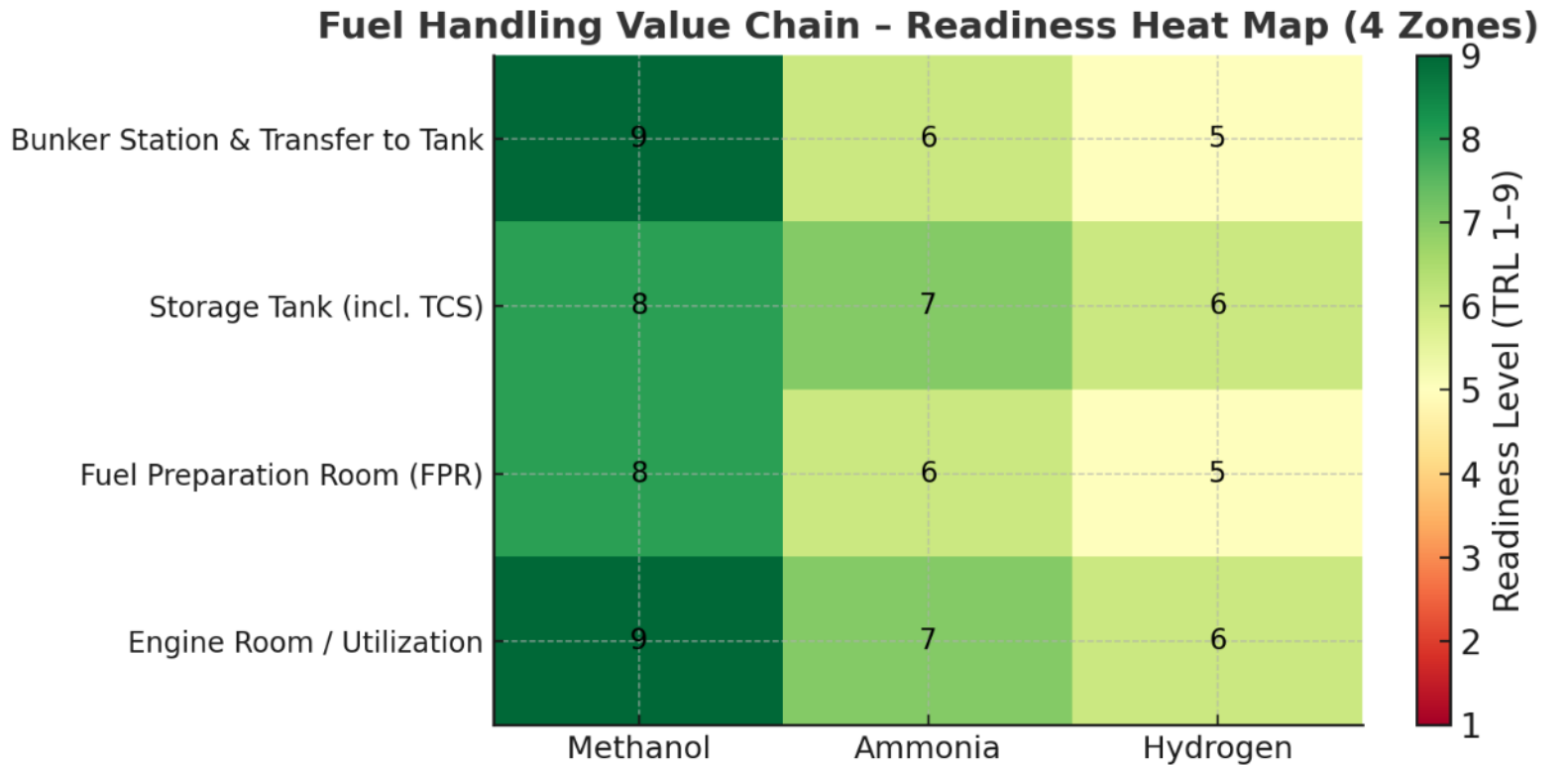
SAFETY CONSIDERATIONS AND SAFETY FUNCTIONS



GAP ANALYSIS MATRIX

— DEVELOPMENT STAGE OF FUEL HANDLING VALUE CHAIN

- **METHANOL SYSTEMS** - (TRL 8–9) with established designs and approval pathways under interim guidelines.
- **AMMONIA** systems mid-development (TRL 6–7), ongoing validation of toxicity management and bunkering practices.
- **HYDROGEN**, especially in liquid form, lower readiness (TRL 5–6), where cryogenic containment, material compatibility, and standardization are still in early development

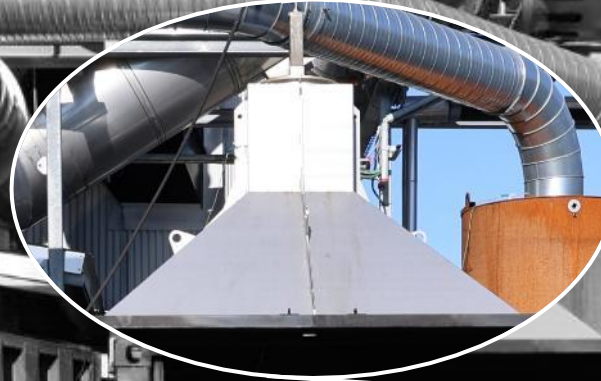


SCENARIO-BASED TESTING AND SIMULATION

- SUPPRESSION TEST OF
METHANOL POOL FIRES



Fire pan
Different positions:
- Center / Side / Corner
- TC for temperature



Two nozzle types:
- Different K-factor
- Same pressure, location and orientation

Thermocouple tree (TT)
Measurements @ 0.5m



THE INVISIBLE FLAME – METHANOL FIRE TESTS

SCENARIO-BASED TESTING AND SIMULATION

- SUPPRESSION TEST OF METHANOL POOL FIRES

KEY FINDINGS

- Higher K-factor improves suppression
- Nozzle positioning matters
- Tenability improved ($<48^{\circ}\text{C}$)

Future work → Further testing needed.





SCENARIO-BASED TESTING AND SIMULATION

- SIMULATION OF AMMONIA LEAK DURING BUNKERING

Scenario ID	Ammonia bunkering method	Location	Weather	Operating conditions
Scenario				
Scenario 1.1	Ship-to-ship (STS)	Alongside the future quay	Summer	Fully refrigerated
Scenario 2.2	Ship-to-ship (STS)	Alongside Quay 34 and 35	Summer	Semi-refrigerated
Scenario 3.3	Ship-to-ship (STS)	Alongside Quay 33	Winter	Fully refrigerated
Scenario 4.4	Ship-to-Ship (STS)	2 nautical miles west of the port	Winter	Semi-refrigerated
Scenario 5.1	Terminal/Pipeline-to-Ship (PTS)	Alongside Quay 33	Summer	Fully refrigerated

SCENARIO-BASED TESTING AND SIMULATION

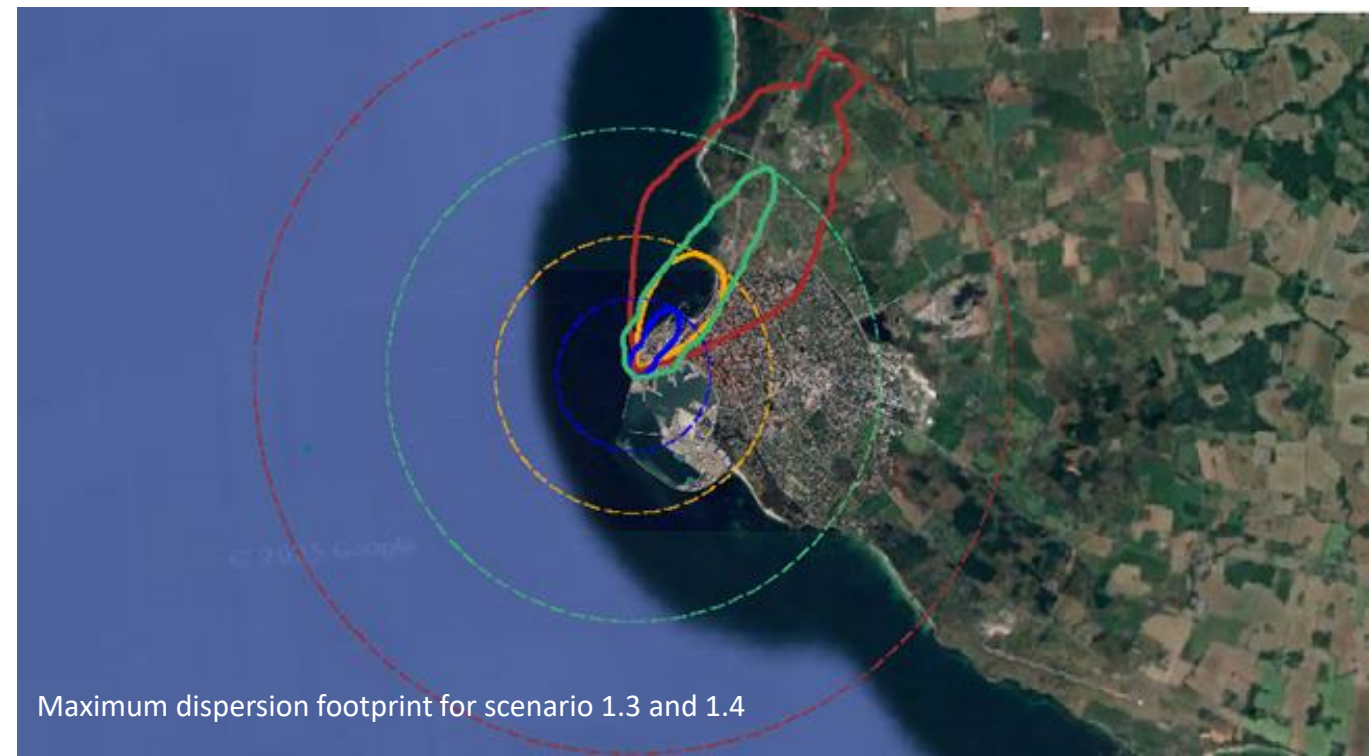
SIMULATION OF AMMONIA LEAK DURING BUNKERING

KEY FINDINGS

- Fully refrigerated → longer pool, shorter lethal range
- Semi-refrigerated → larger vapor cloud; the longest lethal ranges in both summer and winter
- Winter → shorter lethal distances; atmospheric stability and reduced mixing

Legend:

	Fully refrigerated @ 2700 ppm		Semi refrigerated @ 2700 ppm
	Fully refrigerated @ 220 ppm		Semi refrigerated @ 220 ppm



INTEGRATED DECISION SUPPORT FRAMEWORK

OPERATING PHILOSOPHY:

1. Evidence-Based Alignment:

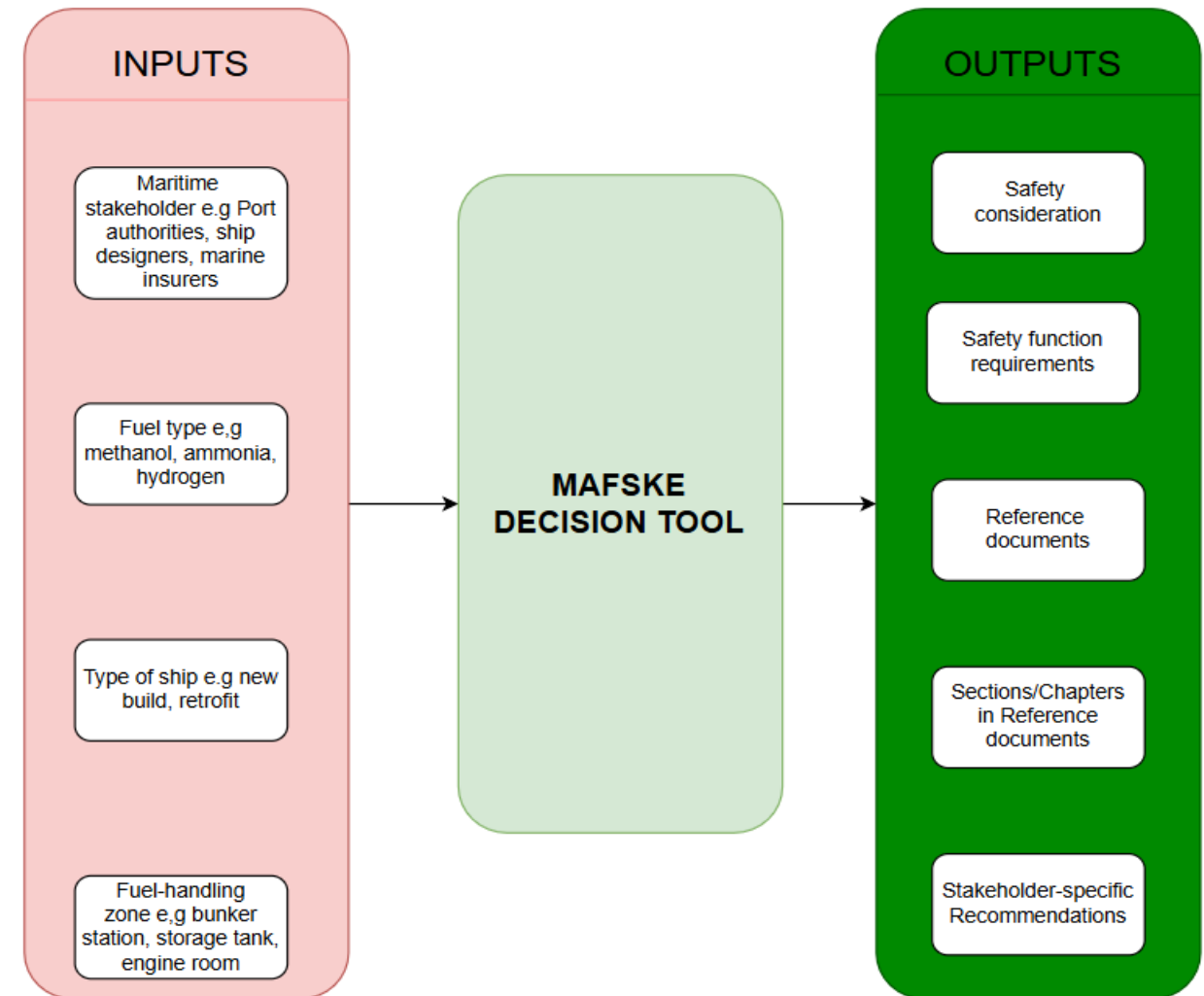
- Maps safety functions and regulatory sources

2. Analytical Core:

- Computational and comparative logic integrated within the engine
- Based on a structured and systematic regulatory gap analysis

3. Dynamic Adaptability:

- Allows future updates to accommodate regulatory evolution, new fuels, or refined safety data without altering the core structure



MAFSKE = Maritime Alternative Fuel Safety Knowledge Engine

INTEGRATED DECISION SUPPORT FRAMEWORK

INPUTS TO THE DECISION TOOL

Parameter	Input
Maritime stakeholder	Marine insurer
Fuel type	Methanol
Type of ship build	Retrofit
Fuel handling area	Engine Room

OUTPUTS (AS PRESENTED TO THE MARINE INSURER)

Output Category	Example Output
Safety Consideration	Low flash point, low-luminous flame; heightened reliance on detection and automatic suppression to avoid delayed human confirmation.
Safety Function Requirement	Fire detection, active fire protection, ignition source control, ventilation, emergency shutdown, process monitoring—drawn from the project’s safety-function set.
Regulatory References	IMO Interim Guidelines for Methanol (MSC.1/Circ.1621); Class rules (DNV, BV, ABS & LR); SOLAS II-2/10 (Fire Extinguishing Systems).
Guideline Chapters	Interim guideline Chapter 15.5, 8.3, 13.5, 11.6, 17.4.3, 7.3.10; Classification Society Rules (e.g., DNV Pt.6 Ch.2 Sec.6 §3 Fire Protection).
Stakeholder-Specific Recommendation	- Require dual-phenomenology flame detection suited to low-luminous methanol fires and integration to ESD/ventilation cutback. - Verify fixed system efficacy for alcohol fuels (water-mist configuration and/or AR-foam where required); align test evidence with your lab work and lessons captured in Chapter 11. - Confirm cause-and-effect linkages (detector → alarms → shutdowns → suppression) are documented and tested. Evidence checklist to request (bind these to pricing/terms): - Fire detection design basis + placement rationale for methanol; commissioning function tests. - Fixed system test reports or analogue evidence aligned with your Chapter 11 findings for methanol pool fires (time-to-control/extinguishment, visibility factors). - Cause-and-effect matrix (C&E) and FAT/SAT records (detector → ESD/vent/LAFF). - Maintenance & re-test intervals for detectors/nozzles; spare stock for critical components. Insurer policy levers (example wording) - Warranty: “Maintain detection and fixed suppression per approved C&E; test quarterly with records available to underwriters.” - Pricing credit: Evidence of dual-tech flame detection + successful methanol-representative suppression tests. - Deductible loading: If AR-foam provision or equivalent strategy for open-pool scenarios is absent where design basis indicates need. KPIs you can track - Mean alarm-to-ESD time (target ≤ X s). - Nozzle availability at inspection (% in-tolerance). - Detector proof-test pass rate per quarter (≥ 99%).

INTERGRATED DECISION SUPPORT FRAMEWORK

Maritime stakeholder engagement

<https://forms.office.com/e/w6YCmCRG0m>

Decision Support Tool for
Alternative Marine Fuels –
Stakeholder Survey





RECOMMENDATIONS AND ROADMAP

A PATH TOWARDS PRESCRIPTIVE SAFETY FOR ALTERNATIVE FUELS

- Near-term → Use existing frameworks - Decision tool + Scenario evidence
- Medium-term → Codify recurring outcomes into guidance
- Long-Term Vision → “From goal-based to prescriptive”

FINAL PROJECT REPORT

Get notified by signing up



QUESTIONS ?



Leonard Sang Tuei

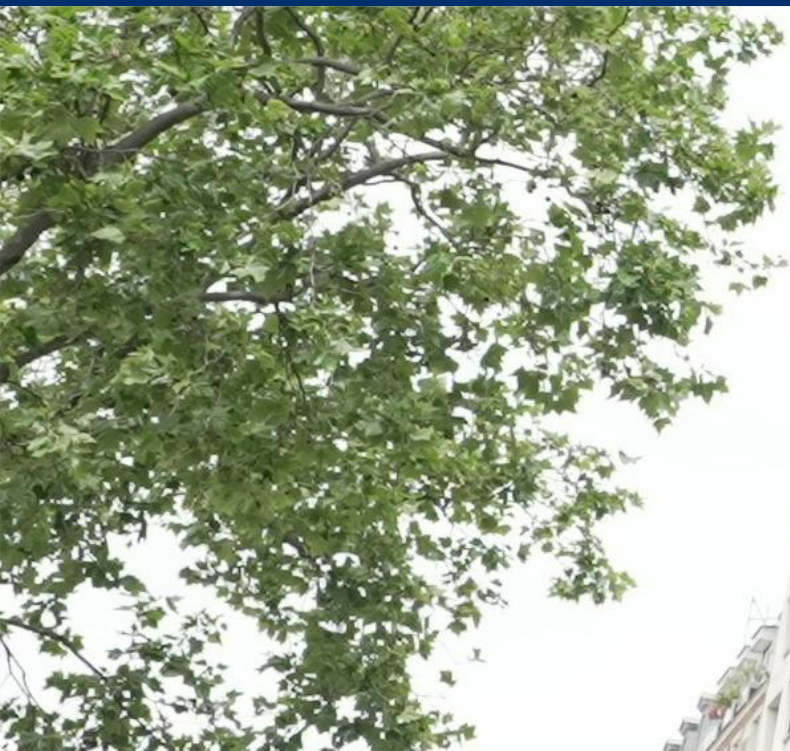
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MARINE ALTERNATIVE FUELS

IUMI / DBI-METAFUEL SUPPORT
E.SENARD - 27/11/2025



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METHANOL, AMMONIA, HYDROGEN

Safety moment : the broom-test

Hydro-gen = making water ? Titanic of the skies

Methanol : works in racing cars, why not in ships ? Because tank size matters when next station is far far away

Ammonia : already used as a refrigerating fluid in fishing vessels for decades, not without tragedies

Training, human factor, acceptability...

SAFETY MOMENT

Do you know this high-tech life-saving safety device used by NASA during Apollo program ?



Credit : picture of [Magnus S](#) on [Unsplash](#)

SAFETY MOMENT

The broom test, only way to detect hydrogen and methanol fires until modern infra-red cameras development !



NASA engineer Heidi Barnes demonstrates the antiquated "broom method" of detecting invisible hydrogen and alcohol fires (Credit : NASA)

Reminder : beside explosion risks, hydrogen and methanol fires are very dangerous because nearly invisible to human eyes, no colored flame, no smoke but very high temperature !

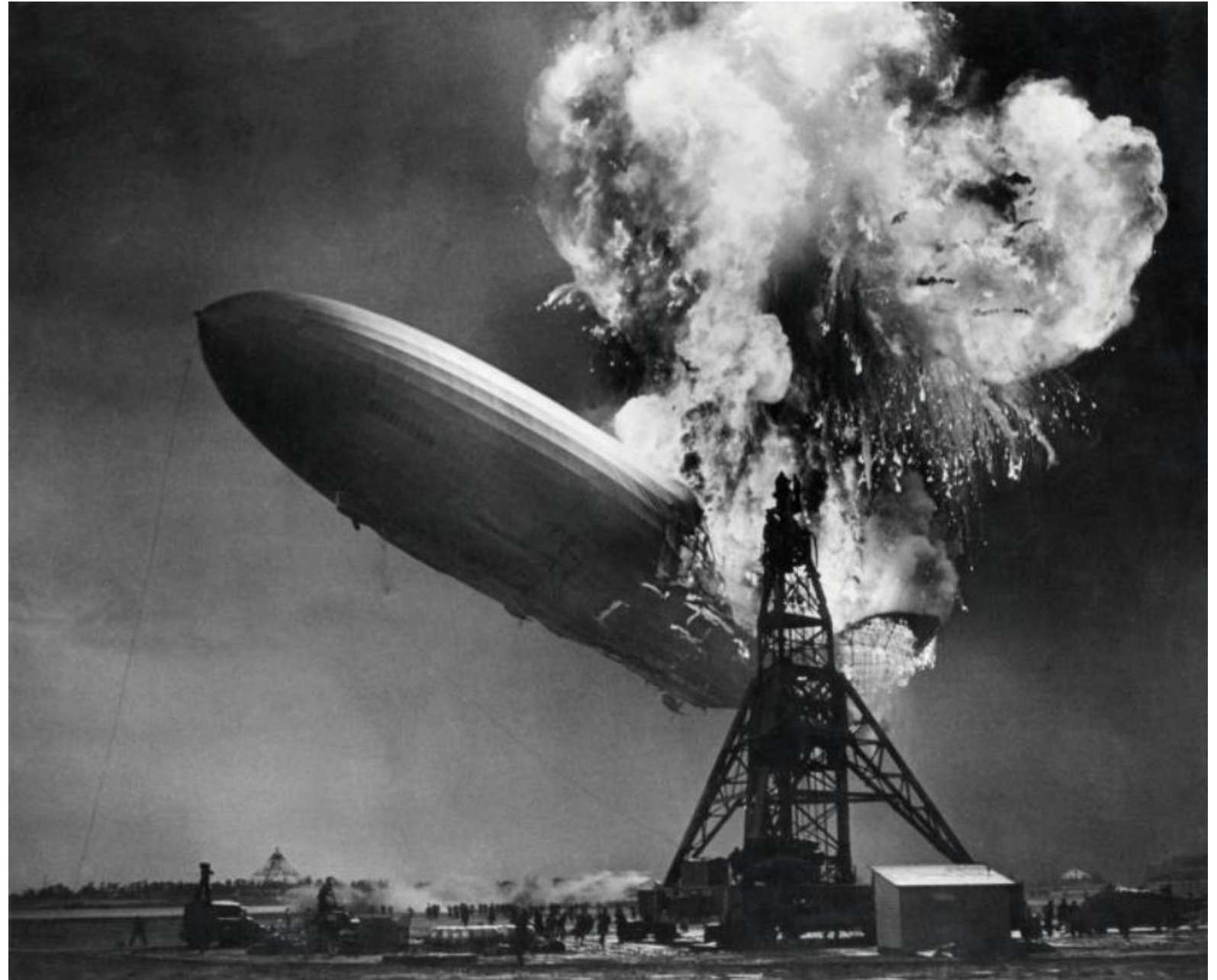
LZ129 HINDENBURG – 06 MAY 1937

Hydrogen in transportation, a new idea, really ?

Used in airships as a lifting gas when helium gas wasn't readily available (while these were diesel-powered for propulsion)

LZ129 HINDENBURG crash near New York was known as the "Titanic of the skies" (35+/97)

Not an isolated case, same had previously occurred to the French DIXMUDE airship (ex-LZ114), 50 victims in 1923, due to a thunderstrike near Sicily Island.
Or British R101 airship, crashed in France in 1930 while en-route from London to Karachi (48+/54)



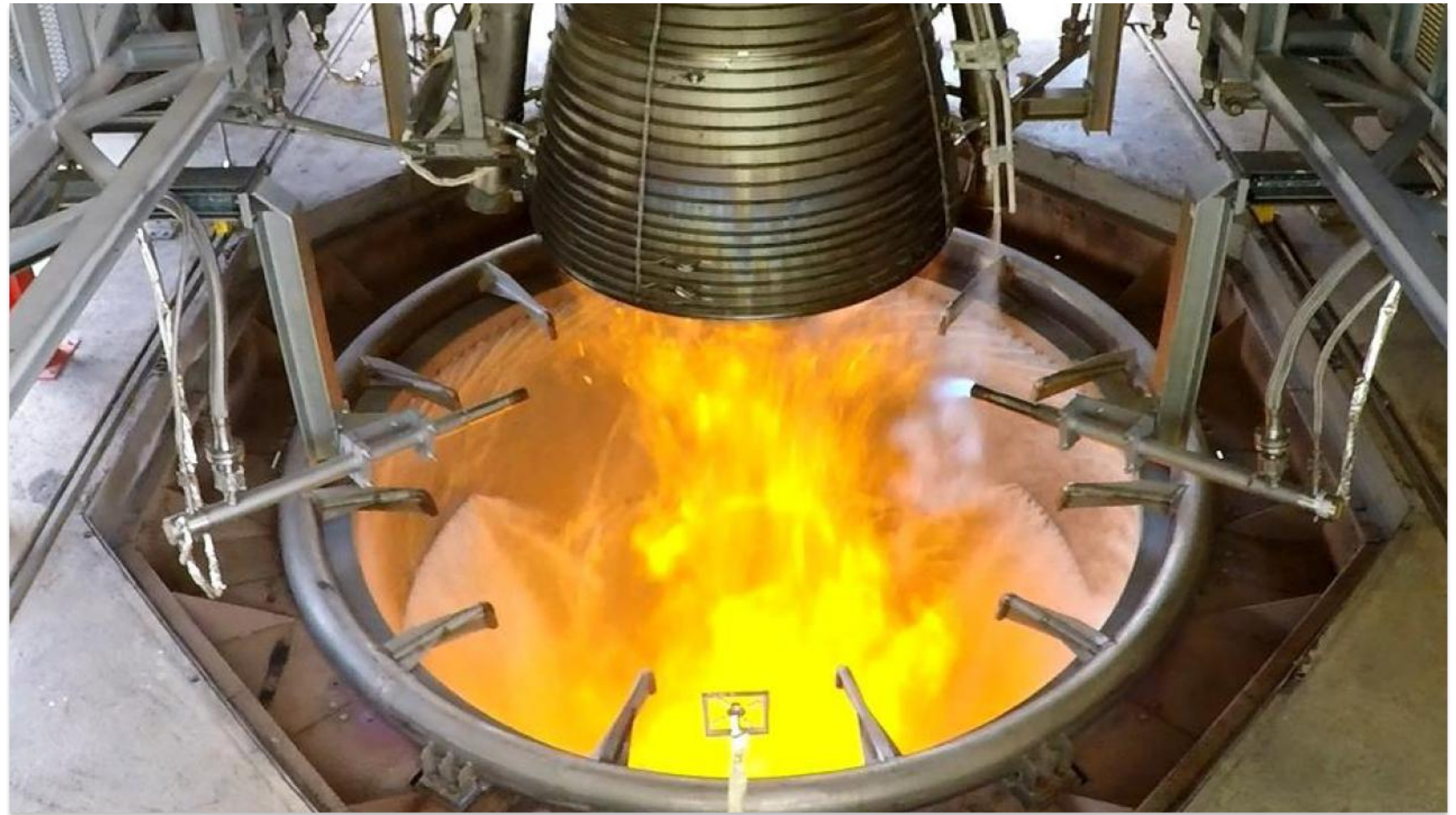
KNOWN USE CASE FOR LARGE-SCALE PROPULSION

ARIANE 6 – PROPERGOLS : LIQUID HYDROGEN AND LIQUID OXYGEN (LH2/LO2) $\text{H}_2 + \text{O}_2 \Rightarrow 2\text{H}_2\text{O}$

Need for an industrial cryogenic know-how to produce, store and dispense liquid hydrogen

Very low temperature:
-252,87°C at atm.P
Low density at only
70,973 kg/m³

Space technology, not realistic for shipping...



@Arianegroup

HYDROGEN INDUCED CRACKS / HYDROGEN EMBRITTLEMENT

Phenomenon known since 1875, small molecule, high reactivity, big effects

When not in a cryogenic liquid state, H_2 can be stored at 700bars to feed fuel cells or small turbines but small molecule at very high pressure = sensitive and expensive technology



"© CEphoto, Uwe Aranas"

So far H_2 remains confined to short-sea demonstrators and small-scale applications.

METHANOL

Methanol-ready vessels exist with dual-fuel engines, but use of methanol is so far reported limited to sea-trials.

Methanol availability for bunkering is still very limited

Breaking news ! "This week 24 Nov 2025, the Maritime and Port Authority of Singapore (MPA) announces it will issue licences to supply methanol as marine fuel in the Port of Singapore from 1 January 2026, following the Call for Applications launched in March 2025. This marks an important step towards establishing methanol bunkering at scale and driving Singapore's ambition to be a sustainable multi-fuel bunkering hub."



Make smart drink choices overseas

Protect yourself from **methanol poisoning**

Don't drink
From unlabelled bottles, free shots, **homemade** or **bootleg** alcohol.

Do choose
Drinks in **sealed bottles and cans** from trusted brands.

Learn more on [smartraveller.gov.au](https://www.smartraveller.gov.au)

Methanol poisoning
—Know the signs—

WATCH FOR:
A hangover that's worse than it should be or gets worse over time.

Get urgent medical help if you suspect methanol poisoning.

Knowing the signs and how to avoid it **could save your life.**

Learn more on [smartraveller.gov.au](https://www.smartraveller.gov.au)

AMMONIA

Smells like fish, no ?

Used on board industrial fishing vessels for decades, as a refrigerant fluid, but corrosive, asphyxiating and often lethal in case of leakage,

August 25, 2023

Tragedy in the Bering Sea: Seaman Dies in Ammonia Leak



by Paul Molyneaux in Alaska, West Coast & Pacific, News

Ammonia leak kills 2 Spanish nationals on tuna vessel anchored in Seychelles

Victoria, Seychelles | June 16, 2022, Thursday @ 15:39 in Business » FISHERIES | By: Rita Joubert-Lawen Edited by: Betymie Bonnelame | Views: 7892

Police probe deaths on French ship in Seychelles



REUTERS

Friday, December 05, 2008

VICTORIA, Dec 5 (Reuters) - Seychelles police launched an investigation on Friday into the deaths of five men killed in an ammonia leak on a French fishing vessel.

LET'S TALK ABOUT IT

What if each vessel becomes a gas or chemical tanker ?

What about :

- *Human factors engineering*
- *Training*
- *Acceptability*
- *Operational safety*
- *Harbour operations*
- *Idiot-proof design ?*



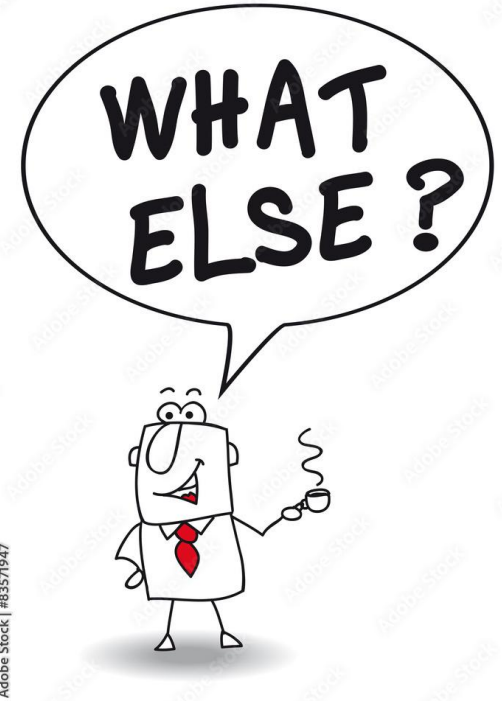
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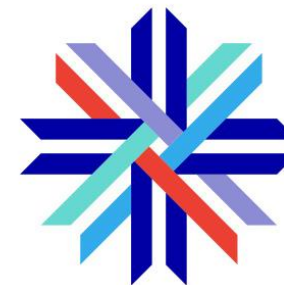
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Thank you!

- ✓ Feedback survey
- ✓ Next webinar 20 January 2026:
Global trade dynamics: Navigating tariffs and turmoil
- ✓ First Masterclass Cargo Asia in Singapore, April 2026
– registration now open!



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