Key Aspects for Design of Hydrogen Vessels

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H2SHIPS seminar in Paris

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FutureProofShipping

futureproofshipping.com

Our zero-emissions (ZE) marine services:

ZE Transportation

We are building our own fleet of zero-emissions inland and short-sea vessels, which we offer for charter.

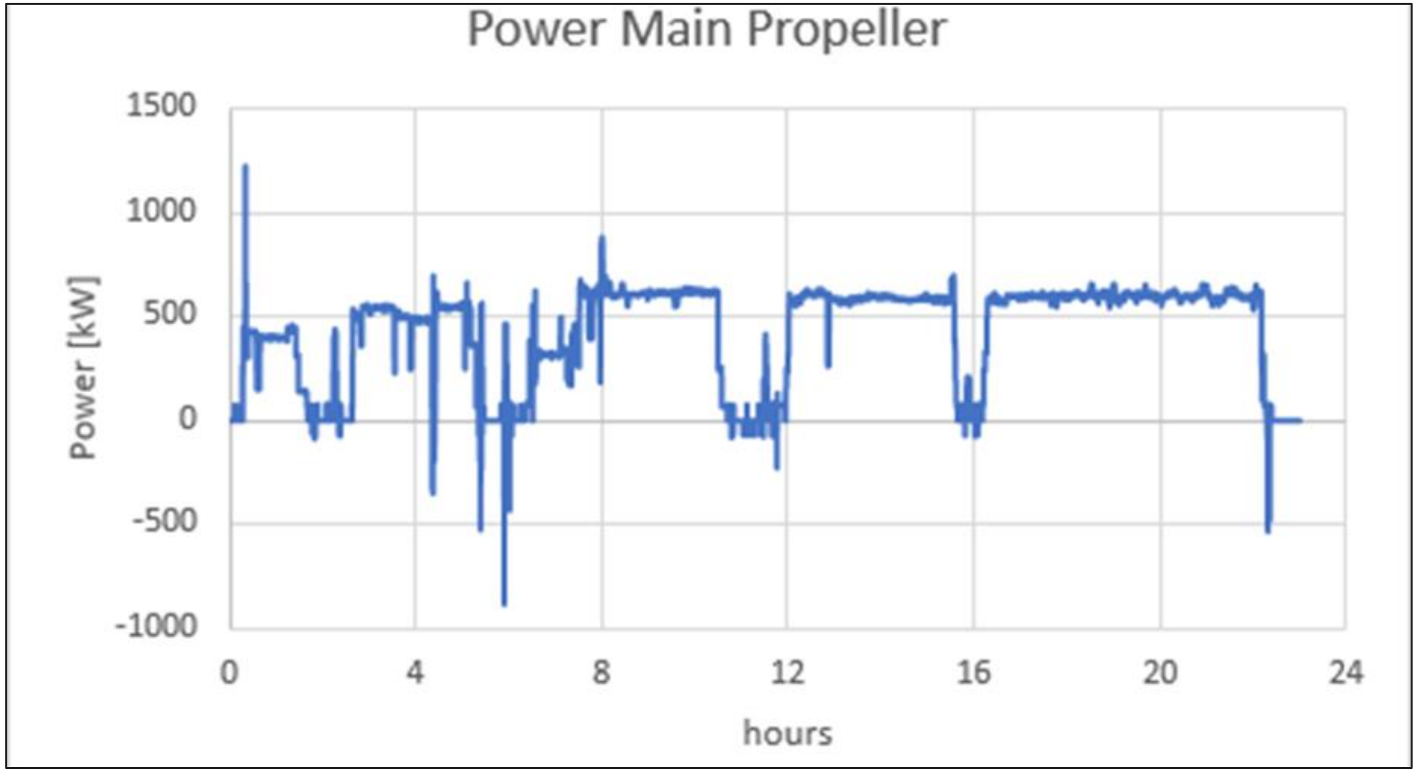
ZE Advisory

We enable others to make the transition to zero-emissions. We support on technical, financial and commercial aspects as well as project development and management.

We will retrofit an existing inland vessel

- Typical 'Rhine' container/dry cargo vessel
- 110m * 11.45m, Installed power is ~ 1.4 MW
- Operates between NL and BE, around 200 km one way
- Expect to reduce emissions by 2000 tons CO_2e annually
- 'Profiling' conducted to understand energy consumption in detail, select the zero emission technology and size it accordingly
- Profiling measurements included propulsion power (main and bow) and hotel load

Measurements for profiling



- Worst case conditions on one way representative trip
- Occasional peaks caused by the operator
- Typical propulsion power around 650 kW
- Total energy around 10 MWh
- White paper with more details about the measurements on our website
- Based on power profile and availability of solutions, we opted for compressed hydrogen and PEM fuel cells

Selected configuration

Completely remove diesel technology and replace with zero emission solution

825 kWe PEM fuel cell installation (3 x 275 kWe)

Around 1.100 kg of compressed H2 for sufficient reserve for operational and aging aspects

Four 40ft container spaces allocated for PEM+H2 in modified cargo hold

Battery installation for additional/start-up power (210 + 290 kWh)

Where to begin with design?

Advantages H2	Disadvantages H2
No harmful exhaust emissions	Space requirements
Less vibrations	Low ignition energy
Hydrogen is non-toxic	Low and wide explosion level limits
Hydrogen is highly buoyant and dissipates quickly	Limited maritime experience and regulations

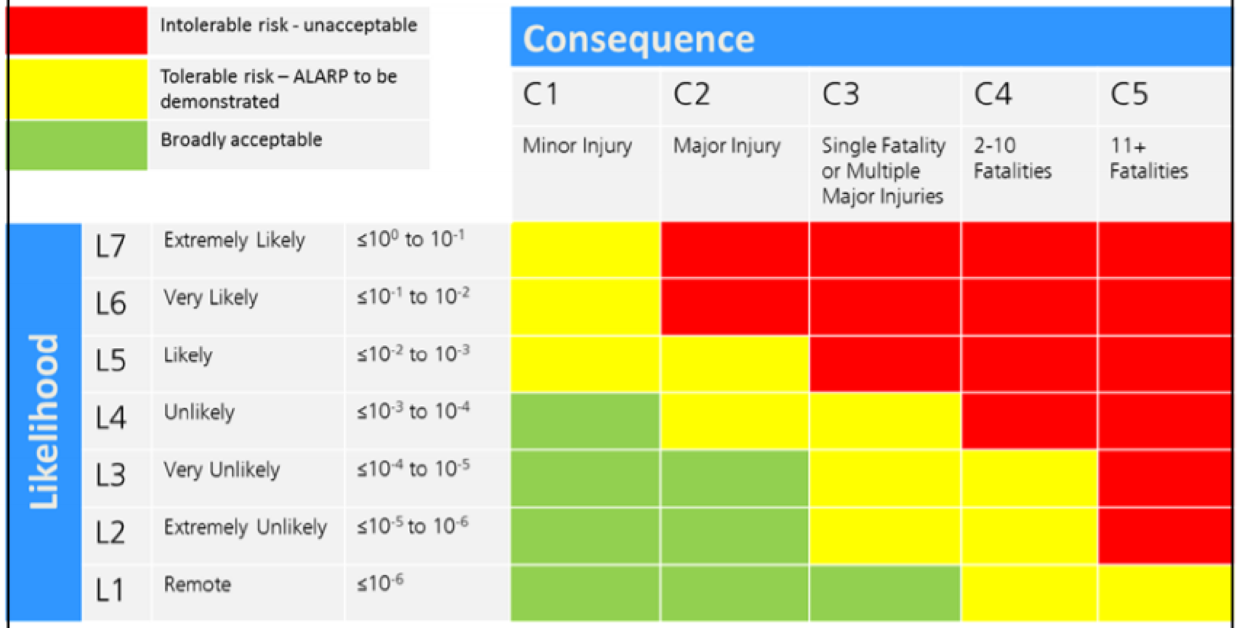
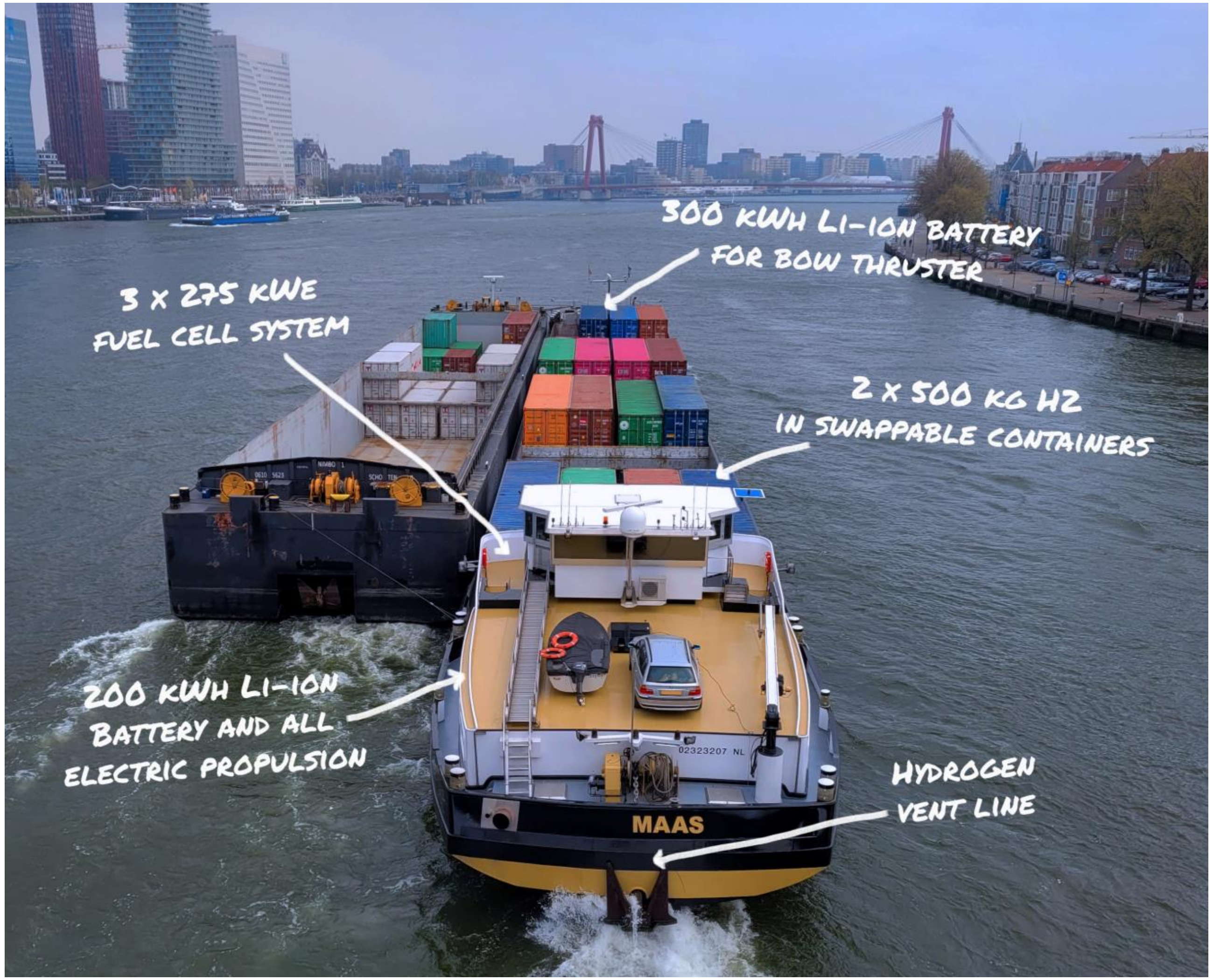


Figure 1.7.1 Acceptable Risk Criteria, reflecting aversion to escalating fatalities

Source: LR Risk Based Design

- Starting point are rules for LNG vessels (Estrin, Chapter 30 and Annex 8, and many other applicable rules).

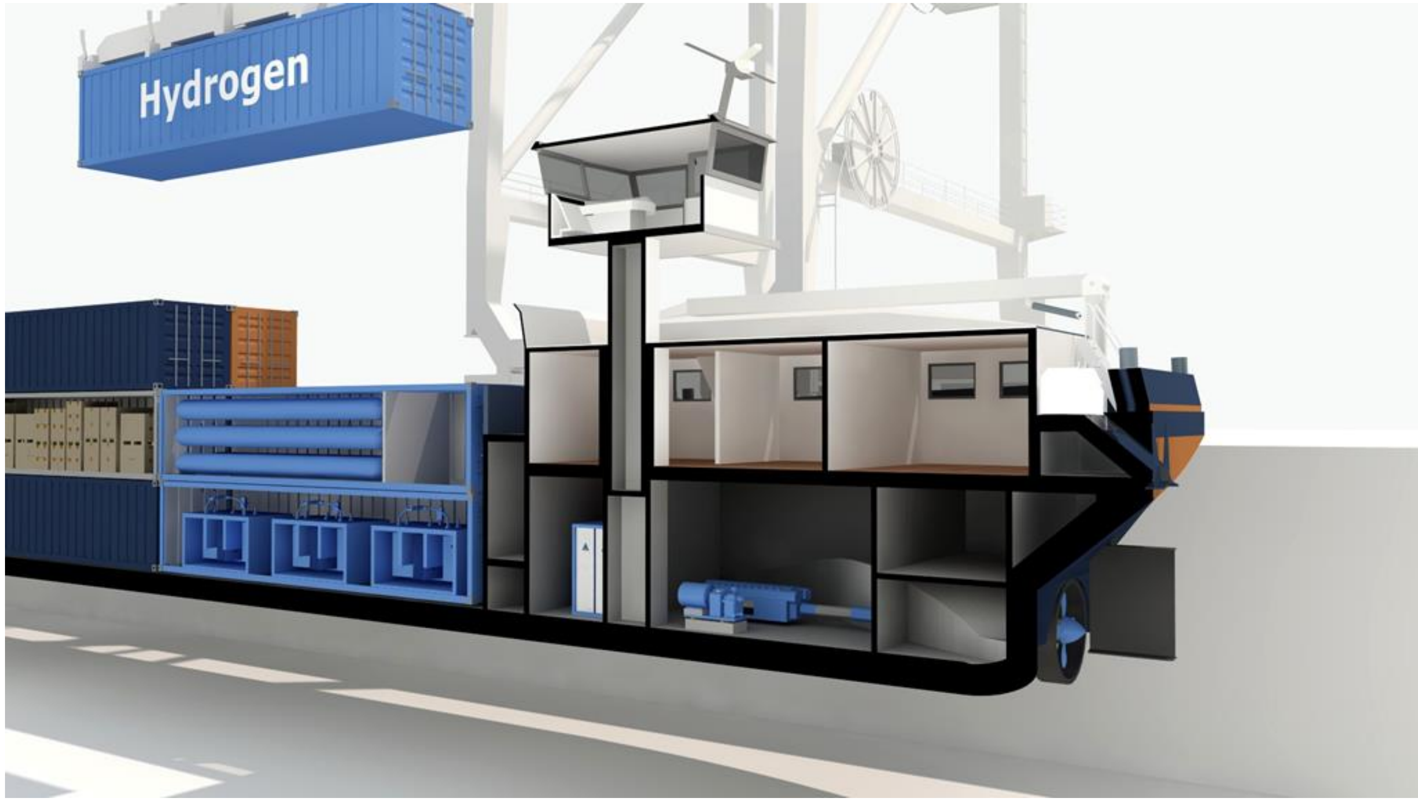
Our design and main safety aspects



- Swappable hydrogen container tanks
- Redundant battery and fuel cell system
- Hydrogen installation mostly in open air
- Ventilation crucial for enclosed spaces
- Often triple safety barrier present
- Inherently safe solutions applied where possible
- Additional fire fighter monitors on the deck
- Hydrogen vent line at the aft and *Hydrogen containment approach*

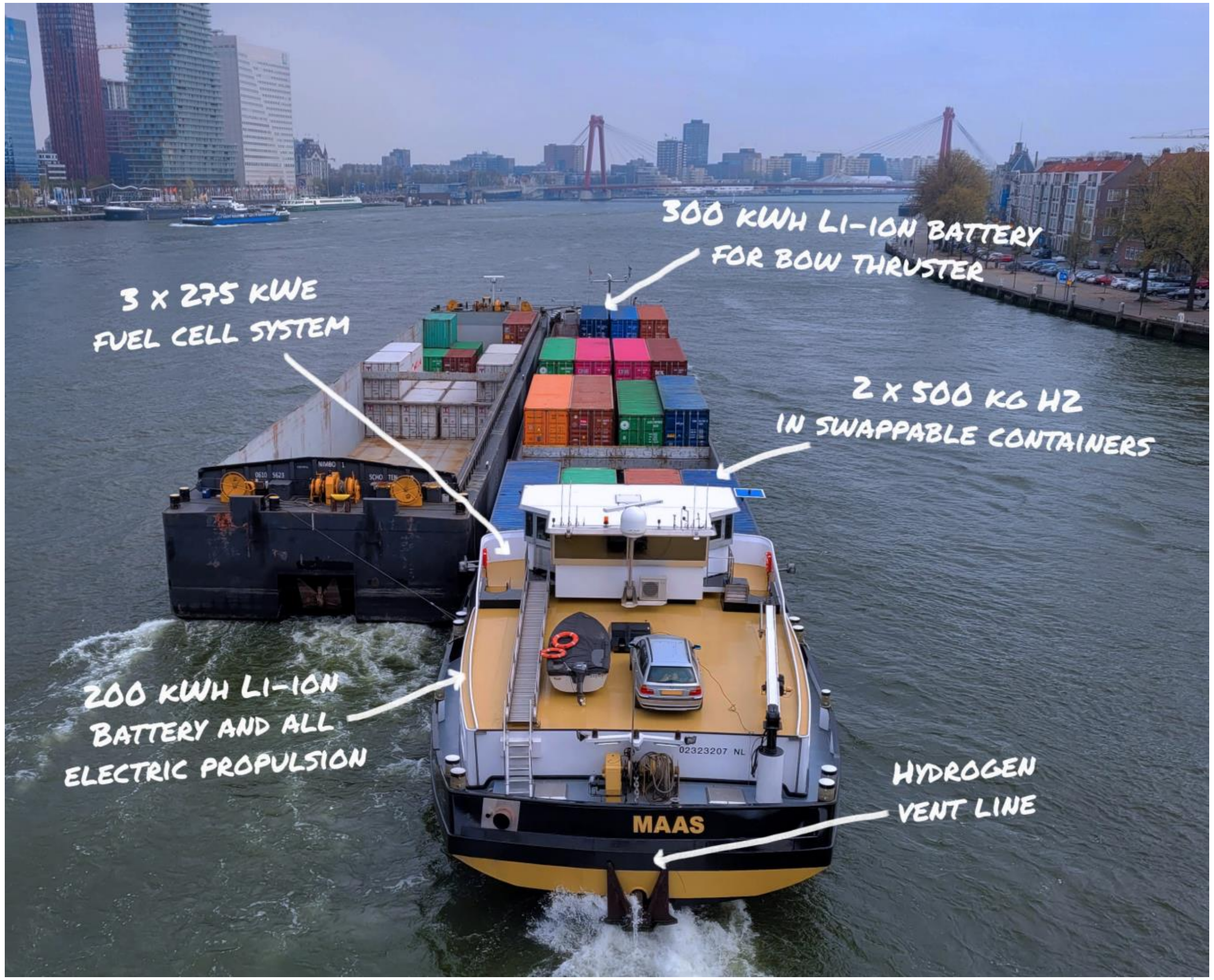
Project update
How far are we?

- Conceptual design and HAZID completed with all recommendations closed
- Recommendation to continue with approval process obtained from CCNR
- Contracts signed with fuel cell supplier, yard and subcontractors, electrical integrator and batteries, hydrogen supply secured for 7 + 7 years
- Working on documentation for final approval
- Expected sailing date: mid 2022



Discussion and future work
Is it applicable for others? Other considerations?

- Safe and efficient operation ensured
- Our design includes secondary and often tertiary safety barrier:
  - Ventilation and double walled piping
  - Sectioning of hydrogen zones
  - Enhanced firefighting capabilities
  - State of art sensors and leakage detection systems for system monitoring
- Future work
  - Other types hydrogen tubes require other approach, but same questions remain
  - Retrofit of two more ships is to start soon



Let's define shipping's new normal together!

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