LH2 SHIPPING

Advancing from LH2-fuelled car passenger ferry, M/F Hydra, to shortsea cargo ship

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ZESTA, London 11-12 September 2023

Company mission

Develop and build LH_2 driven ships

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Pictures: Westcon Yard/Norled/LMG Marin

Development, construction and commissioning of LH_2 driven ships towards:

- Cargo owners, cargo traders, ship brokers, ship operators, ship owners

Ensure technical and commercial viability of ship projects:

- Detailed technical and operational analysis of LH_2 ship operations
- Cooperation with energy producers for LH2 supply chain and bunkering solutions

Ensure safe operation of the LH_2 onboard ship systems:

- Crew training, certification, alternative design, risk assessment and operational support

Background

Regulatory outlook

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Shortsea fleet consists of older tonnage where 80% is built before 2010.

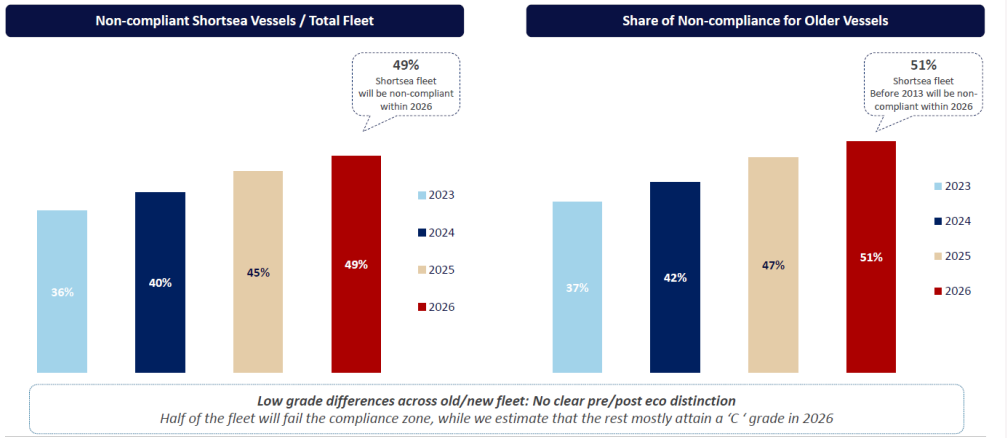
Grieg Shipbrokers analysis' shows that more than half the fleet will be in non-compliance with stricter emission regulations from the EU.

This will result in added OPEX costs.

LH_2 fuelled vessels will be timely by 2026 and represent an opportunity for ship owners.

M/F Hydra, world's first ship sailing on LH_2 fuel, is in operation in Norway since March 2023 with DNV certified technology and good operational performance.

Non-Compliance Alert: Shortsea Fleet at Risk



GRIEG SHIPBROKERS

Definition: Older vessels are built before 2013
Source: Grieg Shipbrokers Internal Analyses; MRV DATA

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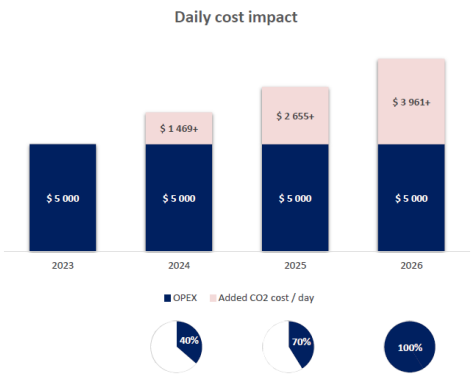
Case Study: Shortsea and EU ETS Cost Implications

	Vessel Description
GT	5 598
DWT	8 100
Age	15
Days Spent at Sea	164
Fuel	2 103
	Yearly description
Total CO2 Emissions (m tons)	6 034
CO2 emissions in EU ETS (m tons)	3 155

	2023	2024	2025	2026
EU ETS Phase-in	0%	40%	70%	100%
CO2 price / EUAs*	€ 86.5	€ 92.3	€ 95.4	€ 99.6
Added CO2 cost / year	-	$ 241 219	$ 435 988	$ 650 472
OPEX	$ 5 000	$ 5 000	$ 5 000	$ 5 000
Added CO2 cost / day	-	$ 1 469+	$ 2 656+	$ 3 962+



GRIEG SHIPBROKERS

Source: Grieg Shipbrokers Internal Analyses; MRV Data; Oceanbolt
*EUA price based on DEC-23 future contract (December EU carbon contract)

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Introduction

LH2 SHIPPING

LH2 Shipping, with partners LMG Marin and Seam, are developing LH_2 driven shortsea cargo ships.

LH_2 as fuel offers zero-emission operation with certified ship technology ready for commercial use.

Car and passenger ferry M/F Hydra has been in operation since March 2023 and sails with very good performance.

CEO of LH2 Shipping was project manager for M/F Hydra.

LH2 Shipping is targeting several shipping segments.

The LH_2 solutions shown in this presentation can be implemented for all three targeted ZESTA shipowner cases/challenges with modifications to storage and fuel cell capacities.

M/F Hydra, world's first ship sailing with LH_2 as fuel.
Ship and technology certified by DNV (class) and NMA (Flag).
Picture: Norled

LMG MARIN

SEAM

LH_2 supply chain

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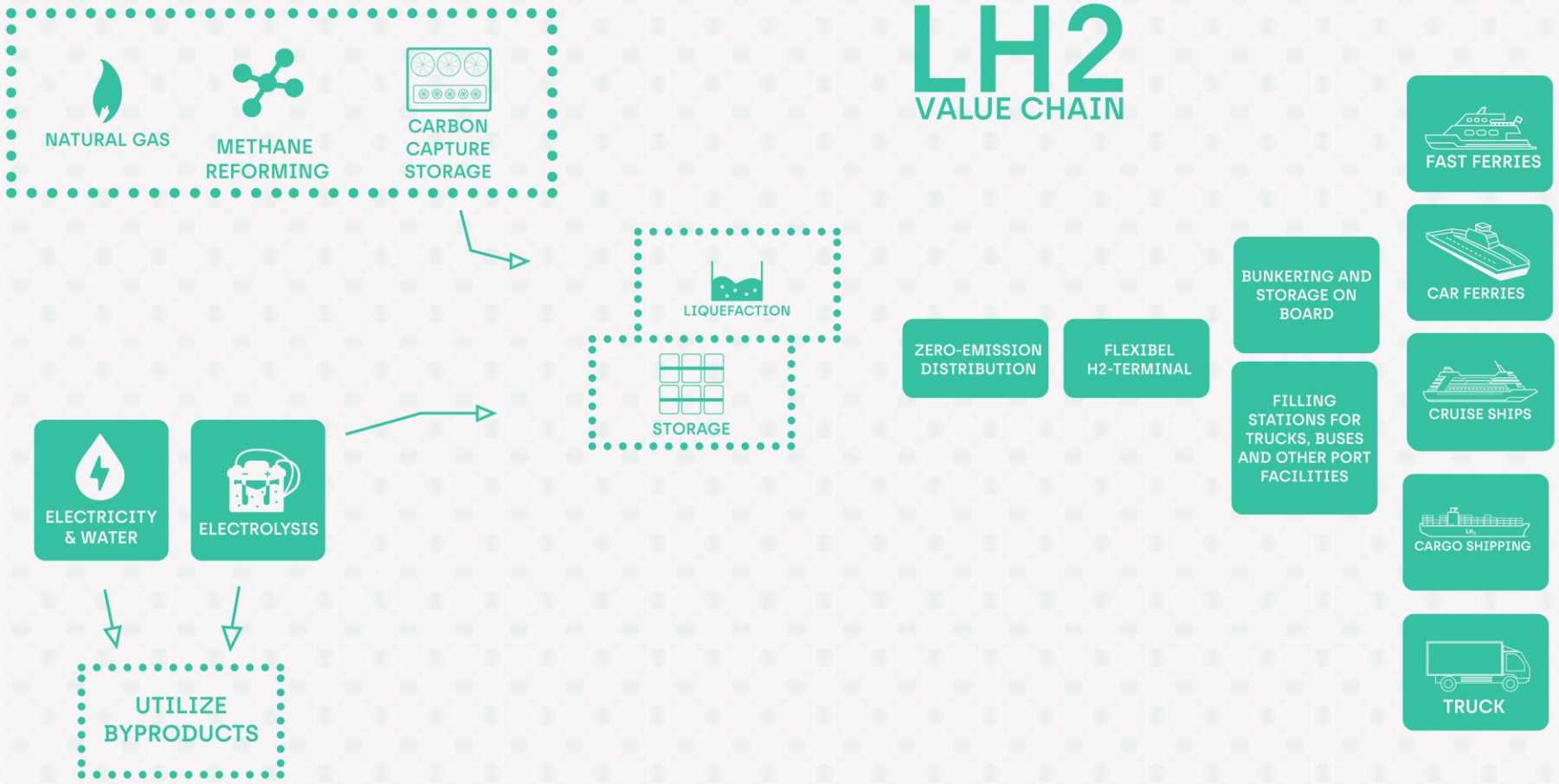

Picture: LH2 Shipping

LH_2 bunkering operations

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LH_2 fuel is transported from production sites for blue/green hydrogen to dedicated LH_2 bunkering sites.

M/F Hydra is bunkering 3 tons per hour from LH_2 delivery trucks/containers.

Future solutions will see a mix of trucks, containers and bunker vessels delivering LH_2 to ship bunkering sites.

LH_2 bunkering of M/F Hydra using LH_2 transport containers.
Method to be scaled for future projects.
Picture: Østvik

LH_2 ship systems

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Certified LH_2 ship system can be developed, installed and commissioned for cargo ships.

New development projects use learnings from M/F Hydra, world's first LH_2 driven ship.

The LH_2 system are designed to meet roundtrip requirements for North, Baltic and Irish Sea operations:

- LH_2 storage capacity 10-20 tons (ops profile related)
- Fuel Cell installation 1,5-2,5 MW @ 50% load
- Battery capacity 2,0-4,0 MWh

Alternative design/risk assessment for storage system, whereas FC/FC room is moving towards rules-based design.

Certification and training required for crew.

M/F Hydra's onboard LH_2 system with 4-ton storage tank, processing area and fuel cell room with 400 kW PEM FCs.
LH_2 storage and fuel cell systems certified by DNV.
Picture: Westcon Yard

Ship design and operations

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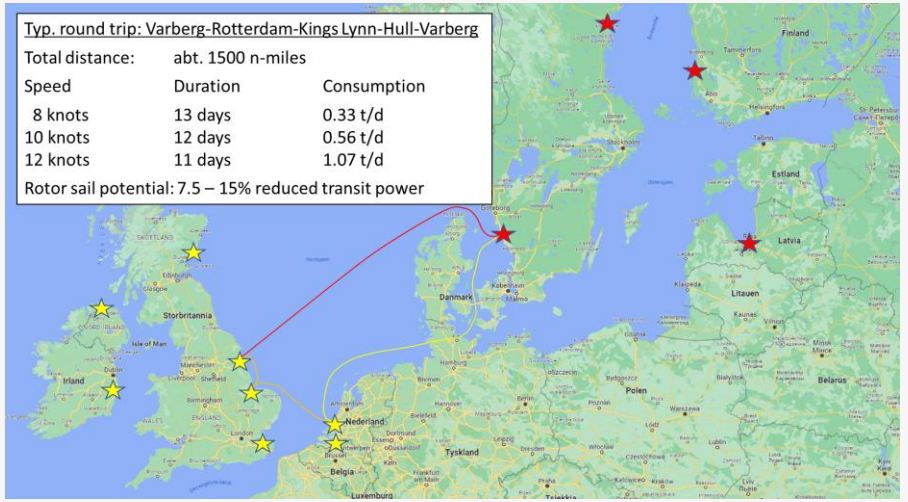
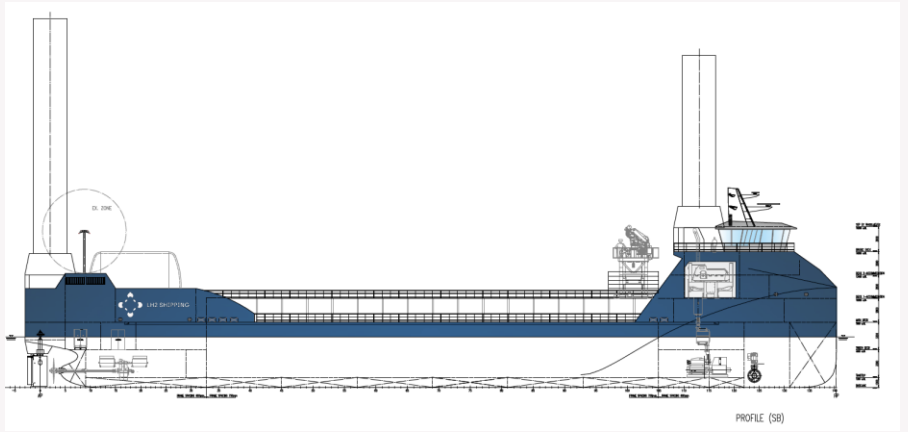
Detailed voyage analysis are conducted to:

- Define energy requirements for all voyage elements
- Define fuel costs and other OPEX
- Assess energy reduction equipment (sails, etc.)
- Optimise the onboard LH_2 system
- Develop bunkering schedules as part of voyage
- Plan port stays with shore power and/or FC operations

Resulting in cargo ship designs, such as:

Length over all:	95m
Molded depth:	8m
Beam:	16m
Fully loaded draught:	6m
Deadweight capacity:	5000t
LH2 storage capacity	15 tons
FC system	2MW





Pictures: LMG Marin

Veer Voyage challenge

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Veer Voyage sailing ship to operate in North Atlantic with container transport. A hydrogen fuel consumption of 3,9 kg/nm @ 10 knots and 4,9 kg/nm @ 11 knots is provided by Veer Voyage.

LH_2 ship storage and fuel cell operations onboard is available for zero emission operation. This is proven by M/F Hydra, sailing with DNV certified solutions.

An example fixed, relatively small onboard LH_2 tank, 10m long og 4m diameter, located at stern, can provide app. 5 tons of LH_2. This provides an energy content of up to 165 MWh and a nautical range (sailing without sails) of 1280nm/1020nm. Note that a larger tank with 10 tons capacity has only a marginal higher CAPEX costs and will thus provide double range.

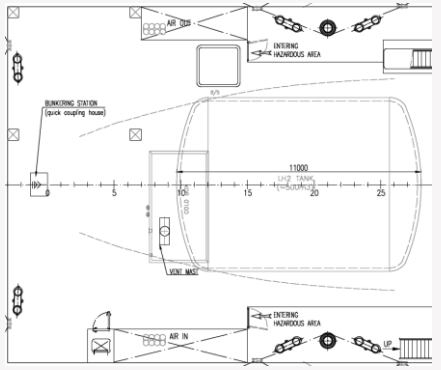
Fuel cells to be located under deck in a FC room with required 1,5-2,0 MW capacity.

Main challenge is currently LH_2 supply in ports. LH_2 supply issue is improving and by 2027 is should be available in US and Europe, thus contracts for LH_2 supply can be made.

Bunkering times will be 2 hrs. based on current technology. Small safety area in port for bunkering operations, 25m radius, with limited influence on ship container operations.

Operational support, certification and crew training can be provided.

Picture: Veer Voyage



Picture: LH2 Shipping. Stern location of LH2 tank, FCs located on deck below.

Wah Kwong challenge

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Ships are operating world-wide and represents a set of ship types; gas tankers, oil tankers, bulk carriers, container vessels and LNG. The example is utilising the lower ship segment: 8MW engine, energy consumption of 4MW/hr and a 20-day voyage. This vessel uses 1920 MWh per journey.

A potential LH_2 ship storage and fuel cell solution for this vessel is:

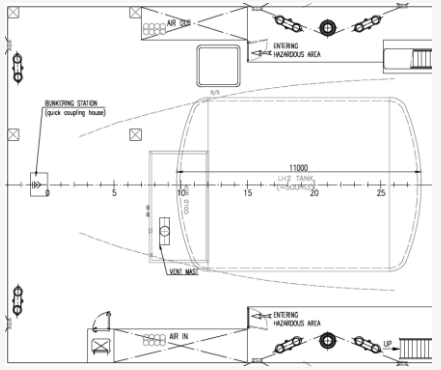
- A fuel cell efficiency of 50% requires LH_2 onboard storage of 3840 MWh.
- The vessel deck is large, and crew is experienced with ex-zones. Retrofit may be possible, check deck strength, ex-zones.
- With six -6- fixed, onboard LH_2 tank, 12m long og 8m diameter, located on top deck at dedicated positions, each storing 20 tons of LH_2 (660 MWh each) provides sufficient energy content for such a journey. Larger tanks can also be made.
- 8-10 MW fuel cells can be divided into 6 smaller parts and located at each tank location in a FC room with required app 1,5 MW capacity.

Main challenge is currently LH_2 supply in ports. LH_2 supply issue is improving and by 2027 is should be available in US and Europe, thus contracts for LH_2 supply can be made.

Bunkering times will be 6-7 hrs. per storage tank based on current technology. Small safety area in port for bunkering operations, 25m radius, with limited influence on other ship operations. Several bunkering stations can be made available for ship.

Operational support, certification and crew training can be provided.

Picture: Wah Kwong



Picture: LH2 Shipping

LH2 SHIPPING

Enabling safe, sustainable and cost-competitive sea transport using LH_2 as fuel

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