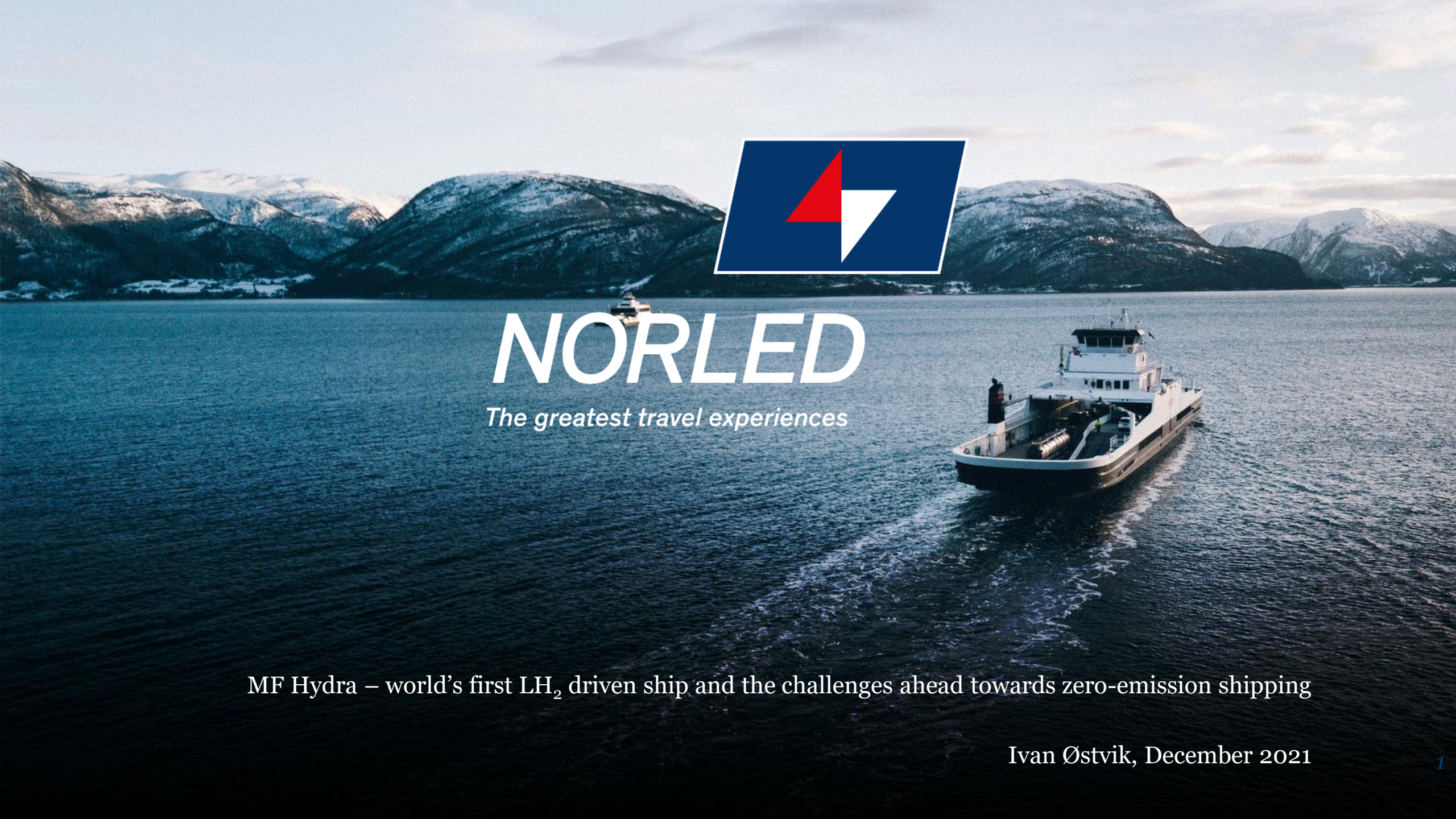


MF Hydra – world's first LH_2 driven ship and the challenges ahead towards zero-emission shipping

Ivan Østvik, December 2021

A major ferry operator in Norway

NORLED
The greatest travel experiences

#2 Ferry company

57 ro-ro ferries

29 routes

#1 Express boat company

28 fast ferries

18 routes

“Fuel transition” for ferries in Norway

NORLED
The greatest travel experiences

2015: The first el-ferry “Ampere” is launched

2022: About 80 el-ferries in Norway

2022: World-first LH2-driven ship “Hydra” in operation with others to come

MF Hydra

(Picture: Skipsrevyen 2021)

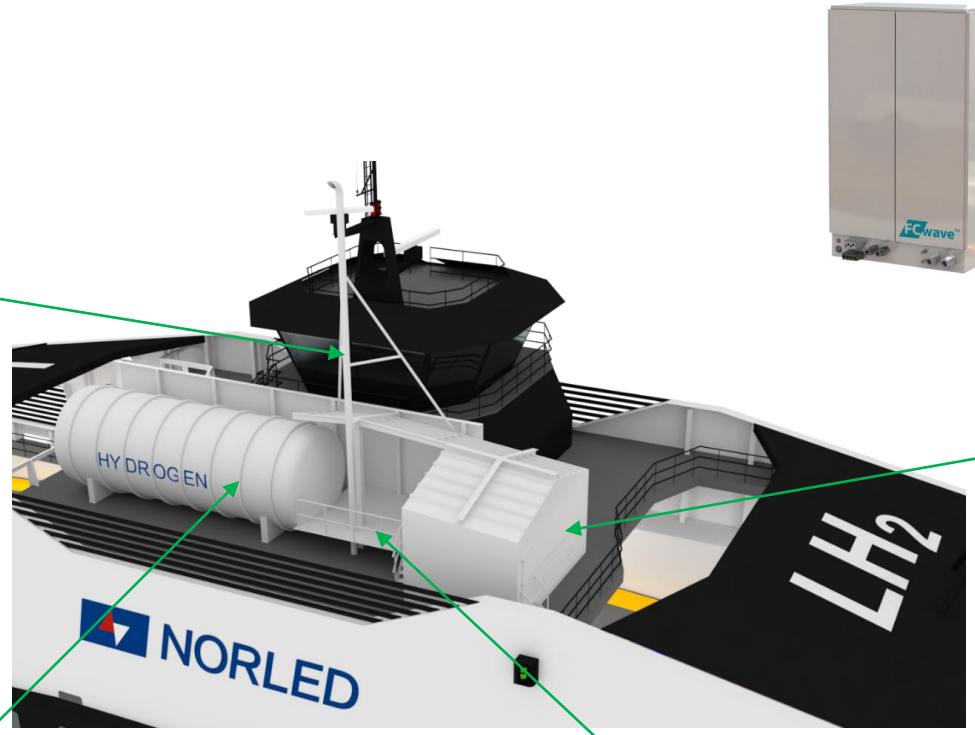
82m long, 80 cars and 299 pax

4 ton capacity LH2 tank, PEM FC 400 kW, Battery 1,5 MWh

The LH_2 arrangement

Vent mast:

- Evacuate emergency releases to safe location
- Inherent safe
- No releases during normal operation



Fuel cell modules:

- Ballard FC Wave
- 2 pcs. 200 kW
- 30-80% load
- DNV certification

FC room:

- Accommodate safe FC operation
- Potential FC explosion loads to be catered for

LH_2 storage:

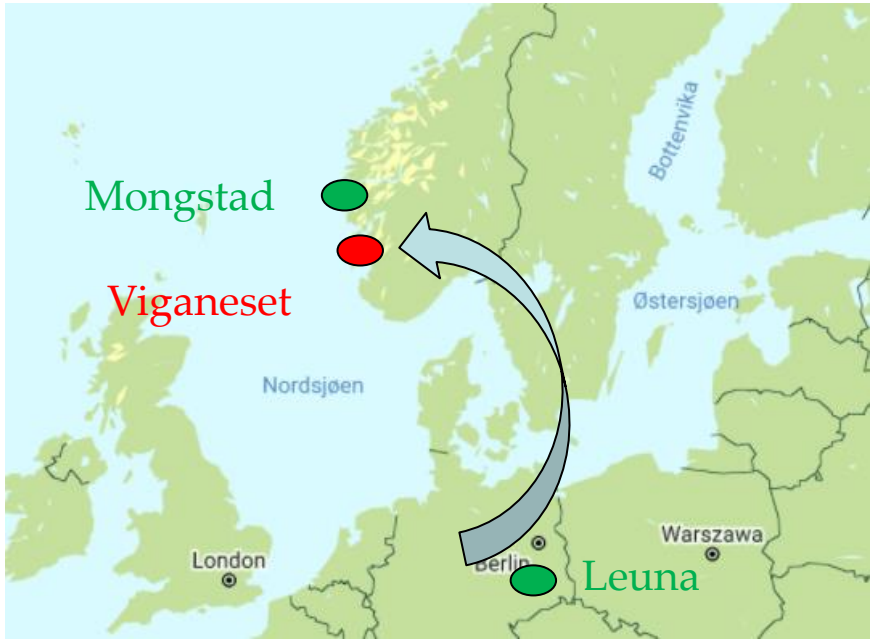
- Linde LH2 tank
- 4 ton capacity
- 10m length, 3,5m diameter
- DNV certification
- 2-3 bar operational pressure
- Vacuum insulated

Processing area:

- Vaporizer
- LH2 to GH2 (3-5 bar, 10-30° C)

LH_2 supply from Germany

(Picture: Linde Gas)



- Truck transport from Leuna, Germany to Viganeset, Norway from 2022-2025
- 3,2 tons capacity with delivery every 3rd week
- Shift to LH2 supply from Norway when available (2025?)

LH_2 bunkering for Hydra

LH_2 bunkering for Hydra

- Risk-based approach towards authorities, incl. QRA
- Safety zones on site (ATEX and access zones)
- Short bunkering time
- No over-filling, venting or LH2 spillage
- Trailer de-pressurization through tower post-bunkering
- Patent pending for bunkering operations

LMG MARIN

NORDWEST3D

Barriers to adoption

1. Missing the maritime hydrogen supply chain and bunkering hubs

LH2/GH2 sites:

- Nominated sites in Norwegian (Enova) support scheme

LH2 sites planned in Norway:

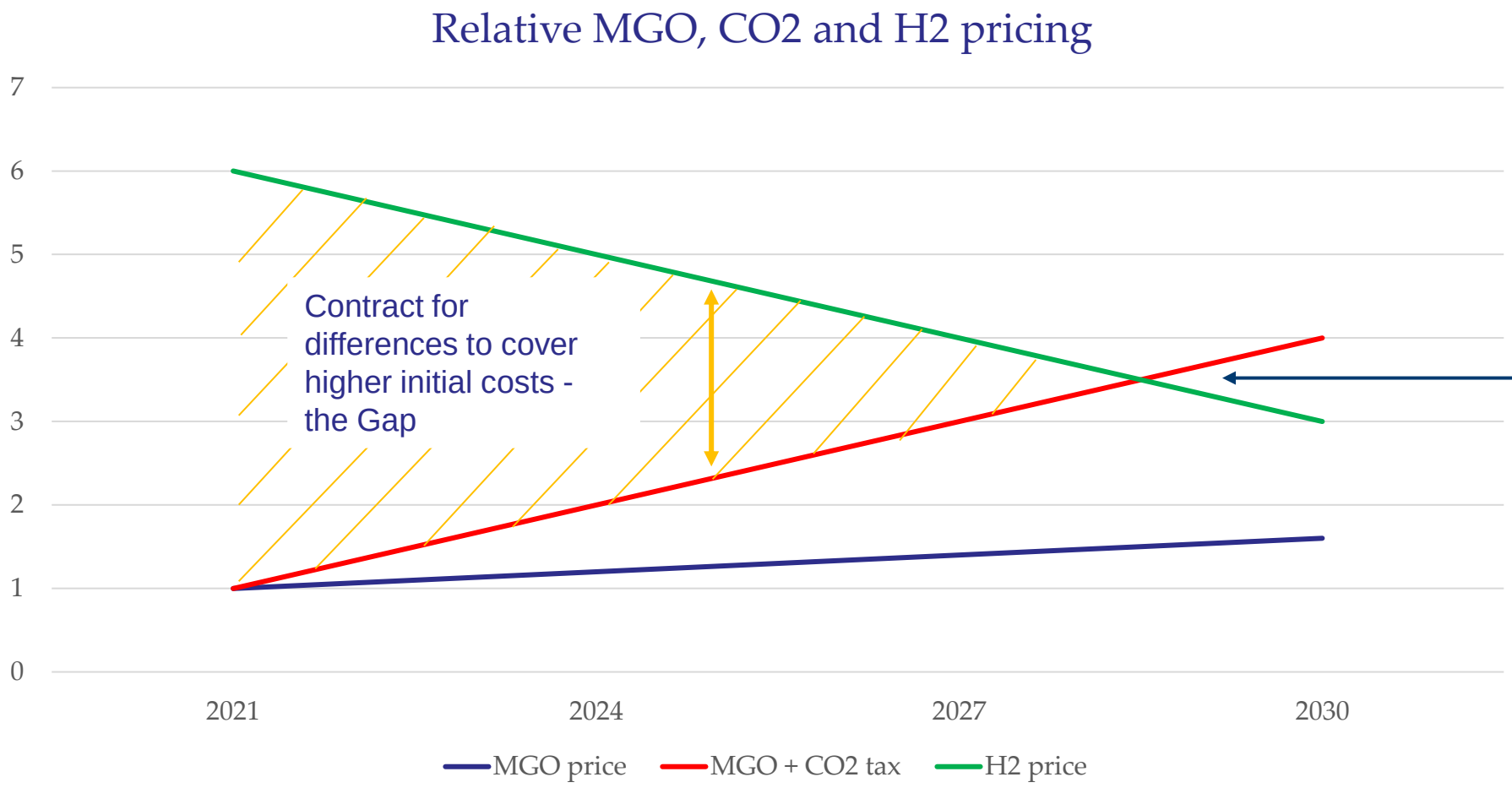
- Vestfjorden
- Mongstad

Prosjekteier
1 Troms Kraft AS
2 Statkraft AS
3 Mosjøen og omegn Næringsselskap KF
4 NTE Energi AS
5 TrønderEnergi Kraft AS
6 Green H AS
7 Norwegian Hydrogen AS
8 Hyfuel AS
9 Htwo-Fuel AS
10 Hydrogen Solutions AS
11 Glencore Nikkelverk AS
12 North Ammonia AS
13 Green Industry Cluster Norway
14 Borg Havn IKS
15 Hydro Hydrogen AS

Example on future bunkering hub with integrated LH2/GH2 production on-site. Source Norled/HYDS

Barriers to adoption

2. High initial cost for hydrogen as fuel, CfD mechanism



Hydrogen Europe study:

- 150 Euro/ton CO2 tax

Barriers to adoption

3. Ship technology becoming available

NORLED
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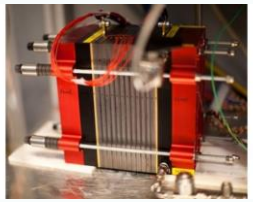
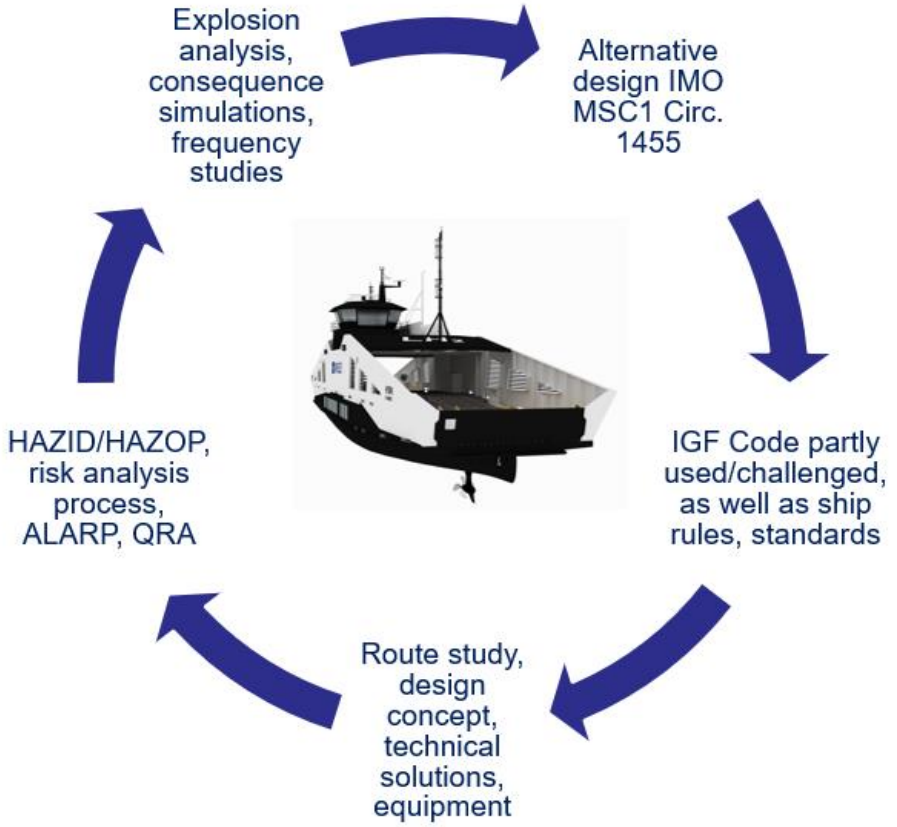
PEM	ICE	SOFC	LH_2 tank	GH_2 tank
				
BALLARD	WÄRTSILÄ	ceres	Linde	HEXAGON
POWERCELL	MAN B&W	cmr Prototech	MAN	UMOE ADVANCED COMPOSITES
TECO 2030	BEHYDRO		CHART	
Nedstack PEM FUEL CELLS				

Barriers to adoption

4. Bridging regulatory gaps

The alternative design process for MF Hydra is bridging the gap:

- Risk-based design following IMO Circ. 1455, utilised to:
  - Identifying and quantifying the **dimensioning risk scenarios**
    - Establish the design input
  - Assessing and challenging IGF Code and FC rules
    - **Deviation report** for LH2 system vs. “old rules”
- First **QRA** conducted
  - No other references
  - Risk contribution for hydrogen system vs. rest of ship?



Hydrogen-fuelled ship projects

Overview (some) announced projects

NORLED
The greatest travel experiences

Beffen 2009

2017

Energy Observer

Race for Water

2019

Elektra

Maranda

2020

Future Proof Shipping

Susio Frontier

2022

Hydra

Water-Go-Round

2023

Heidelberg/Felleskjøpet

Hydrogen Viking

Hydrotug

HYSEAS III

YANMAR TOYOTA

Topeka

2025

Hydrogen fast ferries

Vestfjorden ferry

Finnøy

Havila

Ulstein OSV

Bill Gates Yacht

Viking Cruises

Østensjø OWSP

Samskip

Moss LH2 carrier

DFDS

Veidekke

Kawasaki LH2 carrier

Thanks for listening

(Picture: Norled 2021)

Ivan Østvik, ivan.ostvik@norled.no, December 2021