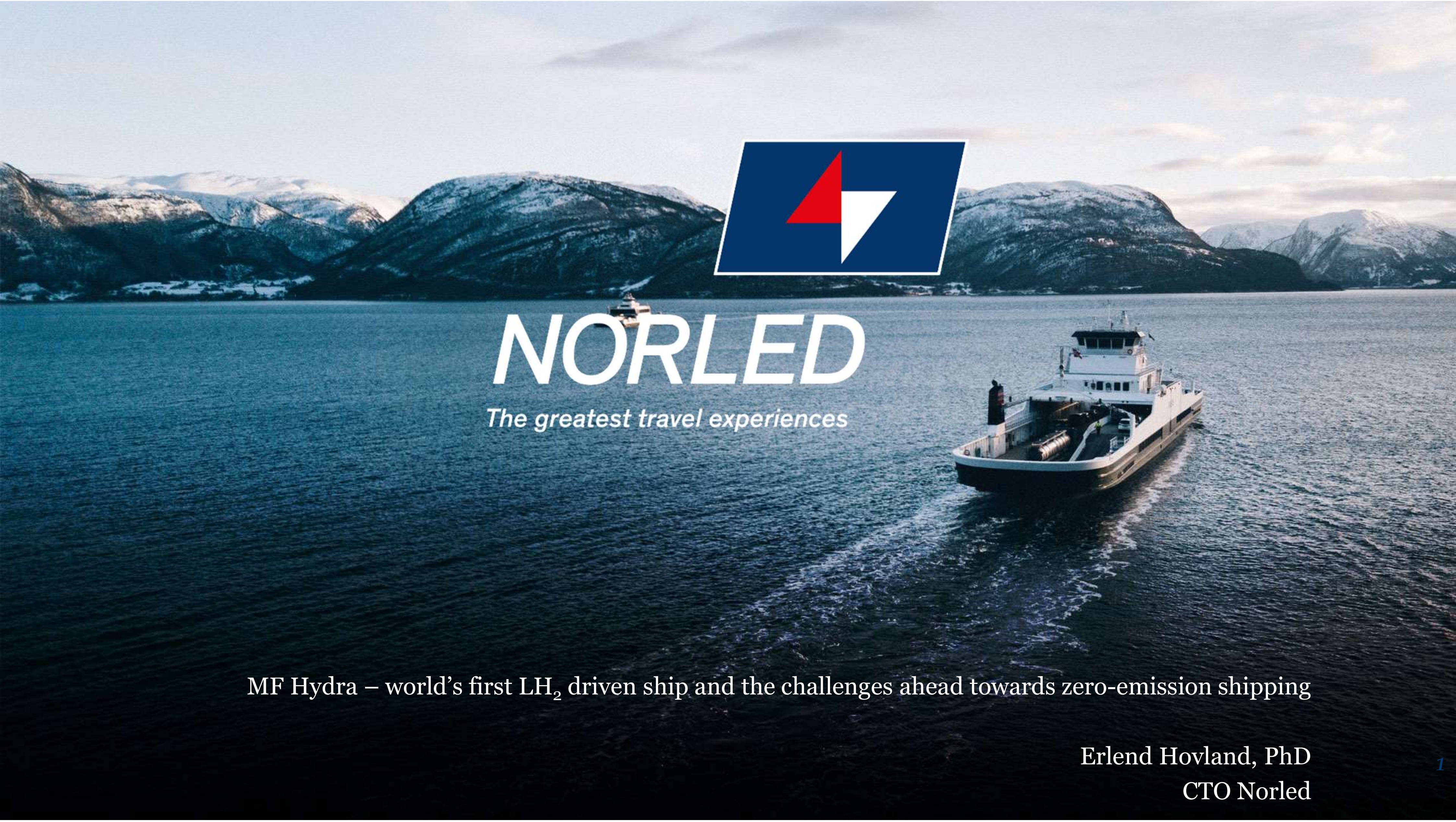


MF Hydra – world's first LH_2 driven ship and the challenges ahead towards zero-emission shipping

Erlend Hovland, PhD
CTO Norled

NORLED
The greatest travel experiences

A major ferry operator in Norway

	#1 Express boat company

45 ro-ro ferries	35 fast ferries

NORLED
The greatest travel experiences

"Fuel transition" for ferries in Norway

2015: The first el-ferry "Ampere" is launched

SHIP OF THE YEAR AWARD

THE HEYERDAHL AWARD

2022: About 80 el-ferries in Norway

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

SHIP OF THE YEAR AWARD

SHIPPAX AWARD

- What has changed fundamentally?
  1. Cost of fuel and energy / access to energy
  2. Requirements and desire to cut emissions
  3. The possibilities opened to us through digitalization

- How to achieve reduced energy consumption and lower emissions?
  - Alternative fuels to diesel (and batteries - battery electric considered mature technology)
  - Reduced resistance of the vessels by altering hull design philosophies
  - OPEX is increasing -> shift in balance CAPEX/OPEX -> reduced Total Cost of Ownership through increased CAPEX (as an example, it now makes sense to invest in larger expressboats for same service as fuel usage is reduced and hence TCO)

Fuel

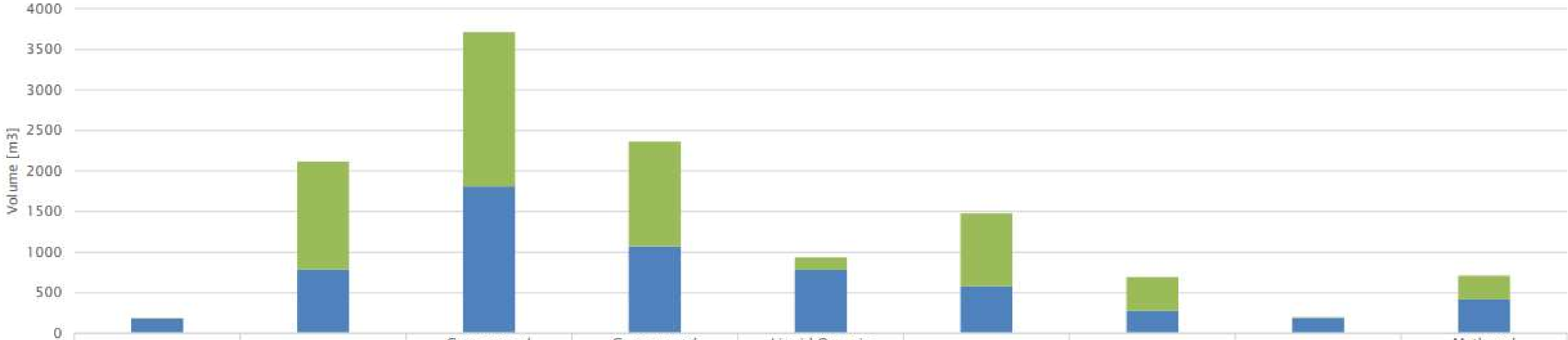
NORLED
The greatest travel experiences

Current state (May – 2022)

Fuel	Technical complexity	Regulatory Complexity (N)	Availability / cost of fuel	Potential for our business	Stakeholder interest
Bio/synt. diesel					Limited focus for new tenders in Norway
Methanol (e/bio)					Not on radar
Di Methyl Ether					Not on radar
LH2					In focus
CH2		Note: color reflects situation for smaller passenger vessels			In focus
LOHC					Not on radar
Ammonia		Note: color reflects situation for smaller passenger vessels			Currently considered a «deep sea» fuel option

Note that all fuels (except bio and synthetic diesel, comes with a significant weight / space and CAPEX penalty compared with diesel, both on fuel weight and system weight)

Fuel



	MGO reference	Liquid Hydrogen	Compressed Hydrogen (350BAR)	Compressed Hydrogen (700BAR)	Liquid Organic Hydrogen Carriers	Ammonia	Liquified Natural Gas	Biodiesel	Methanol (Renewable)
Add. Storage volume	9	1332	1902	1289	156	898	415	9	293
Fuel Volume	182	784	1811	1074	781	579	277	190	418

Fuel	Converter	System efficiency
MGO reference	ICE	44%
Liquid Hydrogen	ICE	44%
Compressed Hydrogen (350BAR)	FC	58%
Compressed Hydrogen (700BAR)	FC	58%
Liquid Organic Hydrogen Carriers	FC	55%
Ammonia	ICE	44%
Liquified Natural Gas	ICE	48%
Biodiesel	ICE	44%
Biogas	ICE	48%
Methanol (Renewable)	ICE	44%
Battery	-	97%

Source: Salt Ship Design / Equinor

MF Hydra

82m long, 80 cars and 299 pax
4 ton capacity LH2 tank, PEM FC 400 kW, Battery 1,5 MWh

The LH_2 arrangement

NORLED

The greatest travel experiences

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:

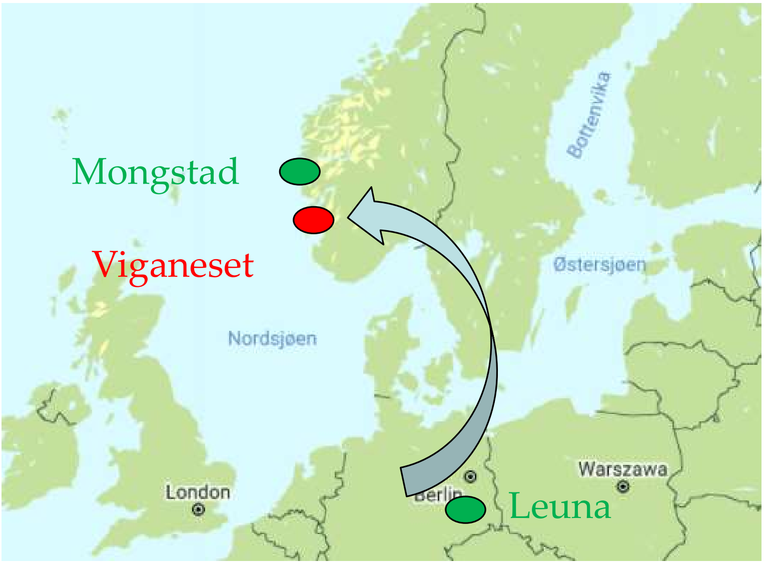
- Linde LH2 tank
- 4 ton capacity
- 10m length, 3,5m diameter
- DNV certification
- 2-3 bar operational pressure
- Vacuum insulated

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

LH_2 supply from Germany

NORLED
The greatest travel experiences

(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

LMG MARIN

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

Barriers to adoption

1. Missing the maritime hydrogen supply chain and bunkering hubs

LH2/GH2 sites:

- Nominated sites in Norwegian (Enova) support scheme

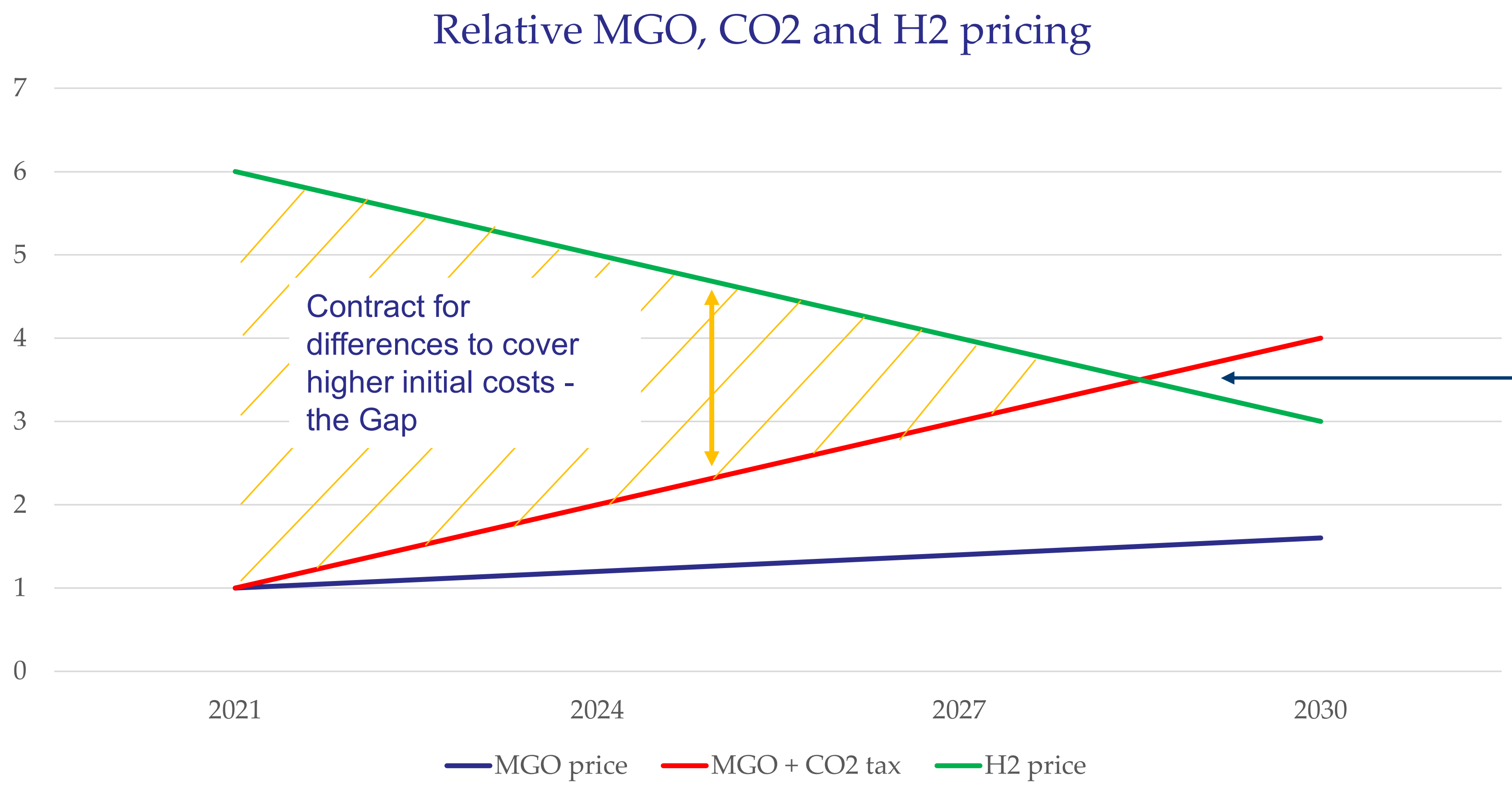
LH2 sites planned in Norway:

- Vestfjorden
- ~~Mongstad~~

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



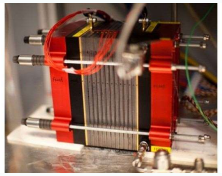
Hydrogen Europe study:

- 150 Euro/ton CO2 tax

NORLED
The greatest travel experiences

Barriers to adoption

3. Ship technology becoming available

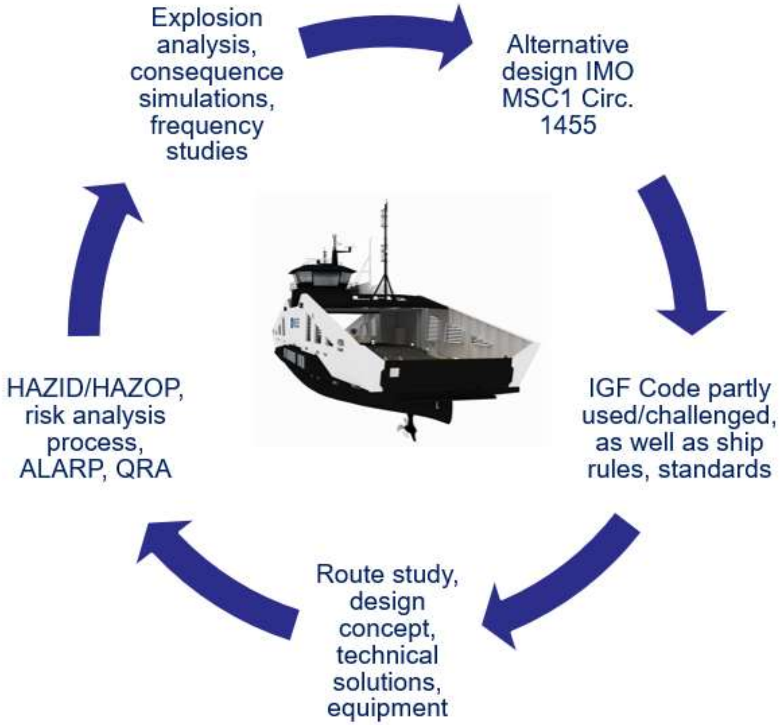
PEM	ICE	SOFC	LH_2 tank	GH_2 tank
				
BALLARD	WÄRTSILÄ	ceres	Linde	HEXAGON
POWERCELL	MAN B&W	cmr Prototech	MAN	UMOE ADVANCED COMPOSITES
TECO 2030	BEHYDRO		CHART	
Nedstack PEM FUEL CELLS				

Barriers to adoption

4. Bridging regulatory gaps

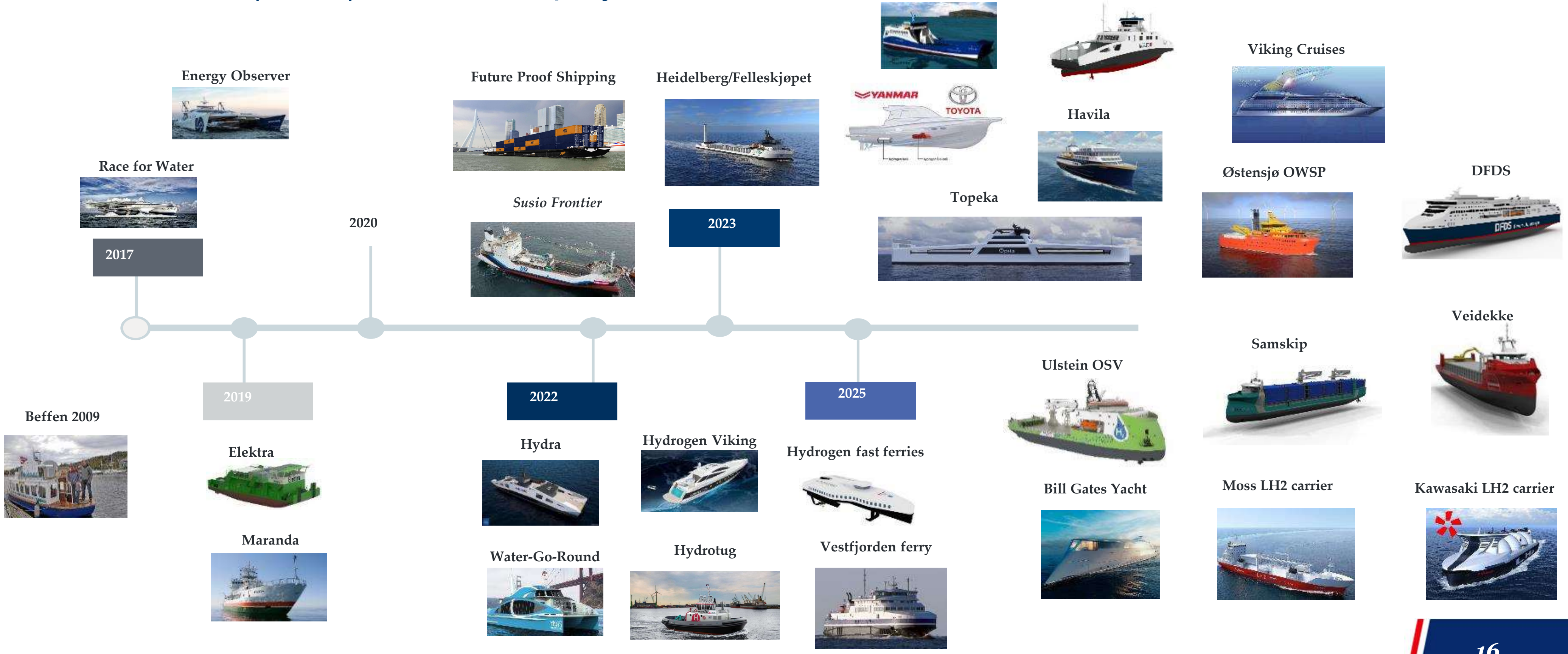
The alternative design process for MF Hydra is bridging the gap:

- 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



Whats next for Norled?

- Autonomous batterty swap for expressboats.

Thanks for listening

(Picture: Norled 2021)

Erlend Hovland, May 2022