NORLED

World's first ship driven by LH_2

Florø 18.09.2019

Norled at a glance

- One of the major Ferry operators in Norway.
- Market leader within Fast Ferries («High speed crafts») in Norway and #4 Globally.
- Major player within Fjord tourism.
- Nationwide operations from Oslo to Tromsø.
- ~300 MUSD (NOK 2.4 billions) in revenue
- 1 200 employees, HQ in Stavanger
- Founded in 1855
- Innovation-driven right for more than 160 years
- Norled aims to operate with low and zero emissions

Different types of new-builds ongoing

Remontowa 4ea.

Sembcorp 3ea.

Westcon 1ea.

ADA 2ea.

Westcon 2ea.

Oma 3ea.

From grey to green – the icon

From grey to green – the story

2015:

The el-ferry MF Ampere is launched

2022:

72 siblings in Norway

The entire sector – transformed from predominantly grey to predominantly green in just a few years – huge savings in fuel costs – helps finance a renewal of the fleet

Creating yet another icon for zero emission shipping

World's first ship driven by LH_2

Length	82.40 m	Car capacity	80	
Beam	16.75 m	Truck capacity	10	
Draught	2.8 m	Passenger capacity	299	LMG80-DEH2

Hjelmeland-Nesvik ferry route

Ryfylke in Rogaland - Riksveg 13:

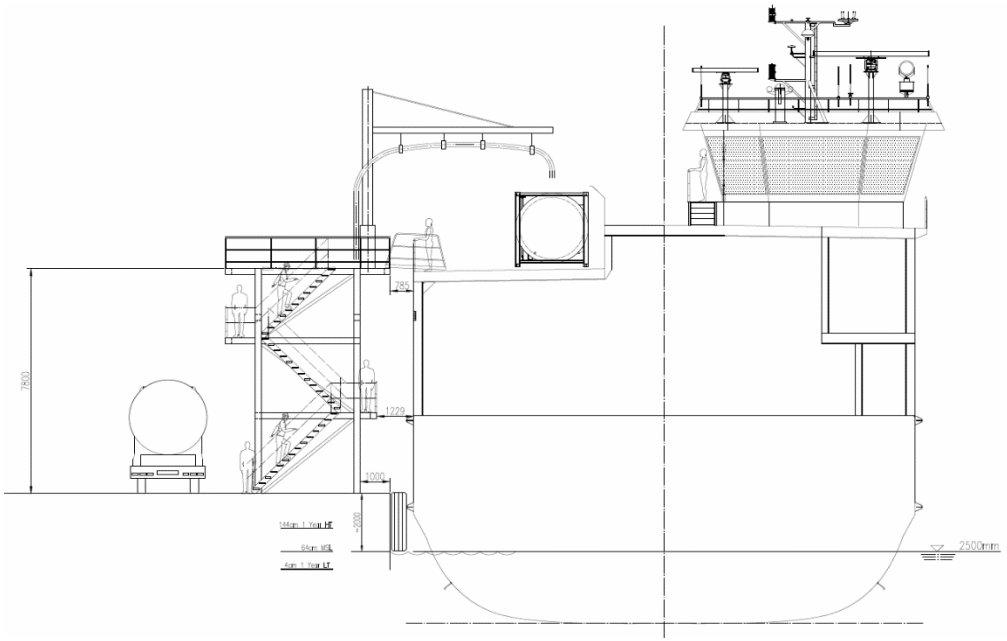
Hjelmeland-Nesvik	3010 meters
Hjelmeland-Skipavik	4450 meters
Nesvik-Skipavik	3890 meters

Norled operates the route today with two diesel-electric ferries.

The new contract for this route is one battery-electric ferry, as well as the hydrogen-electric ferry, from 2021 to 2031.

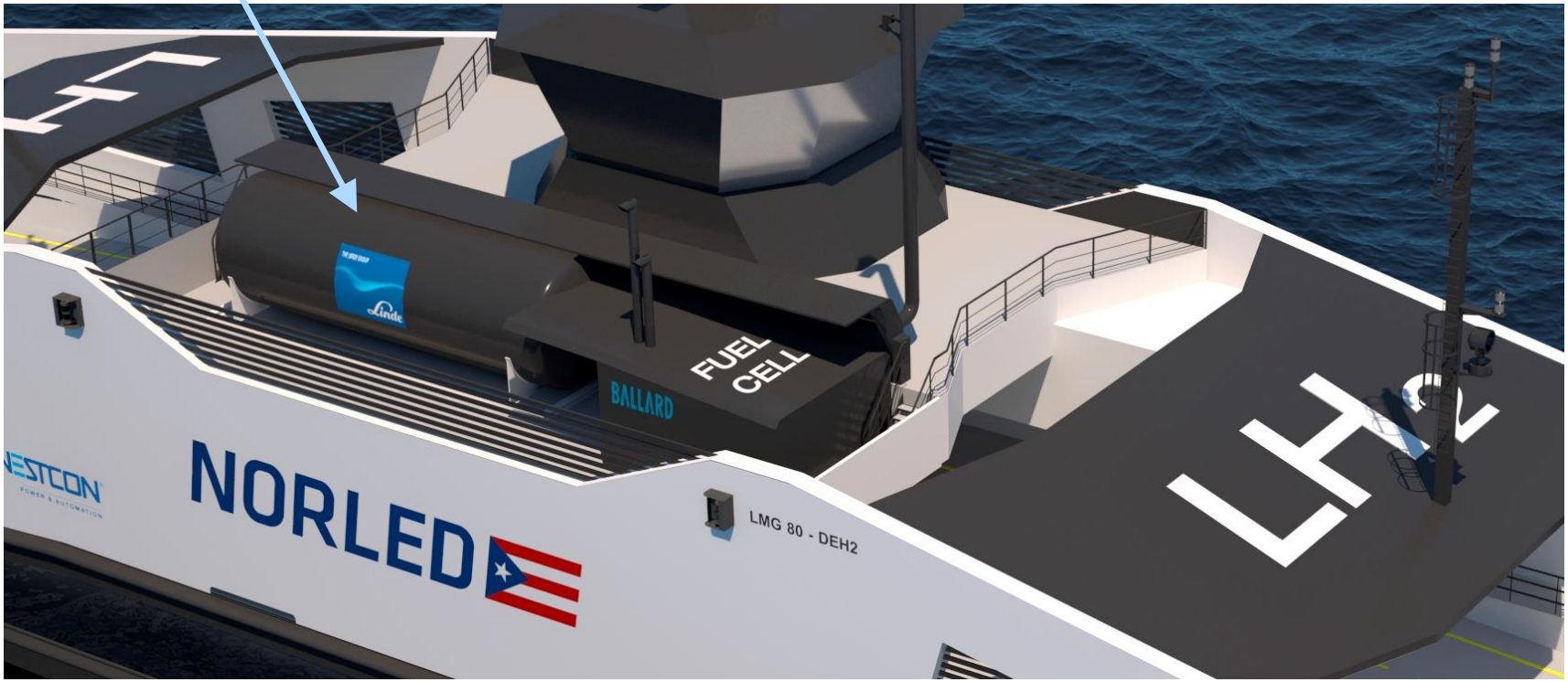
Hydrogen supply

- LH_2 truck from Europe
- 3,5 tons capacity
- Every three week bunkering operations
- 150 kg daily consumption



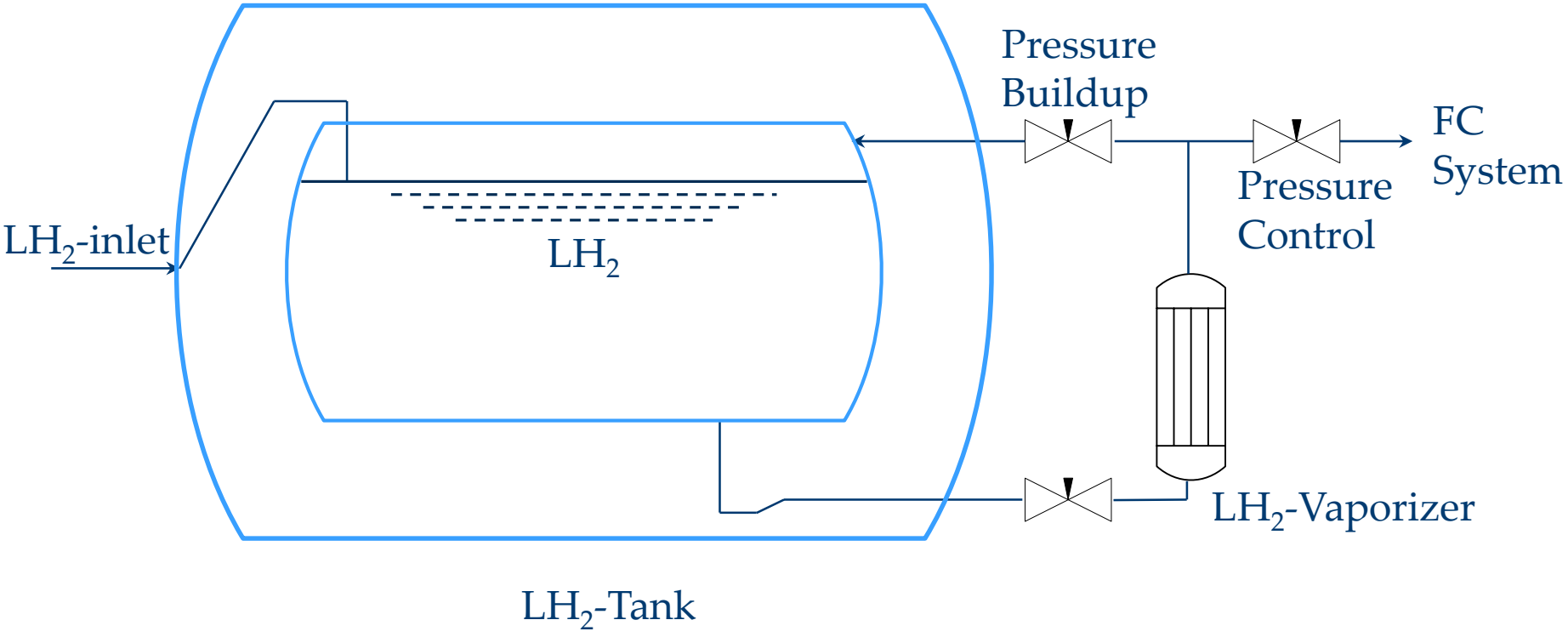
Hydrogen arrangement

LH_2 System



Onboard LH_2 System

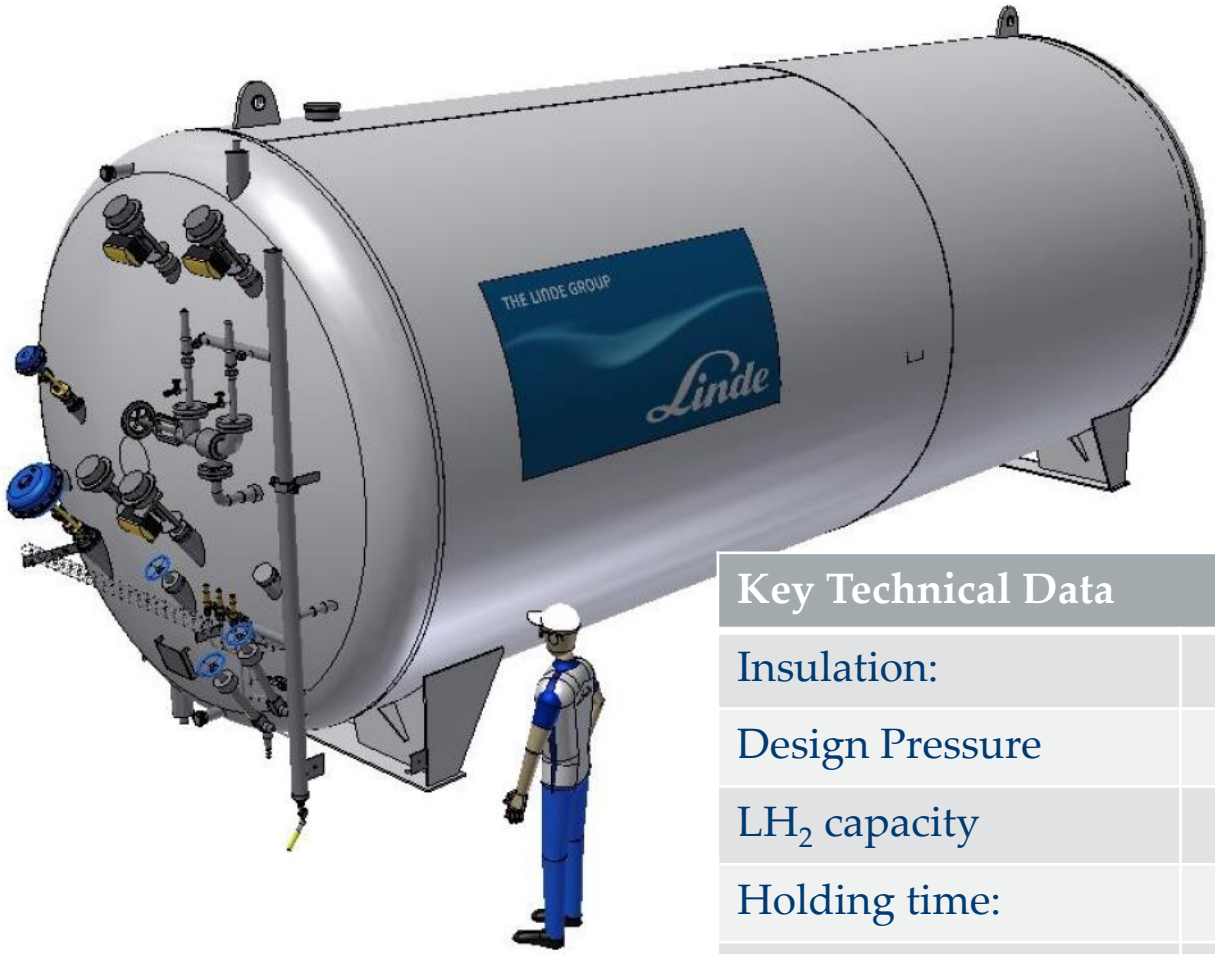
Process Flow Diagram



- Safety: all PSV lines are routed to vent mast

Onboard LH_2 System

LH_2 Tank – Key Data



Key Technical Data	
Insulation:	Multi-Layer & Vacuum
Design Pressure	10 bar(g)
LH_2 capacity	≈3.8 tons (20% ullage)
Holding time:	15 days
Standards/Approval:	DNV GL, IGF

Onboard LH_2 System

Technical Challenges – 1 of 2

- **System size:** Footprint on the ship quite limited!

- **Holding Time Requirement:**
  15 days at operating pressure, but …
  - which residual amount at refueling?
  - which LH_2 temperature is delivered during refueling?
  - tank operating pressure during refueling?

- **(Onshore) Bunkering System & Procedure:**
  - develop special refueling procedure for maritime application
  - minimize or completely avoid GH_2 losses during refueling
  ➔ achieve sufficient distribution of subcooled liquid during refueling, and condense vapor
  - Special cryogenic coupling is under development
  - Safety study of complete bunkering procedure

Onboard LH_2 System

Technical Challenges – 2 of 2

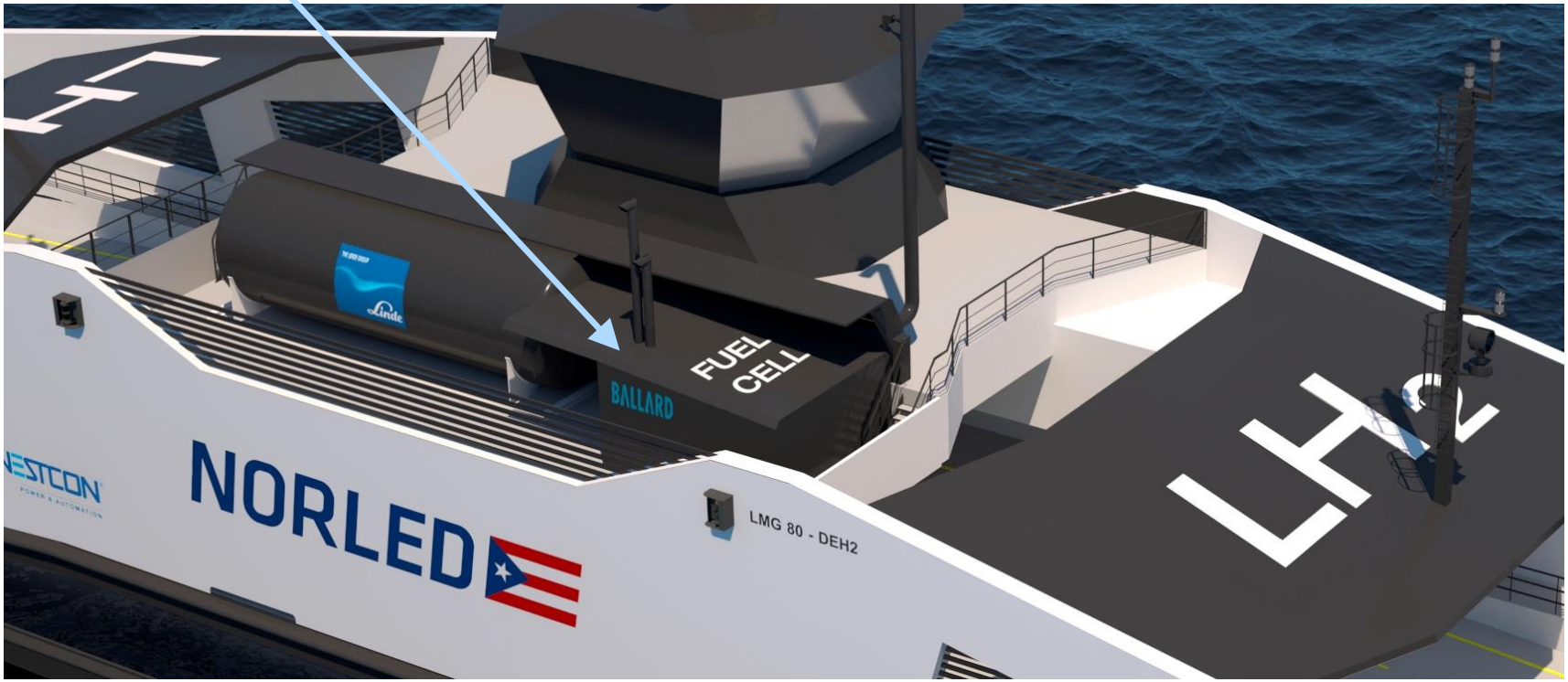
- **Stable Operating Pressure:**
  Must be maintained to support continuous vaporization and fuel cell operation. Various options available:
  1. operate tank at low pressure: LH_2 pump/compressor necessary
  2. operate tank at higher pressure:
     # necessary time to build up pressure after refueling
     # sloshing effects (low viscosity) could cause undesirable condensation of vapor (loss of operating pressure!)
     ➔ special vessel internals and other measures required!

- **Measurement of LH_2 Level:**
  Available types:
  - differential pressure
  - radar, capacity
  - special types: neutron ray, Neon bubble

  ➔ reliability of these measurements under maritime conditions?

Hydrogen arrangement

Fuel cell system

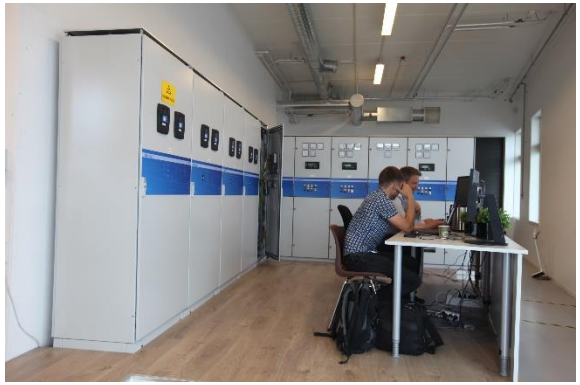


World leading innovative company of electrical propulsion systems

Energy Storage Systems

Battery Hybrid | Fully-electric | Hydrogen-hybrid | Shore Power | F-Cell (H2) - Battery Lab

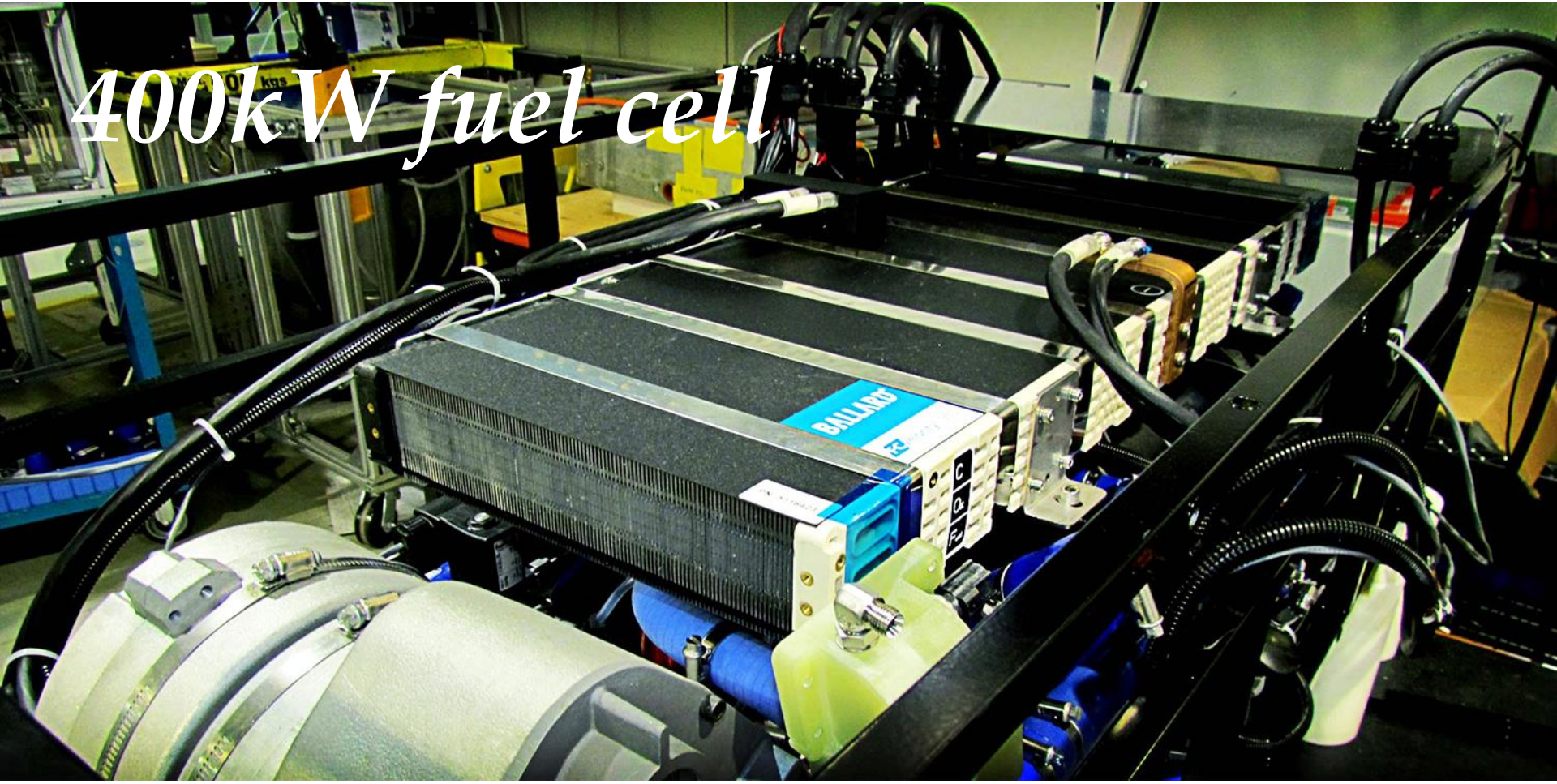
Westcon Power & Automation's Battery & H_2 hybrid laboratory



- Fully integrated energy-system test bench with batteries, fuel cells, drives, switchboards and energy management system
- Dynamic loads
- Facility for testing of next generation hydrogen-hybrid system for future marine projects
- Simulation and optimization of control strategies for hydrogen-hybrid systems
- Hjelmeland ferry testing

WESTCON®
POWER & AUTOMATION

400kW fuel cell



WESTCON® POWER & AUTOMATION

OpenBridge Partner

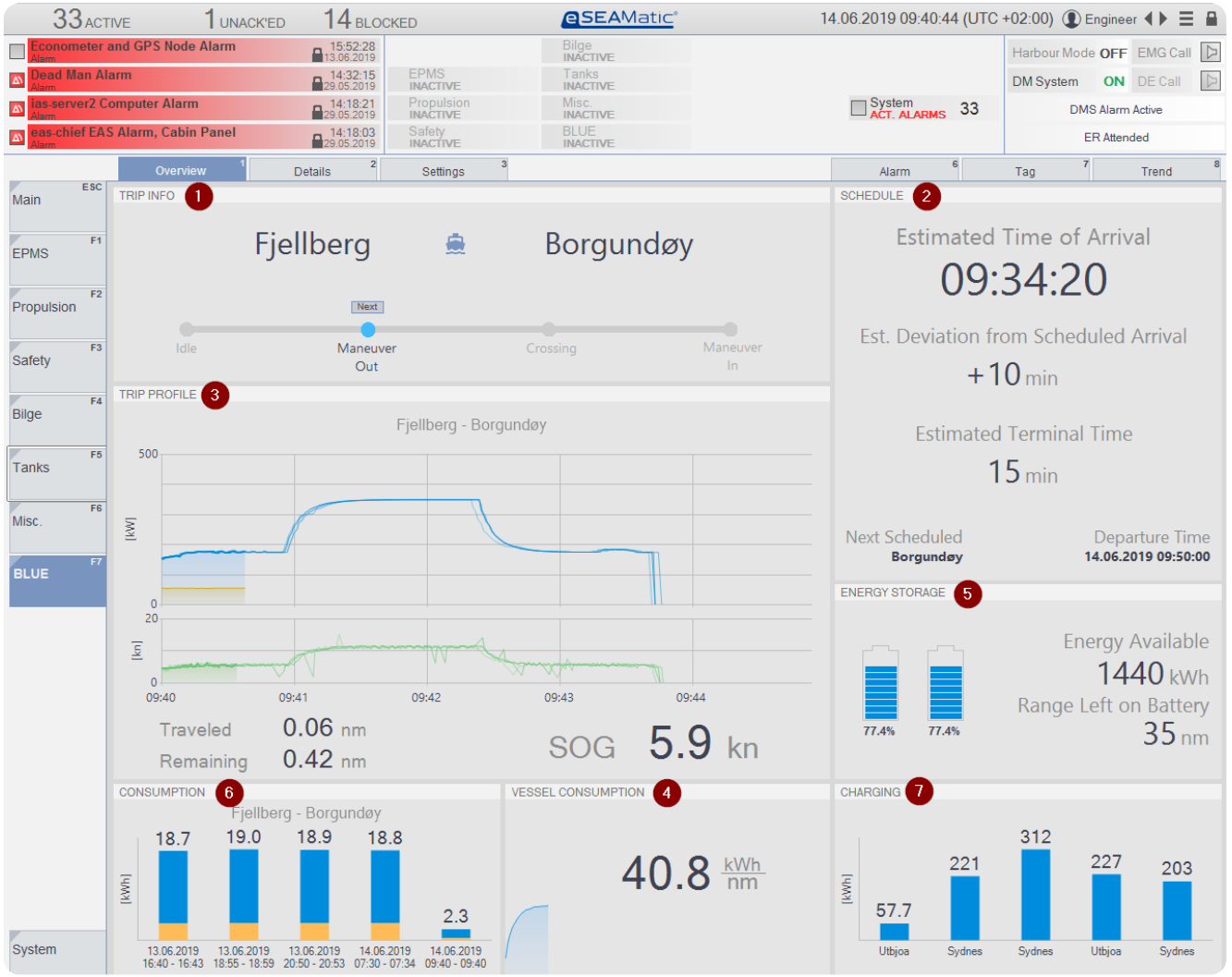
- Harmonising next generation maritime workplaces
- New technologies and open innovation
- Consistent design across vendors
- Cost effective methods, processes and tools

BLUE

Energy optimization

1. Trip info
2. Vessel's schedule
3. Trip profile
4. Instant consumption
5. Current energy storage
6. Trip consumption
7. Battery charging

Data logged to Cronolog databases with 3rd party interface possibilities




The LH_2 vessel is being built at Westcon Yard in Norway, delivery 1Q 2021


Thank you for your attention
NORLED
LH2
SHIP NAME
LMG MARIN
NORDWEST3D