HySEAS III

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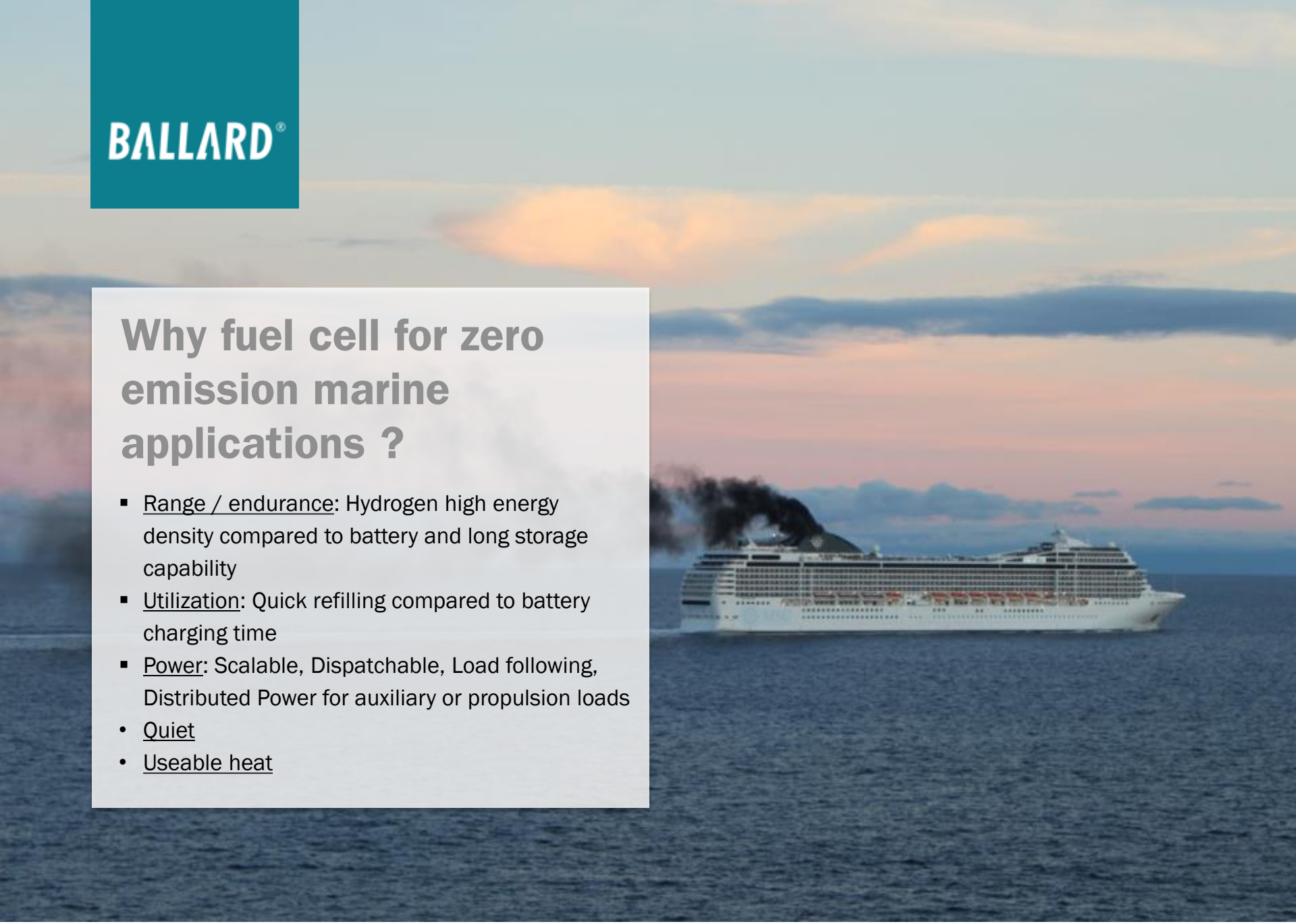
Fuel cells are a necessary, safe and effective power solution for ships and ports

Agenda

- Emission Requirements
- Value Proposition
- Hydrogen and PEM fuel cell
- Marine Projects
- HySeas III Project

Zero-emission requirements are here

- IMO GHG strategy
- Europe EMSA goal to cut CO2 emissions by 50%
- Norway is protecting fjords
- POLA / POLB Clean Air Action Plan
- US EPA working in Ports and Affected Communities
- Alaska Visible Emission Standards

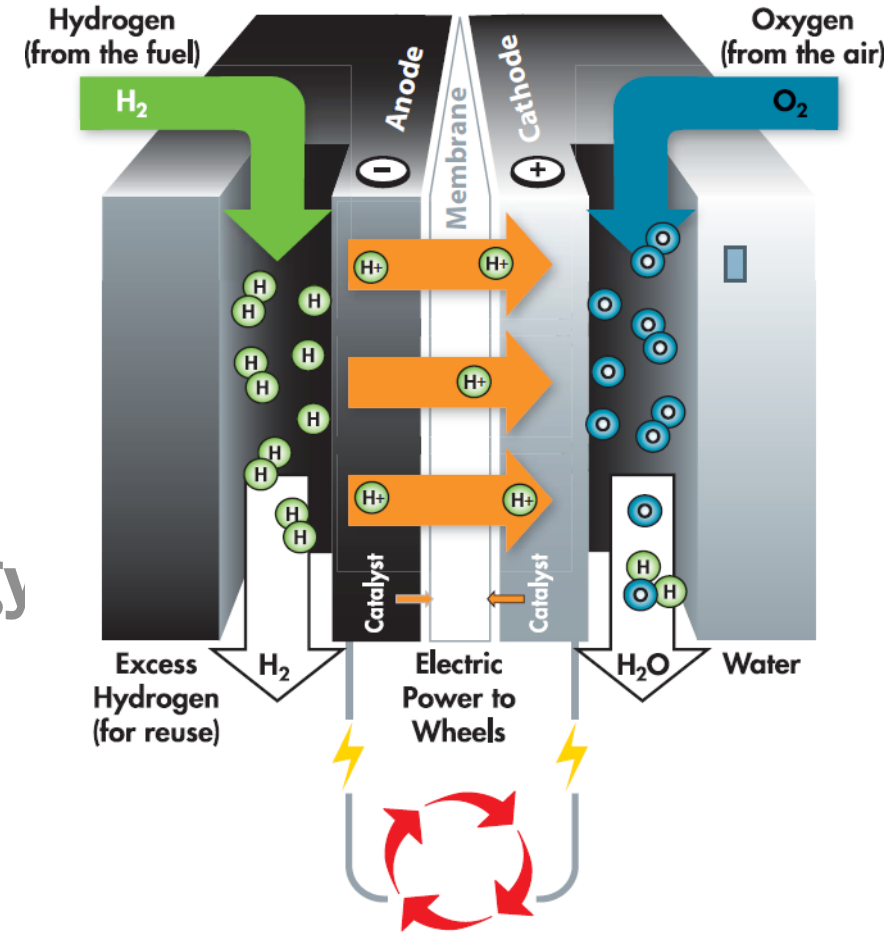


Why fuel cell for zero emission marine applications ?

- Range / endurance: Hydrogen high energy density compared to battery and long storage capability
- Utilization: Quick refilling compared to battery charging time
- Power: Scalable, Dispatchable, Load following, Distributed Power for auxiliary or propulsion loads
- Quiet
- Useable heat

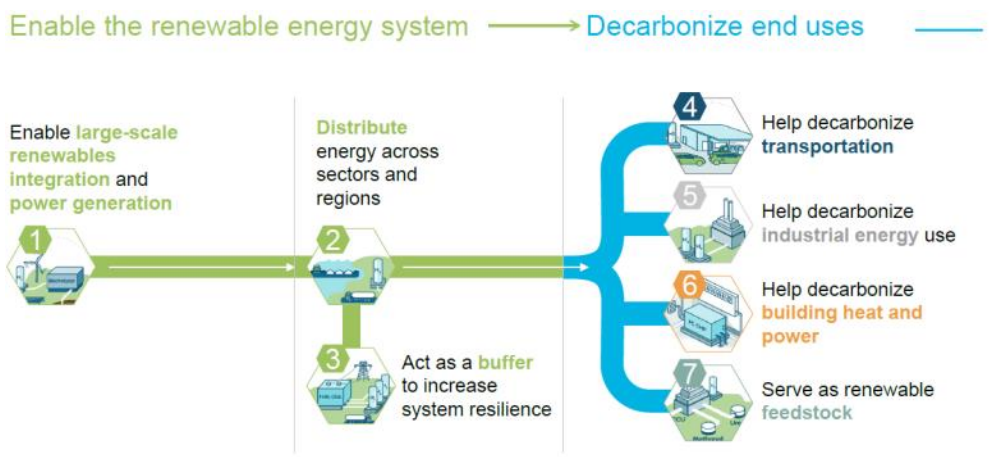
PEM fuel cell technology

- Solid state power generator
- High efficiency
- Zero-emission
- No toxic materials
- Fuel is hydrogen
- Air (oxygen) is needed to complete the reaction
- Cells are “stacked” to achieve required power
- Fuel cell stack materials do not support flame (safety)



A fuel cell produces:

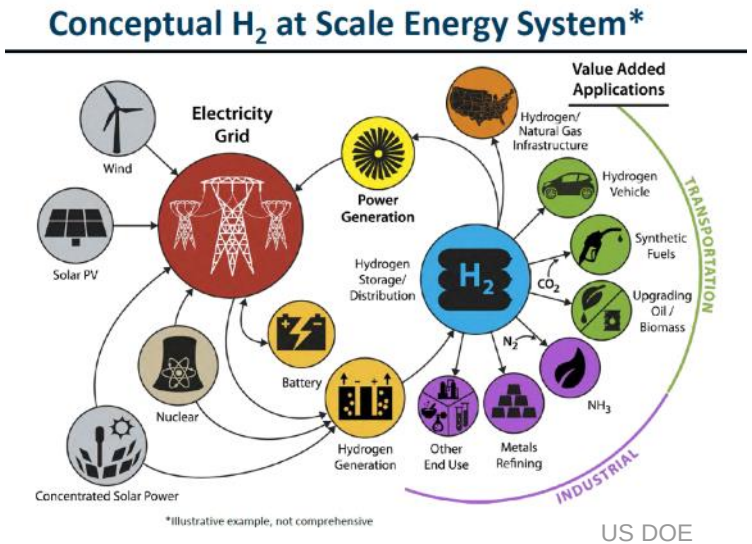
- Electric power
- Water
- Heat



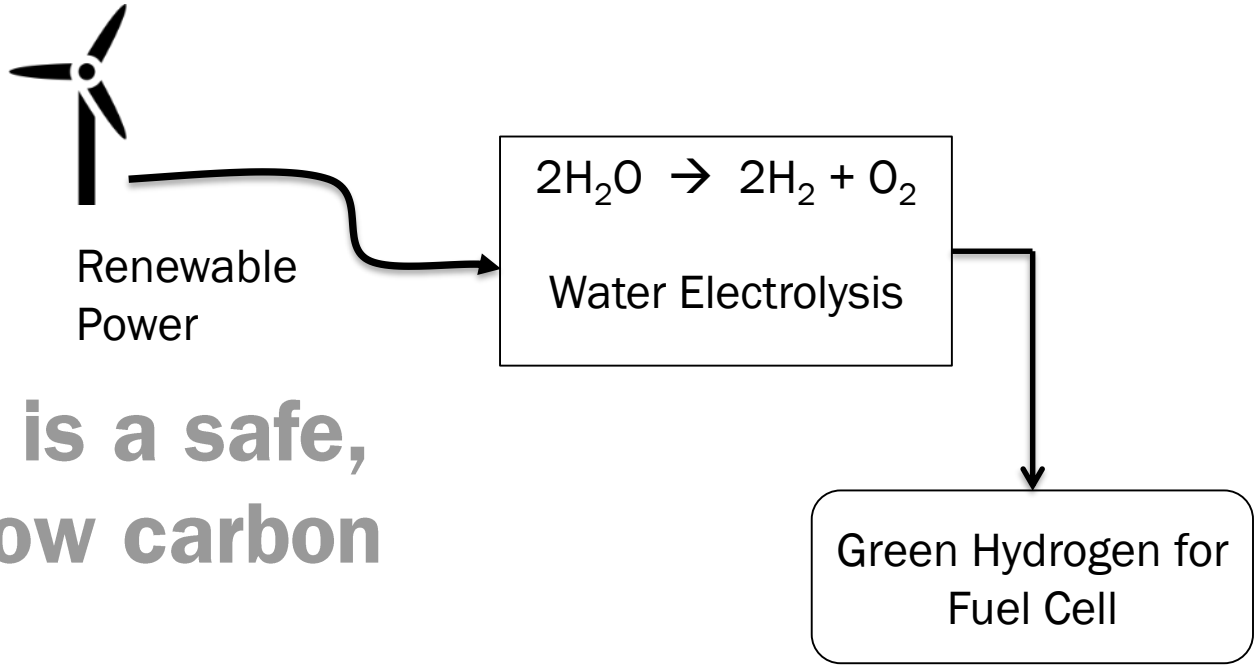
SOURCE: Hydrogen Council

Hydrogen

- Most abundant element in the universe
- Today most hydrogen comes from natural gas
- Many global leaders believe that green hydrogen will become abundantly available
- Hydrogen from water and renewable solar, wind, tidal
- Demonstration projects for renewable hydrogen are already underway



US DOE



Hydrogen is a safe, flexible, low carbon fuel

- Splitting of water into hydrogen using renewable wind and solar
- Conversion of bio wastes to hydrogen
- “Free” hydrogen available as a by-product of some industrial processes
- Hydrogen is an energy carrier – can store energy as hydrogen and transport it

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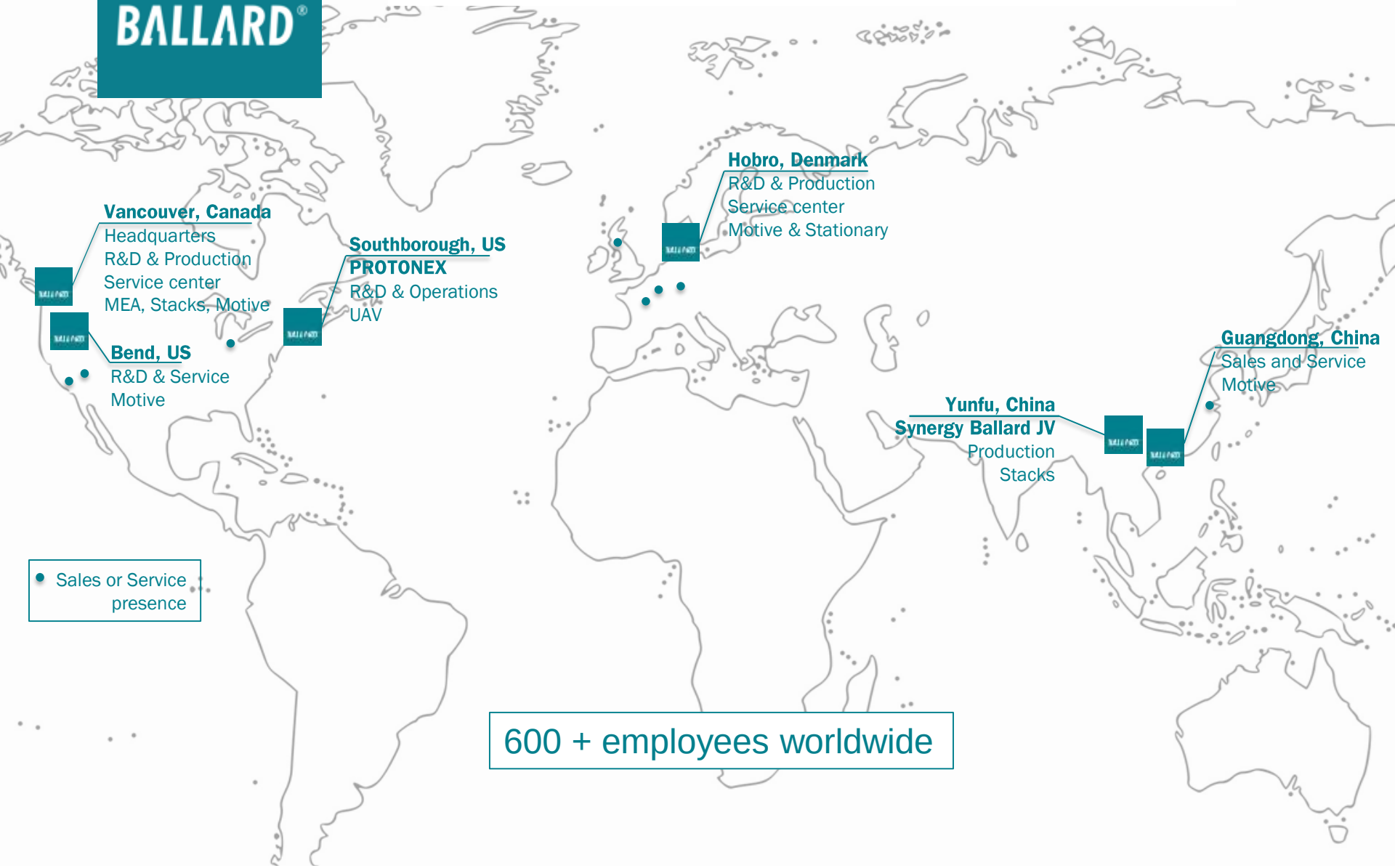
Power to change the World®

- Committed to sustainable mobility and clean air for everyone
- Developed technology over 30+ years
- We have leading talent with >600 people passionate about our mission


BALLARD®
TSX
Nasdaq
39 years of experience
$121M revenue in 2017
25 years on TSX
3 strategic share holders

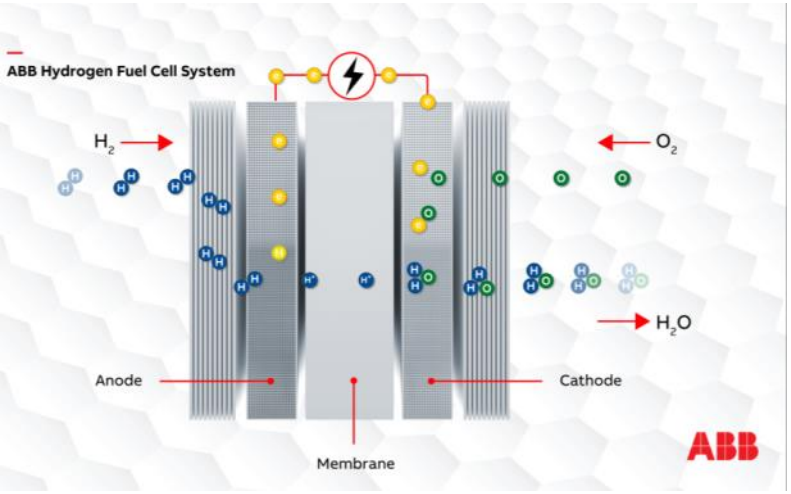
We are a global company



600 + employees worldwide

PEM fuel cell technology

- ABB and Ballard will develop next-generation fuel cell systems for the marine industry.
- The new fuel cell power system will be jointly designed, developed and validated.
- Leverage existing kilowatt-scale systems and optimize them to create a pioneering megawatt-scale.
- 3MW (4000 HP) electrical / single compact module.



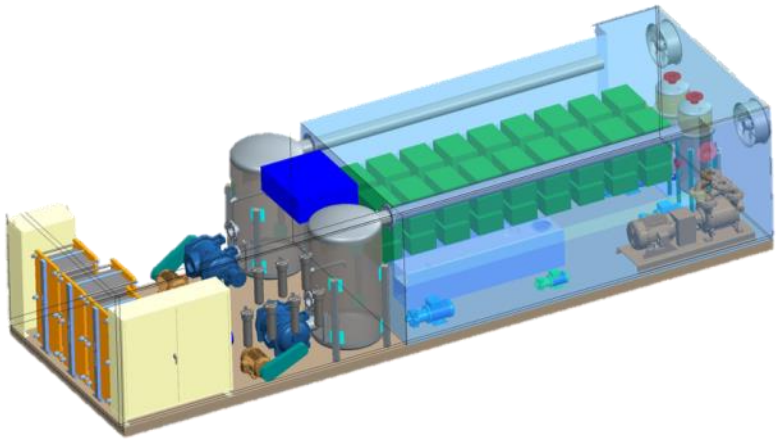
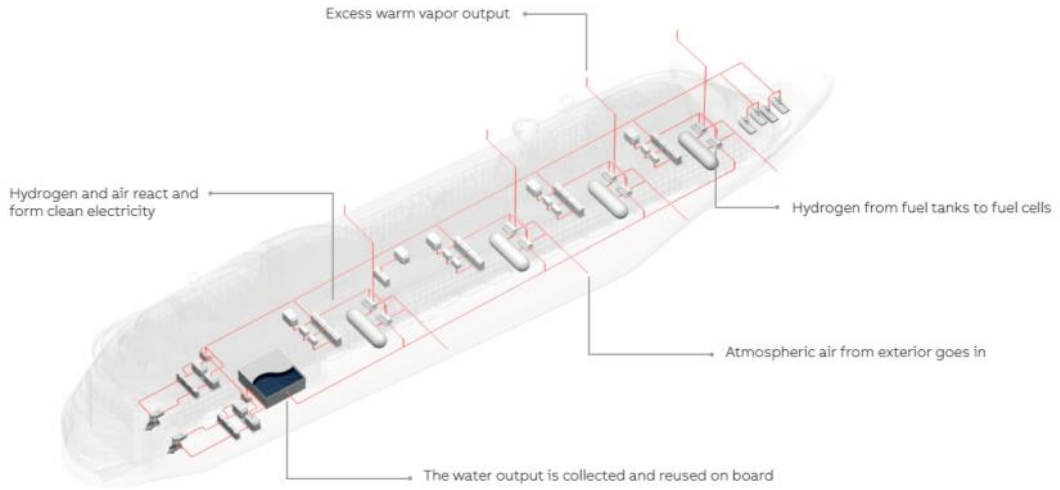


ABB & Ballard's vision for fuel cell cruise ship applications

- Development program for MW class fuel cell system based on Ballard distributed generation fuel cell plant
- Marine environment compliant with hydrogen safe stack compartment
- Integrated power management systems & controls
- Scalable and flexible integration of the one-deck-high system into the ship's architecture and the ship's grid



Fuel cell marine projects

- Norway – HYBRIDship demonstration project for 2020
- Germany – MS Innogy already operating all day without refueling
- Several fuel cell ferries are in development in Scotland and Norway
- Integration of Ballard's fuel cell system into Yanmar's hybrid power train for Japan's NMRI boat
- *HySeas III* hydrogen fueled ferry - Ballard fuel cells for primary propulsion

HySEAS III

Funded by H2020 – LC MG 2017

Grant: 9,3 mEuro

Project duration: 42 months

The Orkney Islands Governance & Vision

Strategic Priorities

Under "Connected Communities" we have priorities of:

- the ferry services
- improve transport infrastructure
- renewable and carbon-neutral transport
- electric vehicle infrastructure

Under "Enterprising Communities" we have priorities of:

- a vibrant carbon neutral economy
- develop strategic projects to capitalize on the renewable sector and use of renewable fuels

Under the delivery plan for "develop strategic projects" the plan is:

- Develop Orkney as a **Low Carbon Energy Systems Innovation Hub**, incl. wave and tidal power generation, wind and solar systems, LNG Distribution, **Hydrogen production and usage** across all modes of transport and Academic Innovation Centre projects.
- Strategic investment in projects to **generate income and/or deliver significant community benefits.**

With outcomes of:

- To **develop innovative low carbon energy projects.**
- To position Orkney as the **globally recognized innovation center** for low carbon transport.
- **Sustainable energy generation, use and export and thereby income** for recirculation within Orkney.

Surf and Turf
Big Hit
Dual Ports
HySeas I, II, III

HySEAS III Consortium

Project coordinator, overall technical, & organizational support

University of St Andrews | FOUNDED 1413

Ferry design/vessel construction

FERGUSON marine

H2 production and supply

McPhy Driving clean energy forward

Power system design for ferry

KONGSBERG

BALLARD PUTTING FUEL CELLS TO WORK

Fuel cell modules and Hydrogen expertise

DLR Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center

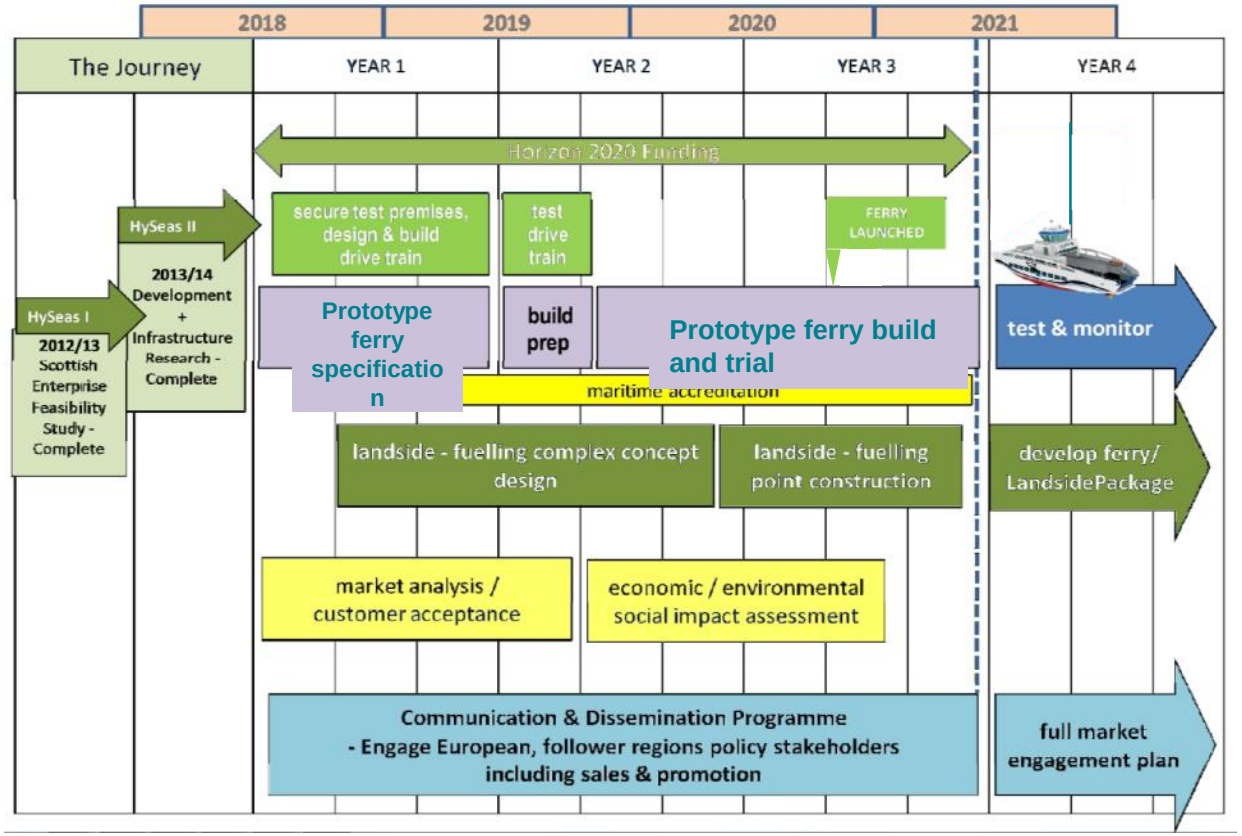
Monitoring, reporting, & regulations process

INTERFERRY

Global association for Ferry industry, Dissemination and public communication

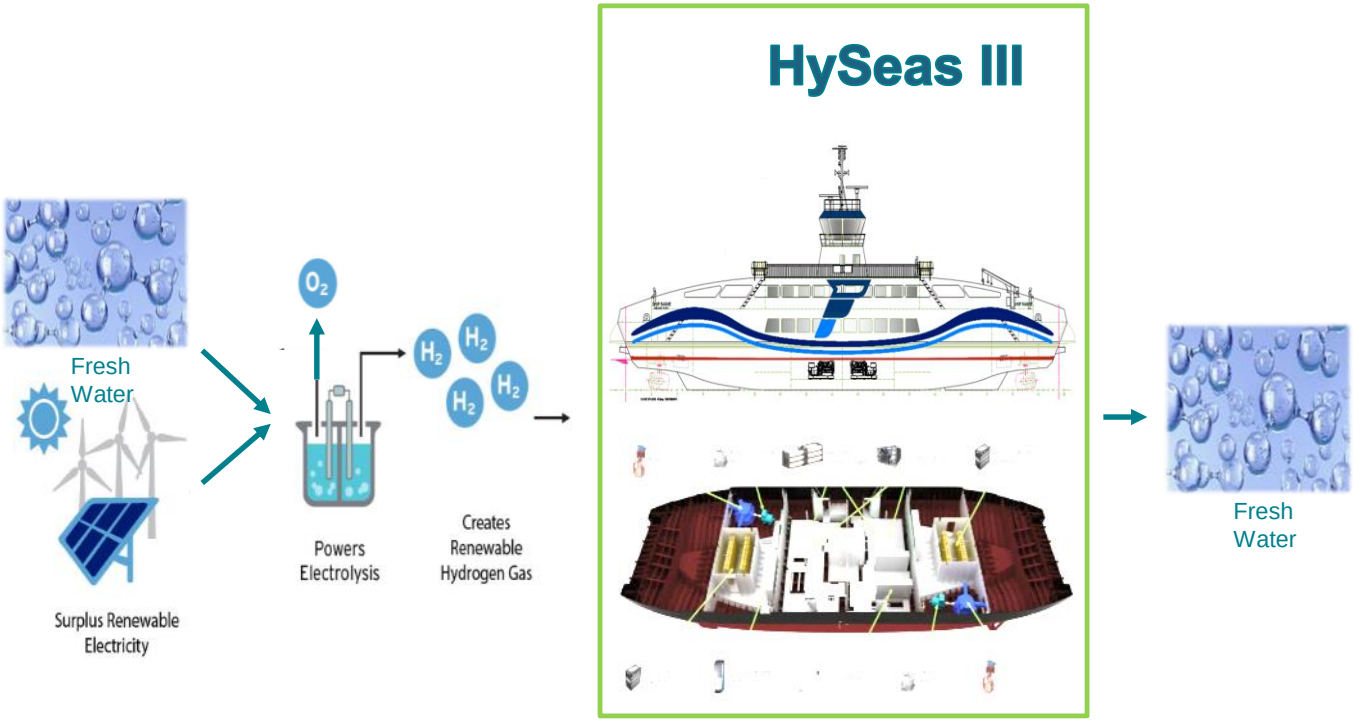
A WORLD-BEATING TEAM

Project Timeline



AGGRESSIVE PROGRAMME

Zero Emission – powered by renewables



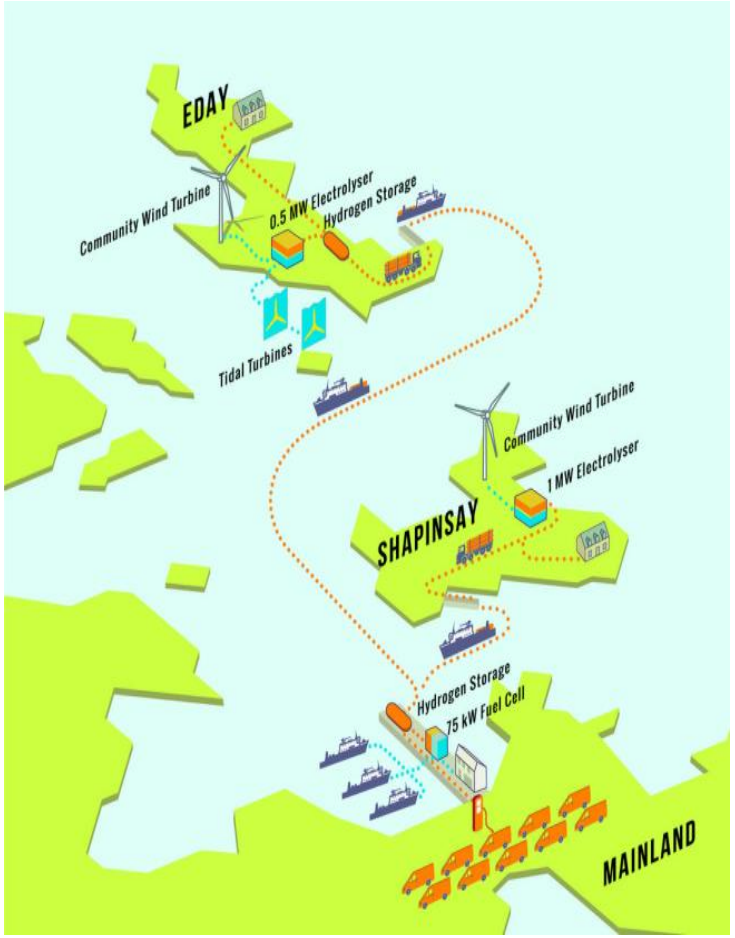
A 100% CLEAN PROCESS

H2 in Orkney – The Hydrogen Islands

Advanced ‘Sustainable Energy Strategy’

Home of EMEC - European Marine Energy Centre

Ongoing projects:
Surf ‘n’ Turf
Big Hit
Dual Ports
HySEAS III



ADVANCED INFRASTRUCTURE

Considerations/drivers for a Hydrogen Ferry

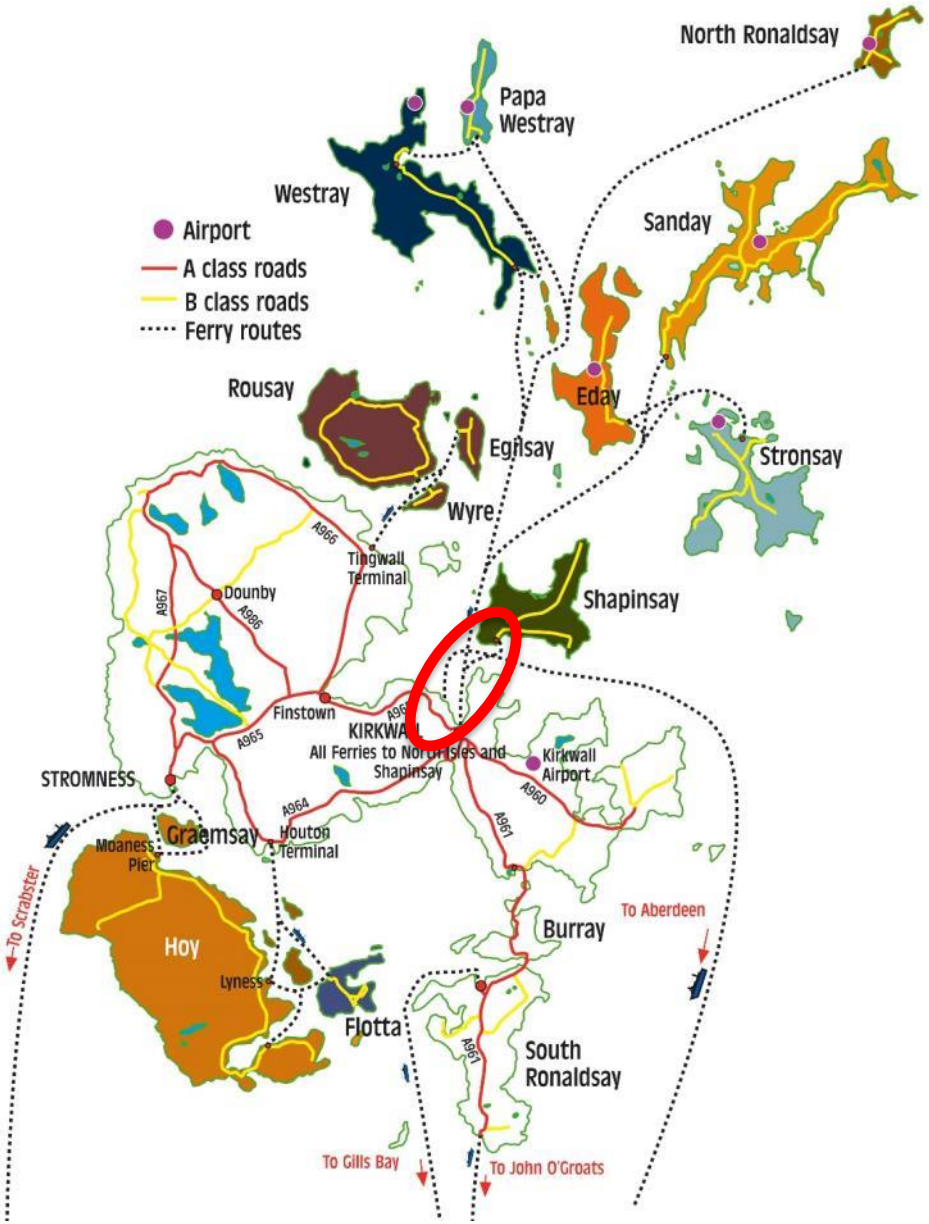
- Asset management – ferry fleet is aging
- A source of low price, low carbon electricity is available
- Conversion of energy to Hydrogen is possible
- Energy Security, local sources is preferred

Practical Requirements for a Hydrogen Ferry

- Transportation of hydrogen
  - Big Hit and Surf n Turf projects
  - Special tube trailer developed
  - Transport regulations are adapted
- Hydrogen bunkering
  - The DUAL Ports project will design this system and study where to locate
- The Hydrogen Ferry
  - The HySeas project has conducted feasibility studies and has a design. Ferguson is prepared to manufacture.

Bureaucratic Requirements for a Hydrogen Ferry

- OIC have an agreed hydrogen strategy
  - The hydrogen stratergy is written and specifically mentions the objective of hydrogen ferries
- The Low Carbon Ferries Study (HySEAS II)
  - This is presently in draft form and considers H_2 suitable for shorter routes
- Training for ferry crews
  - As part of Surf n Turf, a training course has been developed and a training rig built to provide some training and to work on Vessel safety Management procedures



ORKNEY ISLANDS COUNCIL
Ferry Services

13 islands served
74 Routes
9 Vessels
20,000 Sailings per year
329,284 Passengers (2017)
55,653 Cars (2017)
31,685 Commercial Vehicles (2017)

Resources required:
145 Sea Staff
£ 10M Operational costs
3M litres of marine Gas oil
398 MWh shore power

Lifeline Ferries

Supporting
Inner and
smaller islands

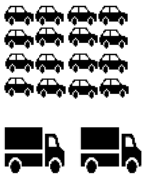
ORKNEY ISLANDS COUNCIL
Ferry Services

The HySeas III Platform

Hydrogen storage | Fuel Cells | DC Li Ion Batteries

Powering:
- 7 x 100kW Ballard Fuel cells
- Li Ion Battery Systems
- 1000kg Hydrogen stored

Capacity Requirement:
- 120 passengers
- 16 cars
- 2 HGVs



Preliminary Dimensions
- 39.9m LOA
- 10m Beam
- 4m Depth Approx.
- Landing craft style hull

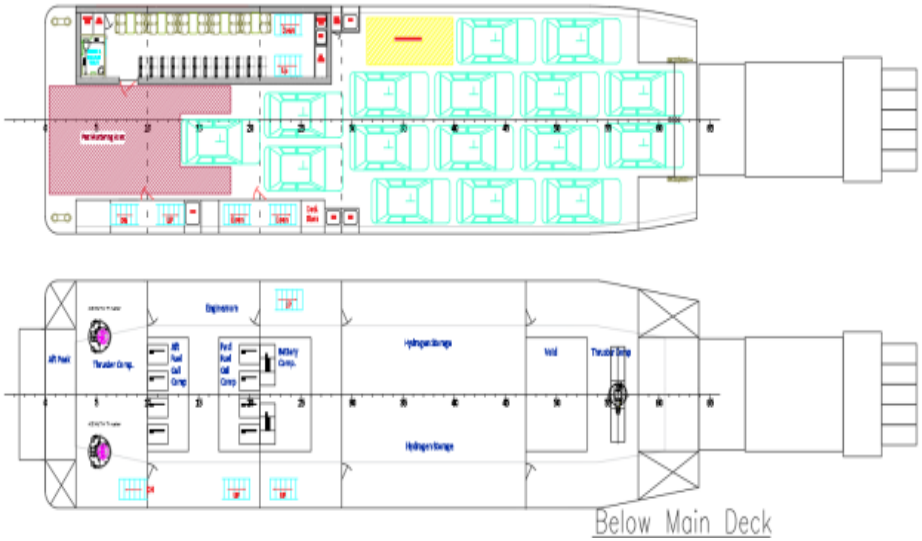
HySeas III

Route:
- Kirkwall-Shapinsay
- 4 miles
- 25 minutes
- Lifeline Service

RE-CONFIGURABLE PLATFORM

HySeas III Project Risks

- Legislation and regulation
  - Lack of Hydrogen-specific rules
  - Risk based design process
  - Suitability of the IGF Code
- Commercial justification / viability
  - Capital investment
  - Market price for hydrogen - projection
  - Through life costing / O&M
- Customer perception
  - Hindenburg and H-Bomb
  - Inefficient and complicated
  - **The Future !!**



CONTINUOUS TECHNOLOGY DEVELOPMENT

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Thank you !

Alan Mace

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