Hydrogen-powered ferries: unlocking the potential

21 September 2020 • 13:00-13:45 BST

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Part of
Passenger Shipping
Webinar Week
21-25 September 2020

PASSENGER SHIP
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REVIEW

riviera

Panellist documents

Page 2: Ryan Sookhoo, Cummins Inc, Fuel Cell and Hydrogen Technologies
Page 10: Joseph W. Pratt, Golden Gate ZERO Emission Marine



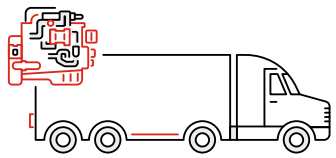
Cummins

Changing Tides of Energy

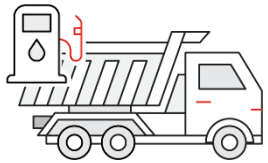
Ryan Sookhoo

Sept 21, 2020

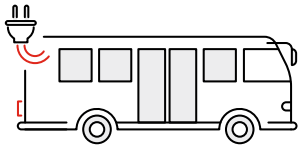
A TECHNOLOGY LEADER WITH A BROAD PORTFOLIO OF POWER SOLUTIONS



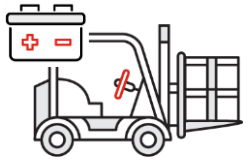
Diesel powertrain



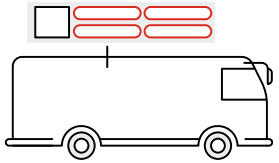
Natural gas powertrain



Hybrid electric



Battery electric

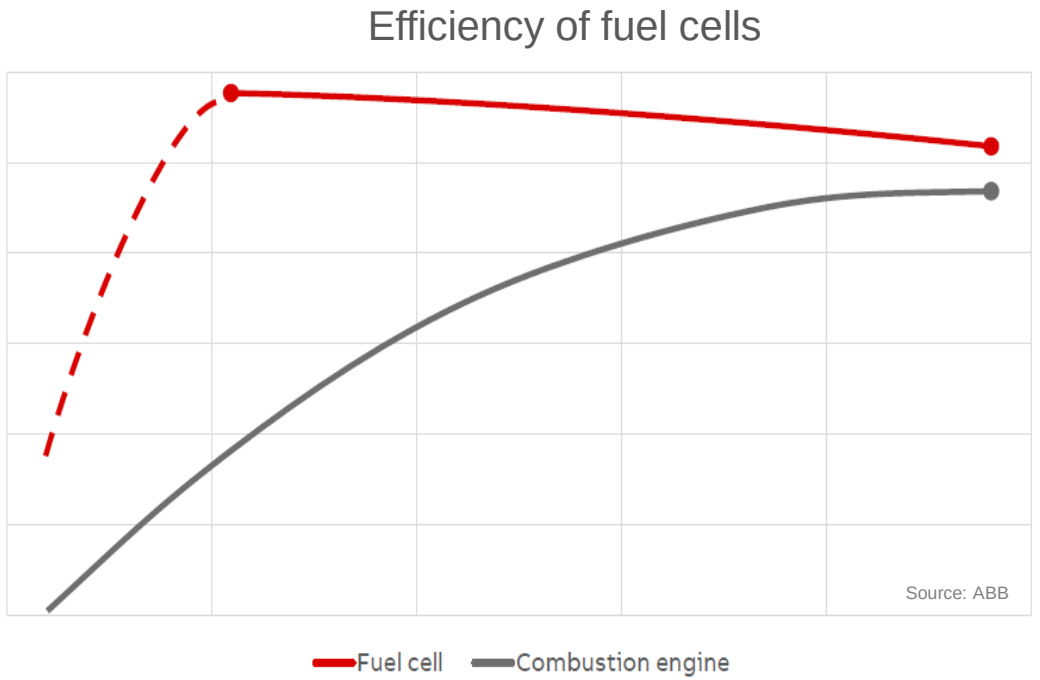


Fuel Cell electric

Feasibility of Fuel Cell Systems

Fuel cells operate at **high efficiency** *and their* **life cycle cost** *is getting closer to combustion engines*

- Life cycle costs are decreasing due to commercial volume and improved stack durability
- Greater predictability in maintenance and operational costs
- Improved hydrogen fuel infrastructure and distribution
- Increased harnessing of renewable energy for fuel (P2G) and incentives for carbon free fuel
- Fuel cells have a high efficiency at a wider operating range, translating to greater operational flexibility
- Favourable operating range for fuel cells is between 30% and 80%
- Efficiency of fuel cells decrease moderately towards the end of life



Hydrogen Marine Applications

1



Zero/V
Feasibility of FC

- Zero Emissions Research Oceanographic Vessel (ZERO/V) powered by hydrogen fuel cells

2



MarFC
Demonstrating in Maritime

- Powering commercial units in demanding marine environment

3



SINTEF and ABB
Test & Model Main Propulsion

- Model operation and control of marine power system for MW-scale propulsion plant

4



Water-Go-Round
Commercial adoption

- First high-speed hydrogen powered fuel cell marine vessel in the U.S.

Zero/V

- Review design, identify potential barriers for technology adoption
- DNV-GL Conditional Approval
- Funded by the MARAD

MarFC

- Lower the technology risk
- Estimated Costs – CapEx, OpEx
- Permitting and acceptance
- Engage potential adopters/end users

SINTEF and ABB

- Determine technicalities of scaling-up
- Control of fuel cell plant in combination with energy storage
- Optimize efficiency, reliability and the lifetime of fuel cell stacks

Water-Go-Round

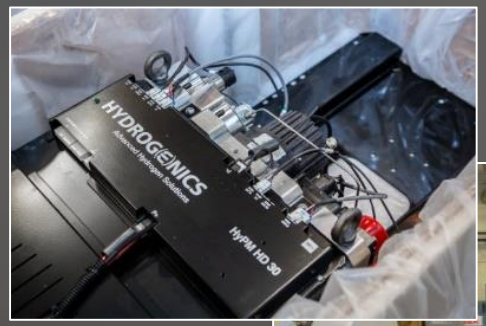
- Commercial operation (2020), 84 passenger (reconfigurable), 22 knot top speed
- 2x 300 kW electric motors, 360 kW PEM fuel cell
- 100 kWh Li-ion battery, H2: 242 kg @ 250 bar

ABB and SINTEF

Test main propulsion fuel cell potential

SINTEF Ocean Laboratory,Trondheim

- Viability testing for main ship propulsion
- MW + power ranges
- Key objectives:
  - Model the operation and control of a complete marine power system in a megawatt-scale propulsion plant
  - How to enhance the control of fuel cell plant in combination with energy storage
  - How to optimize efficiency, reliability and the lifetime of fuel cell stacks





https://new.abb.com/news/detail/9742/abb-and-sintef-test-fuel-cells-for-main-propulsion-potential/

https://www.sintef.no/en/latest-news/abb-and-sintef-test-fuel-cells-for-main-propulsion-potential/

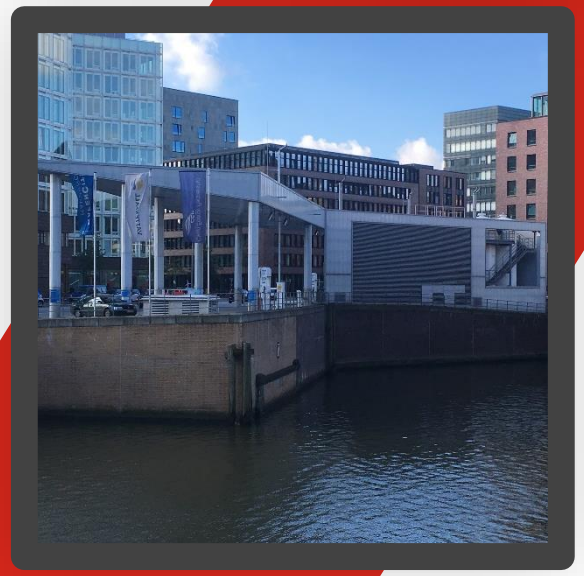
Hydrogen Infrastructure

- **Hydrogenics has supplied zero-emission solutions to over 60 fueling stations – more than any other hydrogen fueling company.**
  - Largest H2 station in EU (780kg/Day) - 2012
  - Refuels busses and passenger cars – *future boats?*

- **Synergy of Ports**
  - The success of one enables another – Land and water fuel cell applications are connected
  - Ports are unique - Maximize H2 refueling infrastructure to support both land and water refuel
  - New but proven – Leverage existing H2 safety protocols & standards. Unknowns still exist
  - Renewable fuel generation and supply –Leveraging the distribution network
  - Scale – The larger the H2 capacity, the lower the $/kg



VATTENFALL

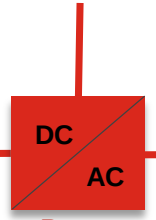


Zero-emission refueling

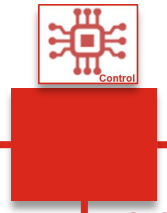
Port H2 Ecosystem



Energy Storage



Power Electronics

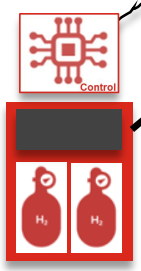


Switch gear

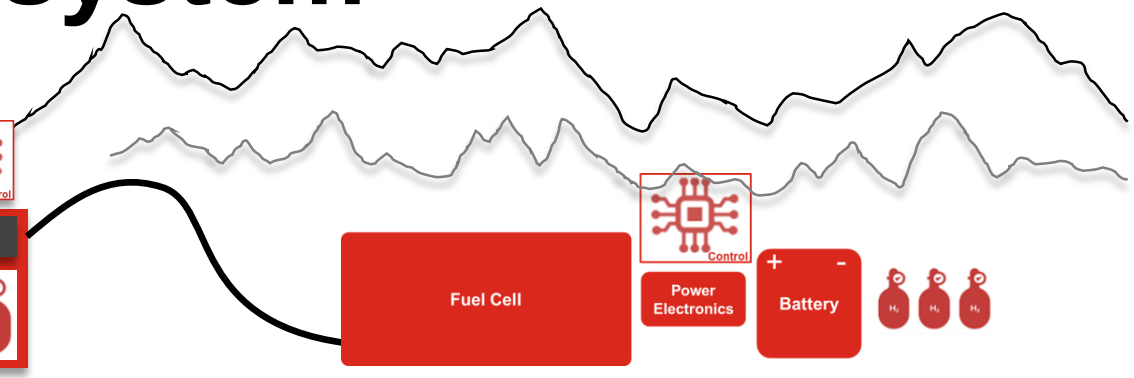


Backup/balance Power

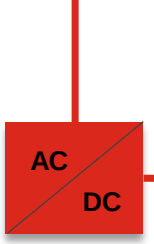
E2P - Micro-grid



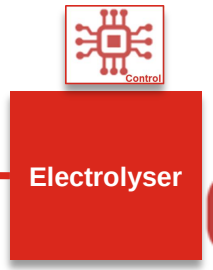
G2V - H2 Fueling Station



In Port Aux Power

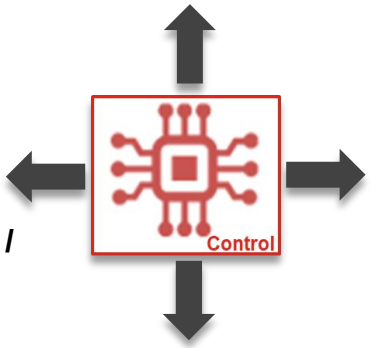


Power Electronics



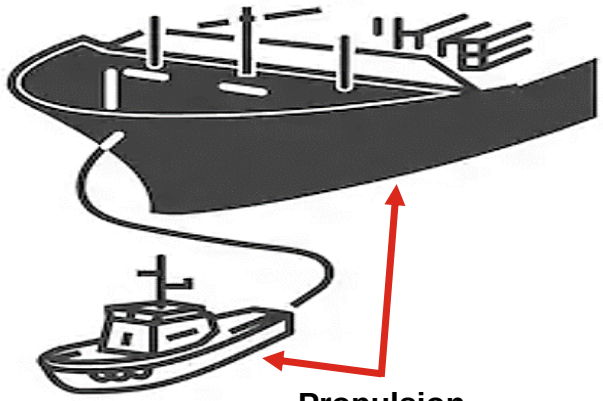
P2G - Electrolyser

Co-located / Remote

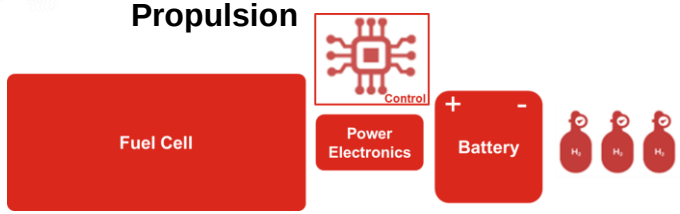


Vessel Electrification

Diesel hybrid
BEV
FC Hybrid



Propulsion



Port / Community / House power



G2P - FC Prime Power

Cummins - Serving marine power needs

- Extensive knowledge and proven experience in all areas
- Offer total turnkey power solution'(s) including: Vessel electrification, Fuelling and or Charging, stations, Microgrid, H2 production, System control, Digital – prognostic, diagnostics, real time comms & optimisation


Cummins



Hydrogen-powered ferries: unlocking the potential

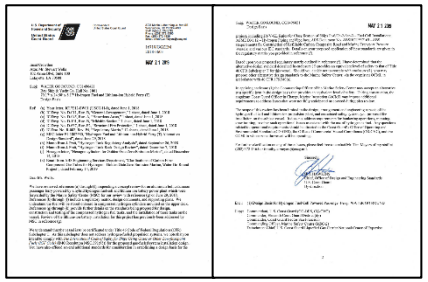
Joseph Pratt, CEO & CTO

GOLDEN GATE ZERO EMISSION MARINE

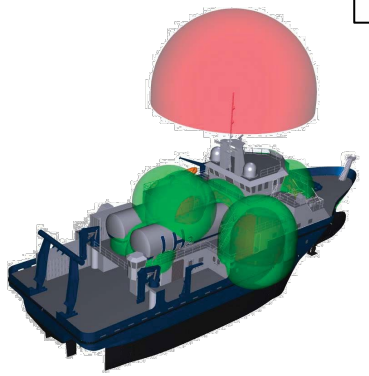
Passenger Shipping Webinar Week
Riviera Maritime Media
September 21-25, 2020

Implementation Aspects

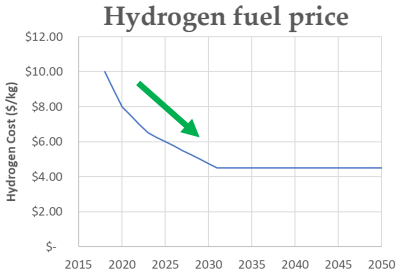
1. Code and Safety Requirements



2. Arrangement Impacts



3. Business Impacts



GOLDEN GATE ZERO EMISSION MARINE

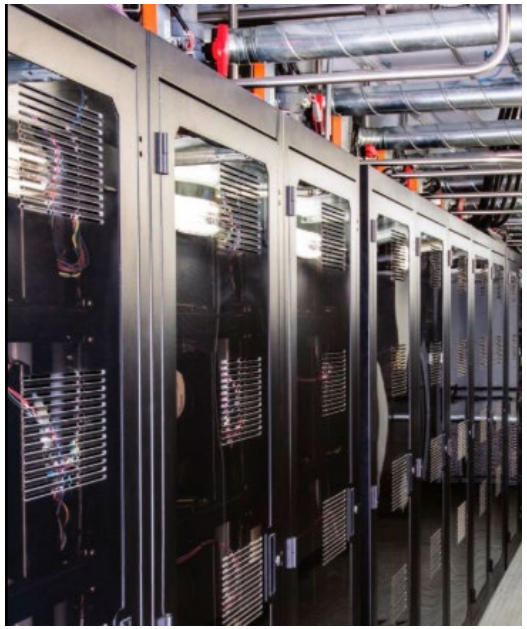
Required Rules, Regulations, Codes, and Standards

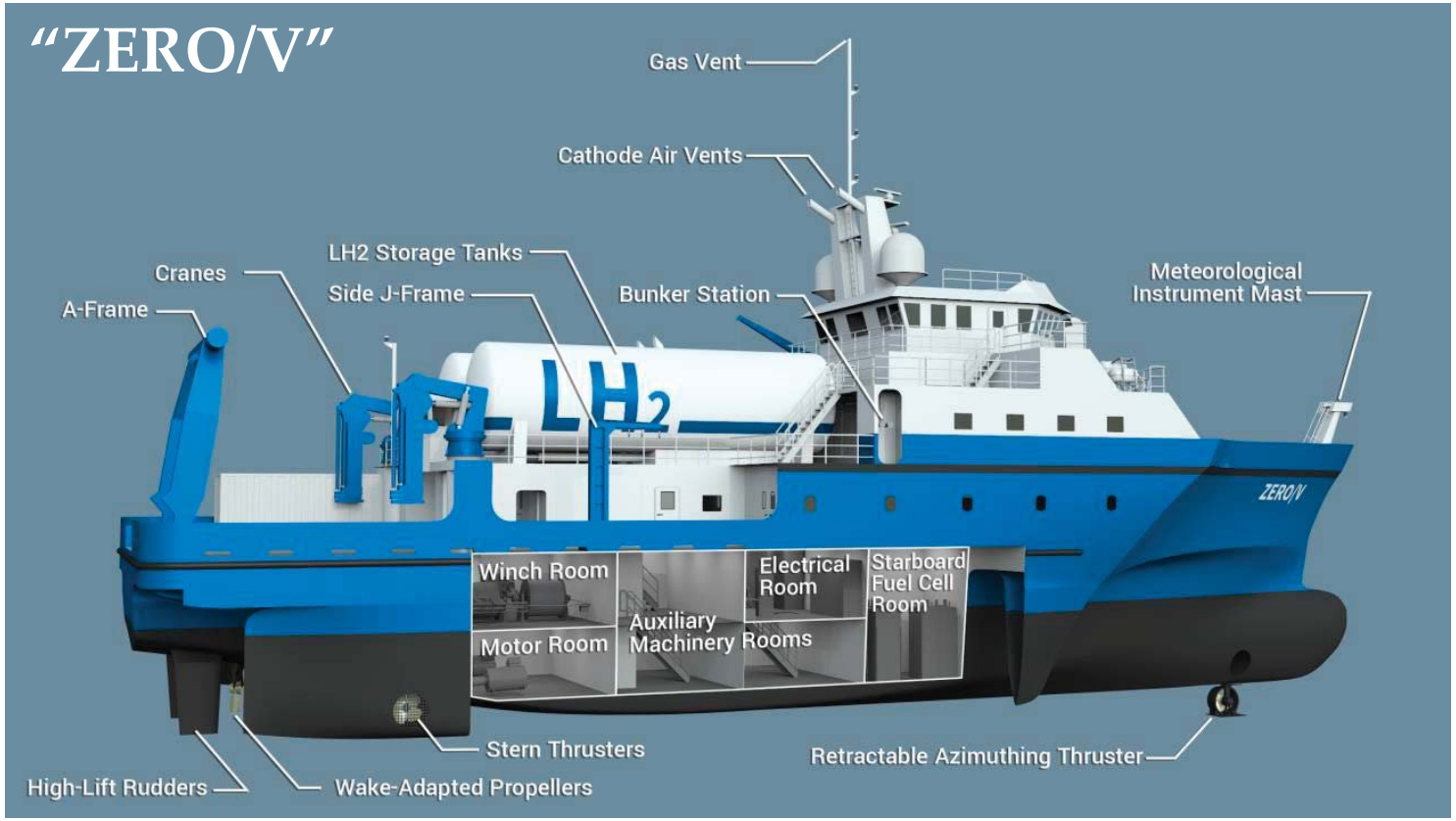
- **Flag State**
  - Ultimate authority
  - Method for determining Equivalent Risk described by IMO MSC.1/Circ.1212
- **International**
  - IMO's *2015 International Code of Safety for Ships using Gases or other Low-flashpoint Fuels* ("IGF Code") was adopted by USCG
    - Written with natural gas / LNG in mind, not hydrogen
    - SOLAS-class vessels, not local vessels in inland/protected waters
- **Class**
  - DNV-GL: Rules for Classification: Ship, part 6, chapter 2, section 3
  - ABS: Fuel Cell Power Systems for Marine and Offshore Applications
- **Industry Standards**
  - IEC, ISO, EN, SAE, ASME, ANSI, CGA, etc.

GOLDEN GATE ZERO EMISSION MARINE

Fuel cells offer flexibility in arrangement…





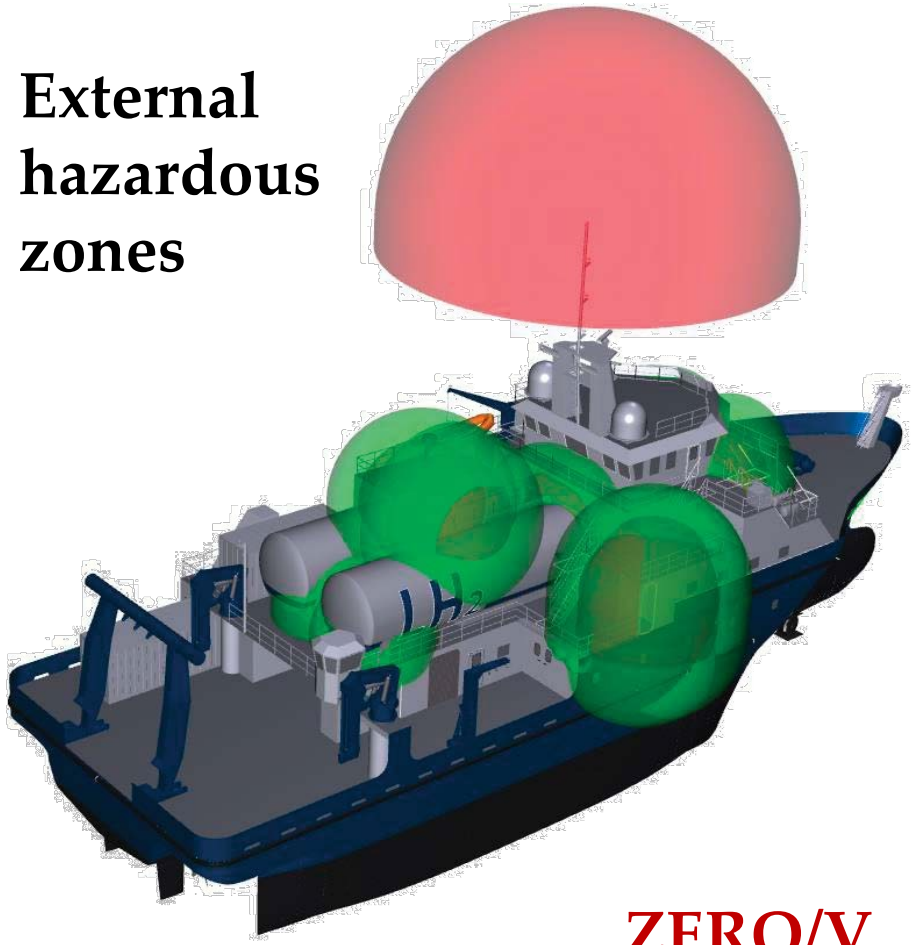


GOLDEN GATE ZERO EMISSION MARINE

Download the ZERO/V report from maritime.sandia.gov

…but come with constraints to meet safety regulations

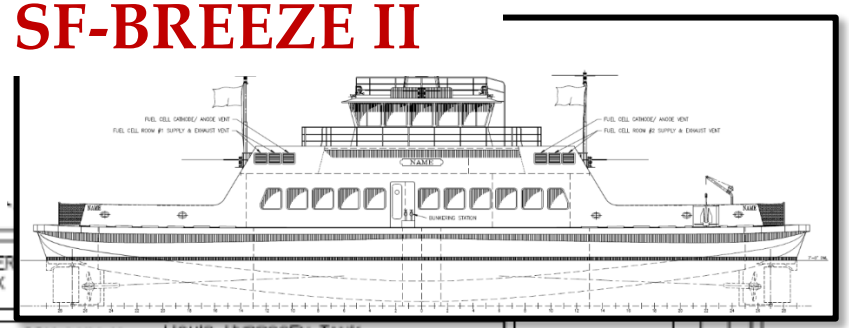
External hazardous zones

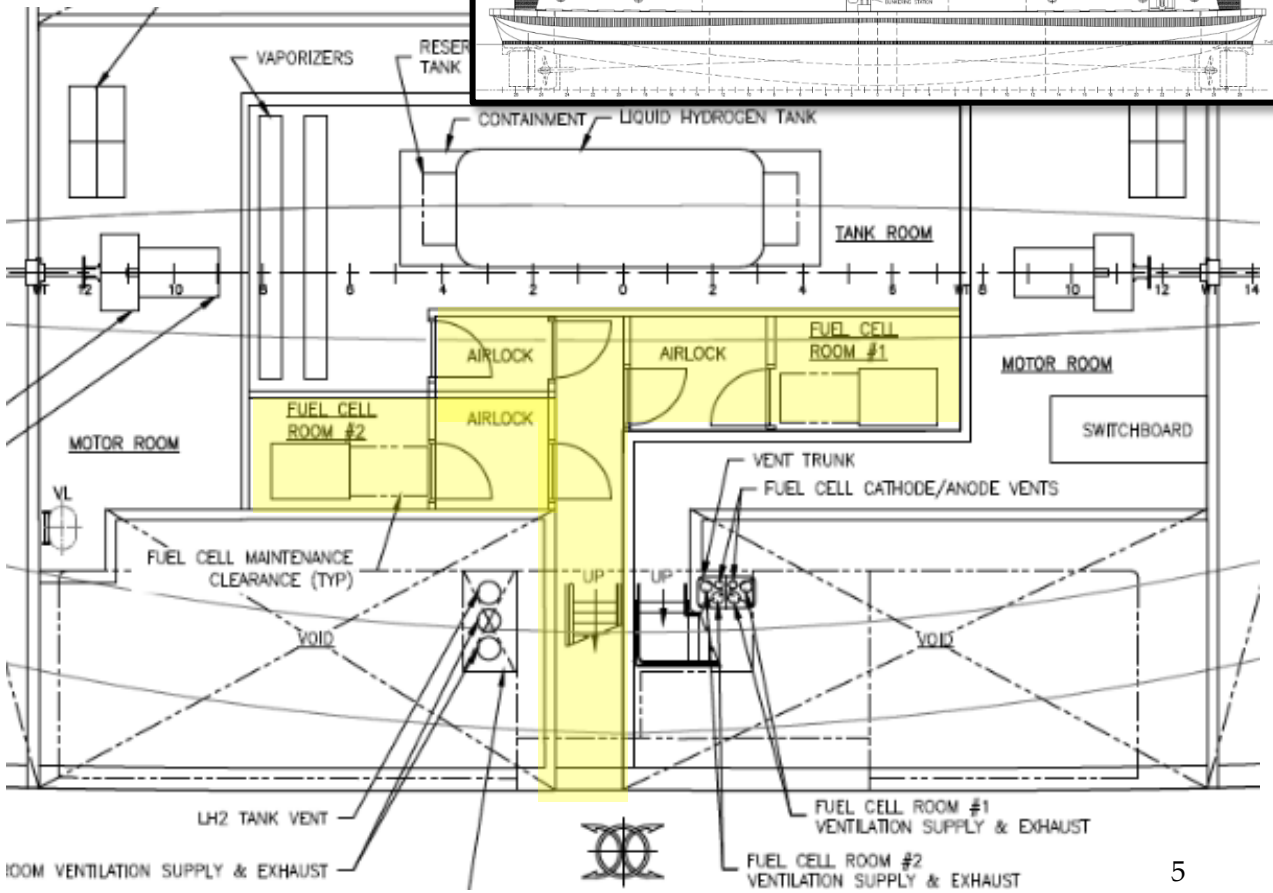


ZERO/V

Internal considerations

SF-BREEZE II

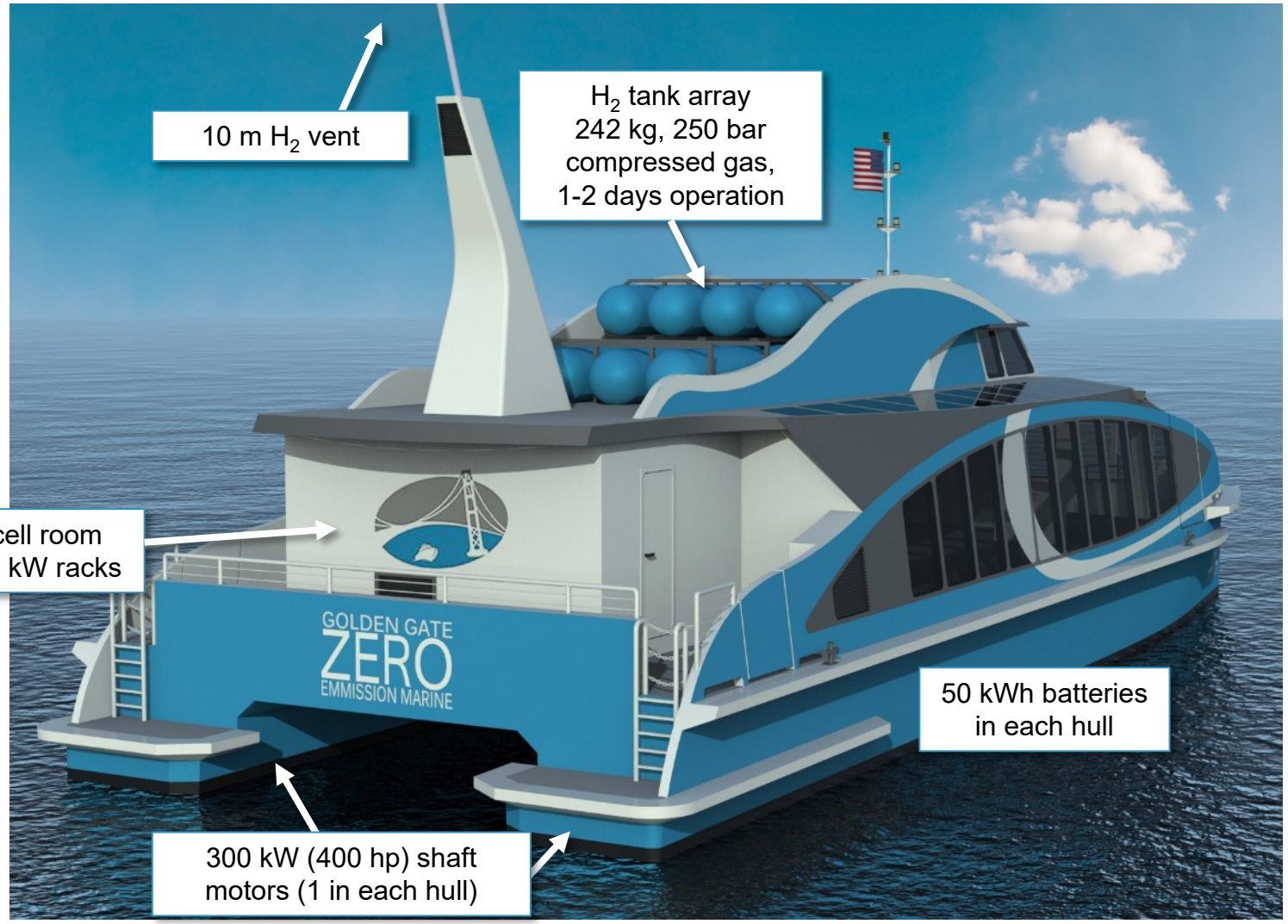




GOLDEN GATE ZERO EMISSION MARINE

Download the SF-BREEZE II report from maritime.sandia.gov

Example: Implementation of fuel cells on the *Water-Go-Round*

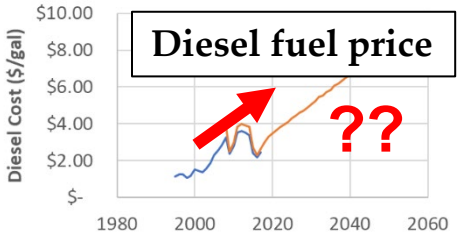


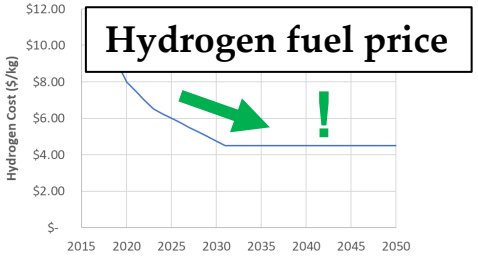
This project is supported by the "California Climate Investments" (CCI) program

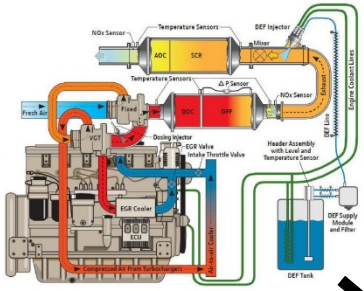
GOLDEN GATE ZERO EMISSION MARINE

Business Benefits of Hydrogen Fuel Cells

- **Higher revenue and Lower total cost of ownership**
- Fuel price certainty
- Less complicated on-board systems with less frequent and simpler maintenance
- No noise or exhaust = happier customers
- Green marketing = more customers
- Win public contracts



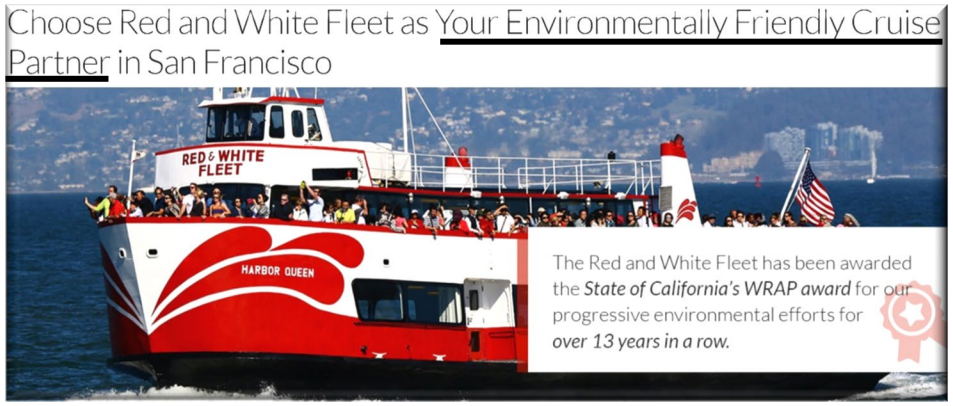




Diesel Engine:
100's of moving parts



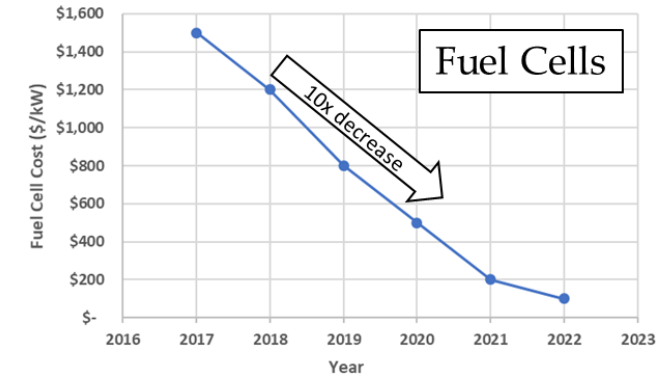
Fuel cell:
< 5 moving parts

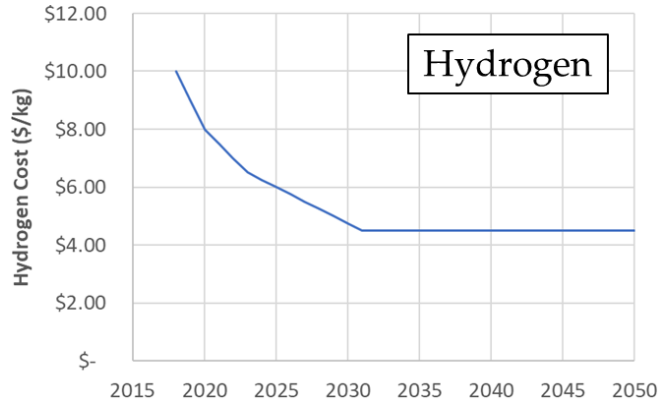


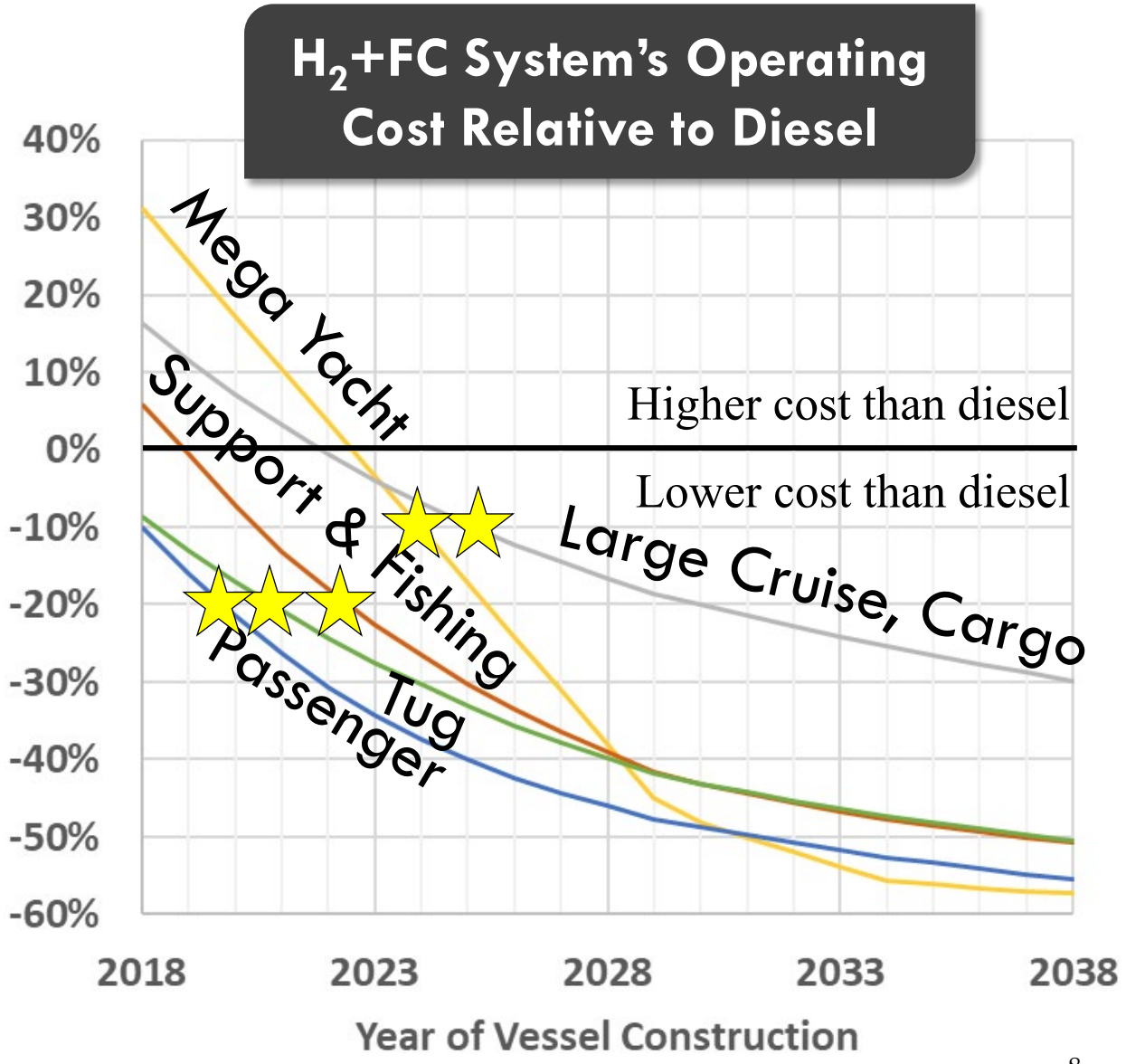
"Your environmentally friendly cruise partner"

GOLDEN GATE ZERO EMISSION MARINE

Hydrogen fuel cell systems have a lower lifetime operating cost than diesel.







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GOLDEN GATE ZERO EMISSION MARINE

- Design
- Engineering
- Technology Solutions
- Markets

Pioneers of the
Marine Hydrogen Fuel Cell
Business

Contact:
Joe Pratt
jpratt@ggzeromarine.com
+1 510 788 5101

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watergoround.com
ggzeromarine.com