Marine Fuel Cells and the *Water-Go-Round*

Dr. Joseph Pratt, CEO & CTO
GOLDEN GATE ZERO EMISSION MARINE

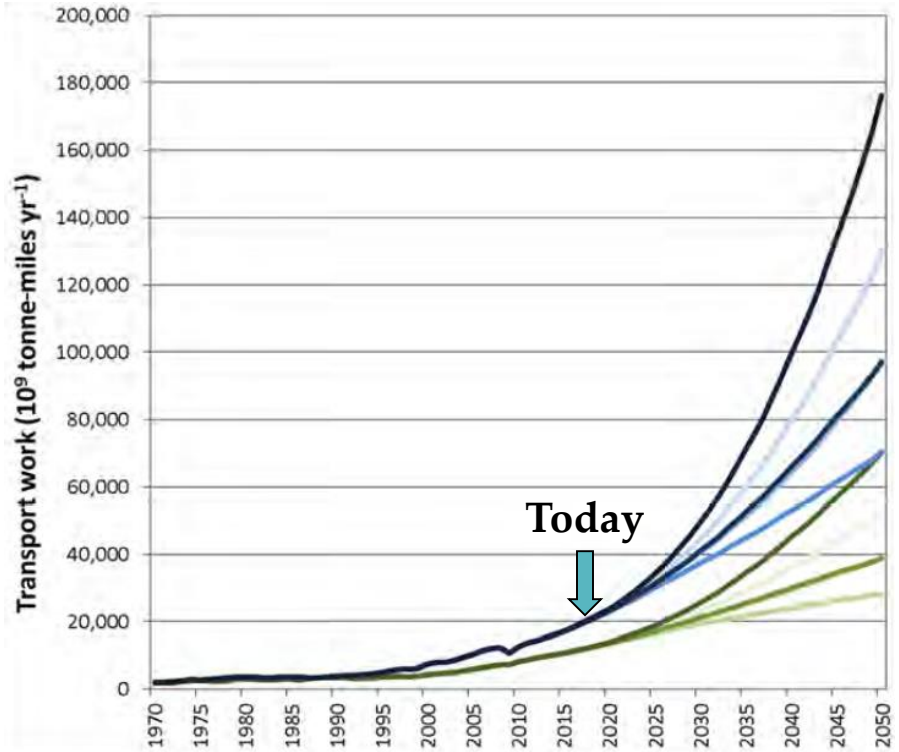
PRESENTED BY:

Mark Kammerer, Business Development Manager
HYDROGENICS

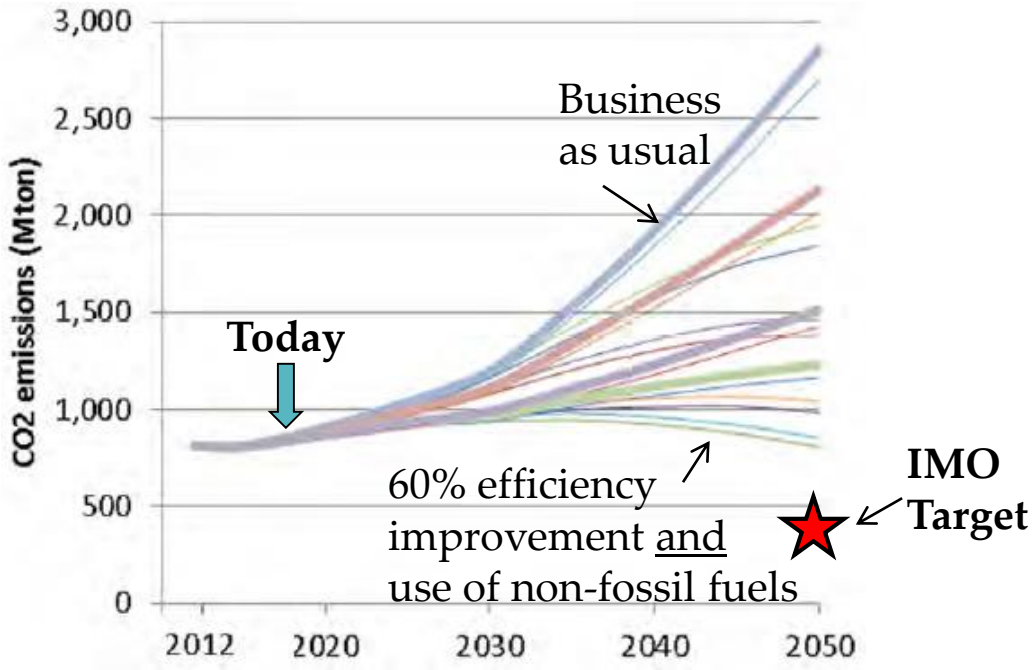
FLORØ, NORWAY, SEPTEMBER 18-19, 2019

The growth of shipping means drastic cuts in emissions are required to meet the targets = Zero Emission

Worldwide shipping trend



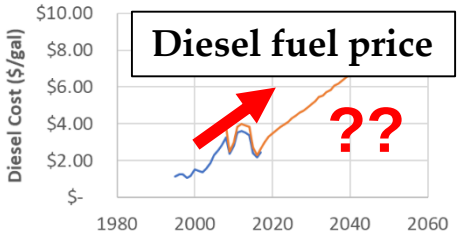
Maritime GHG emissions

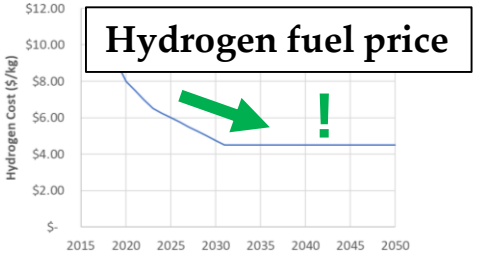


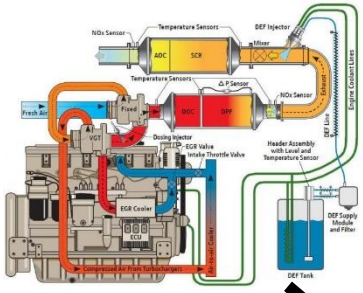
From: *Third IMO GHG Study 2014*

Commercial Benefits of Zero

- **Higher revenue and Lower total cost of ownership**
- Fuel price certainty
- Less complicated on-board systems with less frequent and simpler maintenance
- Low noise, no 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"

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Maritime Fuel Cell (MarFC) Project

DOE: *Project Sponsor*

DOT/MARAD: *Project Sponsor*

Young Bros. and Foss Maritime: *Deployment Partners*

Sandia: *Technology Support and Project Management*

Hydrogenics: *Complete design, build, and integration*

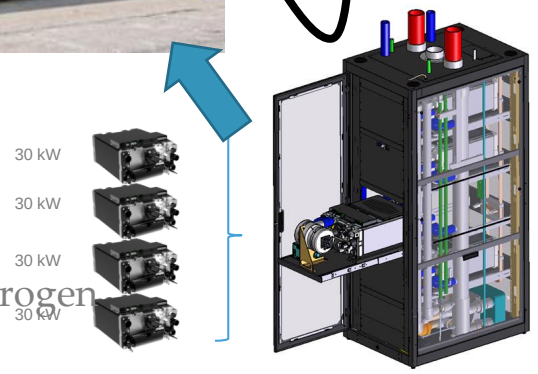
HNEI: *Local H_2 Facilitator*

HCATT: *Hydrogen provider*

Hydrogen Safety Panel: *Project and prototype safety review*

American Bureau of Shipping: *Maritime Product Certification*

US Coast Guard and USCG Sector Honolulu: *Maritime codes and standards*



- Port of Honolulu, Hawaii
- U.S. DOE's FC Office and the U.S. DOT's Maritime Administration funded
- FC Unit replaces diesel generators providing auxiliary power on board to ships at berth
- Four 30-kW fuel cells (Total 100 kWnet), power-conversion equipment and 75 kg of on-board hydrogen storage
- Enough energy to power 10 refrigerated containers for 20 continuous hours of operation

http://www.hydrogenics.com/about-the-company/news-updates/2015/09/01/nothing-but-water-hydrogen-fuel-cell-unit-to-provide-renewable-power-to-honolulu-port

GOLDEN GATE ZERO EMISSION MARINE

"Conditional Approval In Principle" for Zero/V

Nov. 1, 2017

DNV·GL

STATEMENT OF CONDITIONAL APPROVAL IN PRINCIPLE

Glosten/Sandia National Laboratories
Zero-V Hydrogen Research Vessel

This is to certify that Zero-V Hydrogen Research Vessel is granted *Conditional Approval in Principle (CAIP)*.

The approval is based on the prospective DNVGL Rules for Classification of Ships Pt. 6 Ch. 2 Sec. 3 – *Fuel Cell Ship Installations – FC* (01-2018 edition), IGF Code – *International code of safety for ships using gases or other low-flashpoint fuels*, Part A.

Acknowledging that the current regulatory status does not allow for a conventional approval of hydrogen as fuel and fuel cells on maritime applications, this CAIP is a precursor to the more extensive alternative design process as described by the applicable statutory instruments.
No deviations have been identified that would be considered to be major show-stoppers from a regulatory point of view, given the available information in the design drawings in Appendix 2. Compliance with/clarifications of comments in Appendix 1 is a condition for the Approval in Principle, but comments need not be clarified/solved at this stage of the project.

Classification and Certification of specific installations may be granted subject to plan approval and survey as specified by the Rules, findings in future HAZIDS, risk assessments, explosion analysis etc.

DNV GL
Høvik, 2017-11-01

Digitally Signed By: Torill Grimstad Osberg
DNV GL Høvik, Norway
2017-11-01

Torill Grimstad Osberg
Head of Section, MCANO385 LNG, Cargo Handling and Piping Systems

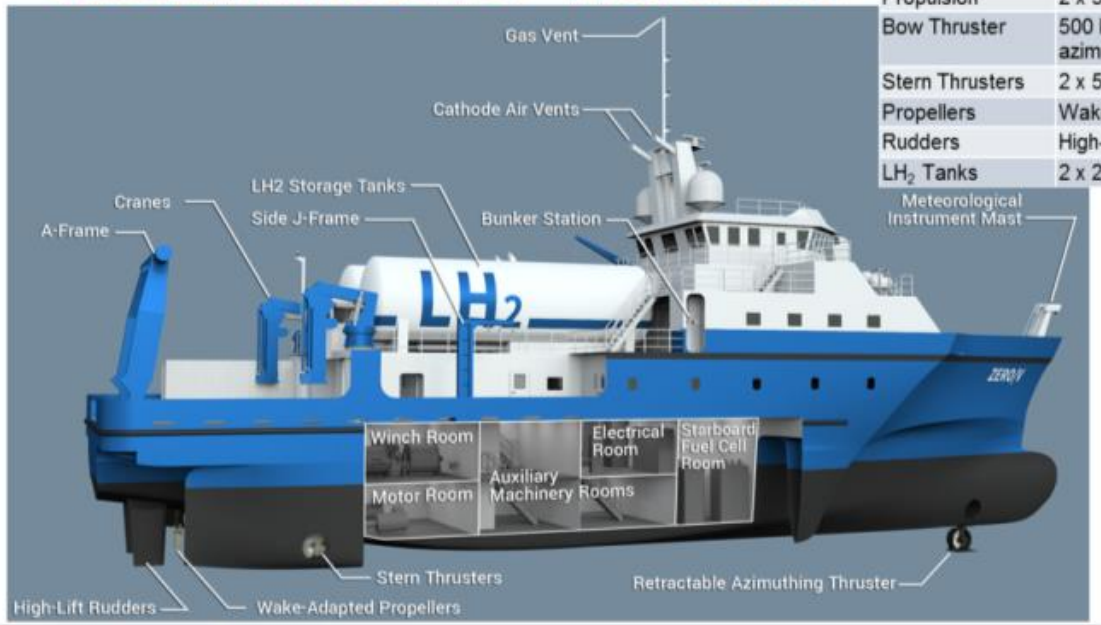
Appendix 1: Drawing status and comments
Appendix 2: Drawings included in the Approval in Principle

DNV GL Headquarters, Veritasveien 1, P.O.Box 300, 1322 Høvik, Norway. Tel: +47 67 57 99 00. www.dnvgl.com

[Legal information] Statement of Approval in Principle 2017.11.01

VESSEL PARTICULARS – PROPULSION

Power	10 x 180 kW hydrogen fuel cell racks
Propulsion	2 x 500 kW PM motors
Bow Thruster	500 kW, retractable azimuthing
Stern Thrusters	2 x 500 kW tunnel
Propellers	Wake-adapted fixed pitch
Rudders	High-lift
LH_2 Tanks	2 x 28,800 gal type C



https://share-ng.sandia.gov/news/resources/news_releases/hydrogen_boat/
http://energy.sandia.gov/transportation-energy/hydrogen/market-transformation/maritime-fuel-cells/

Next Step for the MarFC 100 kW FC Container

MarFC 100 kW FC Container

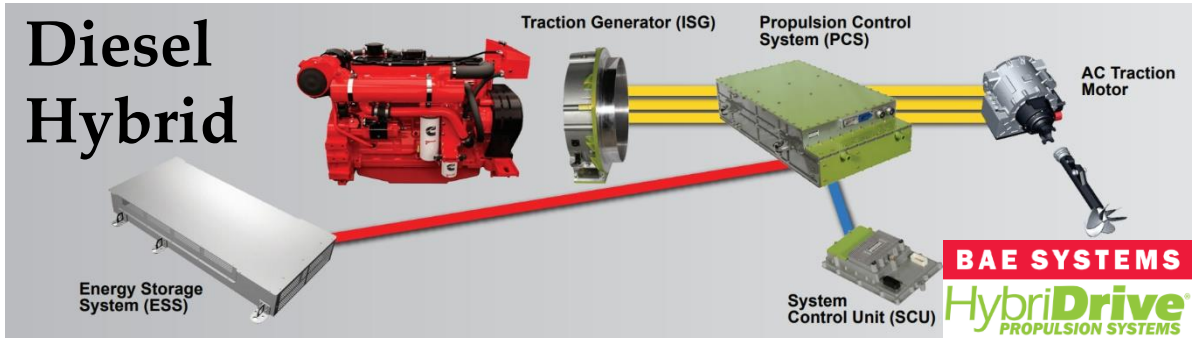
Planned location for the MarFC

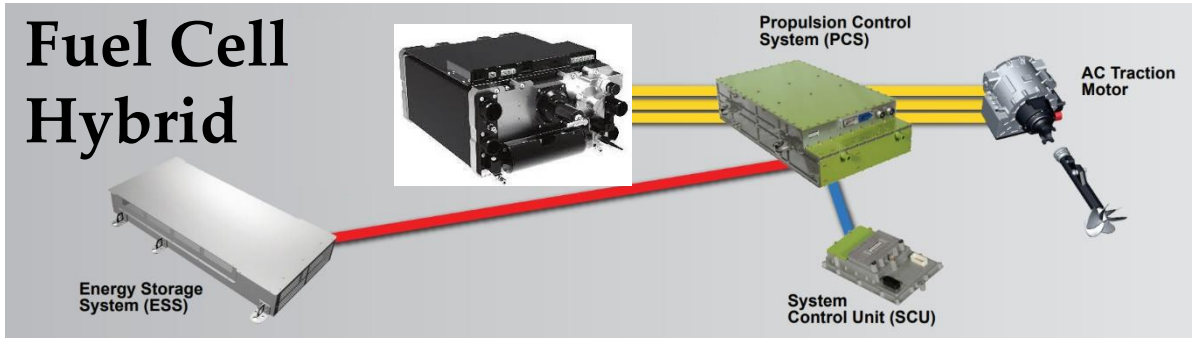
Nimitz Marine Facility

R/V Robert Gordon Sproul
docked at Nimitz Marine Facility

- The Scripps Institute of Oceanography (SIO) to use the MarFC unit to provide shore power for the Research Vessel (R/V) Robert Gordon Sproul
- While in Port, the vessel requires 480 VAC 3-phase shore power 24 hours per day.
- The MarFC unit is currently being refitted for 480 VAC
- Deployment scheduled for 6 months Starting ~ 10/1/2019

Marine hydrogen fuel cell systems can use off-the-shelf technology





Enhydra

Matthew Turner

Water-Go-Round

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The *Water-Go-Round*

- Aluminum catamaran
- 70’ / 21 m LOA
- 84 passenger (reconfigurable)
- 22 knot top speed
- 2x 300 kW electric motors
- 360 kW PEM fuel cell
- 100 kWh Li-ion battery
- H_2: 242 kg @ 250 bar

GOLDEN GATE ZERO EMISSION MARINE

The *WGR* project is a partnership

Project Lead

Golden Gate Zero Emission Marine

Funding & Administration

California Air Resources Board

Bay Area Air Quality Management District

California Climate Investments — Cap and Trade Dollars at Work

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

Cost-Sharing Partners

Bay Ship & Yacht Co.

Red and White Fleet — San Francisco Cruises — Since 1892

Hydrogenics

BAE Systems

Port of San Francisco

Sandia National Laboratories

Switch Maritime

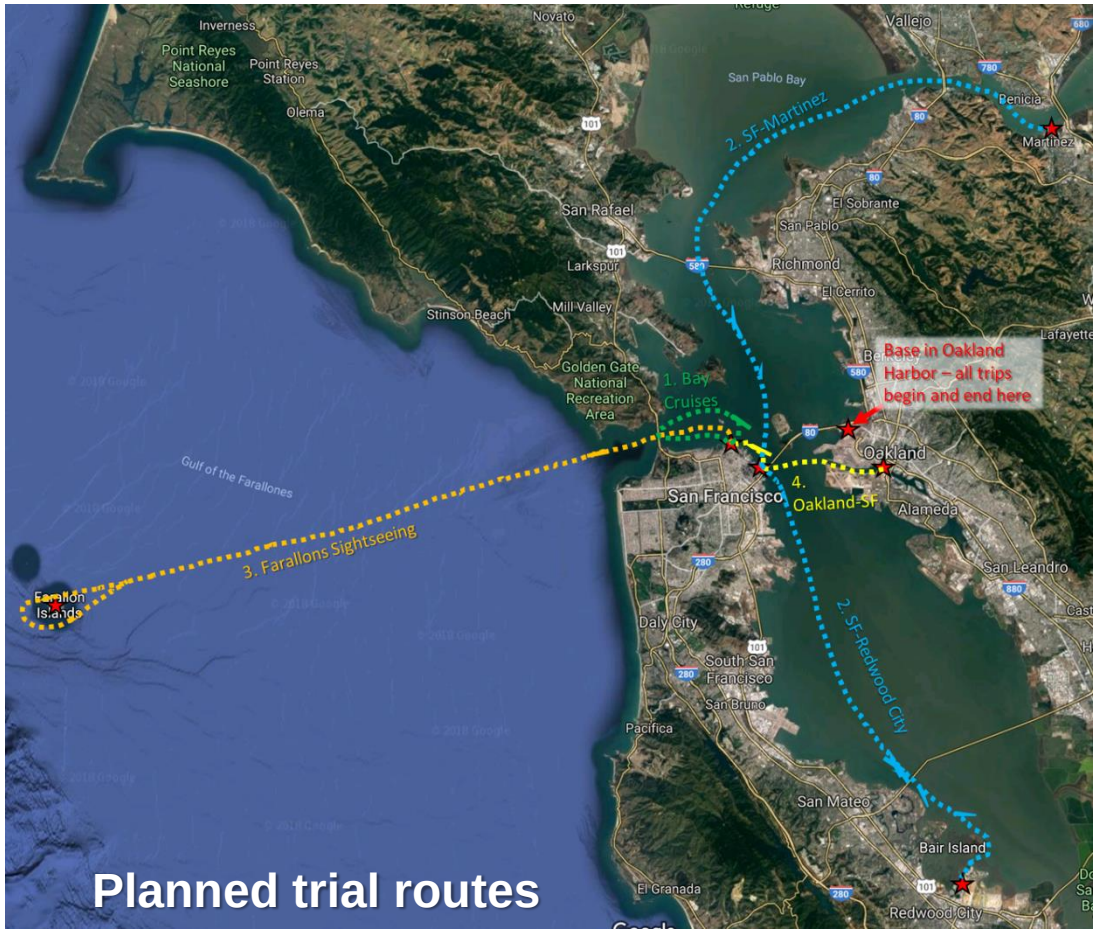
Incat Crowther — Ever Evolving Ever Improving

Hexagon Composites

The *WGR* will be on the water in Fall 2019 and will operate for at least 3 months in trials for CARB

Planned uses during the trial:

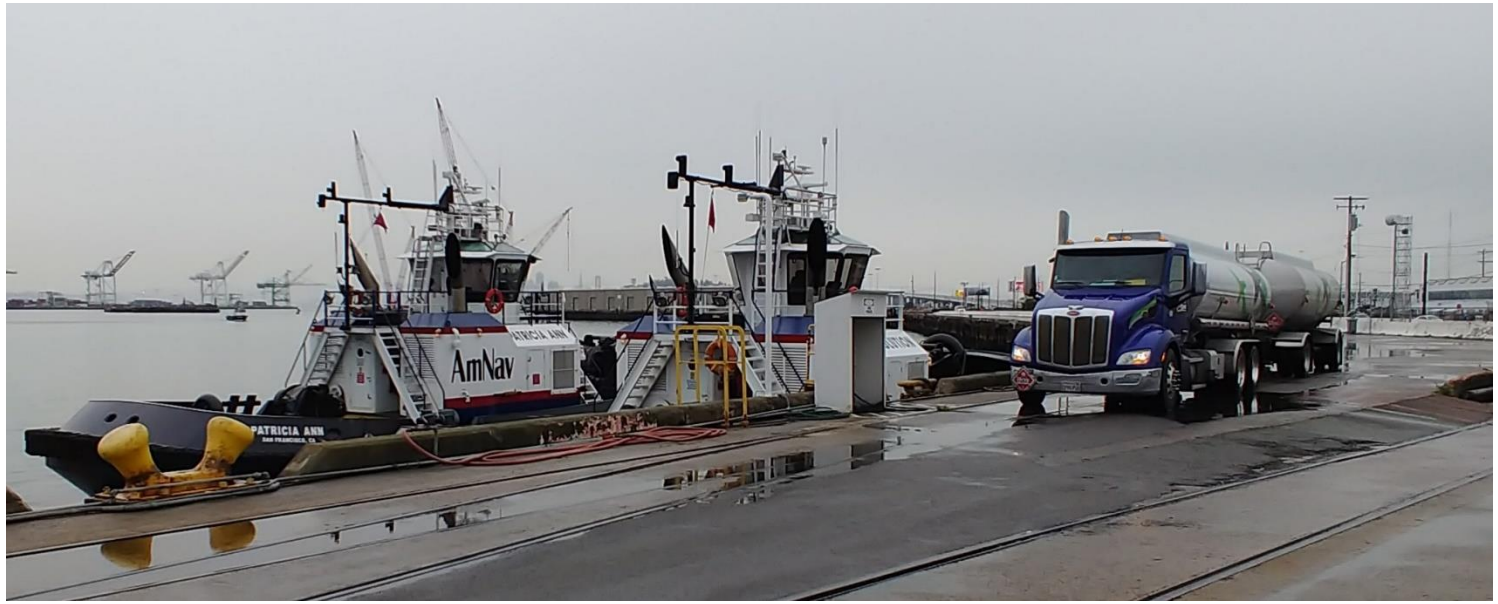
- Commuter ferry
- Excursion/tour boat
- Research/survey vessel
- Package/freight delivery
- Crew boat



After the project concludes, the vessel will enter commercial service (TBD)

GOLDEN GATE ZERO EMISSION MARINE

The fueling will look like today's operation with diesel



California's Office of Spill Prevention and Response (OSPR) has exempted hydrogen fueling from the insurance requirements imposed on diesel fueling

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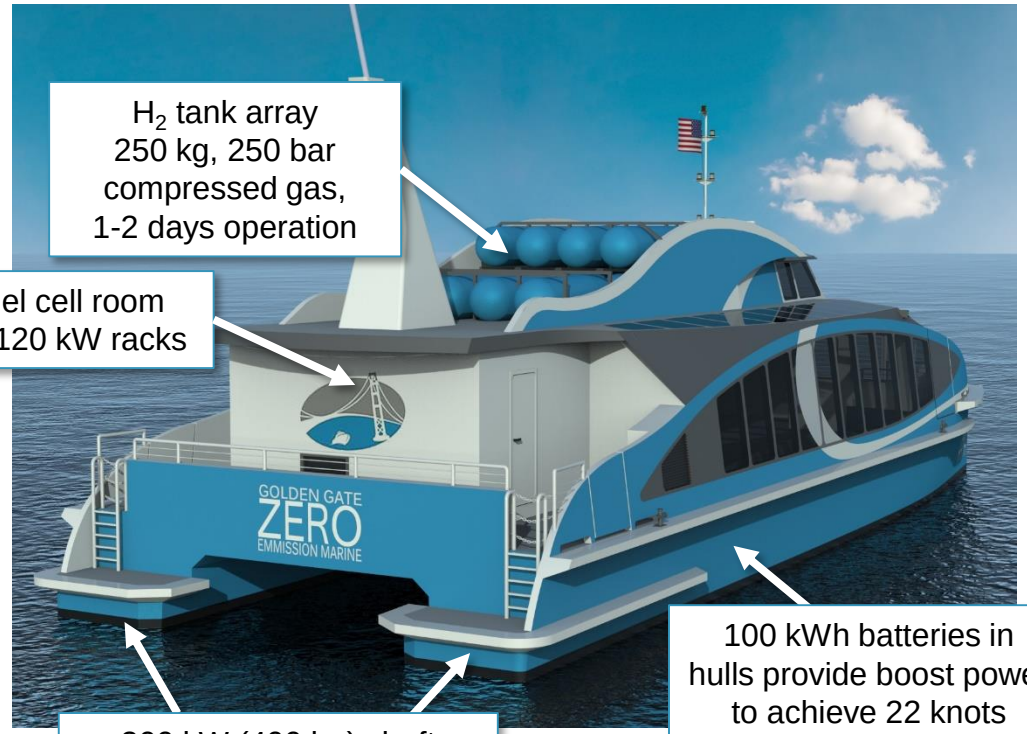
Water-Go-Round Features

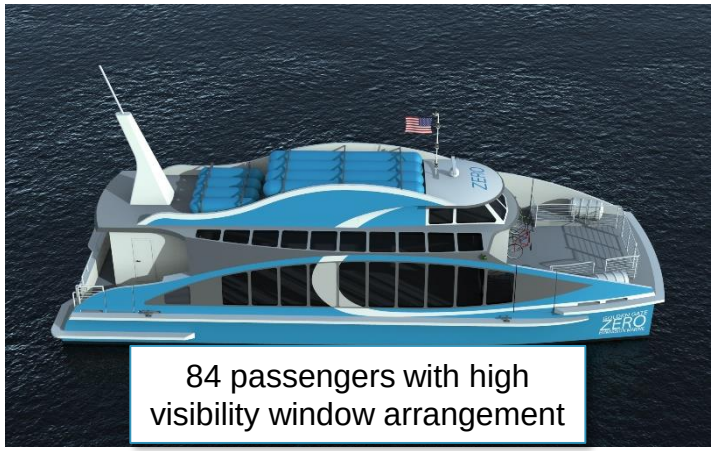


H_2 tank array
250 kg, 250 bar
compressed gas,
1-2 days operation

Fuel cell room
3 x 120 kW racks

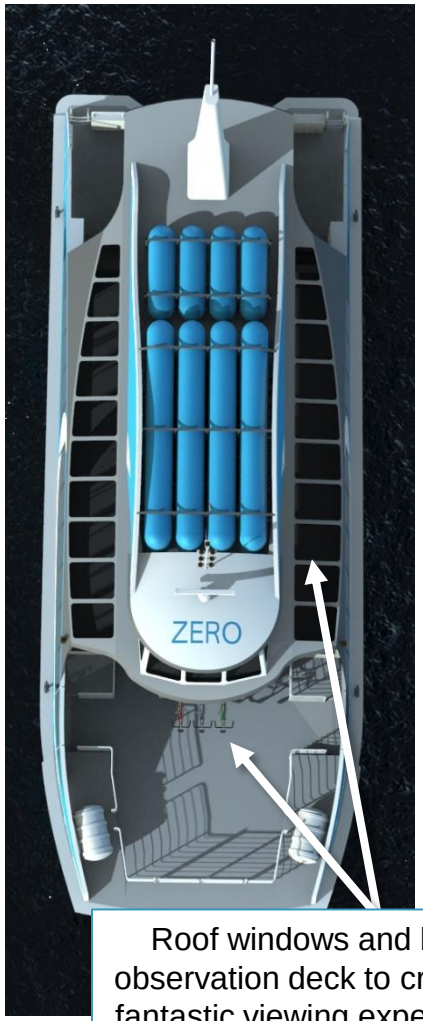
100 kWh batteries in hulls provide boost power to achieve 22 knots

300 kW (400 hp) shaft motors (1 in each demi-hull)



84 passengers with high visibility window arrangement

Boarding from sides and bow for maximum flexibility



Roof windows and bow observation deck to create a fantastic viewing experience

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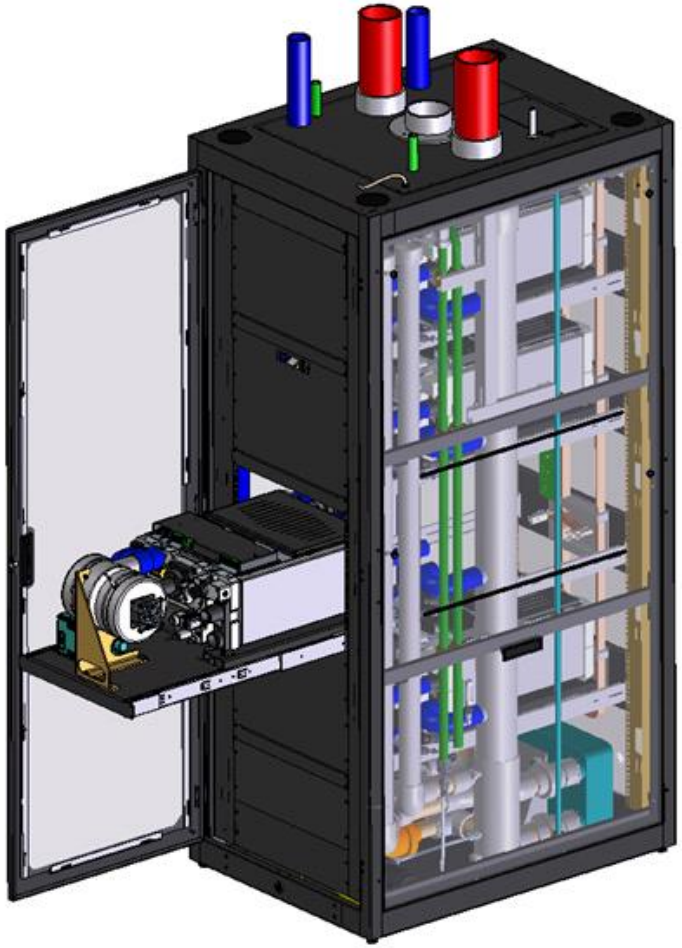
HyPM™-R120 Fuel Cell Power Rack

30 kW

30 kW

30 kW

30 kW



120 kW

240 kW
+ 1 more rack = 360 kW for the WGR

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Keel laying ceremony (Nov. 8, 2018)

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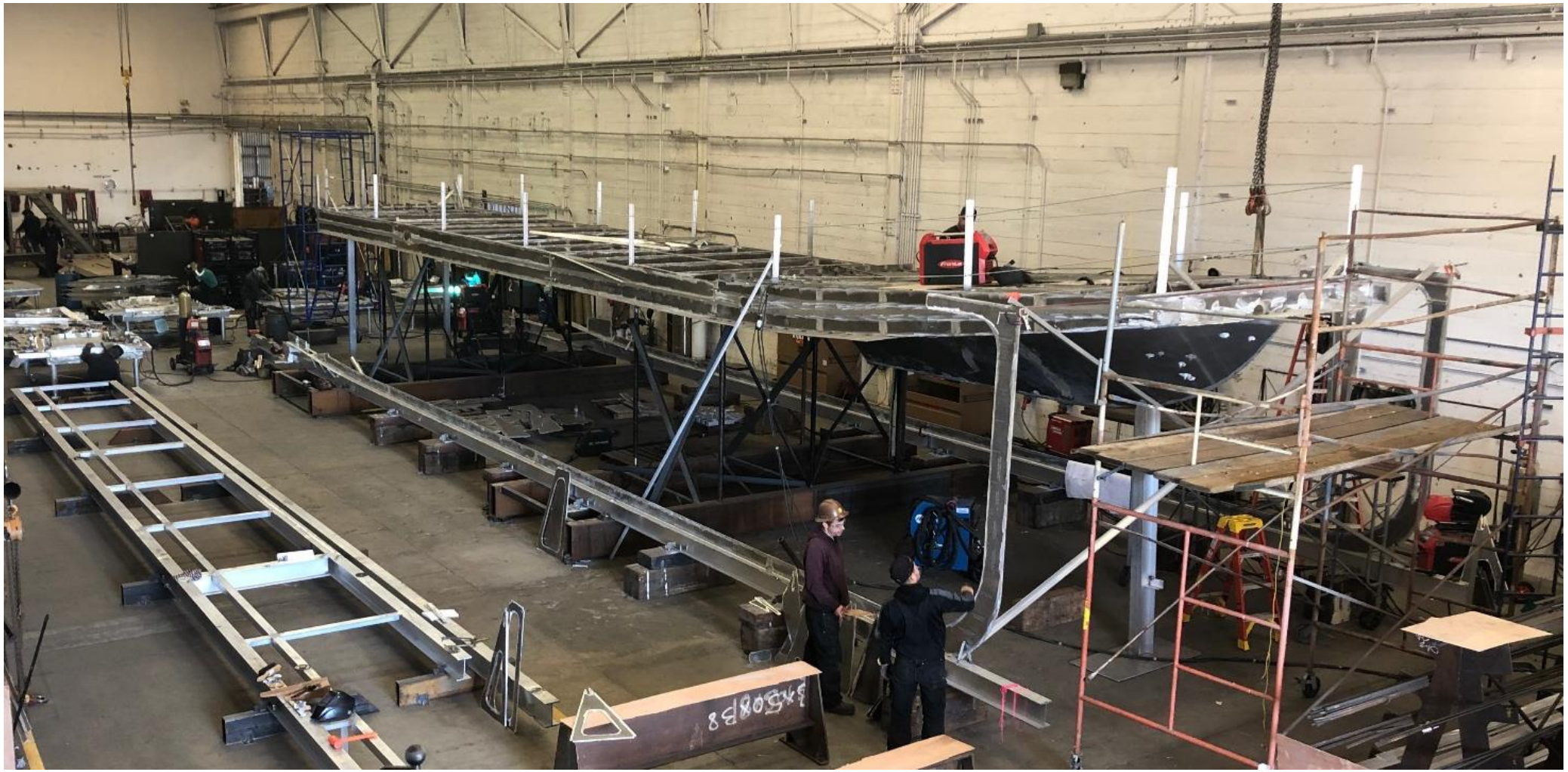
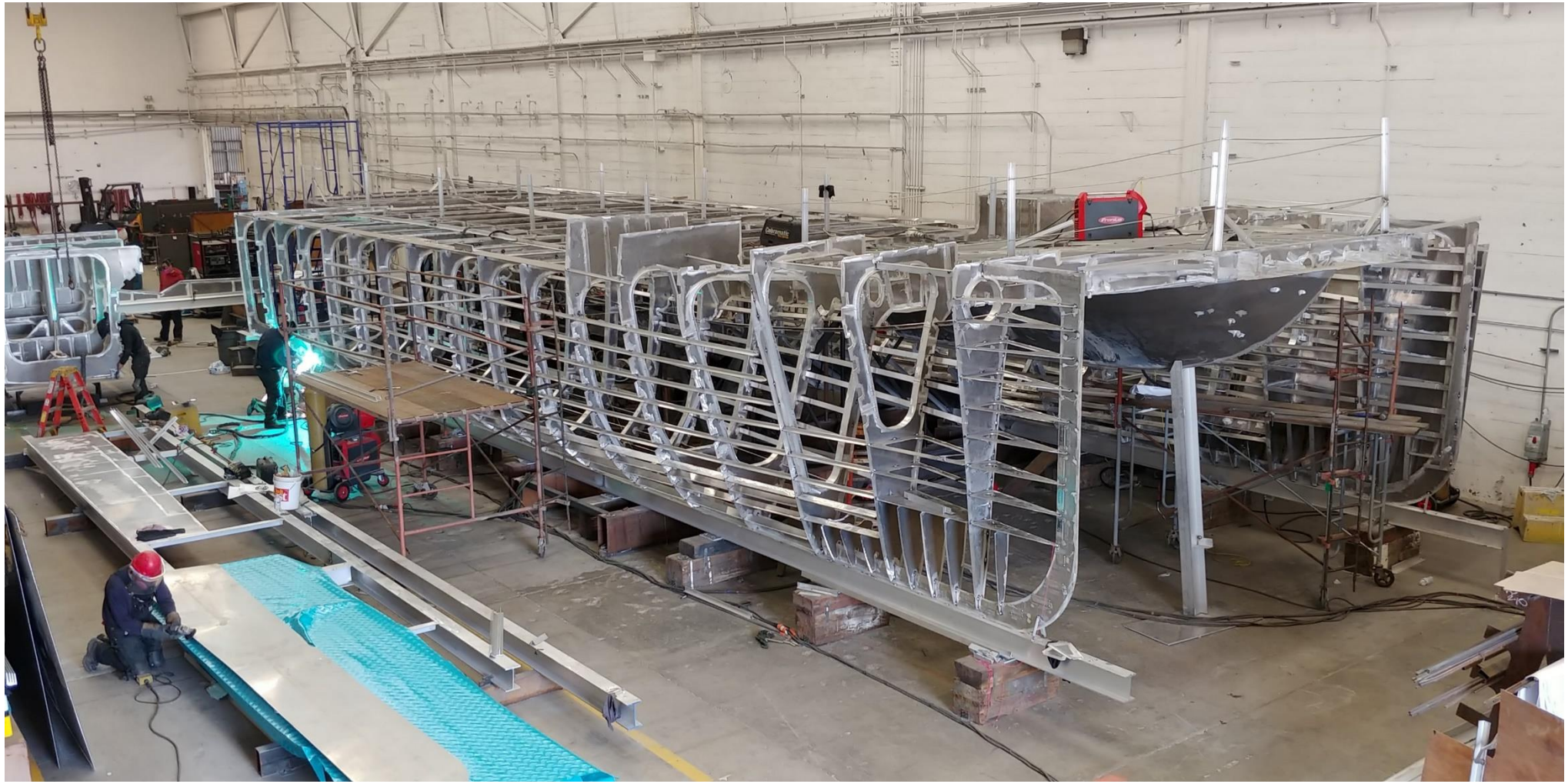
End of April



GOLDEN GATE ZERO EMISSION MARINE

End of May



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The *Water-Go-Round*

Launching Fall 2019

Cap and Trade Dollars at Work — California Climate Investments

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

Cleaner

Lower Cost

Better

Learn More

Visit

watergoround.com

ggzeromarine.com

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