



Considerations for On-Board Hydrogen Fuel Cells

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GOLDEN GATE **ZERO** EMISSION MARINE

H2@Ports Workshop

San Francisco

September 10-12, 2019



Implementation Process

- Select technology
 - Requirements
 - Options and Capabilities
- Arrangement
 - Sizes and weights
 - Safety and regulations
- Fuel availability

Understand Operating Requirements



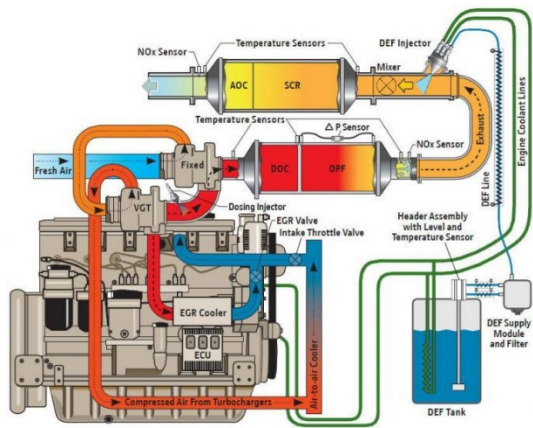
- 6 cruises per day
- 800 kW installed power
- 300 kWh energy used per cruise



- 1 trip
- 38 MW installed power
- 237 MWh energy used per trip

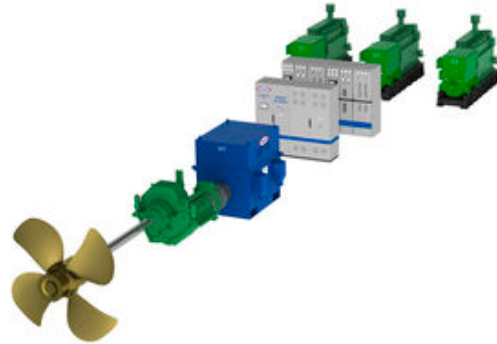
Emission Reduction Technology Options

Tier 4 Diesel



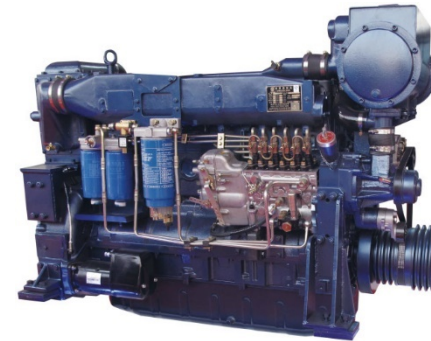
NOx: Low
SOx: Low
CO₂: no change
(0 if biofuel)

Electric Hybrid



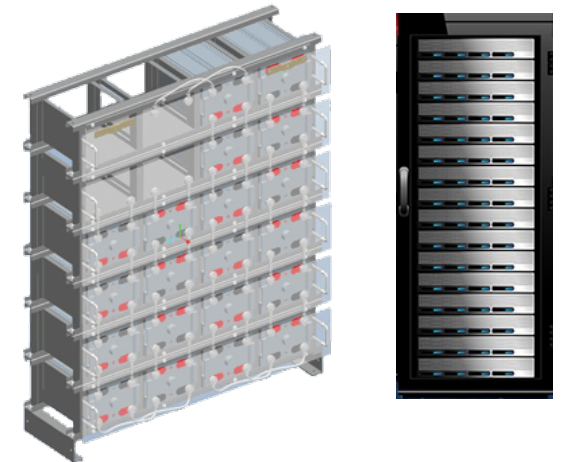
NOx: Low
SOx: Low
CO₂: 10%-40% lower

LNG



NOx: Low
SOx: 0
CO₂: +/- 10%

**Zero Emission:
 Battery or Hydrogen
 Fuel Cell**



NOx: 0
SOx: 0
CO₂: 0

For Zero Emission, hydrogen and batteries are suitable for different kinds of vessels – they are complimentary.

Best Application Space



Higher Power

Lower Power



Battery

Fuel Cell

Either

Fuel Cell

Shorter Range

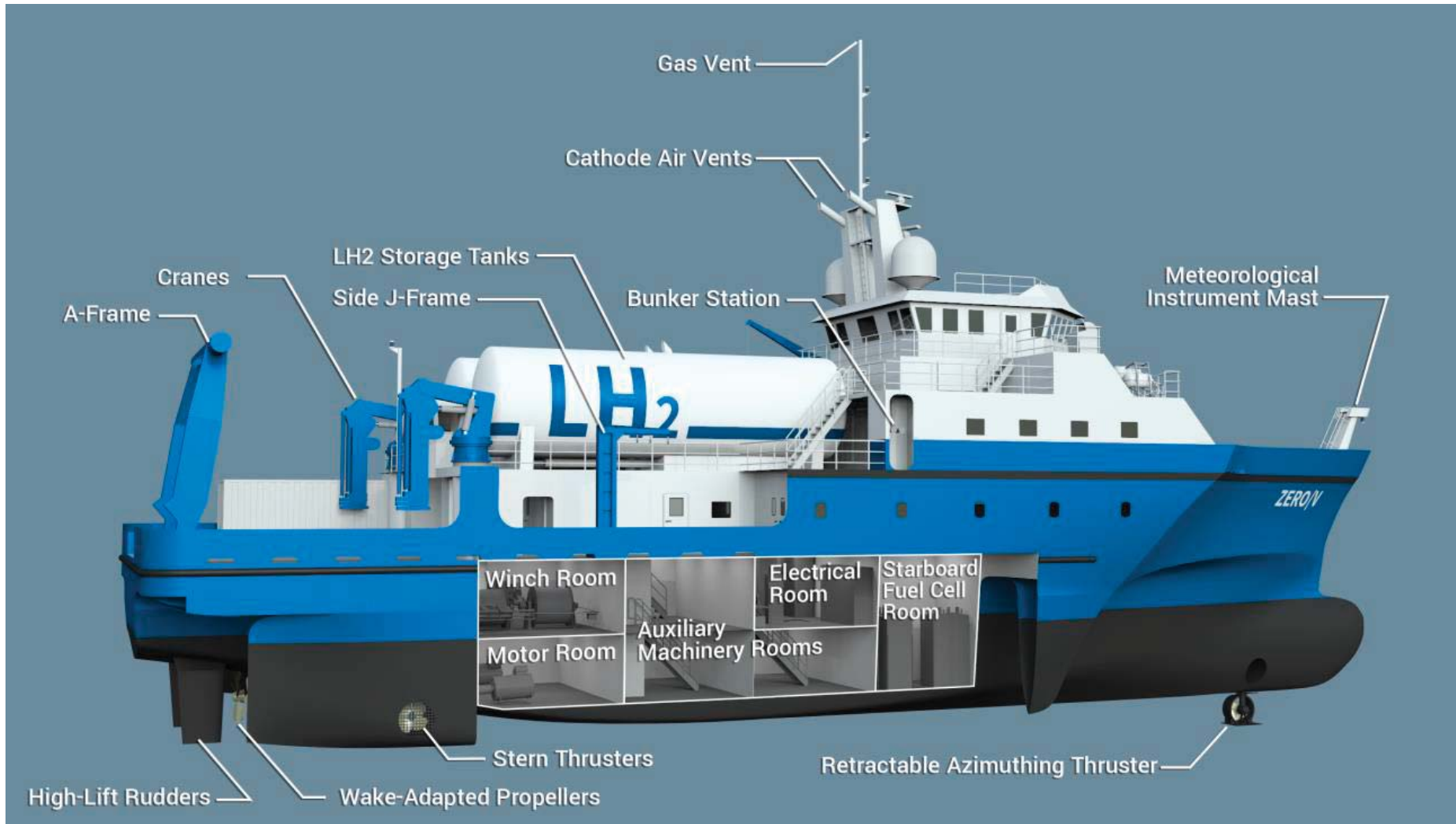


Longer Range



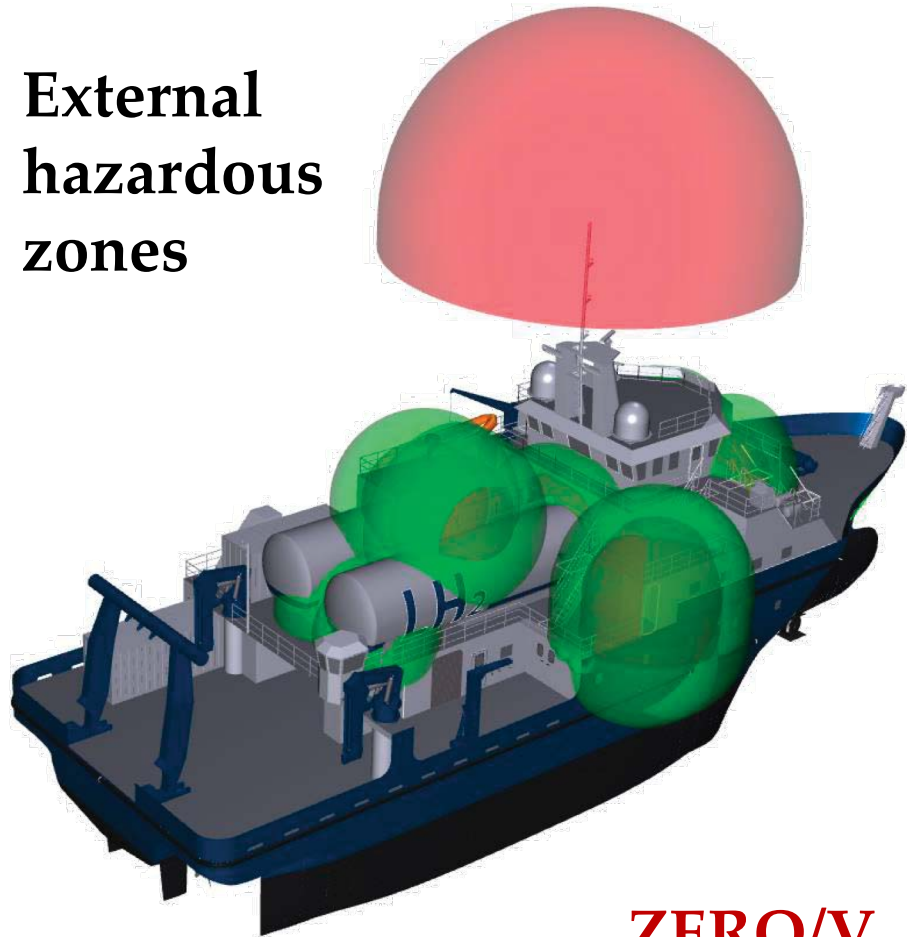
Reference: *Practical Application Limits of Fuel Cells and Batteries for Zero Emission Vessels* (download from: maritime.sandia.gov)

Fuel cells offer flexibility in arrangement...



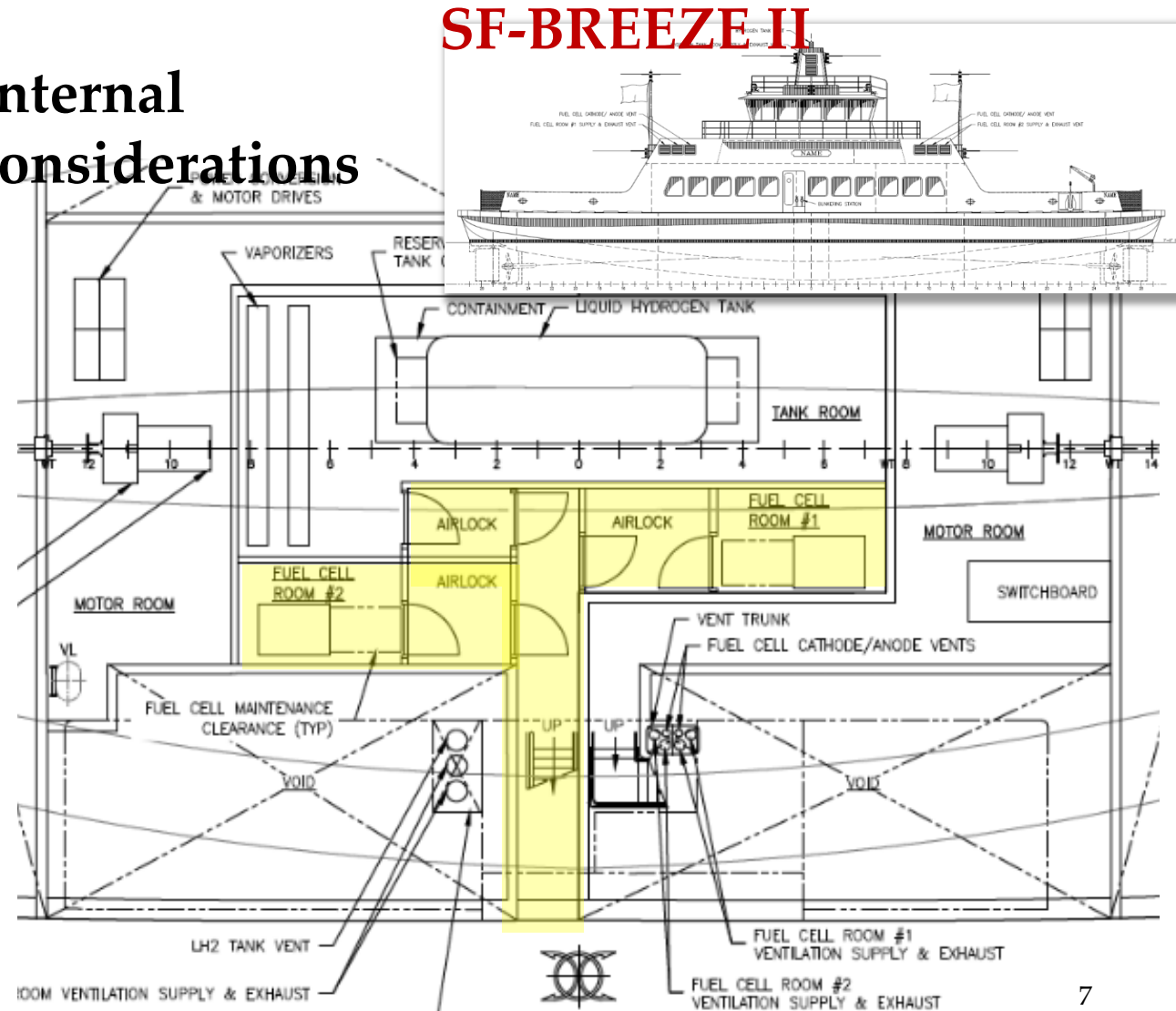
...but come with constraints to meet safety regulations

External hazardous zones



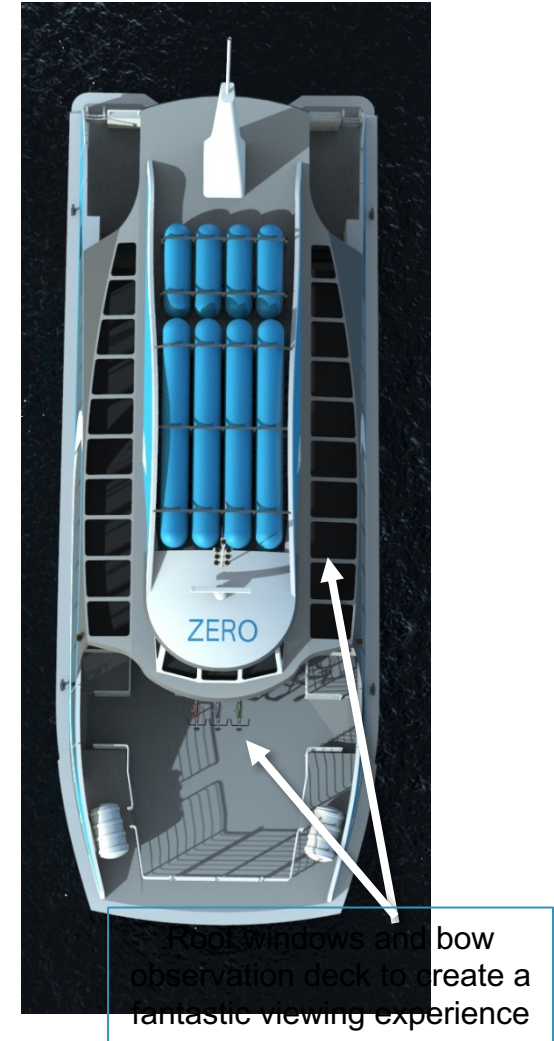
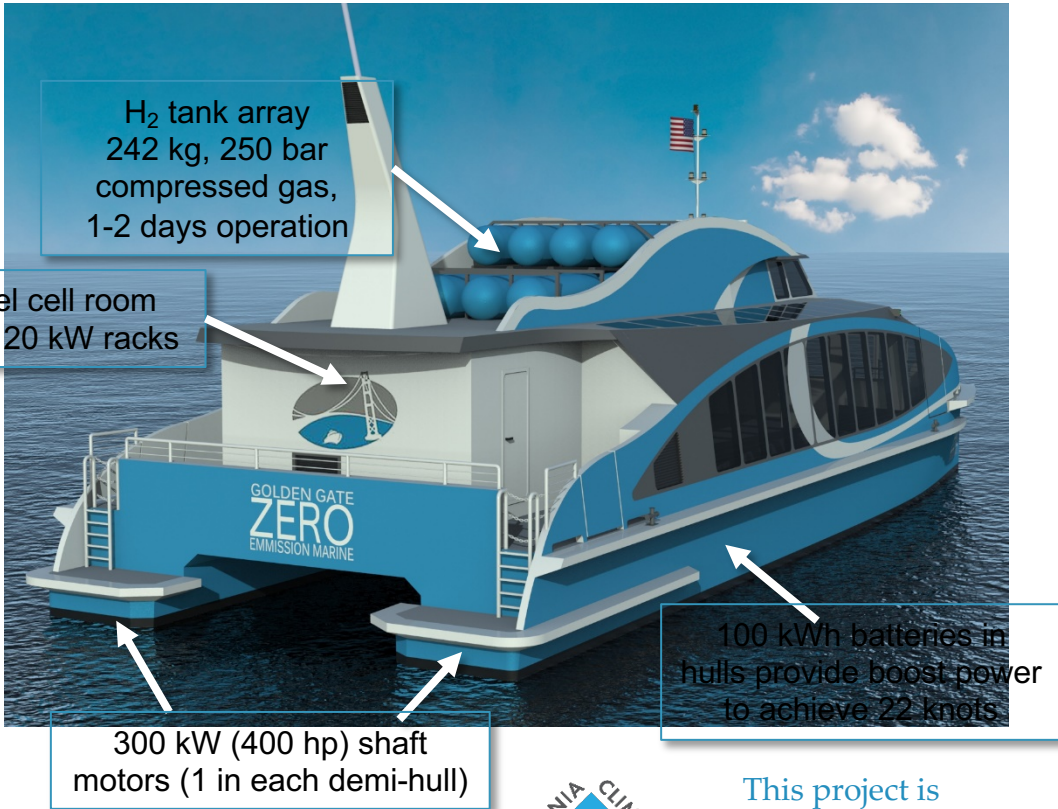
ZERO/V

Internal considerations



SF-BREEZE II

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

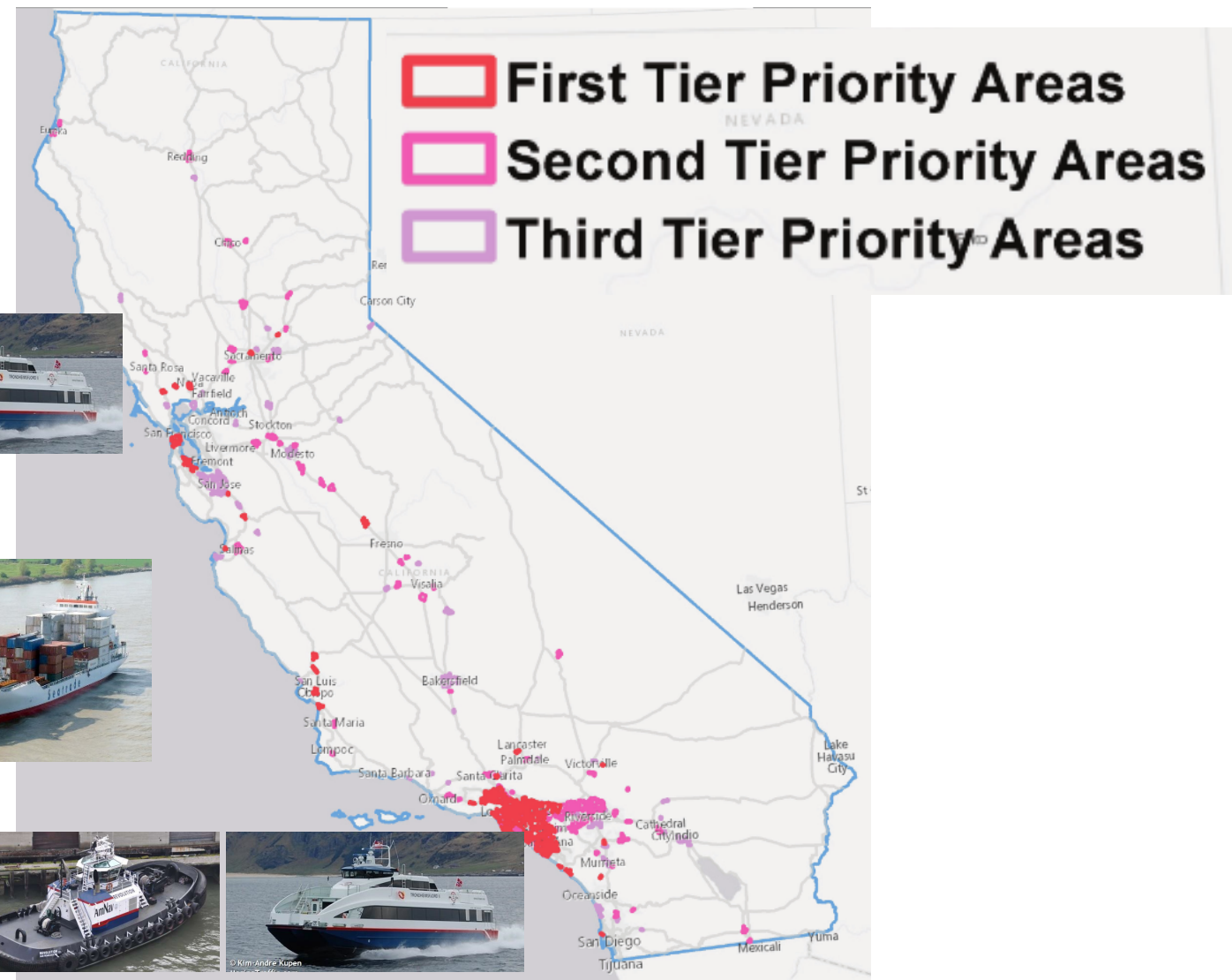


This project is supported by the "California Climate Investments" (CCI) program

Cap and Trade Dollars at Work



Maritime can use the “cluster strategy” to establish H₂ infrastructure



The consumption of a small fleet or a single ship could justify new cost-effective H₂ production facility



GOLDEN GATE **ZERO** EMISSION MARINE – Scaled Hydrogen Fuel Cell Power

New builds and repowers:

- Offshore Transfer/Supply
- Tugs and Workboats
- Cargo
- Cruise
- Yachts
- Passenger/Vehicle Ferries
- Excursion Vessels

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