

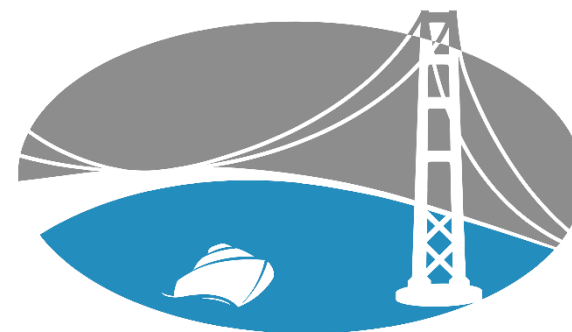


Zero Emission Vessels

Dr. Joseph Pratt, CEO & CTO

GOLDEN GATE **ZERO** EMISSION MARINE

5th ICCT Workshop on Marine Black Carbon Emissions
September 19, 2018
San Francisco, CA



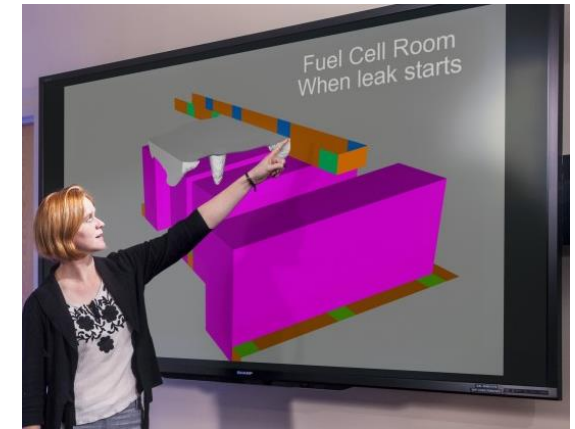
Sandia Zero Emission Maritime Work: maritime.sandia.gov



SF-BREEZE
High Speed Ferry



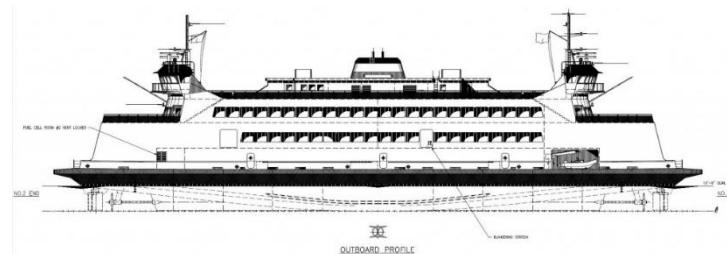
ZERO/V
Research Vessel



On-Board Safety



Portable Port Power



**Cost and Emissions
Optimization**



**Practical Limits of
Technology**

Regulatory Drivers: It's not just IMO

Report: 28 of 100 World's Largest Ports Offer Incentives for Green Ships

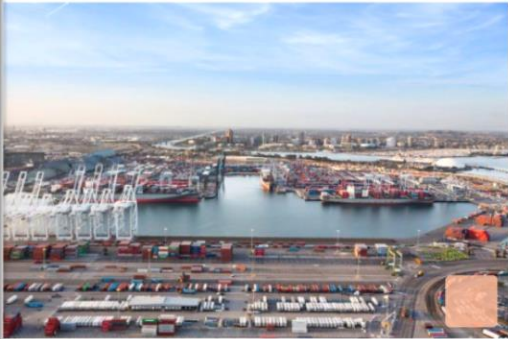


Image Courtesy: Port of Long Beach

Today, 28 of the 100 world's largest ports in terms of total cargo volume handled offer incentives for environmentally-friendly ships, a new report released by the International Transport Forum (ITF) shows.

Greenhouse gas emissions from shipping currently represent around 2.6% of total global emissions. Without reduction measures, this share could more than triple by 2050.

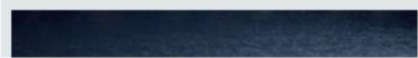
Norway Mandates World's First Zero-Emission ECA for No Later Than 2026

Friday, May 4, 2018

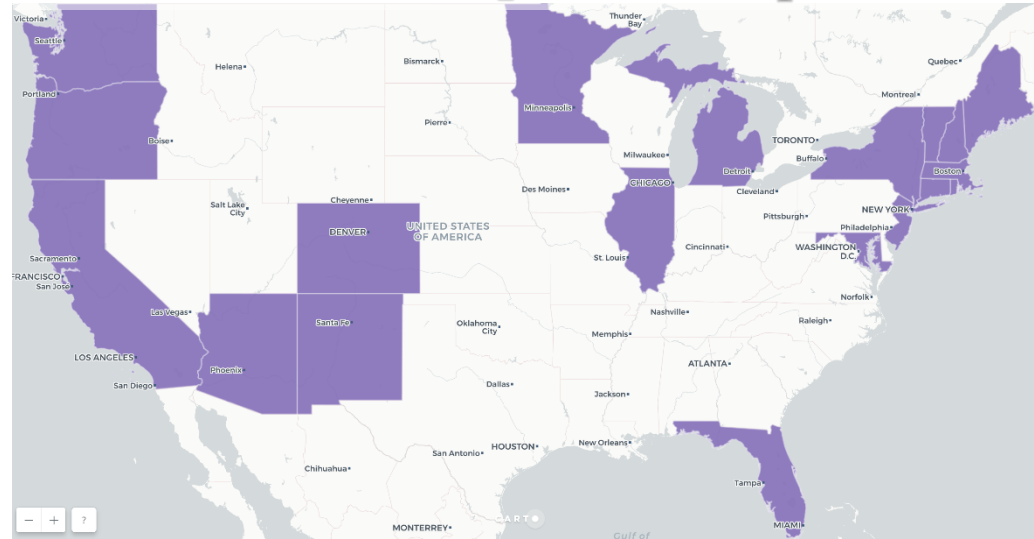


6,149 followers

Norway has set its sights on creating the world's first zero emissions control area (ZECA)



US states with CO₂ reduction policies

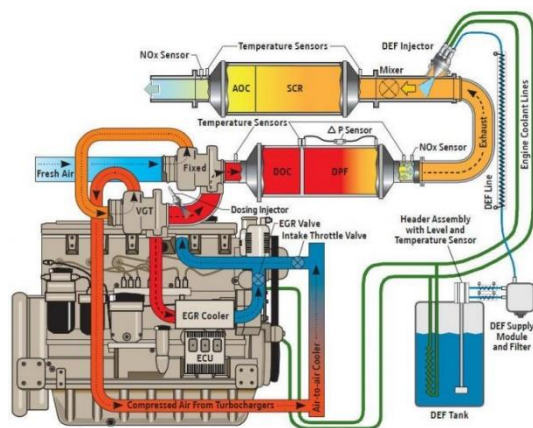


Governments with Carbon Taxes:

British Columbia, Chile, Costa Rica, Denmark, Finland, France, Iceland, Ireland, Japan, Mexico, Norway, South Africa, Sweden, Switzerland, UK

Emission Reduction Technology Options

Tier 4 Diesel



NO_x: Low
SO_x: Low
CO₂: no change
(0 if biofuel)

Electric Hybrid



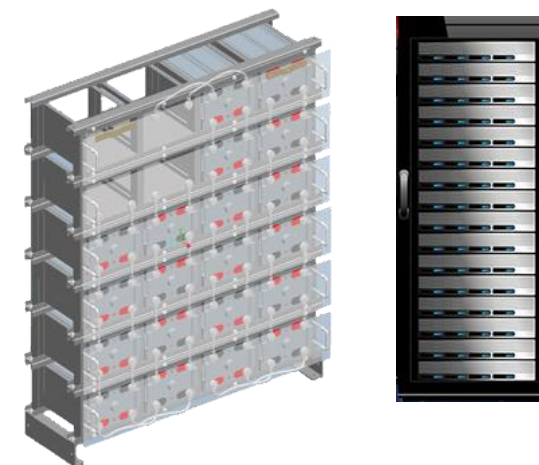
NO_x: Low
SO_x: Low
CO₂: 10%-40% lower

LNG



NO_x: Low
SO_x: 0
CO₂: +/- 10%

All-electric Battery or Hydrogen Fuel Cell



NO_x: 0
SO_x: 0
CO₂: 0

Now

Next

Bridge

Final

Many kinds of vessels can be powered by zero emission propulsion systems



Batteries and fuel cells offer complimentary solutions, enabling all kinds of vessels to run with zero emissions

Best Application Space



Higher Power

Lower Power



Battery

Fuel Cell

Either

Fuel Cell

Shorter Range



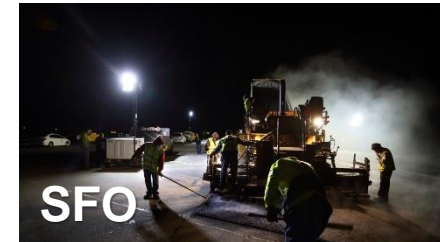
Longer Range



Fuel cell: Directly converts hydrogen to electricity, and is used all around us today.

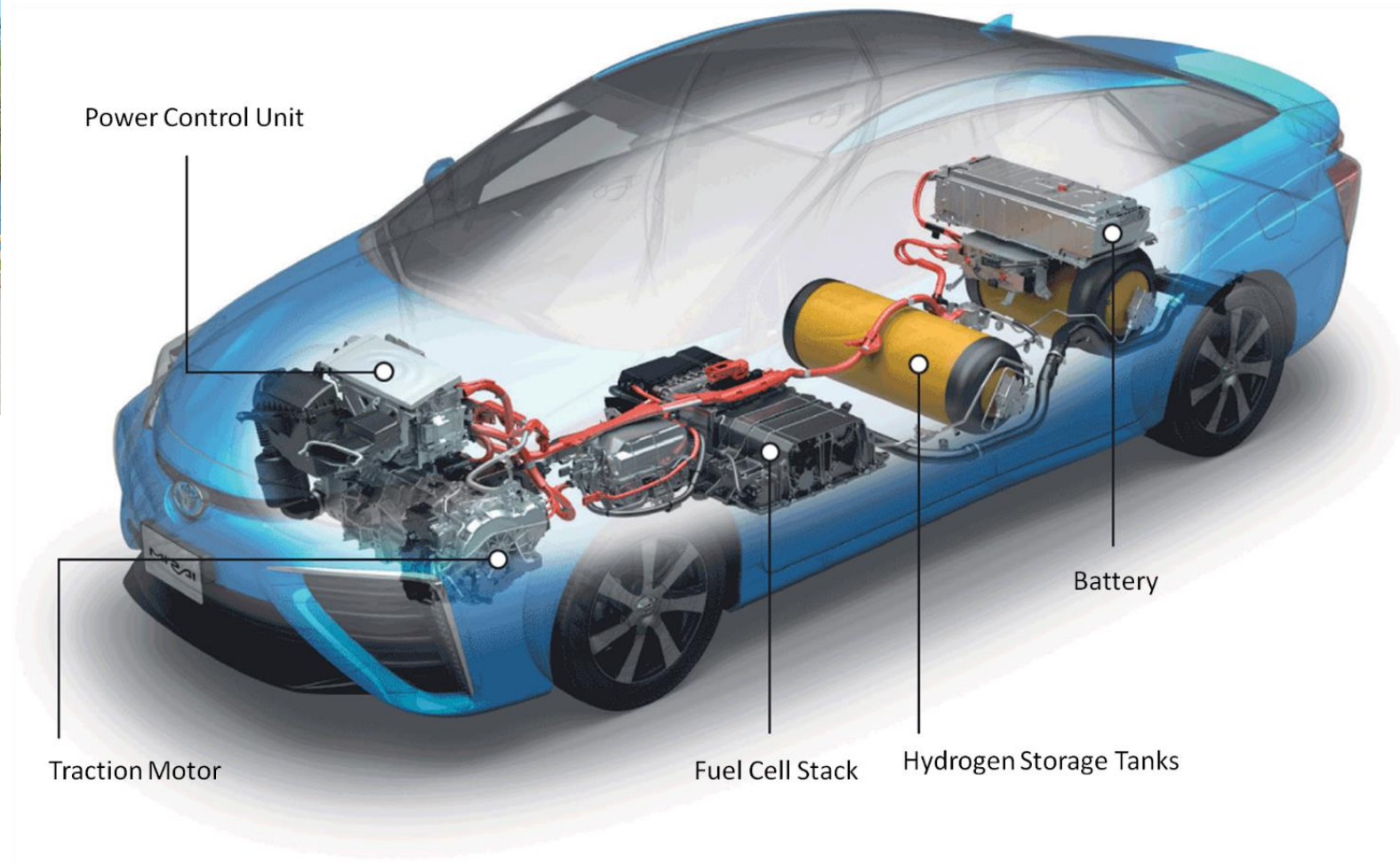


Going In: H_2 and air
Going Out: Electricity
Water
Heat (150 F)
Warm humid air

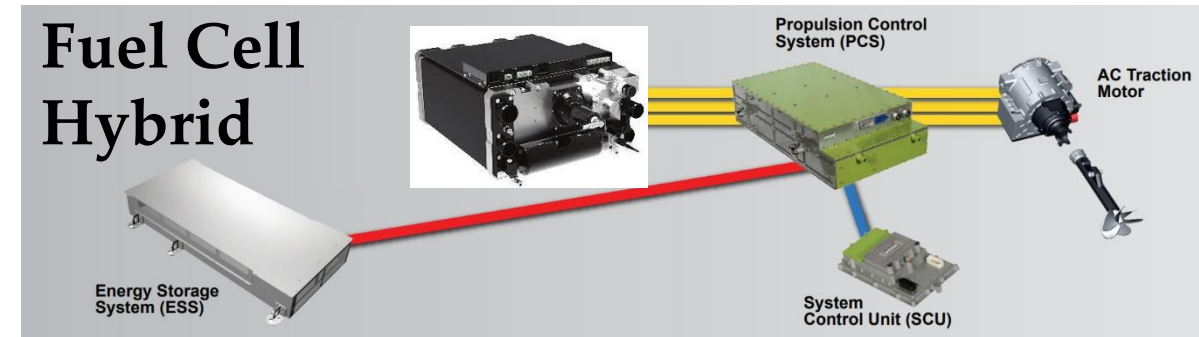
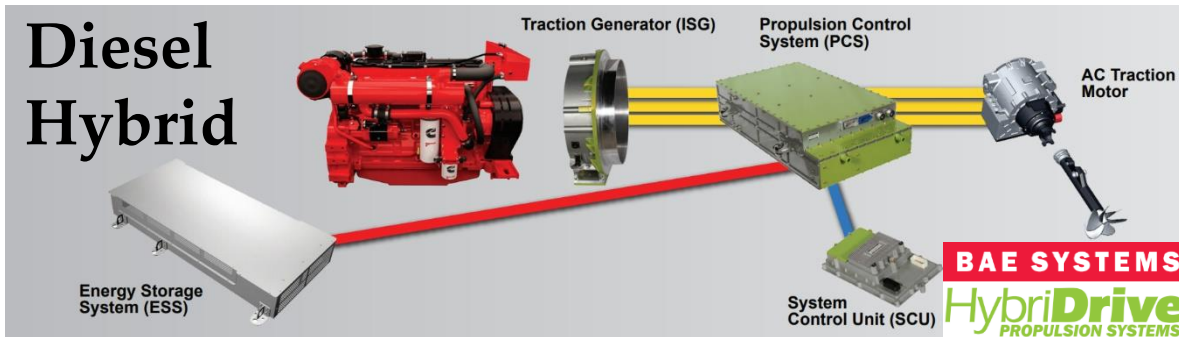


How a fuel cell car works

Toyota Mirai



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



Enhydra

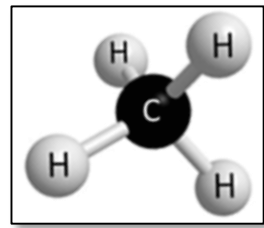


*Matthew
Turner*



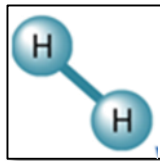
*Water-
Go-Round*

Hydrogen: Similar to natural gas, but does not contain carbon. It is also the lightest gas.



Natural gas / LNG

energy
water
CO
CO₂
CH₄
NO_x (smog)



Hydrogen / LH₂

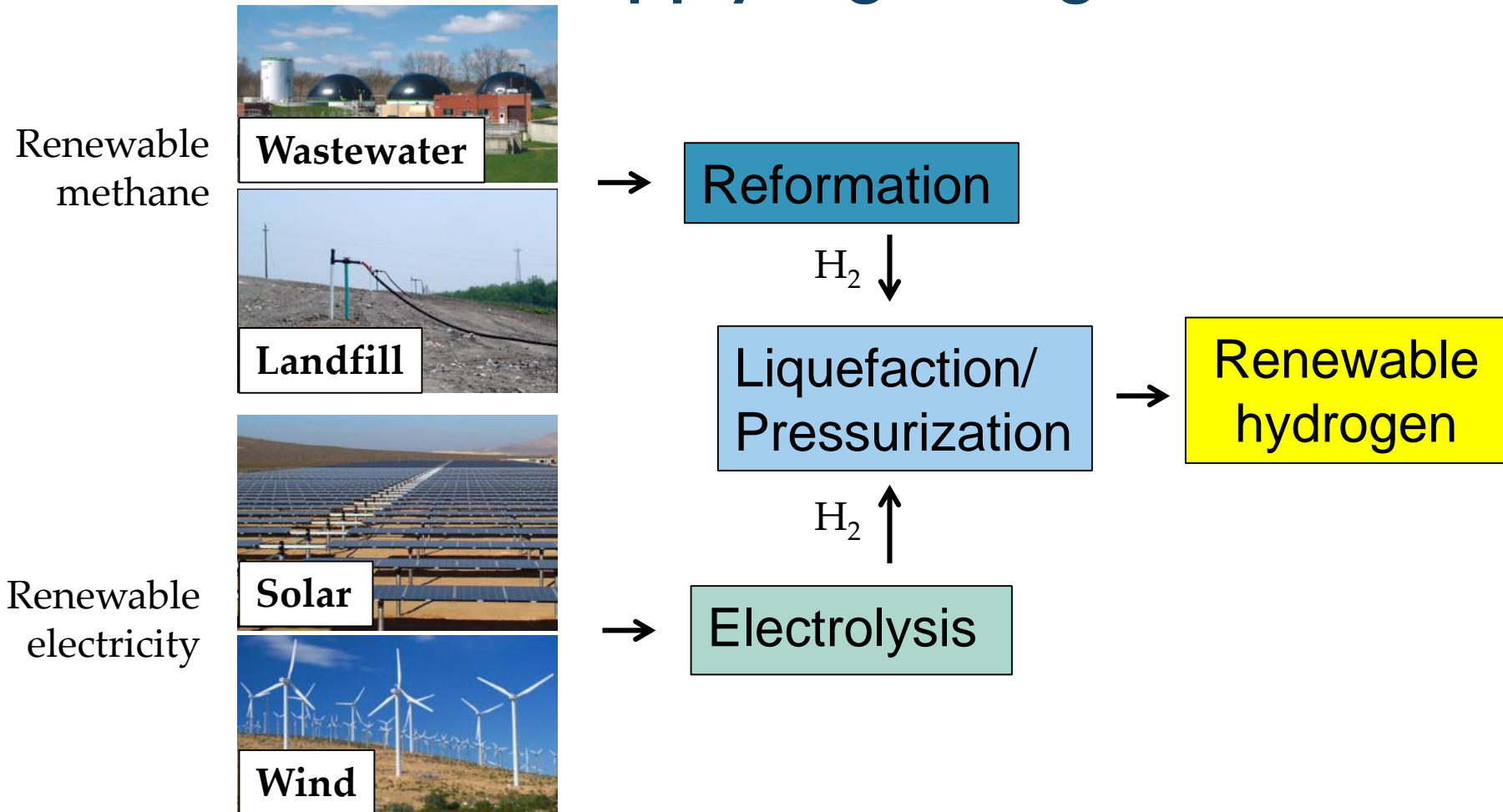
- Non-toxic
- Not a GHG
- No possible water contamination if spilled

Travels upward at ~45 mph
(8 stories in 5 seconds)



NG H₂

Most hydrogen today is made from natural gas, and has emissions during production. But 100% zero-carbon hydrogen is available and supply is growing.



Ways to Store Hydrogen for Transportation

- High pressure gas

~2,000 psi steel
or aluminum



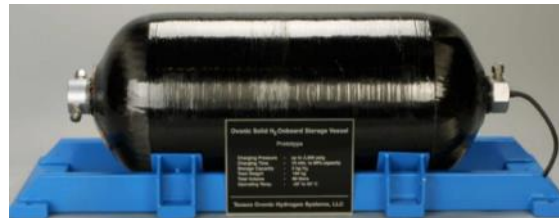
5,000-10,000 psi carbon fiber
composite tanks



- Liquid (-253 C)



- Experimental



Hydrogen vessels can be fueled in ways similar to conventional fuels or LNG

Diesel



LNG



Gaseous H₂

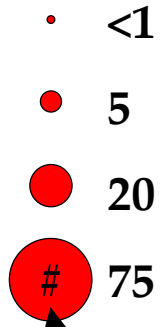


LH₂

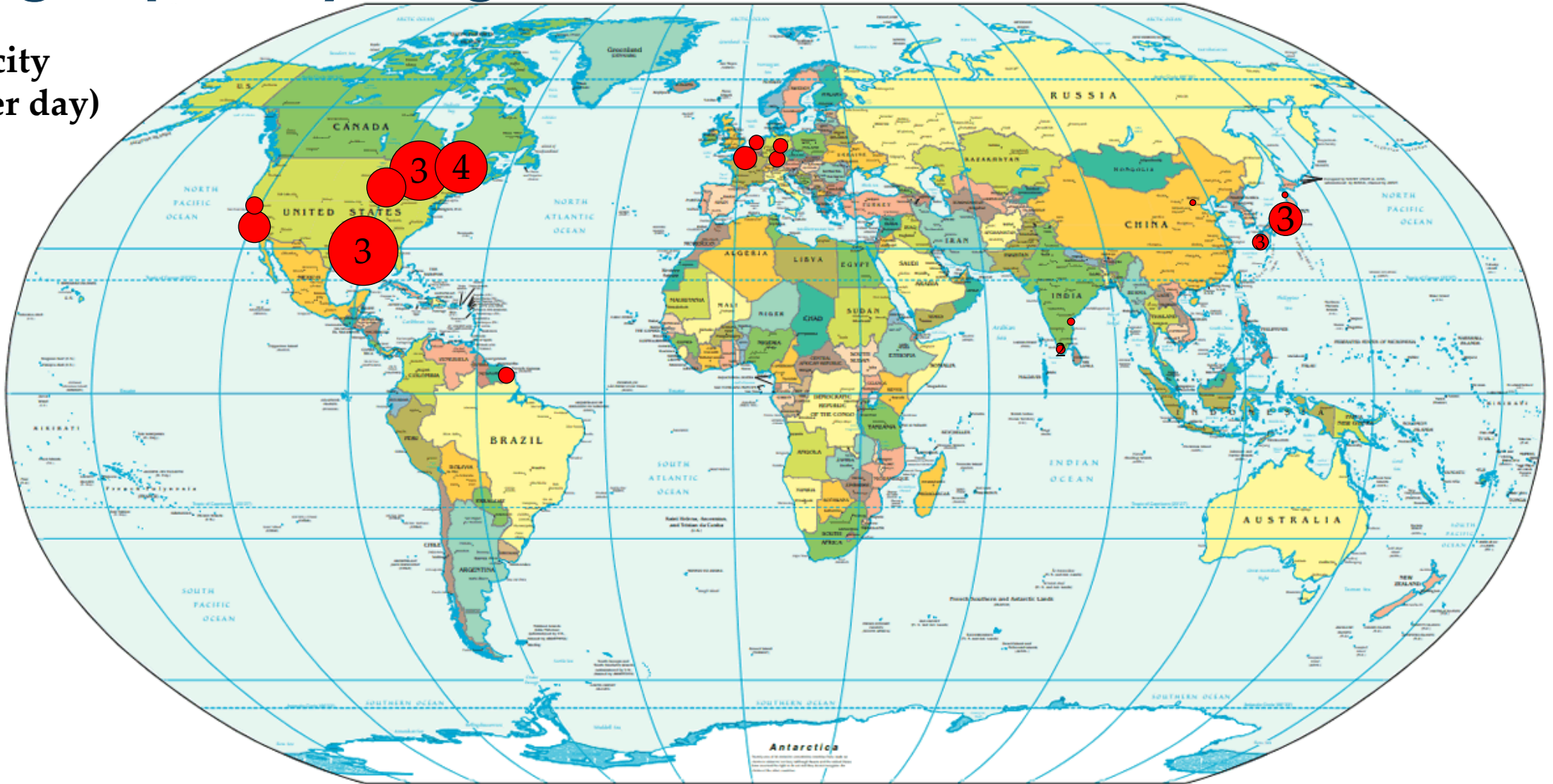


Existing Liquid Hydrogen Production Facilities

**Plant Capacity
(metric tons per day)**

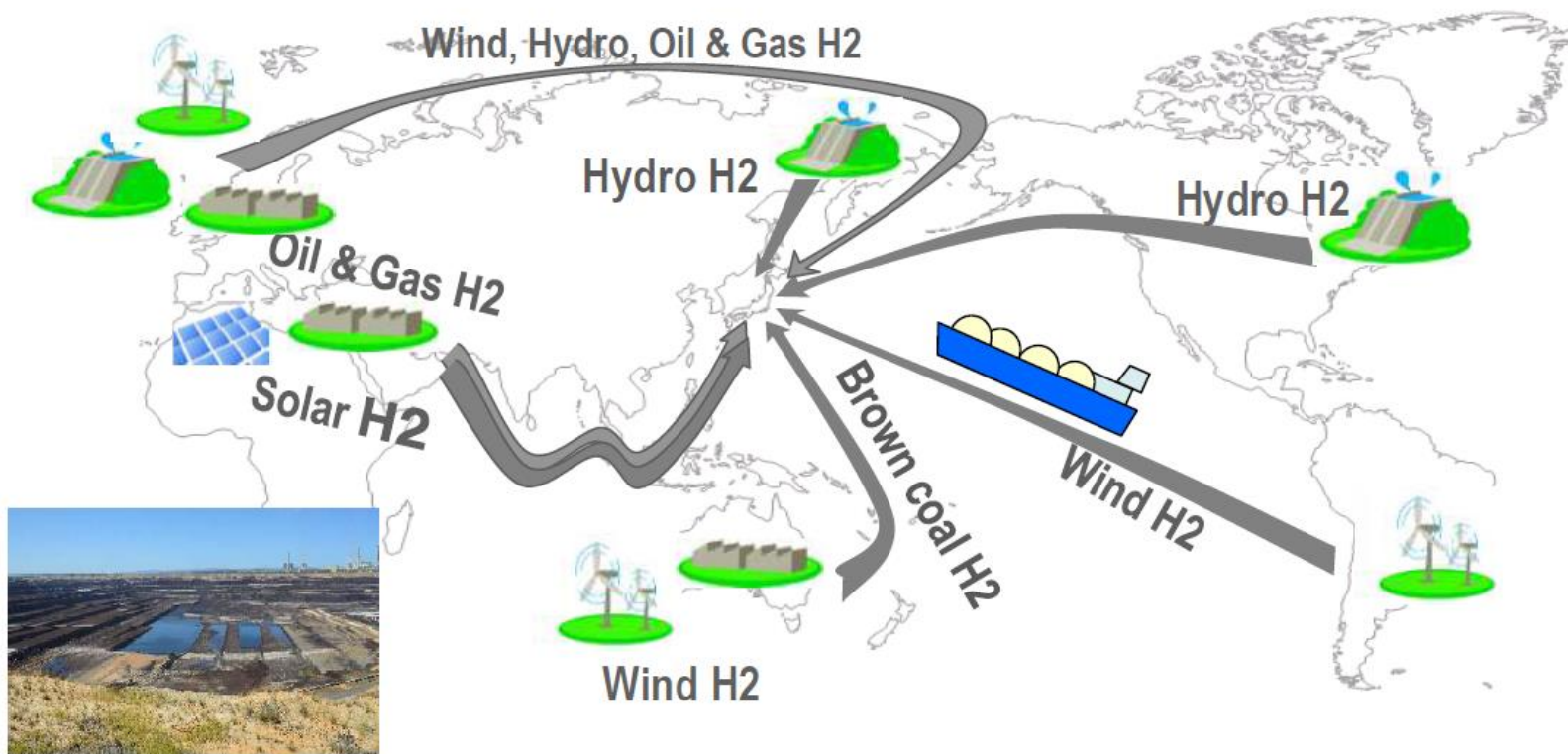


Number of clustered facilities



Global LH₂ production is expected to ramp up

Hydrogen Energy Consuming Society in Japan Potential from Overseas





Cleaner
Lower Cost
Better

Learn More
Visit

ggzeromarine.com
watergoround.com

Contact

Joe Pratt

+1-510-788-5101

jpratt@ggzeromarine.com

The Water-Go-Round Launching Fall 2019

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

