



**CALIFORNIA HYDROGEN
BUSINESS COUNCIL**

California Hydrogen Business Council

Hydrogen and Fuel Cells in the Ports

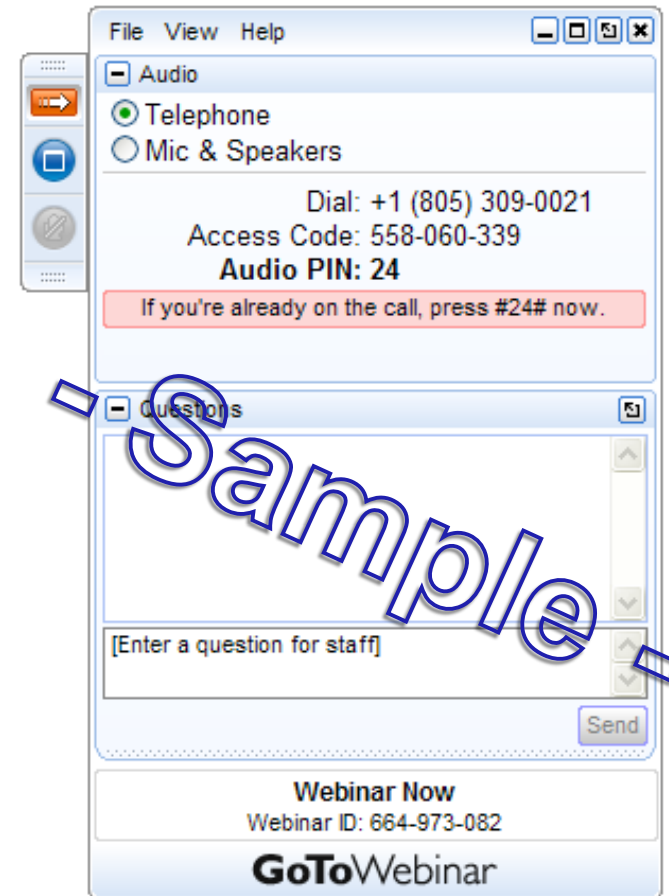
- A CHBC Webinar -

March 2, 2017

www.CaliforniaHydrogen.org



- Two Audio Options: Streaming Audio and Dial-In.
 - Streaming Audio/Computer Speakers (Default)
 - Dial-In: Use the Audio Panel (right side of screen) to see dial-in instructions. Call-in separately from your telephone.
- Ask questions using the Questions Panel on the right side of your screen.
- The recording of the webinar and the slides will be available after the event. Registrants will be notified by email.





Webinar Speakers & Outline

- Welcome – Emanuel Wagner
- Overview of Workshop and Report Highlights – Cory Shumaker
- Ports Perspective & Next Steps - Rick Cameron
- Stationary Hydrogen Industry Perspective & Next Steps - Ryan Sookhoo
- Mobile Hydrogen Industry Perspective & Next Steps - Dr. Abas Goodarzi
- Discussion/Q&A

MEMBER ORGANIZATIONS

Platinum



Gold



Silver



Innovators



Affiliates



Our Members Include:

- Hydrogen producers and distributors
- Automotive companies
- Public transit systems and suppliers
- Fuel cell, electrolyzer, compressor and storage manufacturers
- Fueling station developers, engineers and consultants
- Municipal, state and federal agencies
- Component suppliers



CHBC Advocacy

- Overall goal is inclusion of Hydrogen and Fuel Cells in transportation, energy and clean air decisions made in Sacramento & beyond

CHBC Market Sector Action Groups (SAGs):

- Hydrogen Energy Storage and Renewable Hydrogen
- Heavy Duty Transportation, Goods Movement, and Clean Ports
- Public Transportation
- Strategic Communications

CHBC Programs and Events

- Private Financing of Hydrogen Refueling Stations
- Roadmap to Renewable Hydrogen
- Heavy Duty Trucking with Hydrogen and Fuel Cells
- Public Transit Powered by Fuel Cells
- Hydrogen and Fuel Cells in the Ports

Signature Event

- 2017 California Hydrogen and Fuel Cell Summit in September 25-27 (Sacramento)



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Overview of Workshop and Report Highlights



Cory Shumaker

Project Coordinator

California Hydrogen Business Council

HYDROGEN AND FUEL CELLS IN THE PORTS WORKSHOP



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Nov. 10, 2016
BANNING'S LANDING - PORT OF LA

- Over 100 attendees, including 20+ port/terminal staff
- Purpose:
 - Start a dialog between the California ports and hydrogen solution providers
 - Show how hydrogen can play a role to help achieve the goals set by both Southern California ports in the CAAP (Clean Air Action Plan)
 - Discuss funding methods available for projects



The Ports of Los Angeles and Long Beach

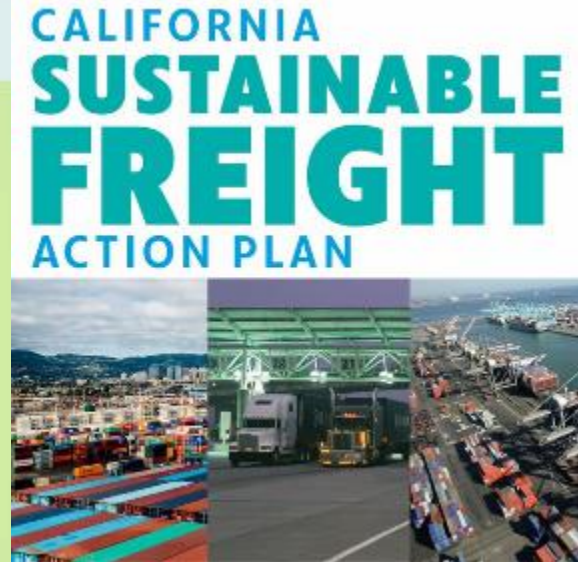
- Account for nearly half of all goods imported into the US
- POLB: 27 terminals; POLA: 22 terminals
- Port of Long Beach's "Energy Island Initiative" encourages testing of hydrogen equipment in the port environment





Regulatory Situation

- Governor Brown's EO B-32-15 created the California Sustainable Freight Action Plan 2030 targets:
 - 100,000 zero emission freight vehicles and equipment
 - Funding pilot projects in advanced technology for truck corridors and corridors at border ports of entry





Opportunities and Challenges for Hydrogen in the Ports

- The Ports (LA & LB) are currently experiencing a transformation in the harbor to move toward greener technologies
- Hydrogen has been predominately absent in the ports
- Maritime industry is not informed about hydrogen solutions
- Cost and economics of hydrogen solutions are key
- Other important considerations are reliability, relatability, scalability, and fueling infrastructure

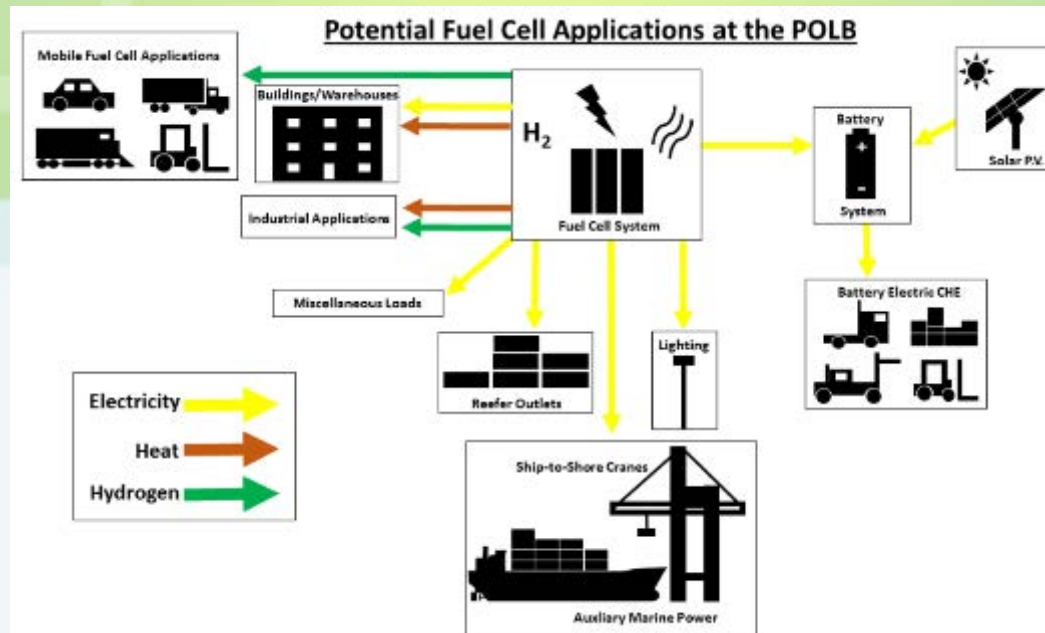


Hydrogen Mobile Application Solutions

- Fuel cell forklifts have become commercialized
- Demonstrations are underway of other heavy duty vehicles such as Class 8 drayage trucks
- Hydrogen mobile applications can be broken down into the following categories:
 - Captive fleet
 - Tethered local fleet
 - Regional fleet
- Critical issue is hydrogen fueling infrastructure

Hydrogen Stationary Application Solutions

- Port tenants have individual utility grid connections
- Port of LA energy demands are projected to increase from 115MW peak to 160MW peak by the year 2022
- Port is a great application for tri-generation system





Hydrogen Supply Solutions for Ports

- Hydrogen production and delivery is a mature industry
- Possible ways hydrogen can be accessible at the port:
 - Delivered
 - Produced onsite using electrolysis or tri-generation system





Government Programs and Funding Opportunities for Hydrogen Applications in Ports and Freight

- SCAQMD: “No longer a black box to achieve air quality”
 - Funding for hydrogen projects in AQMP
- CARB administers project funding from Proposition 1B
- CEC ARFVTP funds both fueling and vehicle projects
- DOE wants CARB/CEC to lead fuel cell deployments
 - Working with MARAD on projects with containerized fuel cells
- FHA has CMAQ, 20,000 projects funded since 1991
 - 12 hydrogen projects
 - \$254M set aside for Southern California



Purpose for Zero Emission Technologies: Community/Environmental Perspective

- “The Californians who live near ports, rail yards, and along high traffic corridors, are subsidizing the goods movement sector with their health.”
- No community should be burdened with more environmental impacts than any other
- “Right now is the time for opportunity and [we] have a chance to make an impact.”
- Advocacy groups can be a resource.



Next Steps/Activities

- **Workshop Report – Completed; Available online**
- **Summary of Workshop Report Webinar**
- **Freight Workshop – Scheduled for May 1st, 2017 at the ACT Expo**
- **Subsequent follow-up workshop – Fall 2017, possibly at California Maritime Academy**



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Ports Perspective & Next Steps



Rick Cameron
Managing Director
Port of Long Beach



Port of
LONG BEACH
The Green Port

Rick Cameron
**Managing Director of Planning
and Environmental Affairs**

2015 AIR INVENTORY

Diesel
Particulate
Matter

Down

84%

2023
77%

From 2005 Baseline

Nitrogen
Oxides

Down

48%

2023
59%

Sulfur
Oxides

Down

97%

2023
93%

Greenhouse
Gases

Down

14%

Up 7%

TEUs

2017 CAAP UPDATE

Supports the State's Sustainable Freight Action Plan

Establishes New Long-Term Greenhouse Gas Reduction Goal

Proposed Strategies:

- Clean Vehicles, Equipment Technology and Fuels
- Freight Infrastructure Investment and Planning
- Freight Efficiency
- Energy Resource Planning



Building the **ZERO EMISSIONS**
PORT OF THE FUTURE

DRIVERS for the ENERGY INITIATIVE

Support Zero Emission Port of the Future

Mitigate vulnerability to outages

Provide cost stability and predictability

Provide added value to our customers

Create new business opportunities

ZERO EMISSION EQUIPMENT NEEDS

Charging and Fueling Infrastructure

- Charging Standardization for Terminal Equipment
- Near-term anticipated demand
 - Tenants receiving grant funds for zero emission equipment
 - Need to develop charging infrastructure plan
- Potential for partnership with SCE
- Potential partnerships for hydrogen fueling

A nighttime photograph of a port. In the foreground, a large ship is docked, illuminated by bright lights. Several cranes are visible, extending over the ship. The background shows a city skyline with lights reflecting on the water. The sky is dark blue with some clouds.

ENERGY PILOT PROJECTS

Maintenance Yard

Joint Command and Control Center

ENERGY PILOT PROJECT OBJECTIVES

Assist in future **decision making** by building technical, financial and regulatory knowledge

Facilitate the development of **operational requirements** and **design criteria**

Support **implementation** through scalable projects



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Stationary Hydrogen Industry Perspective & Next Steps



Ryan Sookhoo

**Director New Initiatives
Hydrogenics Corporation**



HYDROGENICS

SHIFT POWER | ENERGIZE YOUR WORLD

Stationary Port Applications Webinar

Presented by: Ryan Sookhoo
March 2, 2017

Global Leader in Hydrogen Technology

Our raw materials,
water & renewable power are
infinite!

2,000+
fuel cell sites

1 single focus:
hydrogen solutions

HYDROGENICS

**Publicly
traded**

NASDAQ (HYGS) and
TSX (HYG) since 1995

500+
electrolysis plants
in operation

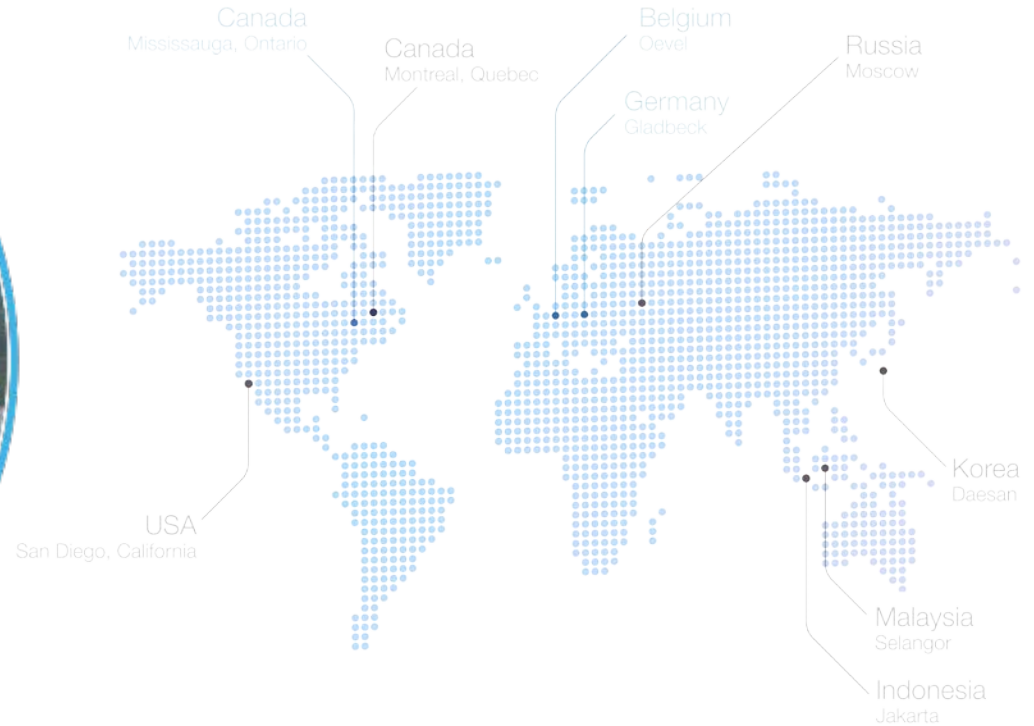
Global leader

in 2 main hydrogen technologies:
electrolysis and fuel cells

65+
years
of experience

1,500+
electrolysis plants
sold since 1948

Shifting Power Across Industries Around the World



Bridging the Gap

Takeaways from the Ports Workshop:

- Poised to significantly increase commercial traffic in the next 5 years
- Day to day operation is measured by the lbs and extremely efficient
- New technology adoption cannot be disruptive to existing operations
- Competitive operating environment
- New technology needs to align with Ports' road maps for commercial growth
- Higher fuel cost and environmental ownership are key drivers

Maritime Fuel Cell System

Ecological and Economical Drivers

- Emission reduction
- Renewable alternatives
- Higher fuel cost
- Improve health
- Energy *Diversity*



Source: officerofthewatch.com





Istanbul, Turkey



Port of Honolulu, Hawaii, USA



Daesan, South Korea

CRITICAL POWER



Surrey, United Kingdom



Nuuk, Greenland



Brisbane, Australia

An Established Leader with Established Technology

Alstom, Germany

- World's first commercial contract for hydrogen fuel cell trains
- 10-year agreement, contract value of €50M



Kolon, S. Korea

- Providing MW power using excess hydrogen
- Multi-MW fuel cells running 24/7



Uniper, Germany

- MW-scale Power-to-Gas facility in Germany
- Wind power and Hydrogenics electrolysis equipment to transform water into hydrogen



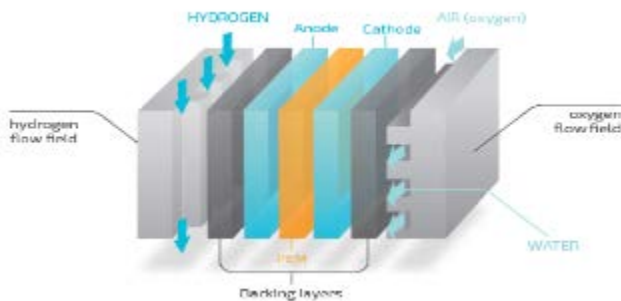
Fuel Cell Buses, China

- Multiple agreements for thousands of fuel cell buses throughout China in the next 2-4 years



Our Fuel Cells: Robust & Reliable

Fuel cells use hydrogen to create electricity for **mobility** and **critical power applications**



1 Fully Integrated Systems

Integrated software and mechanical control

2 Differentiated Technology

Non-humidified, low-pressure stack

3 High Reliability

Unlimited start/stop, sub-zero operation

4 Flexible Architecture

Scalable stack for mobility and stationary applications

Critical Power Solutions

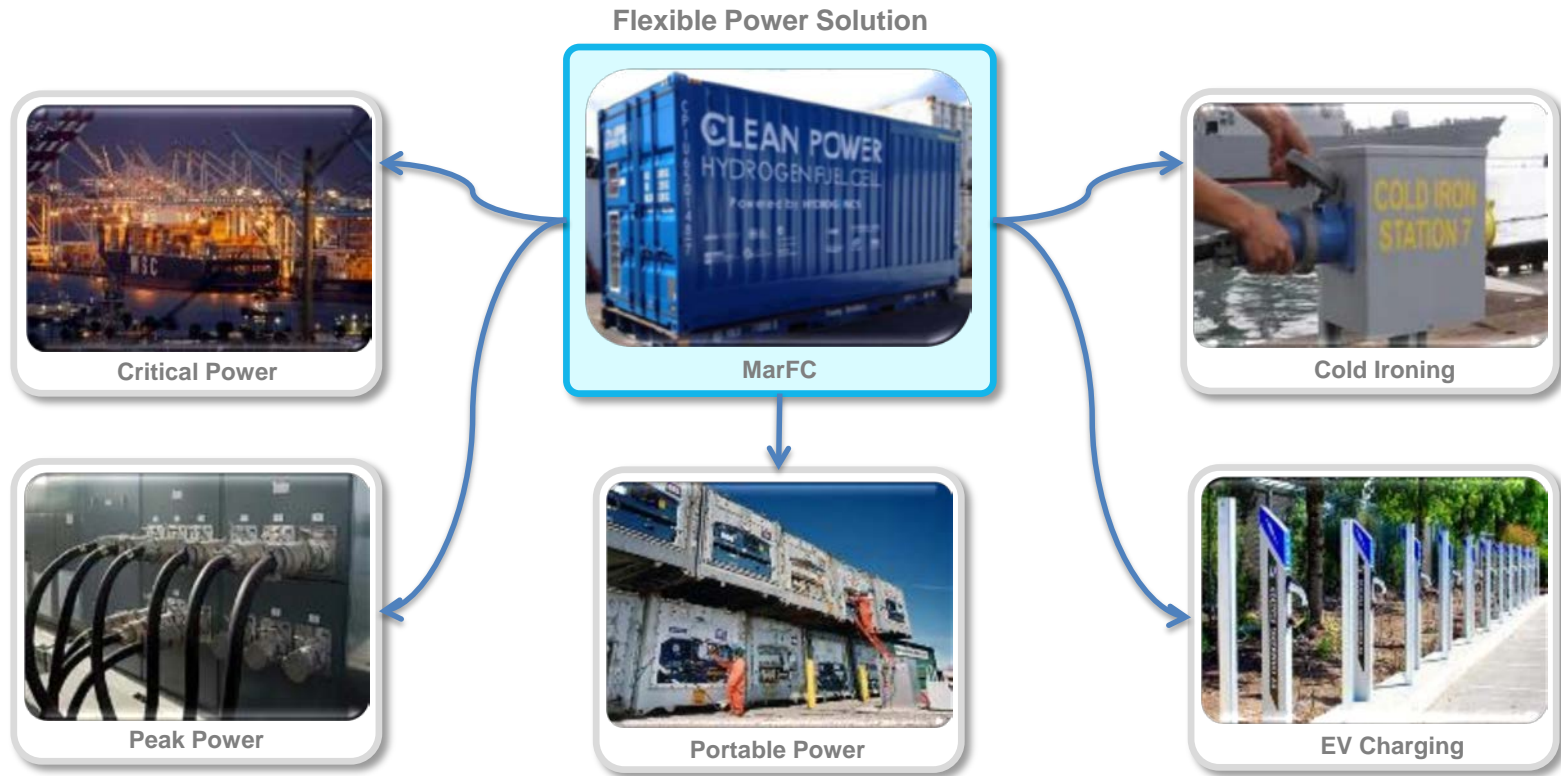
Hydrogenics HyPM™ power modules set the technology benchmark for meeting intermittent and continuous power needs.

- Designed for superior performance
- Fully integrated stack with power range flexibility from 3kW to 50 MW
- Best footprint with scalable design solutions to meet runtime needs
- 10,000+ hour stack lifetime with unlimited stop and start cycles
- Greatest range of kW systems



The ultimate solution for reliable backup, standby and continuous power applications

Operational Energy = Diversity + Reliability



Moving Forward...



Hawaii Honolulu (USA)

MarFC 100kW Generator @ 1,000 kW-hr of continuous operation

OBJECTIVES:

- Replace diesel generators used to power refrigerated containers (“reefers”)

SOLUTION:

- 100kW fuel cell
- 75kg H2 storage
- AC output
- Turnkey portable solution



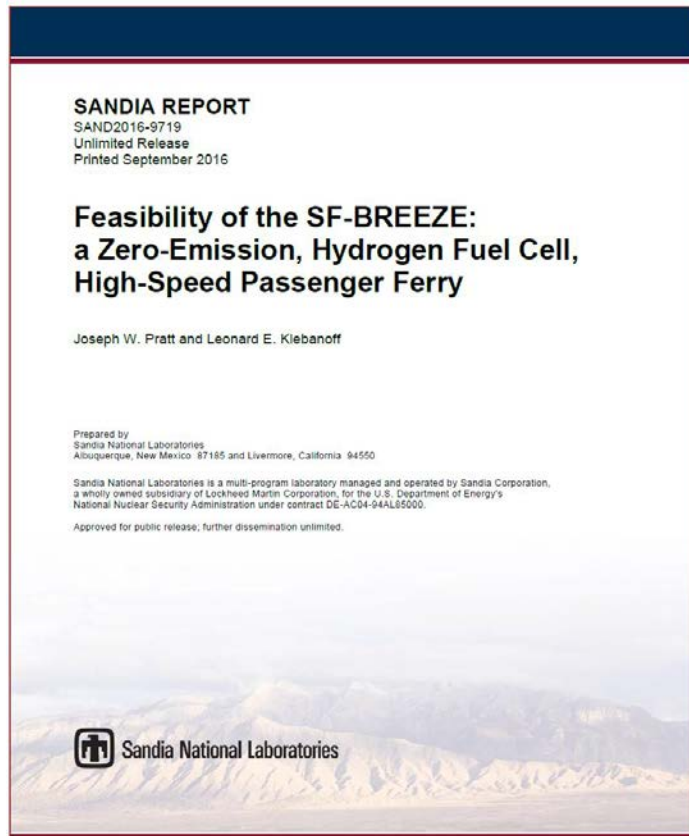
Source: www.sandia.gov



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Leveraging Experience



San Francisco Bay Renewable Energy Electric vessel with Zero Emissions

[Final Report Now Available for Download](#)



Source: www.sandia.gov

[San Francisco Bay Renewable Energy Electric vessel with Zero Emissions \(SF-BREEZE\)](#)

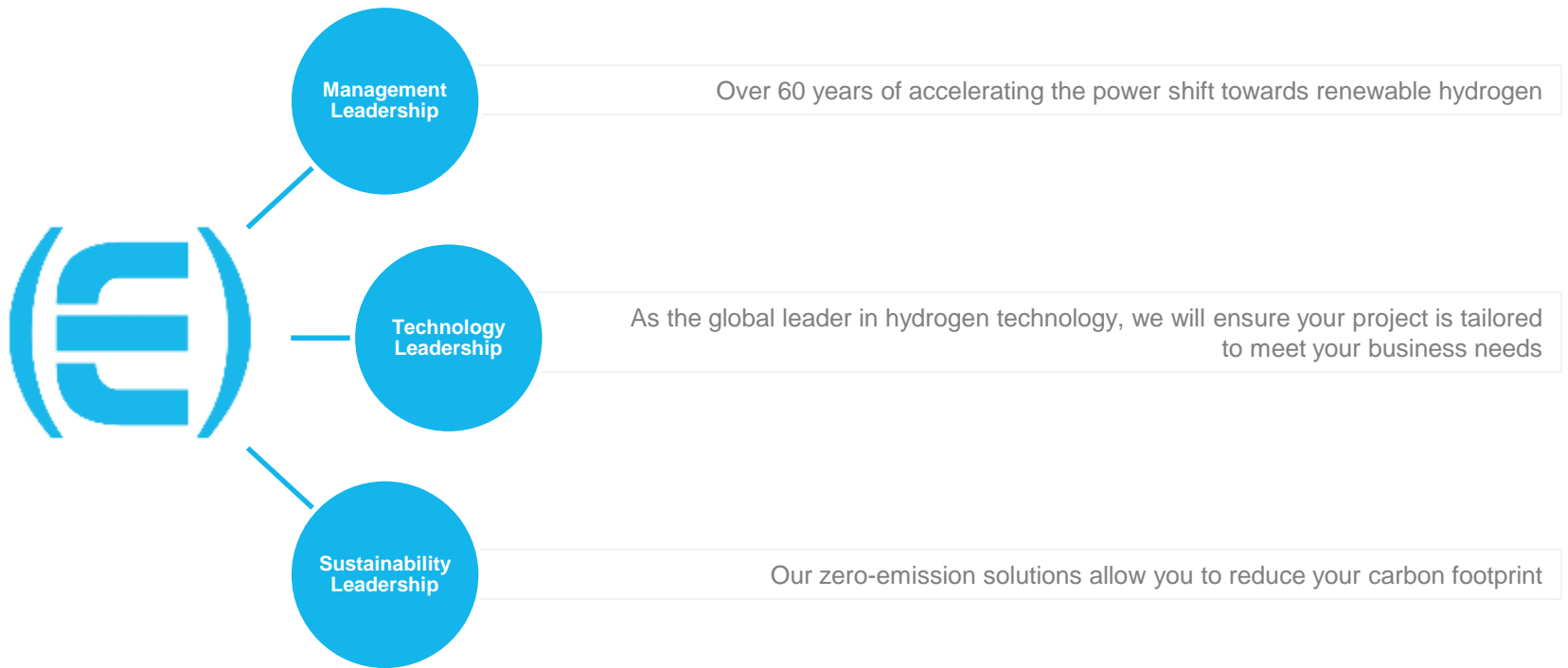
MarFC (Maritime fuel cell) – Sandia 100kW FC

- System design was done leveraging applicable land safety standards with modification for maritime conditions
- Given approval to be operated on a water vessel within US

SF-BREEZE

- Feasibility study - Technical, regulatory, and economic aspects. Funded by the US Department of Transportation's Maritime Administration

Moving Forward as Partners in Clean Technology



We're Ready



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Mobile Hydrogen Industry Perspective & Next Steps



Dr. Abas Goodarzi

**Founder and President of US Hybrid
Corporation and US FuelCell**

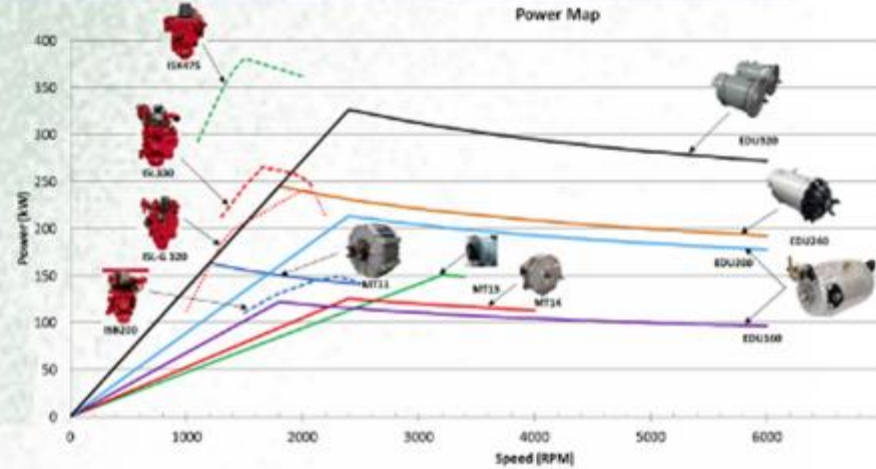


US Hybrid

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Hydrogen and Fuel Cells in the Ports - Status of the Industry and Next Steps

Integrated Electric, Fuel Cell and Hybrid Powertrain Components Powering Clean Mobility

More than 50% of energy is wasted due to urban traffic
More than 80% of emission is due to urban traffic



GVWR
1,800 kg



GVWR
20,450 kg
45,000 lbs.

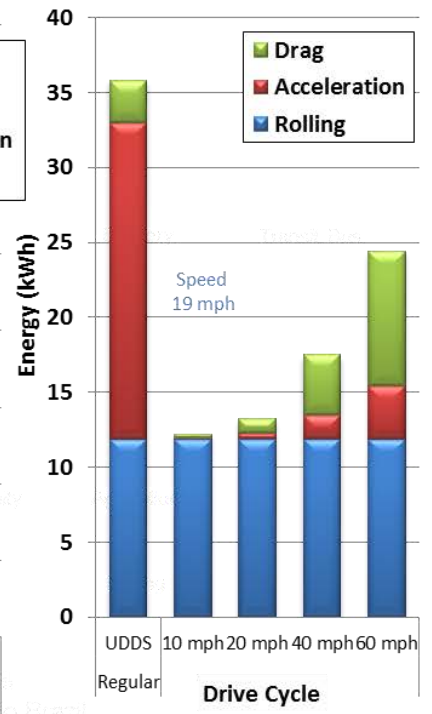
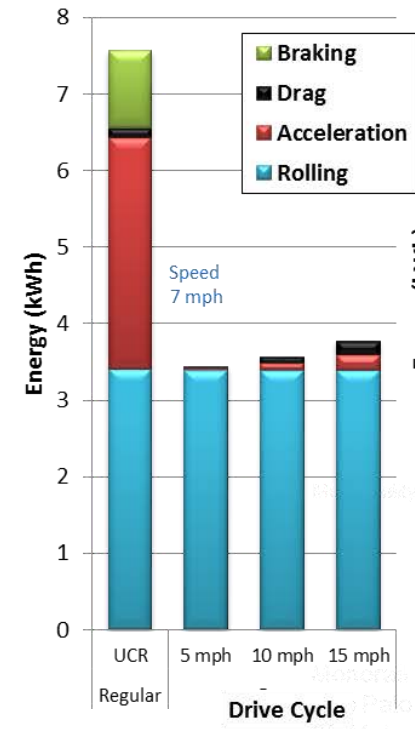
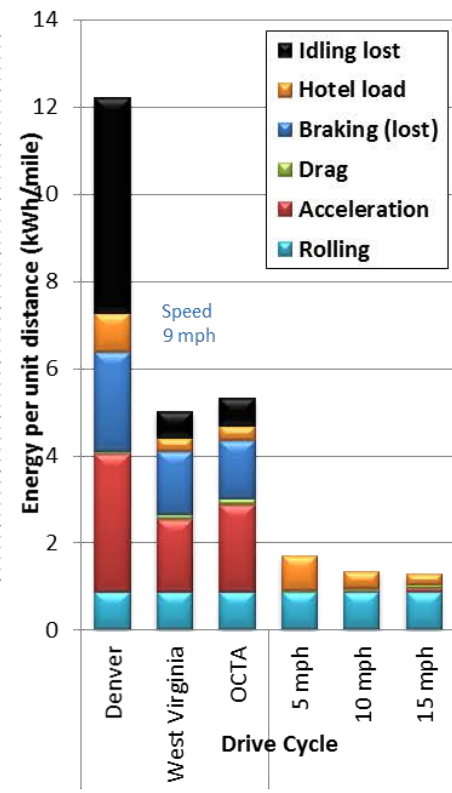
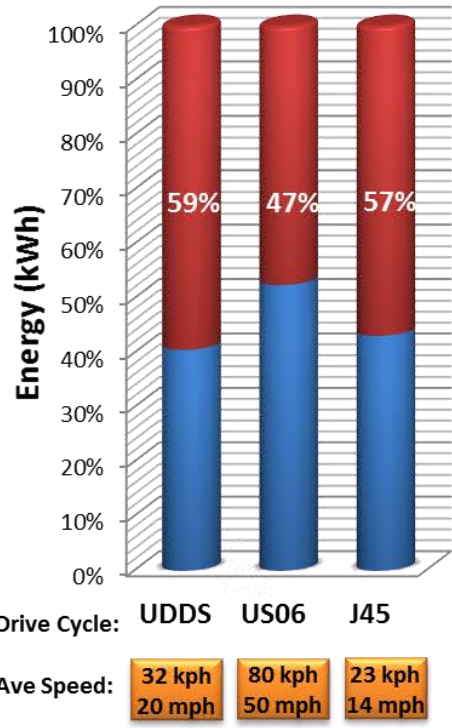


GVWR
36,300 kg
80,000 lbs.

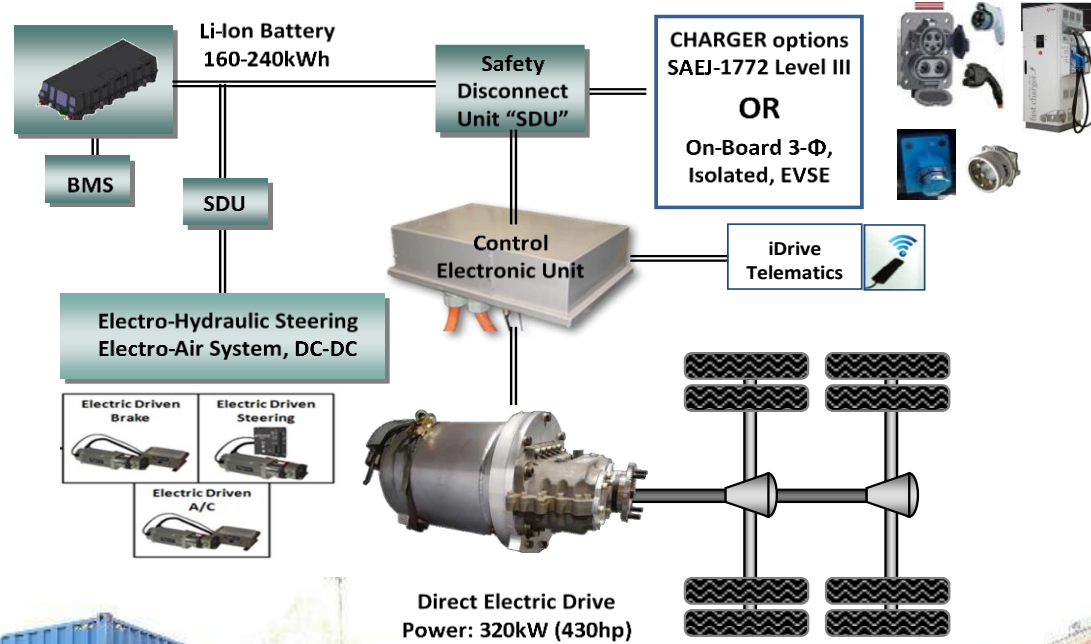


GVWR
29,545 kg
65,000 lbs.

■ Stop/Go (Traffic)
■ Constant

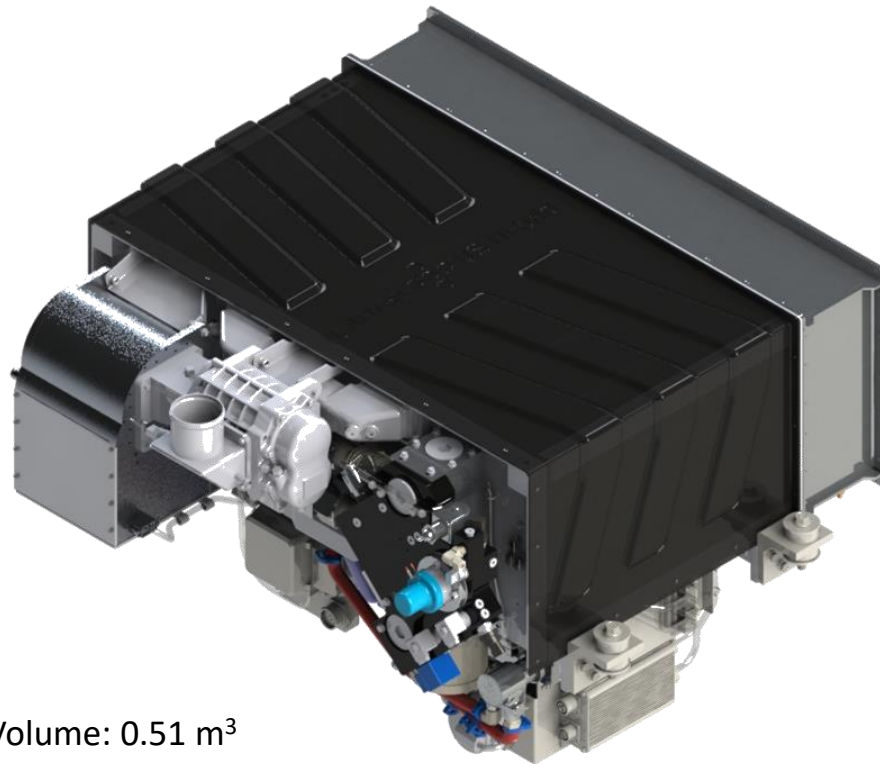
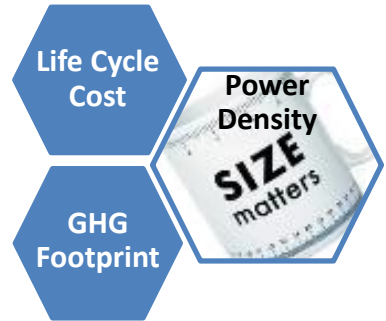


eTruck™ Electric Drayage Class-8 Truck



Electric Propulsion is the future Powertrain

Our Product: Integrated Fuel Cell Engine
for Medium and Heavy Duty Transportation



Volume: 0.51 m³
Weight: 240 kg



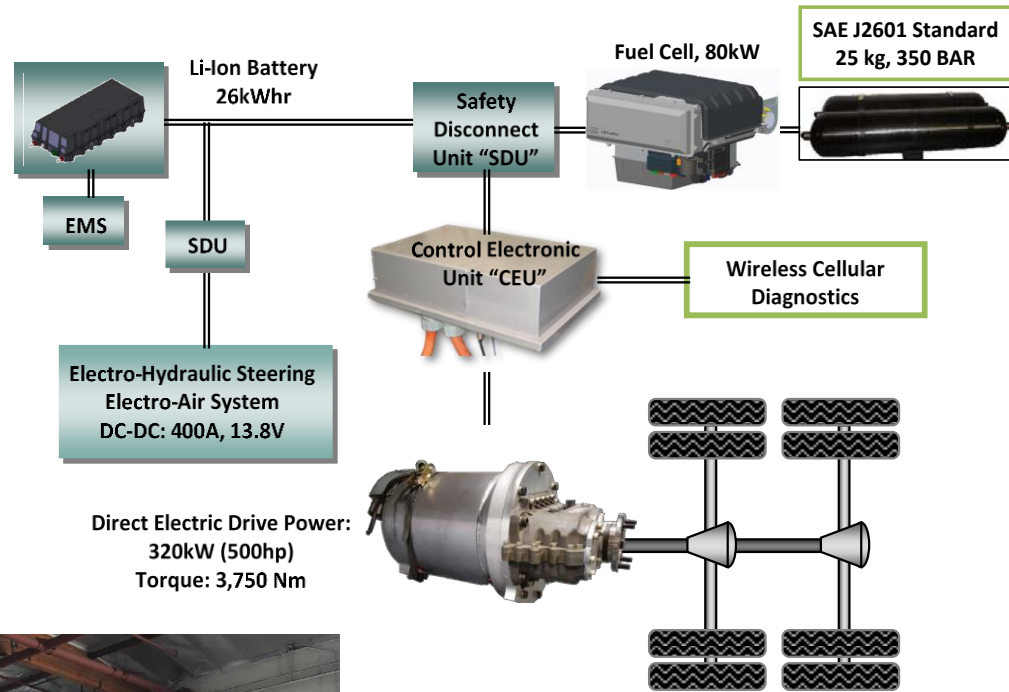
Volume: 1.6 m³
Weight: 998 kg

Hybrid
Electric

Plug-in
Hybrid

Battery
Electric

Fuel Cell
Electric

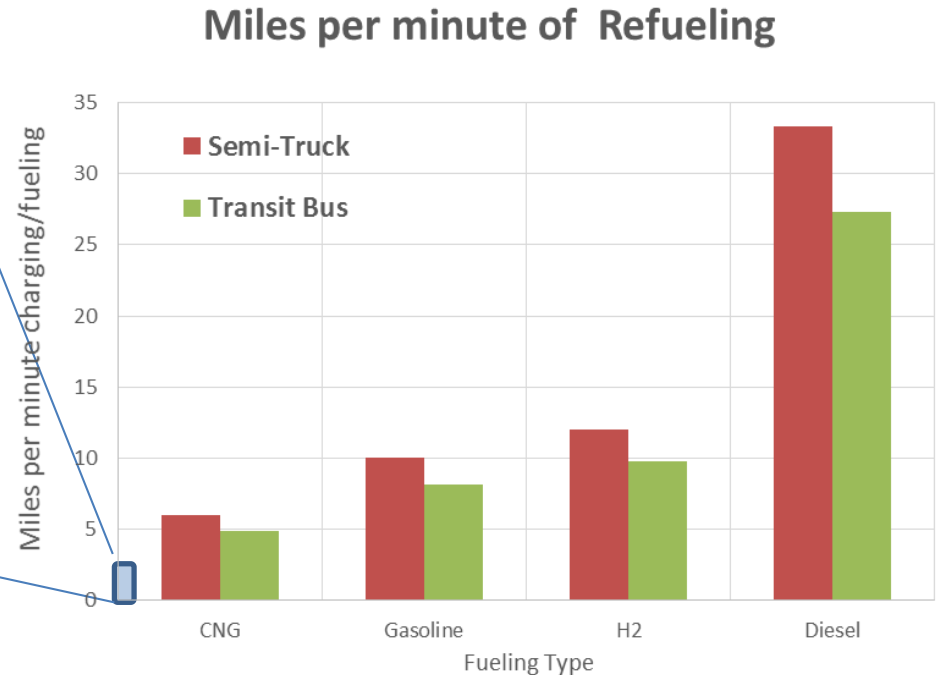
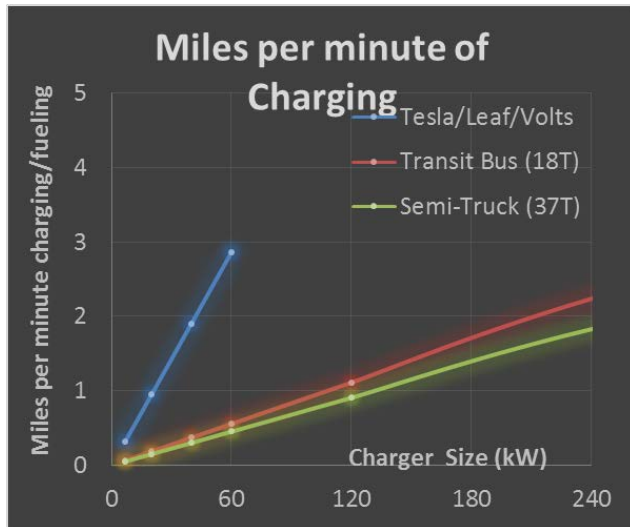


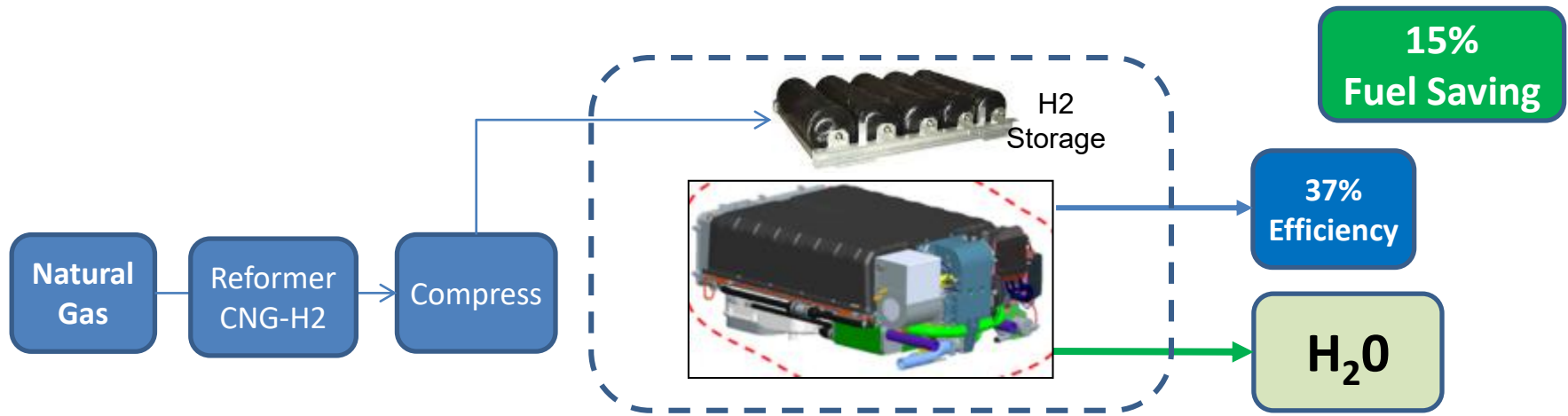
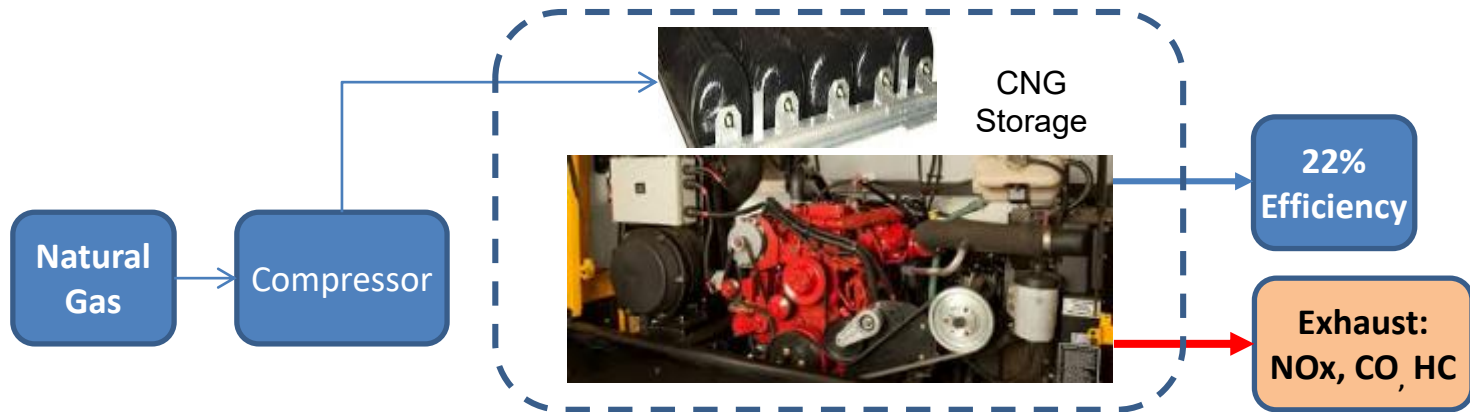
Truck Powertrain System Configuration



Fuel Cells is the key Zero Emission solution meeting Port demand;

1. Fast Fueling, multi-shift , 24/7 operation
2. Best use of fueling infrastructure (4-8 minutes fueling)
3. No range compromise
4. Most Efficient Zero Emission Cargo transportation
5. No cold climate impact





15% Energy efficiency Improvement for Truck Operation with No Tail pipe emission, No combustion and highest efficiency

- **Diesel:** 37.1 kWh/gal (Energy content),
- **Gasoline:** 32.9 kWh/gal, (Energy content),
- **Hydrogen:** 39.7 kWh/kg, (Energy content),
(1kg H2 = 11 gal @5000 psi, same as 2 gal of diesel fuel)
- **Energy Storage Density:** Li-Ion Battery

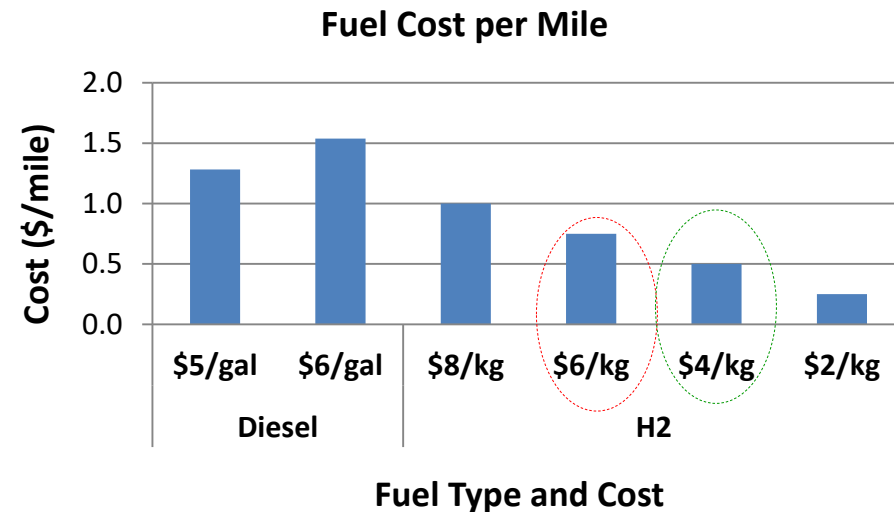
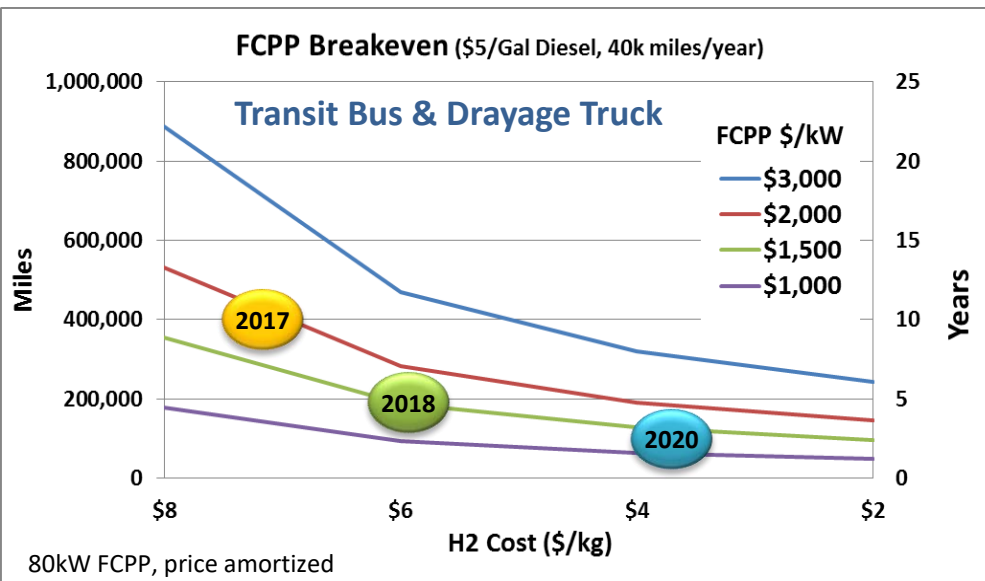
Engine Output: **4.5 kWh/kg**

Engine Output: **2.8 kWh/kg**

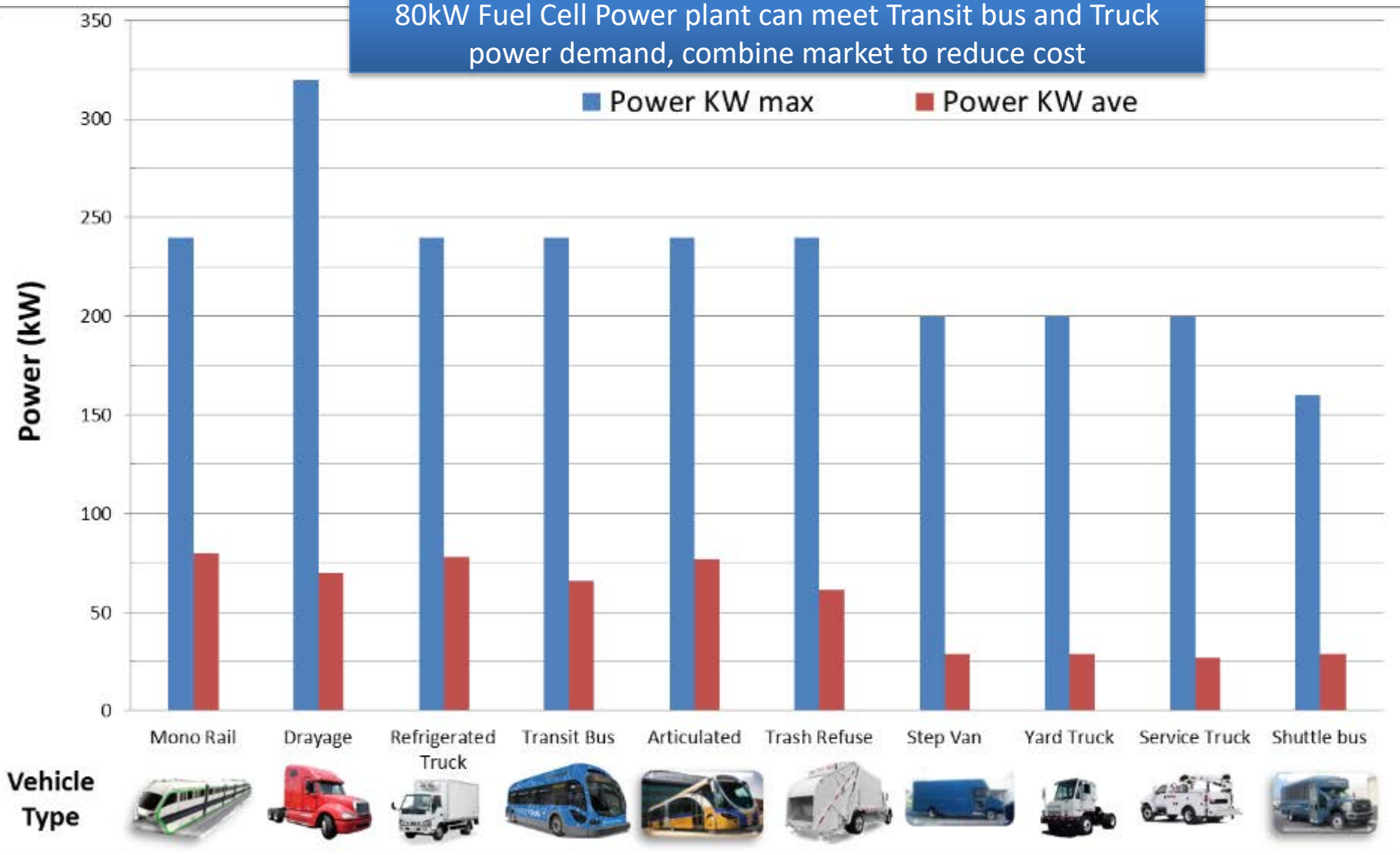
FC Engine Output: **15 kWh/kg**

0.11 kWh/Kg

1kg of H2 (8 miles/kg) > 2-Gallons Diesel (3.8mpg) 40' Transit Bus
1kg of H2 (12miles/kg) > 2.5-Gallons Gasoline (5 mpg) Shuttle Bus

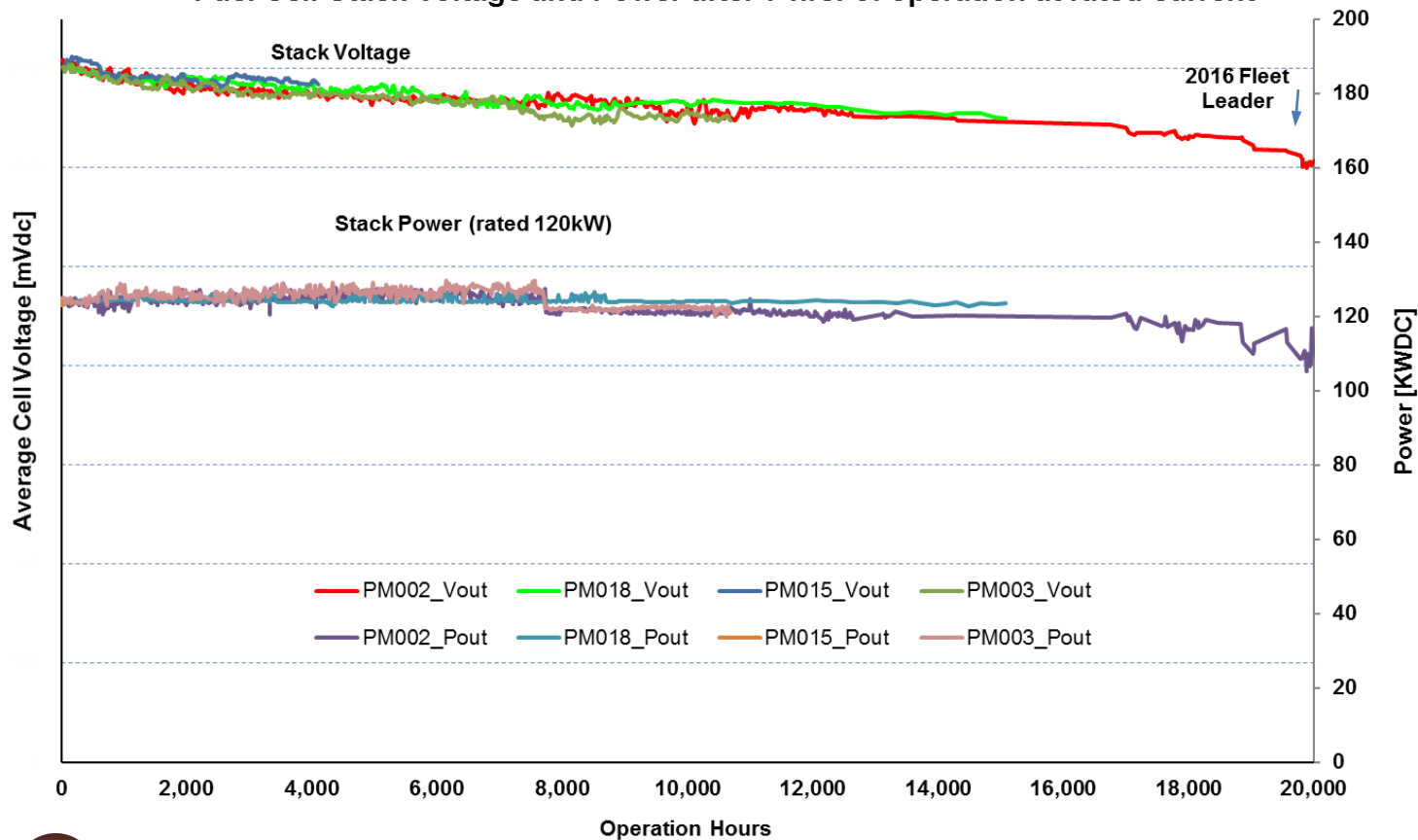


80kW Fuel Cell Power plant can meet Transit bus and Truck power demand, combine market to reduce cost

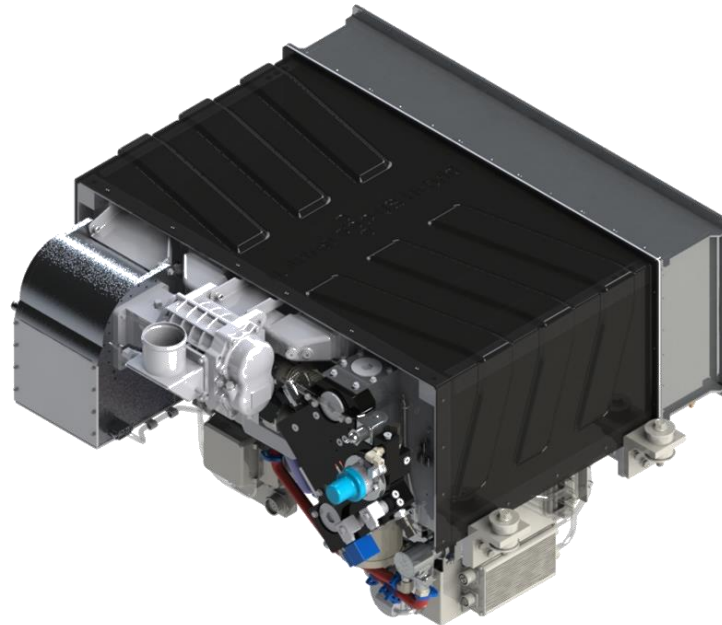




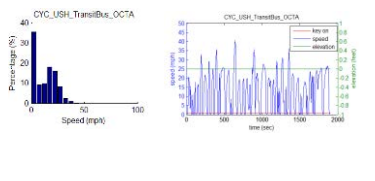









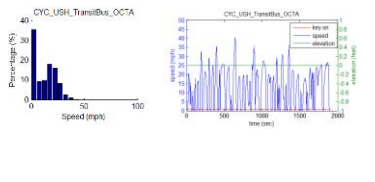



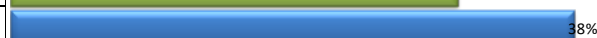


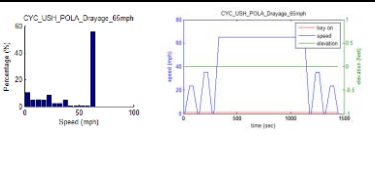






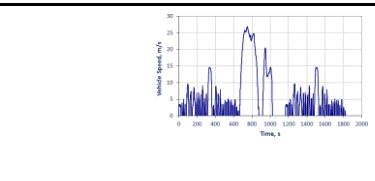






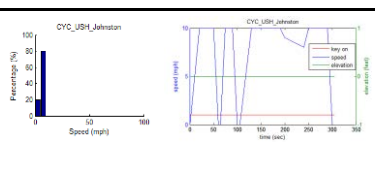




- PC40 Fuel Cell engine has exceeded **>23,000** hours of operation with **ZERO** failure
- Millions of Miles and hundred thousands of hours with Zero Stack failure

Fuel Cell Stack Voltage and Power after 7 hrs. of operation at rated current



**Cost competitive with
Euro-6 Engine + after-treatment + Hybrid Gen-set
Zero Emission, highest efficiency, No CO2, Least GHG**



Vehicle Type	Driveline Config.	Energy Efficiency				Fuel Saving	Annual Emissions and GHG			Drive Cycle
		% Well to wheel					NOx	CO	GHG	
						kg/Year	kg/Year	ton/year		
	Diesel	27%		27%		174	7,909	103		
	Hybrid	32%		32%		140	6,358	83		
	CNG	25%		25%		6	400	80		
	Electric	30%		30%		-	-	-		
	Fuel Cell	34%		34%		9%	-	-		-
	Diesel	27%		27%		134	6,118	80		
	Hybrid	32%		32%		115	5,230	68		
	CNG	26%		26%		5	326	73		
	Electric	30%		30%		-	-	-		
	Fuel Cell	38%		38%		12%	-	-		-
	Diesel	22%		22%		264	12,010	156		
	Hybrid	27%		27%		237	10,809	141		
	CNG	22%		22%		8	510	80		
	Electric	27%		27%		-	-	-		
	Fuel Cell	37%		37%		15%	-	-		-
	Diesel	23%		23%		153	6,989	91		
	Hybrid	28%		28%		139	6,334	83		
	CNG	23%		23%		5	250	48		
	Electric	27%		27%		-	-	-		
	Fuel Cell	34%		34%		11%	-	-		-
	Diesel	25%		25%		120	5,478	71		
	Hybrid	29%		29%		103	4,713	61		
	CNG	24%		24%		3	218	46		
	Electric	28%		28%		-	-	-		
	Fuel Cell	36%		36%		12%	-	-		-



Ask questions using the **Questions Panel**
on the right
side of your screen.

The webinar slides and recording will be
made available after today. Please fill out
survey upon leaving.



Thank you for attending today's webinar and remember to fill out attendee survey. Slides and Recording will be made available within one week.

For more information, contact:

Emanuel Wagner

CHBC Assistant Director

Ewagner@CaliforniaHydrogen.org

310-455-6095 x360



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Grow your Business:

Join the CHBC

Where “Hydrogen Means Business
in California”

www.CaliforniaHydrogen.org