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.
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
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)
Overview of Workshop and Report Highlights

Cory Shumaker
Project Coordinator
California Hydrogen Business Council
• 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
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.
• 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
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
Rick Cameron
Managing Director of Planning and Environmental Affairs
2015 AIR INVENTORY

- Diesel Particulate Matter: Down 84% from 2005 Baseline
- Nitrogen Oxides: Down 48% to 2023 59%
- Sulfur Oxides: Down 97% to 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
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
ENERGY PILOT PROJECTS
Maintenance Yard
Joint Command and Control Center
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
Stationary Hydrogen Industry Perspective & Next Steps

Ryan Sookhoo
Director New Initiatives
Hydrogenics Corporation
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

HYDROG(E)NICS

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 1946
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
CRITICAL POWER
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
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
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
Leveraging Experience

San Francisco Bay Renewable Energy Electric vessel with Zero Emissions
Final Report Now Available for Download

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

Management Leadership
Over 60 years of accelerating the power shift towards renewable hydrogen

Technology Leadership
As the global leader in hydrogen technology, we will ensure your project is tailored to meet your business needs

Sustainability Leadership
Our zero-emission solutions allow you to reduce your carbon footprint

We’re Ready
Mobile Hydrogen Industry Perspective & Next Steps

Dr. Abas Goodarzi
Founder and President of US Hybrid Corporation and US FuelCell
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
Battery Electric Zero Emission Class-8 Truck (37T)

**eTruck™ Electric Drayage Class-8 Truck**

- Li-ion Battery 160-240kWh
- Safety Disconnect Unit "SDU"
- CHARGER options SAEJ-1772 Level III OR On-Board 3-Φ, Isolated, EVSE
- Electro-Hydraulic Steering
- Electro-Air System, DC-DC
- Electro Driven Brake
- Electro Driven Steering
- Electric Driven A/C
- iDrive Telematics
- Direct Electric Drive Power: 320kW (430hp)

**Battery Electric Zero Emission Class-8 Truck**

**eTruck™ Electric Drayage Class-8 Truck**

**Battery Electric Zero Emission Class-8 Truck**

**eTruck™ Electric Drayage Class-8 Truck**

**Battery Electric Zero Emission Class-8 Truck**
Electric Propulsion is the future Powertrain

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

- Volume: 0.51 m$^3$
- Weight: 240 kg

- Volume: 1.6 m$^3$
- Weight: 998 kg
Fuel Cell Zero Emission Class-8 Truck (37T)

- **Hybrid Electric**
- **Plug-in Hybrid**
- **Battery Electric**
- **Fuel Cell Electric**

**Fuel Cell Electric Class-8 Truck Powertrain System Configuration**

- SAE J2601 Standard
- 25 kg, 350 BAR Fuel Cell, 80kW

**Direct Electric Drive Power:**
- 320kW (500hp)
- Torque: 3,750 Nm

**Control Electronic Unit “CEU”**

**Li-Ion Battery**
- 26kWhr

**EMS**

**SDU**

**Safety Disconnect Unit “SDU”**

**Wireless Cellular Diagnostics**

**Electro-Hydraulic Steering Electro-Air System**
- DC-DC: 400A, 13.8V

**Truck Powertrain System Configuration**
Ports Operation demand 24/7 multi shift operation

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

Miles per minute of Charging

<table>
<thead>
<tr>
<th>Charger Size (kW)</th>
<th>Miles per minute charging/fueling</th>
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<tr>
<td>60</td>
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<td>120</td>
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<tr>
<td>180</td>
<td>2.5</td>
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<tr>
<td>240</td>
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Miles per minute of Refueling

- Semi-Truck
- Transit Bus

Fueling Type: CNG, Gasoline, H2, Diesel
Natural Gas → Compressor

CNG Storage → 22% Efficiency
Exhaust: NOx, CO, HC

Natural Gas → Reformer CNG-H2 → Compress

H2 Storage → 37% Efficiency
H2O

15% Fuel Saving

15% Energy efficiency Improvement for Truck Operation with No Tailpipe emission, No combustion and highest efficiency
FC Engines: Most Efficient Engine with Zero Tail Pipe Emission

- **Diesel**: 37.1 kWh/gal (Energy content), Engine Output: 4.5 kWh/kg
- **Gasoline**: 32.9 kWh/gal, (Energy content), Engine Output: 2.8 kWh/kg
- **Hydrogen**: 39.7 kWh/kg, (Energy content), FC Engine Output: 15 kWh/kg
  
  (1kg H2 = 11 gal @5000 psi, same as 2 gal of diesel fuel)

- **Energy Storage Density**: Li-Ion Battery

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

**Fuel Cost per Mile**

- Diesel: $5/gal, $6/gal, $8/kg, $6/kg, $4/kg, $2/kg
- Hydrogen: $5/kg, $6/kg, $8/kg, $6/kg, $4/kg, $2/kg

80kW FCPP, price amortized
Synergetic Bus and Truck market demand **to reduce cost**

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
In Summary: There is a business case for Fuel Cell Engine

Cost competitive with
Euro-6 Engine + after-treatment + Hybrid Gen-set
Zero Emission, highest efficiency, No CO2, Least GHG
<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Driveline Config.</th>
<th>% Well to wheel</th>
<th>Fuel Saving</th>
<th>NOx</th>
<th>CO</th>
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Driveline Config.:
- Diesel
- Hybrid
- CNG
- Electric
- Fuel Cell

Energy Efficiency

Drive Cycle:
- Transit Bus
- Shuttle Bus
- Drayage Truck
- Refuse Truck
- Street Sweeper

Annual Emissions and GHG:
- NOx kg/Year
- CO kg/Year
- GHG ton/year

- Diesel
- Hybrid
- CNG
- Electric
- Fuel Cell

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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.

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