

# APTA Standards Quarterly Webinar Series

Fuel Cell Electric Bus Infrastructure for  
100+ Bus Depot

*Presented by APTA Clean Propulsion  
Committee*

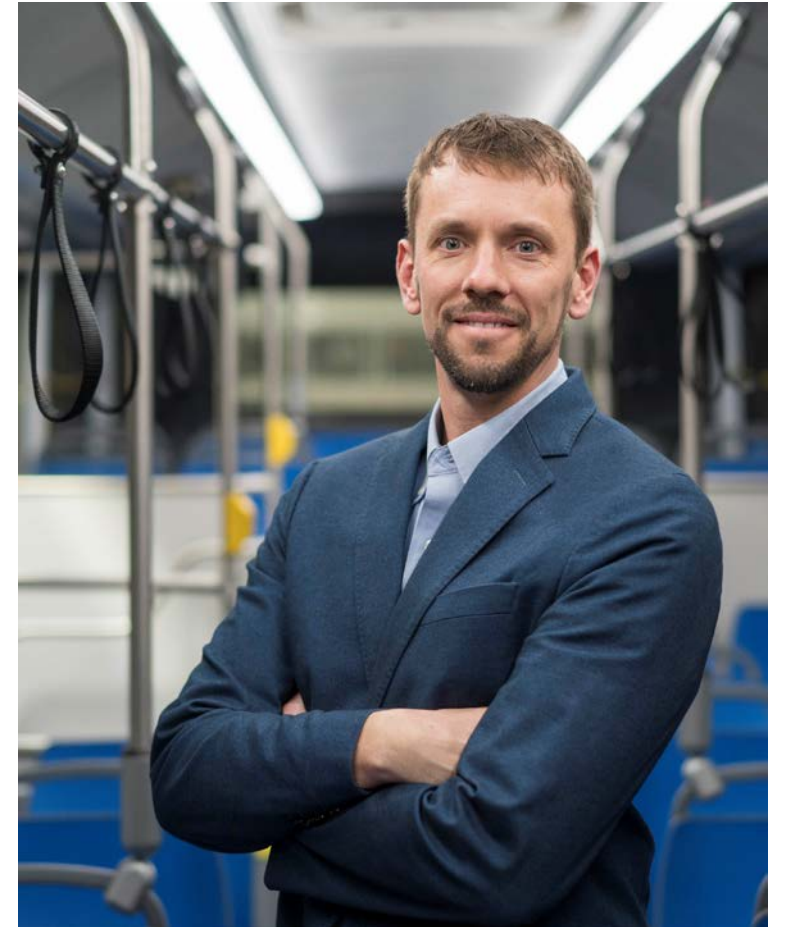




## **Mike Finnern**

*Sr. Director, Customer Service*  
Proterra Inc.

**Chair, APTA Clean Propulsion &  
Support Technology Committee**





# Moderator

## Jaimie Levin

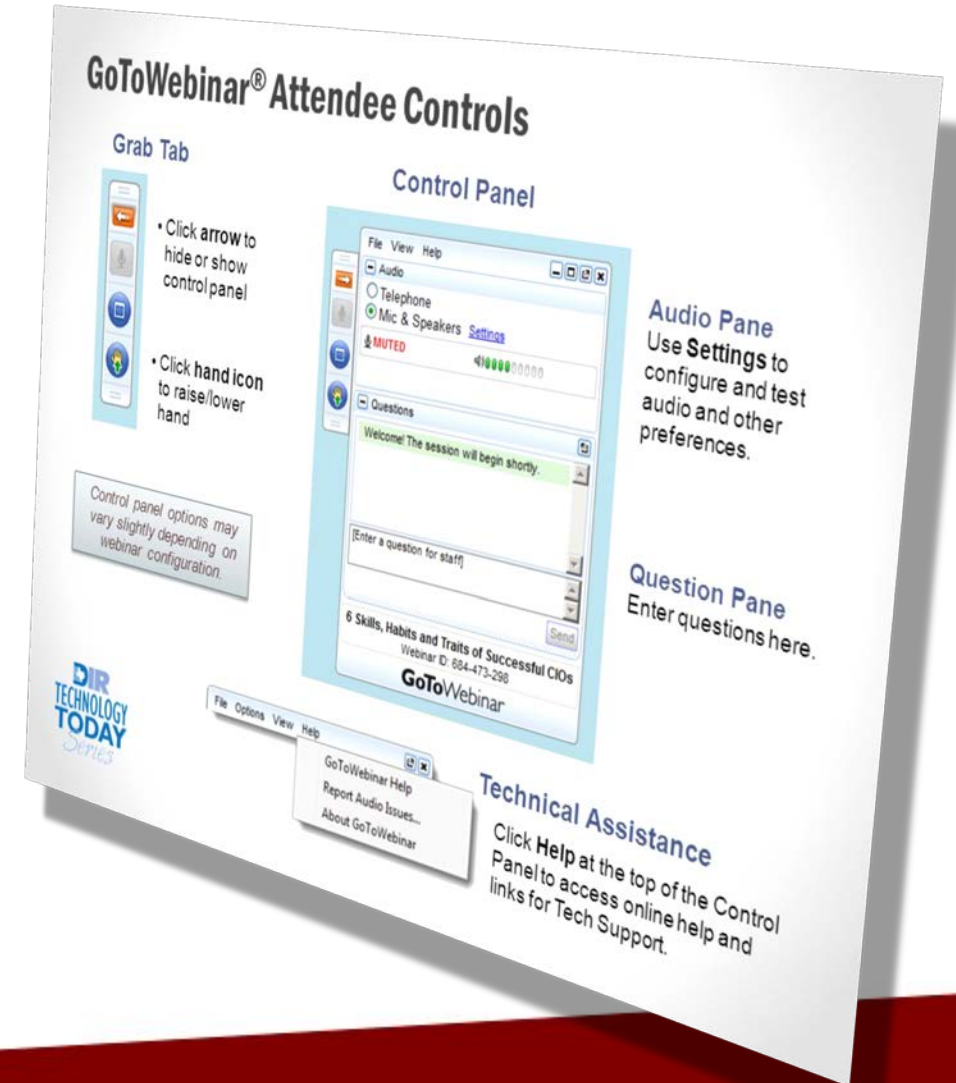
Director of West Coast Operations, Center for  
Transportation and the Environment (CTE)





# Housekeeping Items

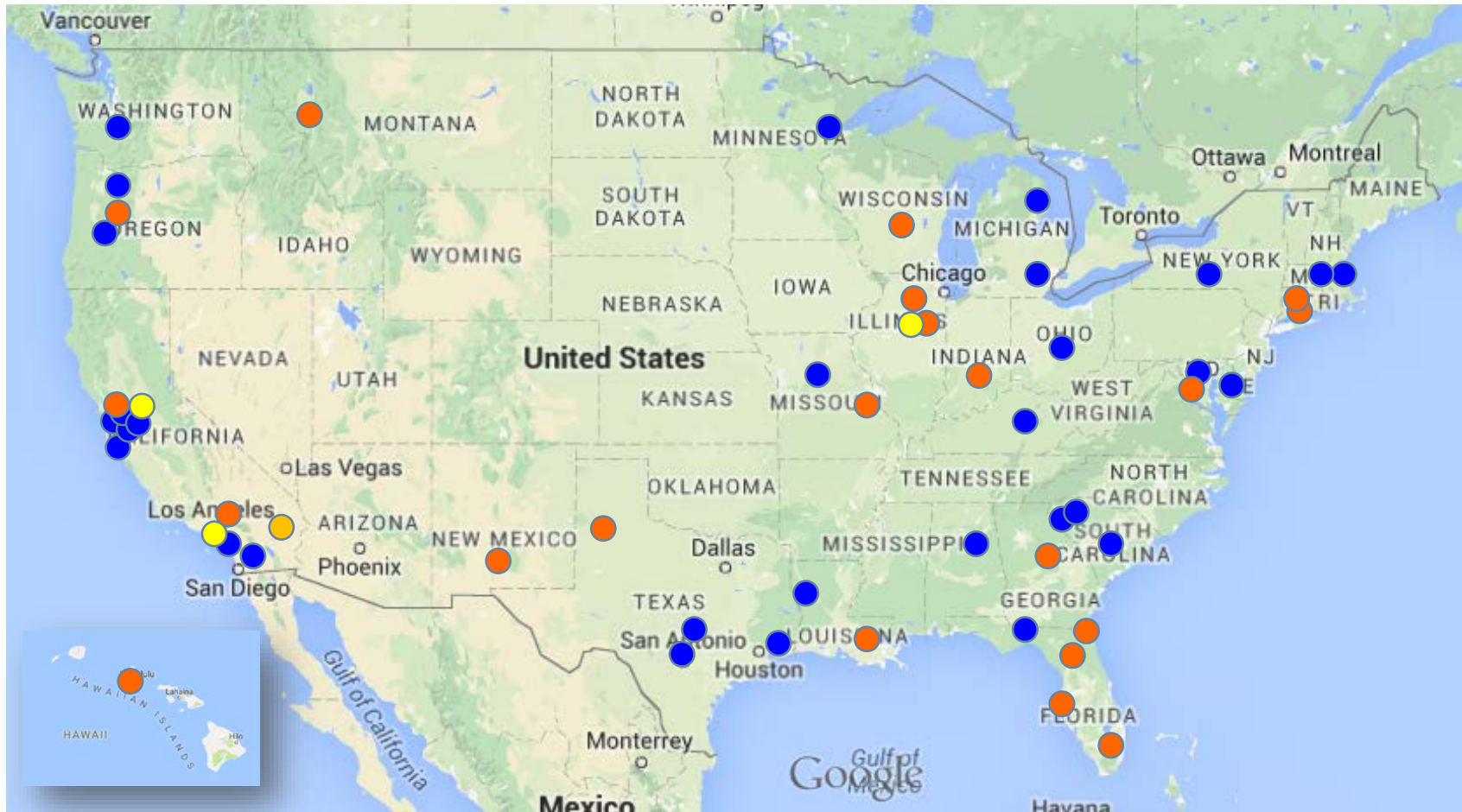
- All attendee audio lines have been muted
- Questions will be addressed at the end of today's presentation
- Questions can be asked via the "question" dock on the attendee control panel
- Please complete webinar survey that will be emailed at the end of today



# CTE ZEB Projects and H2 Stations



25<sup>th</sup> Anniversary  
1993-2018



- Existing Zero Emission Bus (ZEB) Projects (more than 200 ZEB's with over 40 Transit Agencies)
- 2017 Low-No Awards with CTE (more than 50 ZEB's with 25 Agencies)
- Hydrogen Fueling Station Projects (Capacity -- OCTA: 50 Buses; AC Transit: 30 Buses; CUMTD: 2 to 12 Buses)

# Bus Hydrogen Stations



AC Transit – Emeryville (30 Buses)



OCTA Station – Santa Ana (50 Buses)



AC Transit – Mobile Fueler



AC Transit – Reformer



AC Transit – Electrolyzer



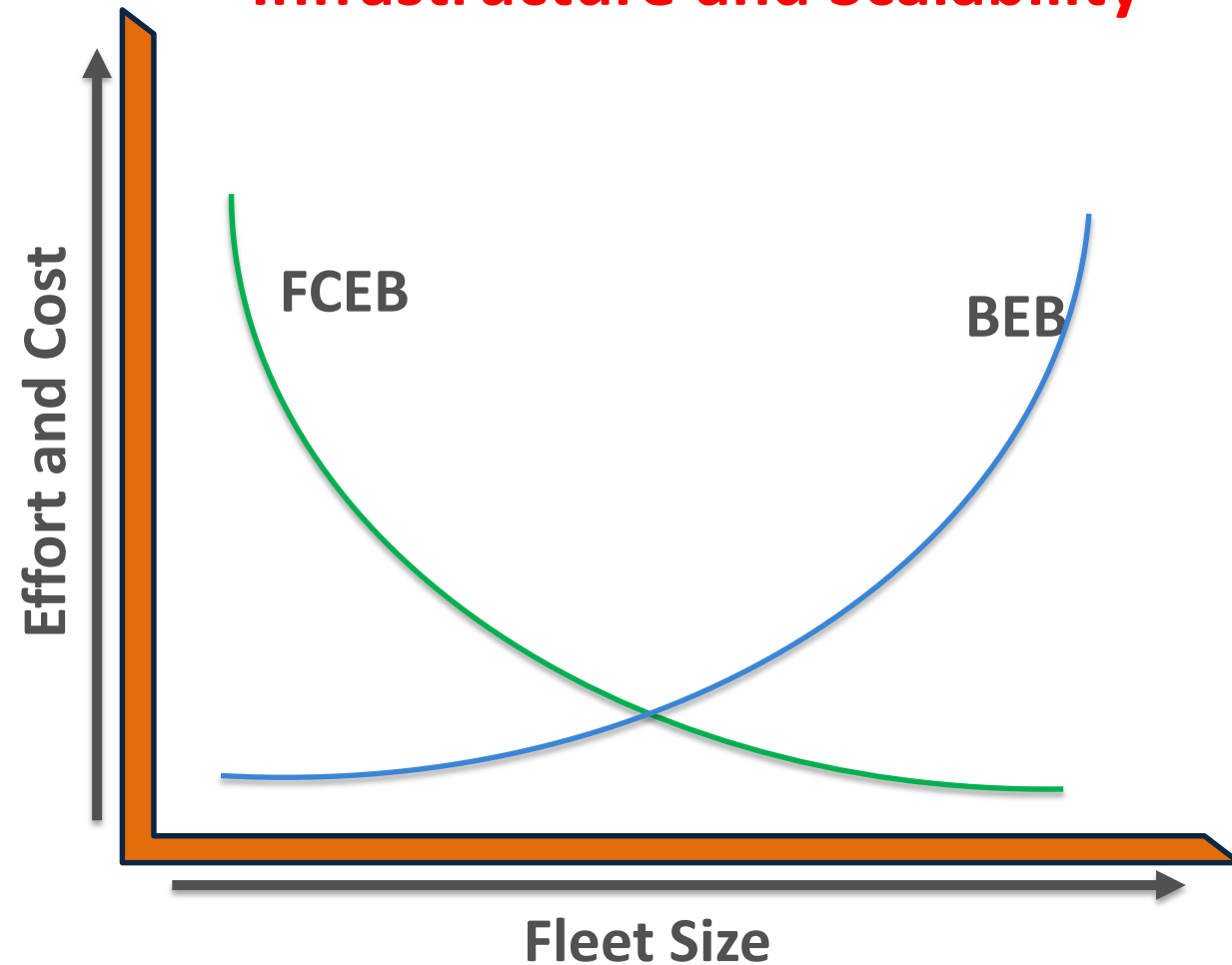
AC Transit – Liquid and Electrolyzer

# H<sub>2</sub> Station Challenges and Promise

## PARSE

- P** **Price** and delivery of H<sub>2</sub> on parity with conventional fuels.  
Also equipment maintenance cost reduction.
- A** **Area** of fueling footprint to refuel 50, 100, or 200 buses.
- R** **Renewables** for hydrogen production; **Resiliency** - Natural Disasters;  
Also **Redundancy** to ensure near 100% service reliability.
- S** **Speed** of refueling in the normal five- to seven-hour night window;  
Also **Scalability** for future expansion.
- E** **Equity**, or CapEX, needed to build at a reasonable price utilizing  
baseline components for future scale up.

## The Challenge for 100% ZEB Deployment: Infrastructure and Scalability





# Today's Presenters

## **Tim Sasseen**

*Business Development Manager,  
Ballard Power Systems*



## **Karl Gnadt**

*Managing Director,  
Champaign-Urbana MTD*



## **Ryan Erickson**

*GM, Strategic Development,  
Trillium*





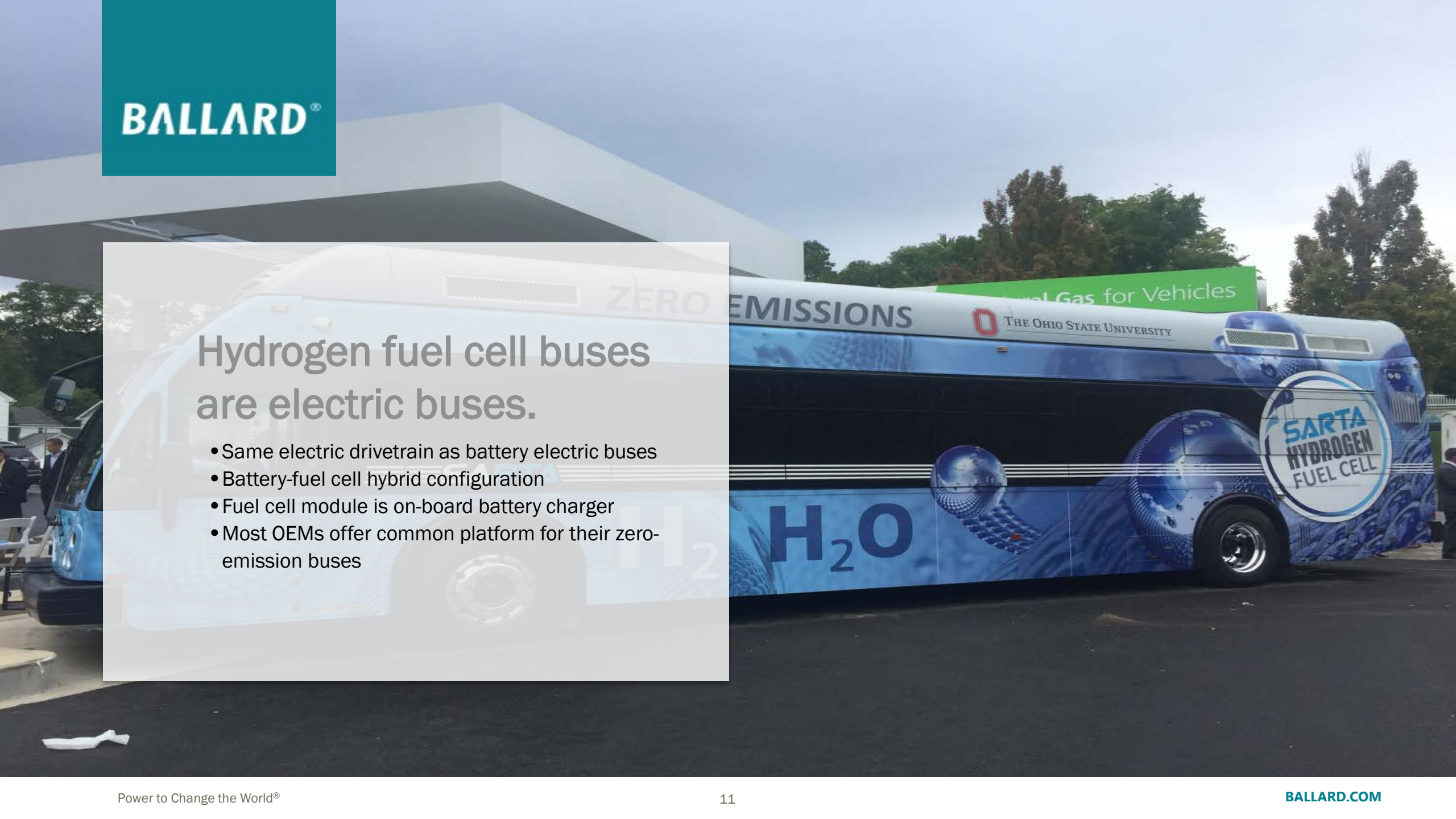
**BALLARD®**

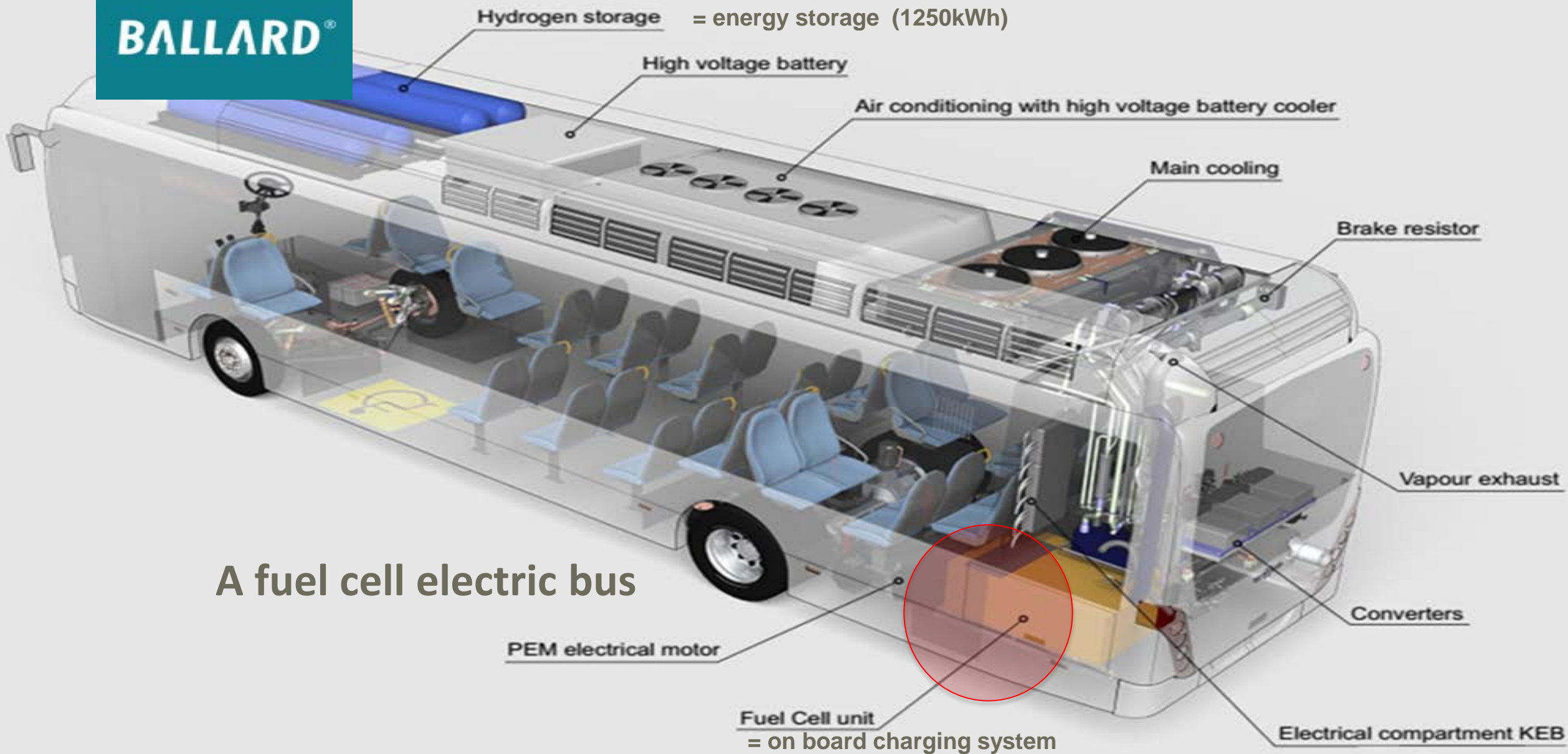


Fuel cell electric buses  
no compromise  
zero-emission transit

## Hydrogen fuel cell buses are electric buses.

- Same electric drivetrain as battery electric buses
- Battery-fuel cell hybrid configuration
- Fuel cell module is on-board battery charger
- Most OEMs offer common platform for their zero-emission buses





# Fuel cells enhance the performance of electric buses.

**250-300 miles** Proven range



Significant reduction in vehicle weight  
(carry more passengers)



Rapid refueling speeds  
(6 to 10 minutes)

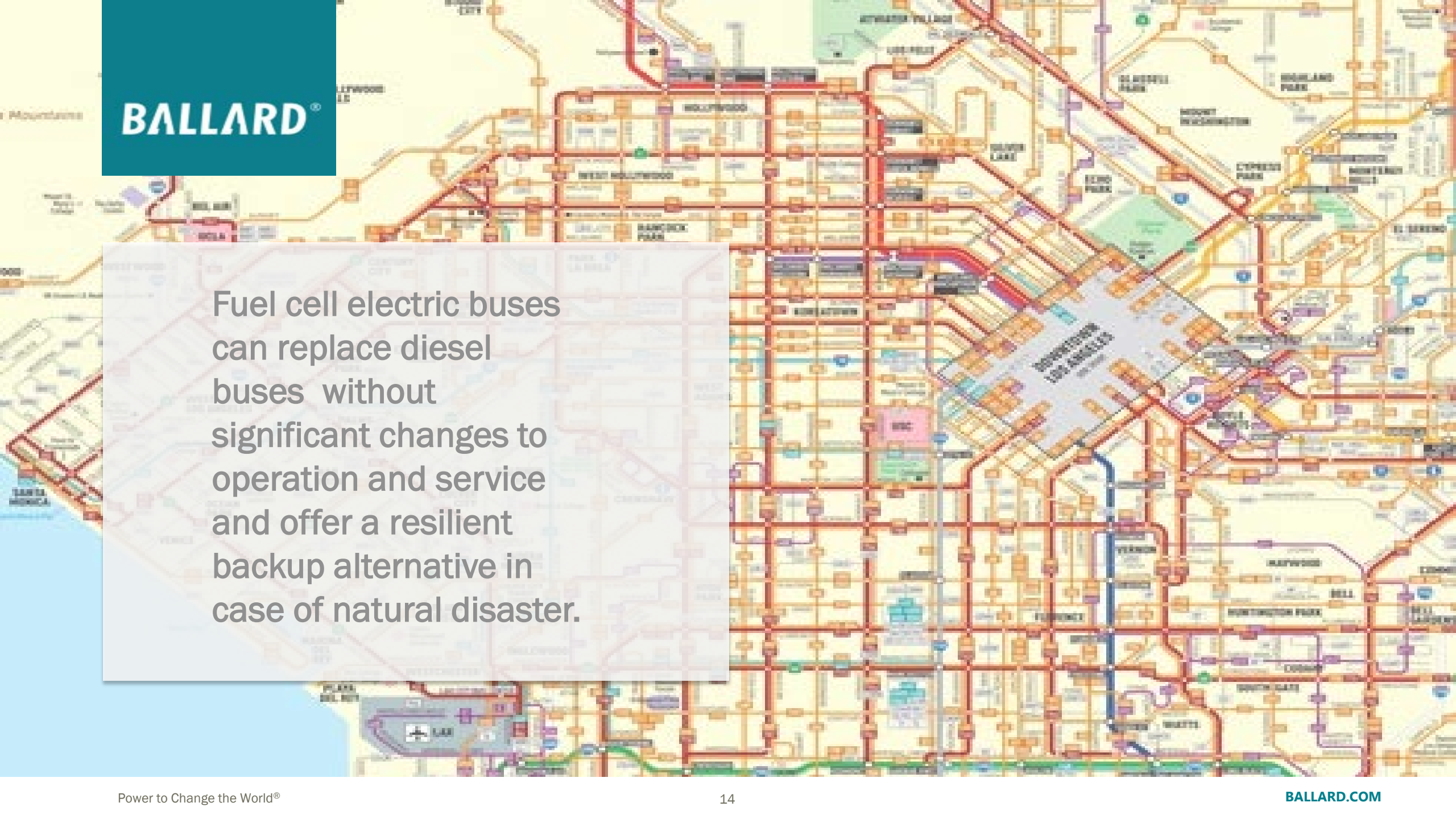


1:1 replacement of conventional vehicles



The Ballard logo consists of the word "BALLARD" in a bold, white, sans-serif font, set against a dark teal rectangular background. The logo is positioned in the upper left corner of the slide.

**BALLARD**

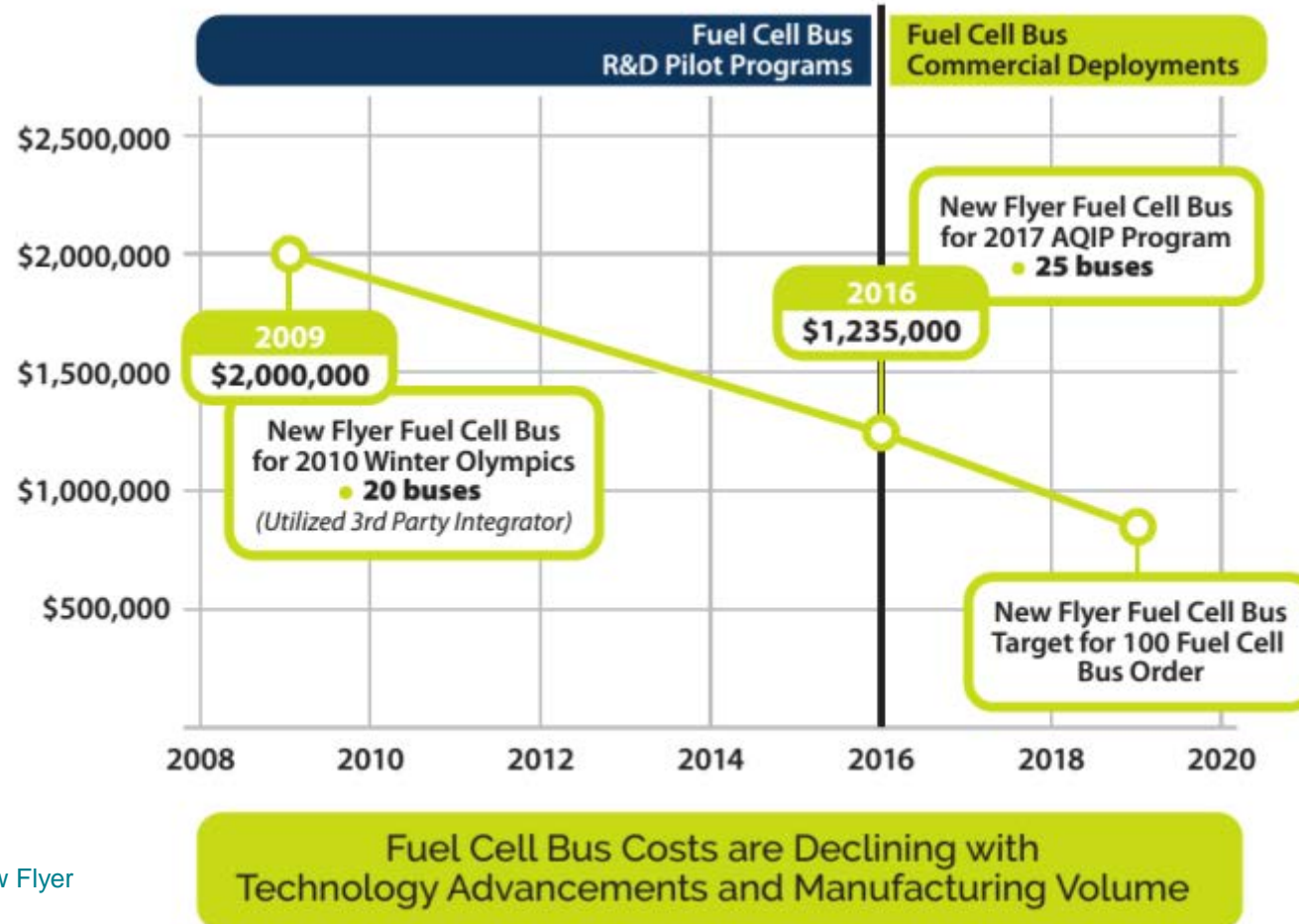
A detailed street map of Los Angeles, California, showing a dense network of roads and highways. The map is color-coded with various shades of red, orange, and yellow to represent different road types and traffic conditions. A semi-transparent grey box is overlaid on the map, containing text.

Fuel cell electric buses  
can replace diesel  
buses without  
significant changes to  
operation and service  
and offer a resilient  
backup alternative in  
case of natural disaster.

## Fuel cell electric buses have demonstrated performance in service

- More than 15 years of road-experience
- Over 7M miles in service
- Bus availability >85%
- FC module availability > 96%
- >30,000hrs stack durability
- Operation in challenging routes and climates

# Fuel cell bus cost is declining with technology advancements and manufacturing volume



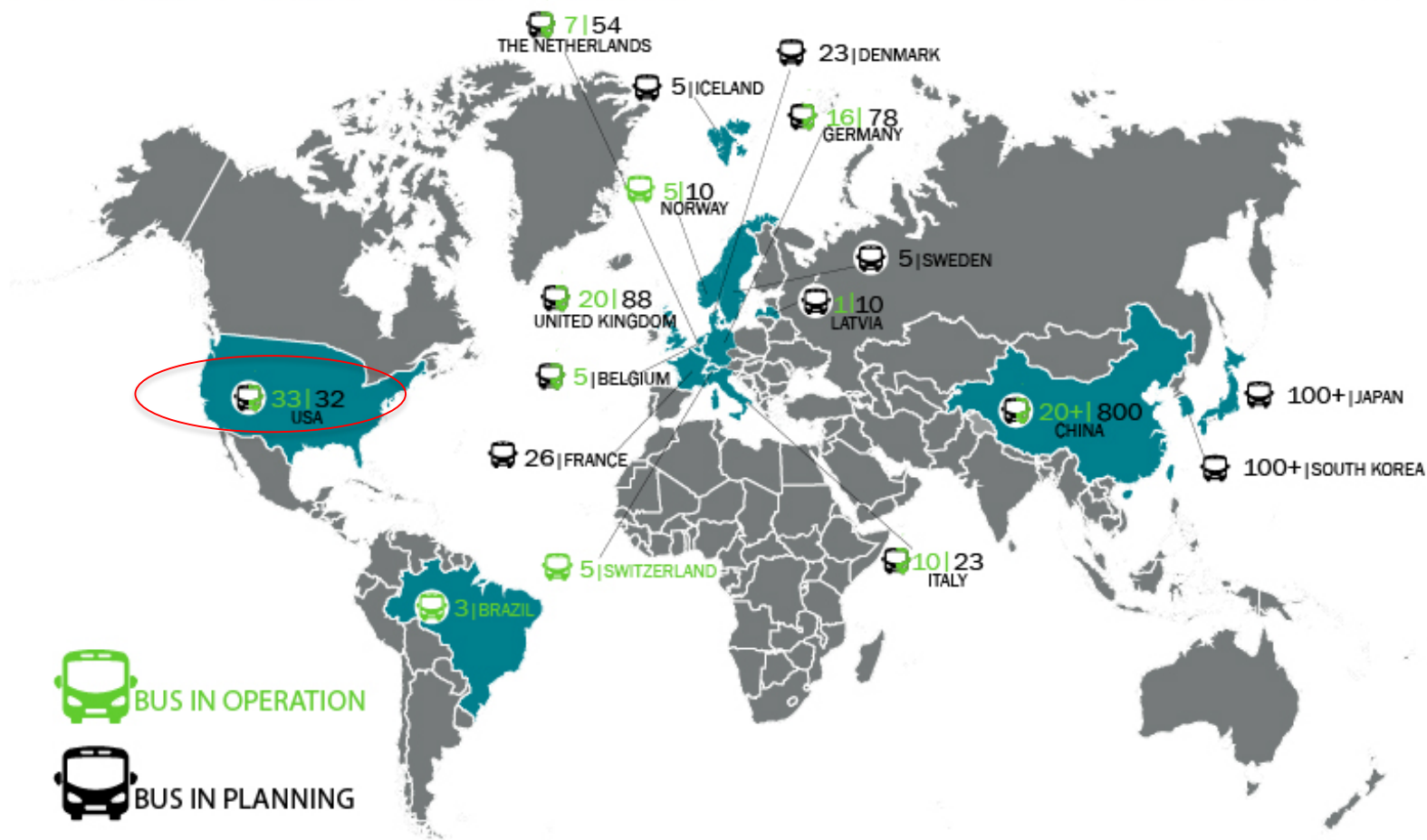
Courtesy New Flyer



There will be more than 1,000 FCEB on the road by 2020.

**FUEL CELL BUSES WORLDWIDE**

 **125** | **1100+**



Learn more about FCEB  
<http://zeroemissionbus.org>

**Fuel Cell Electric Bus**

**Maintenance**  
The facts on maintenance and support

**Fuel Cell**  
What is a fuel cell?

**Value**  
The value proposition of fuel cell buses

**Integration**  
Fuel cell integration in the bus platform

**Proven Technology**  
A proven zero-emission solution

**Hydrogen**  
Hydrogen and infrastructure

Click a category to explore

Powered by **BALLARD**

University of Illinois since 1989

11+ Million

SafeRides, C-CARTS, ADA

Illinois Terminal, CDL Training Facility

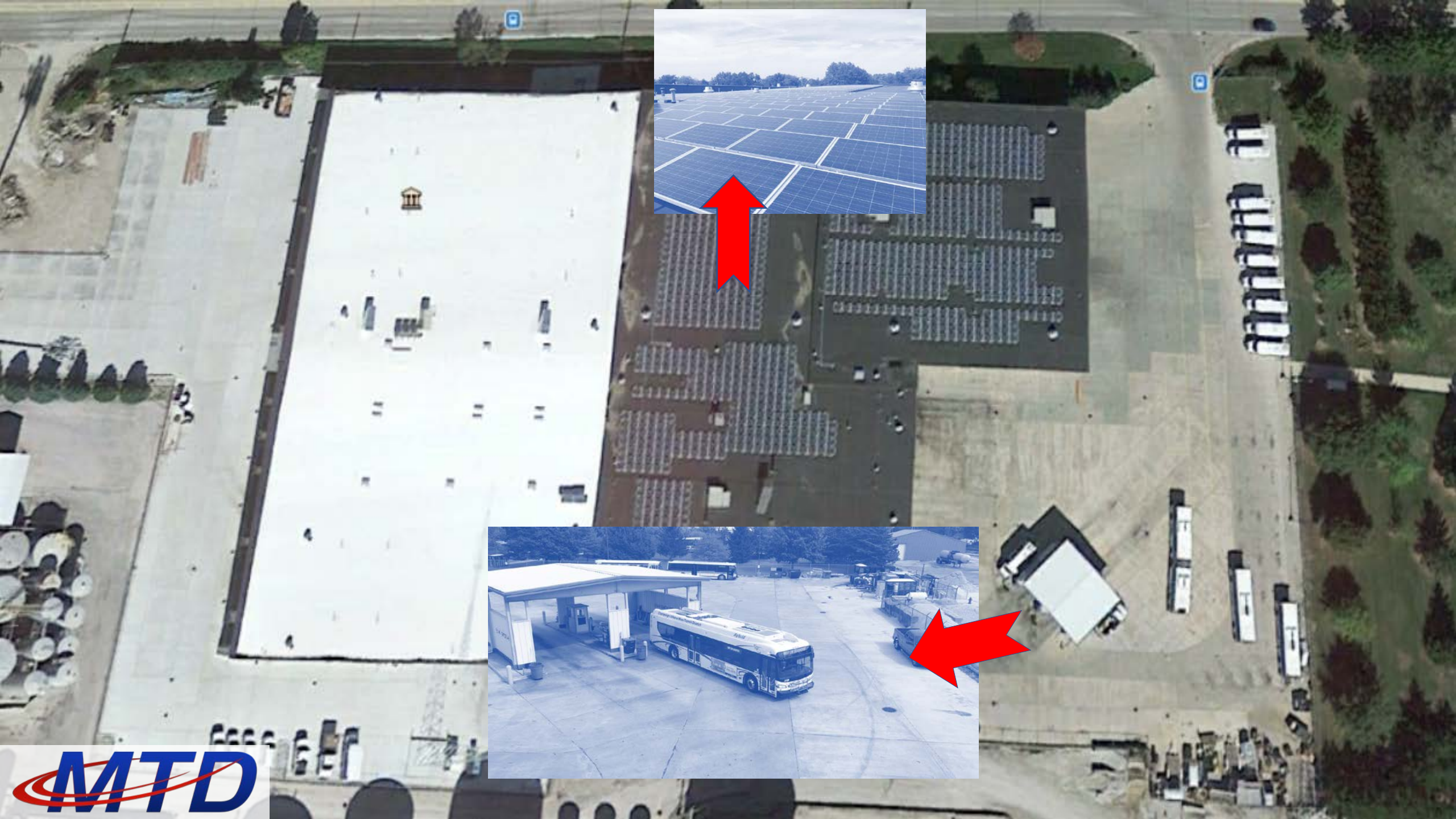
377 Employees



30' x 5  
40' x 90

60' x 16  
= 111





# The Love's Family of Companies



## OCTA State of the Art H2 Fueling Station



## Love's Travel Stops & Country Stores



**#18**

Forbes List of  
America's Largest  
Private  
Companies



**Over  
500**  
Travel Stops,  
Terminals and  
CNG Stations



**\$16**

Billion  
Annual  
Revenue



**25,000**

Employees  
Nationwide

## Trillium



**#2**

Largest  
Distributor of  
CNG in the  
U.S.



**200**

Owned or  
Operated  
Heavy-Duty  
CNG Stations



Design / Build  
Maintenance  
Own or Operate  
Renewable



Transit Agencies  
Municipalities  
Trucking Companies  
Waste Haulers



**Gemini Motor Transport**

650 trucks / 13 million gallons of fuel daily

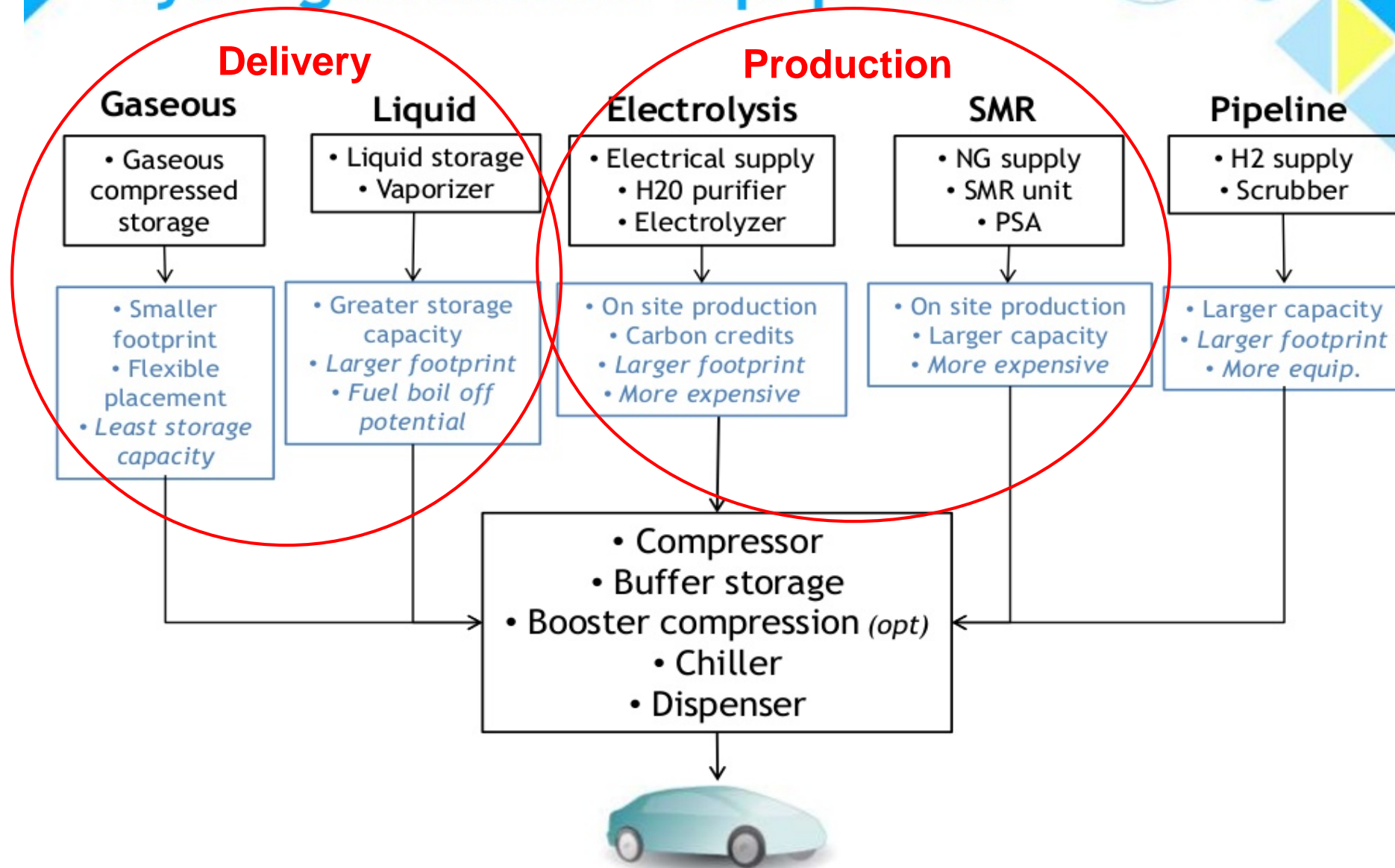


**Musket Corporation**

Wholesale fuel supply, trading and logistics

MUSKET

# Hydrogen station equipment





# Infrastructure Challenges



- Price
- Area/Availability
- Redundancy
- Speed
- Entry Effort



## The 5 & 5 Challenge

Dispensed price < \$5/kg

- Cost of H<sub>2</sub> (delivered or on-site)
- Operating costs (utilities, O&M)
- Capital recovery
- Margin

Speed of fueling > 5 kg/min

- Current LDV solutions to be adjusted for buses at scale

# Footprint & Redundancy



## Area / Availability

- Compressors – Storage – Dispensing + On-site production
- H2 supply suitable for FCs not available everywhere & limited as market grows



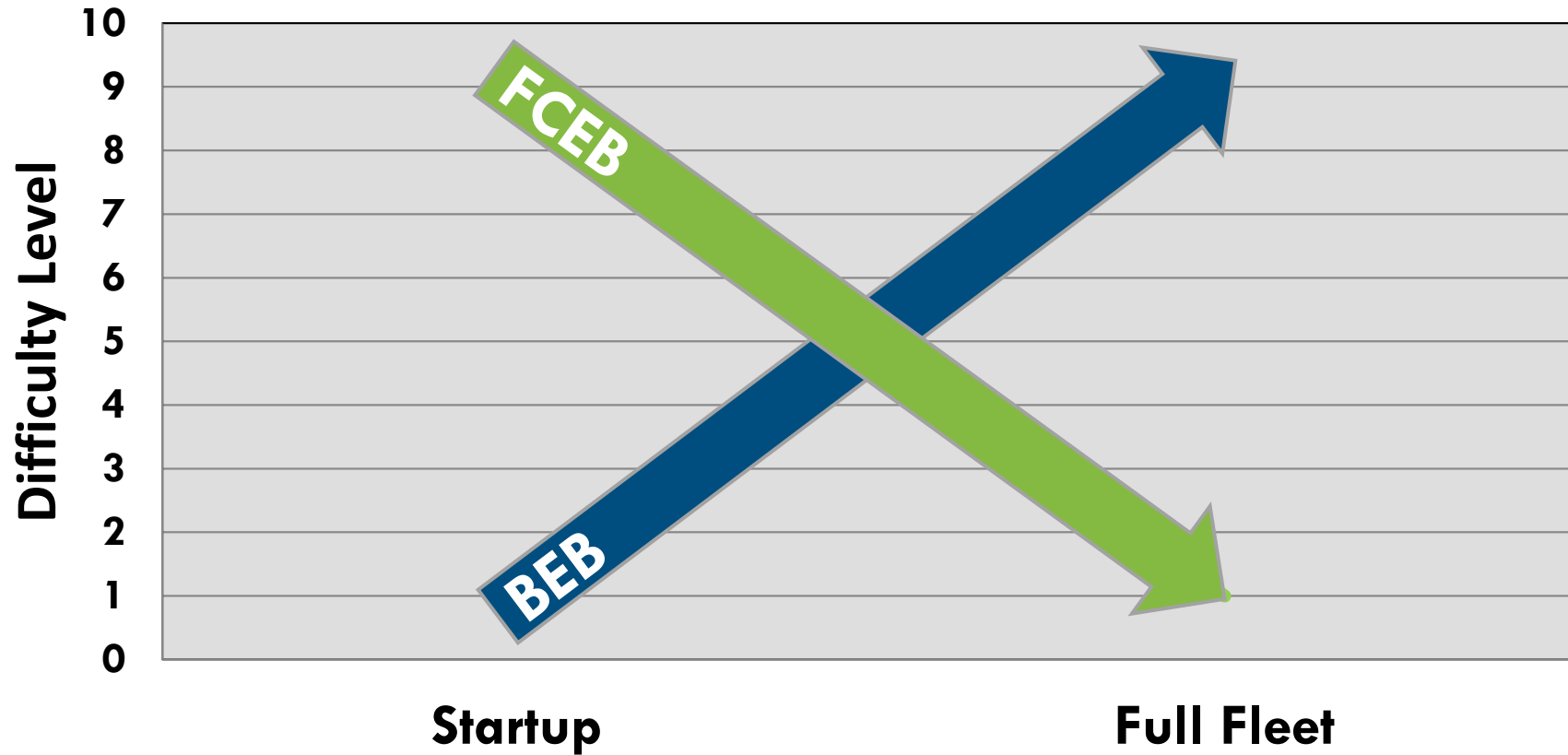
## Redundancy / Resiliency / Renewables

- Several days stored fuel on-site and backup power for 100% fueling
- Longer vehicle range, shorter refuels
- Solar/wind or renewable natural gas

# Entry Effort



## How to get started with FCEBs?



# Price\*



Buses	kg/day	GH2	LH2	SMR	Electrolysis
5	150	\$11+	\$12+	\$11	\$11 - \$16
35	1000	\$8+	\$7+	\$6	\$7 - \$12
200	6000	\$6+	\$4+	\$4	\$4 - \$10

\* Deduct \$6/kg for 5 buses, \$1.50/kg for 200 buses for direct CapEx purchase

## On-Site Production

- SMR – energy input costs \$1.20/kg using mostly natural gas
- Electrolysis – energy input costs range from \$2.50 - \$7.50/kg using mostly electricity (region, time of day, direct to renewable)

## Delivery

- Liquefaction adds \$1/kg, but liquid delivery can be as low as \$0.10/kg
- Gaseous delivery ranges from \$1.50 - \$2.50/kg

# Area (footprint)



Buses	kg/day	GH2	LH2		SMR	Electrolysis
			(bus stalls)			
5	150	2	3		5	5
35	1000	10	6		15	15
200	6000	35	12		50+	50+

## On-Site Production

- Footprint scales with kg/day and requires considerable storage as well

## Delivery

- Gaseous trailers are left on-site until empty (like a BBQ tank)
- Liquid trailers empty into permanent on-site storage (like diesel)

# Redundancy/Resiliency



Redundancy (diesel like)

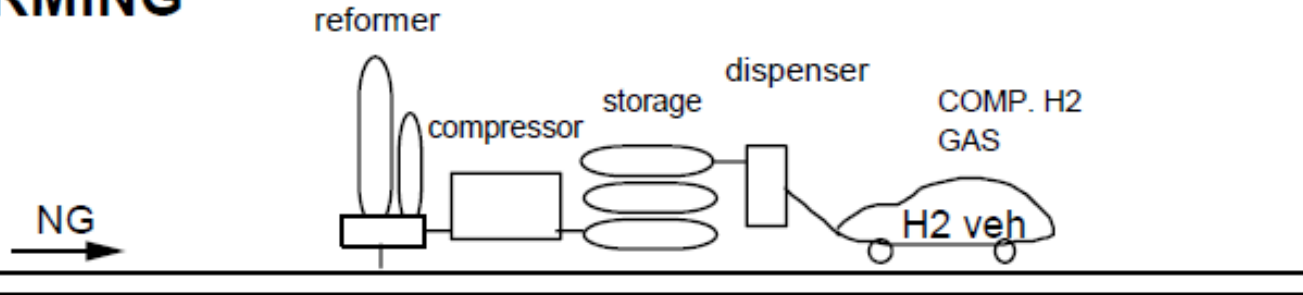
- LH2 includes days/weeks of storage and diesel back-up generator can run entire station
- FCEBs have driving range and refueling time similar to diesel



# Renewable

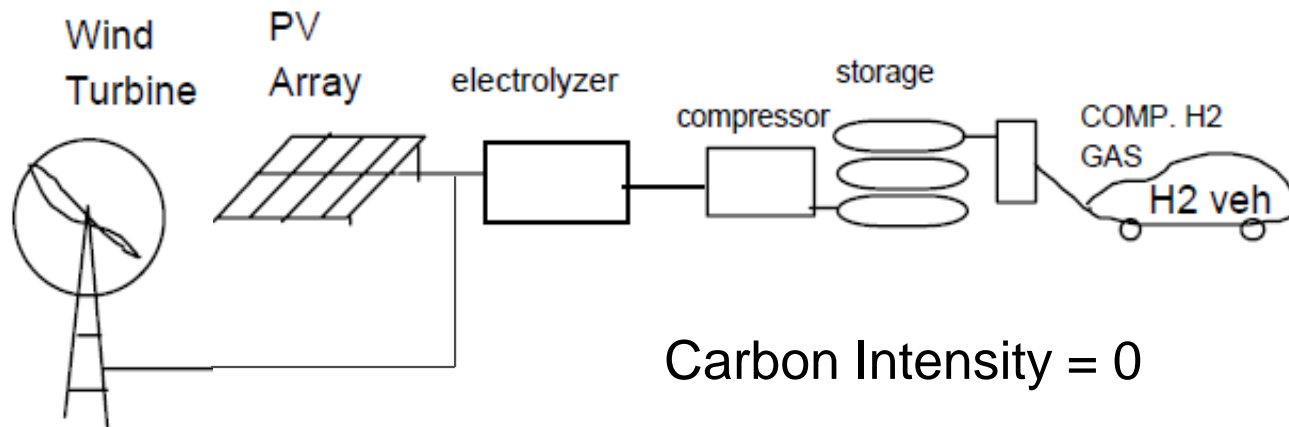


## REFORMING



Range of CIs above and below 0

## SOLAR or WIND ELECTROLYTIC HYDROGEN



Carbon Intensity = 0

# Speed

## LH2

- Liquid pumping at 5kg/min (5+ minute fill)

## GH2 or On-Site Production

- Considerable high pressure storage allows faster fills when storage is full, getting slower as storage empties
- New compression solutions will bring consistent 5kg/min fills





# Entry effort



## OCTA

**30 kg per vehicle in 6+ minutes**

- From 2 dispensers simultaneously
- Up to 1,500 kg/day





**Ryan Erickson - GM Strategic Development**  
(714) 380-2763    [Ryan.Erickson@Loves.com](mailto:Ryan.Erickson@Loves.com)



# Thank you

Webinar recordings can be found at [www.apta.com](http://www.apta.com) under “APTA Standards Quarterly Webinar Series”