California Transit Association

Hydrogen and Fuel Cell Electric Transit 101

(Co-Hosted by California Hydrogen Business Council)

June 6, 2019

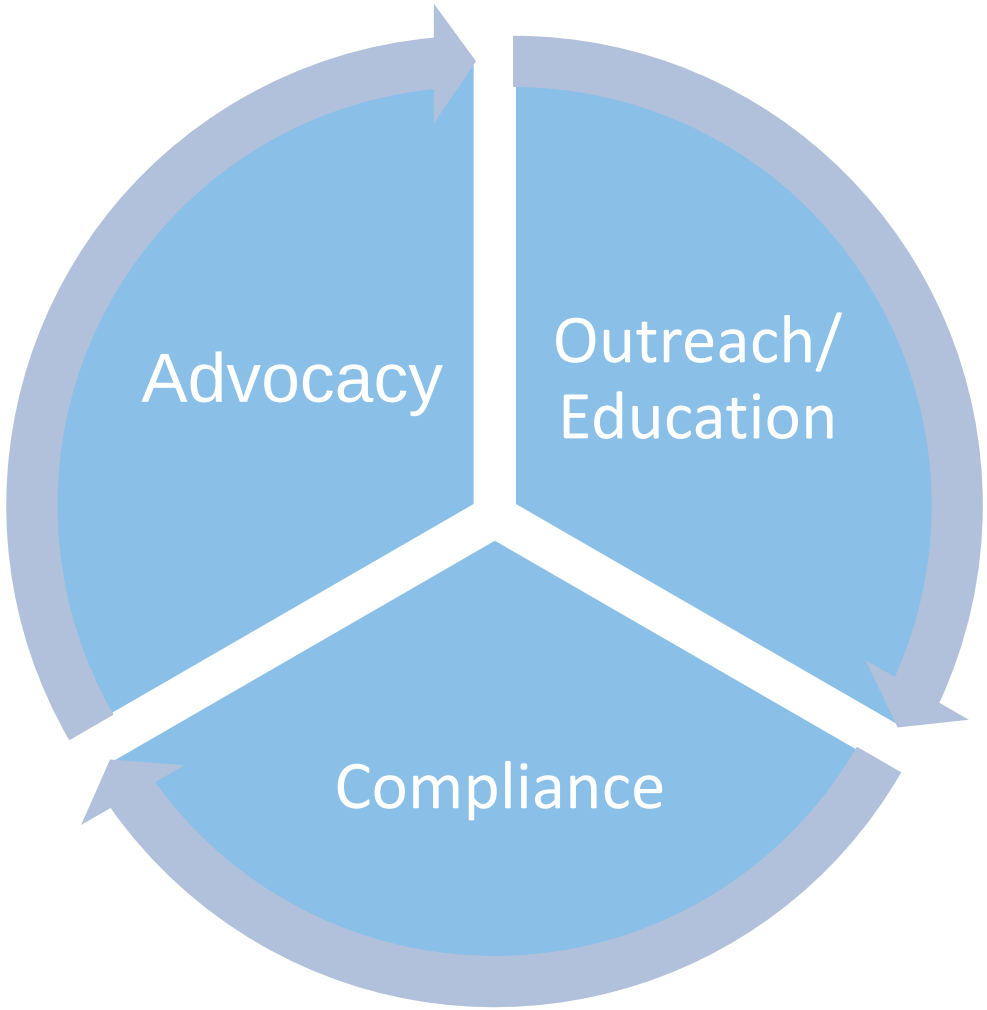
California Transit Association

- Represents more than 200 transit-affiliated entities, including more than 80 transit agencies in CA
- Advocates for policies and funding solutions that support and advance public transit

Involvement in Innovative Clean Transit Regulation

- Led negotiation with ARB on behalf of the transit industry
- Focused our advocacy efforts on the following provisions:
  - Benchmarking & Regulatory Assessment
  - ZEB Purchase Mandate Schedule
  - Waiver for Early Compliance
  - Definition of Small vs. Large Agencies
  - Access to Incentive Funding
  - Excluded Buses

Support for ICT Regulation Implementation



How to Ask Questions

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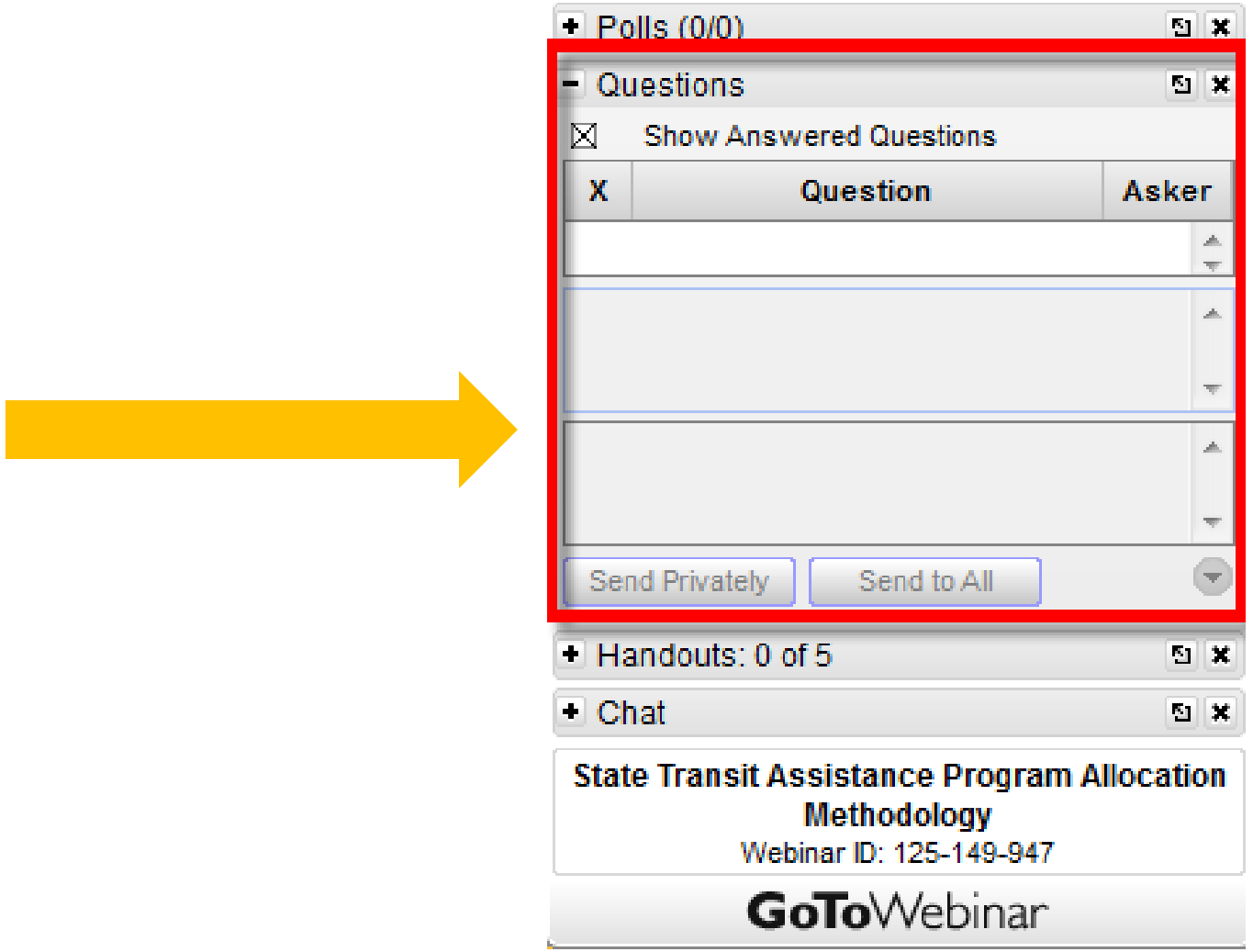

CALIFORNIA HYDROGEN BUSINESS COUNCIL

Emanuel Wagner

Deputy Director

California Hydrogen Business Council

CALIFORNIA HYDROGEN BUSINESS COUNCIL

Mission & Sector Action Groups:

The California Hydrogen Business Council (CHBC) is comprised of over 100 companies and agencies involved in the business of hydrogen. Our mission is to advance the commercialization of hydrogen in the energy sector, including transportation, goods movement, and stationary power systems to reduce emissions and dependence on oil in California.

CHBC Activities:

- Advocacy & Initiatives
  - Renewable Hydrogen, Renewable Energy and Climate
  - Hydrogen Blending and Gas System Integration
  - Hydrogen Fueling Station Build-out
  - Stakeholder Advocacy Campaign
- Communications & Business Expansion
- Goods Movement, Heavy-Duty Transportation, and Clean Ports
- Hydrogen Energy Storage and Renewable Hydrogen
- Public Transport

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 and state agencies
- Component suppliers

CALIFORNIA HYDROGEN BUSINESS COUNCIL

Only 2 Zero Emission Bus Options Available

- **Battery Electric Buses**
  - Ideal for shorter range, smaller size fleets
- **Fuel Cell Electric Buses (the other electric bus)**
  - 1:1 replacement for diesel technology
  - full conventional vehicle performance (e.g. gradeability, highway speeds, fueling times and range
  - Scaleable (infrastructure for 50 buses is not much different than for 200 buses) & small footprint
- **Fact Sheet from CHBC and California Fuel Cell Partnership:** https://www.californiahydrogen.org/wp-content/uploads/2017/10/CHBC-CaFCP-Fuel-Cell-Electric-Bus-Fact-Sheet.pdf


FUEL CELL ELECTRIC BUSES

Emissions and GHG Reductions

Performance

Scalability

Fueling

Cost

CALIFORNIA HYDROGEN BUSINESS COUNCIL

Status of FCEBs in California

Active Deployments

- AC Transit Agency (Bay Area) – 13 FCEBs in operation
- SunLine Transit Agency (Palm Springs Area) – 7 FCEBs in operation
- Orange County Transit Authority – 1 in operation, 20 to be deployed this year

ICT Regulation

- The Innovative Clean Transit Regulation will provide a clear driver for the deployment of zero emission buses in California, help deploy fuel cell electric buses hydrogen fueling equipment
- CHBC Comments in Support of the ICT: https://www.californiahydrogen.org/wp-content/uploads/2018/07/20180727-CHBC-Comments-on-ICT-Regulation_Final.pdf

Looking Forward

- 100% ZEB purchase requirement by 2029
- 100% Zero Emission Transit Fleets by 2040

CALIFORNIA HYDROGEN BUSINESS COUNCIL

Events

- **Policy Summit -** Sacramento (August)
- Enabling Deep Decarbonization with **Utility-Scale Hydrogen Energy Storage Workshop** - San Francisco (Sept./Oct 2019)
- The Other Electric Bus: **Meeting California's Innovative Clean Transit Regulation with Fuel Cell Technology Workshop** (November 2019)
- Hydrogen & Fuel Cell **Ports Briefing** - POLB & POLA (December 2019)
- Stay Informed: https://www.californiahydrogen.org/chbc-events/

CALIFORNIA HYDROGEN BUSINESS COUNCIL

Thank You!

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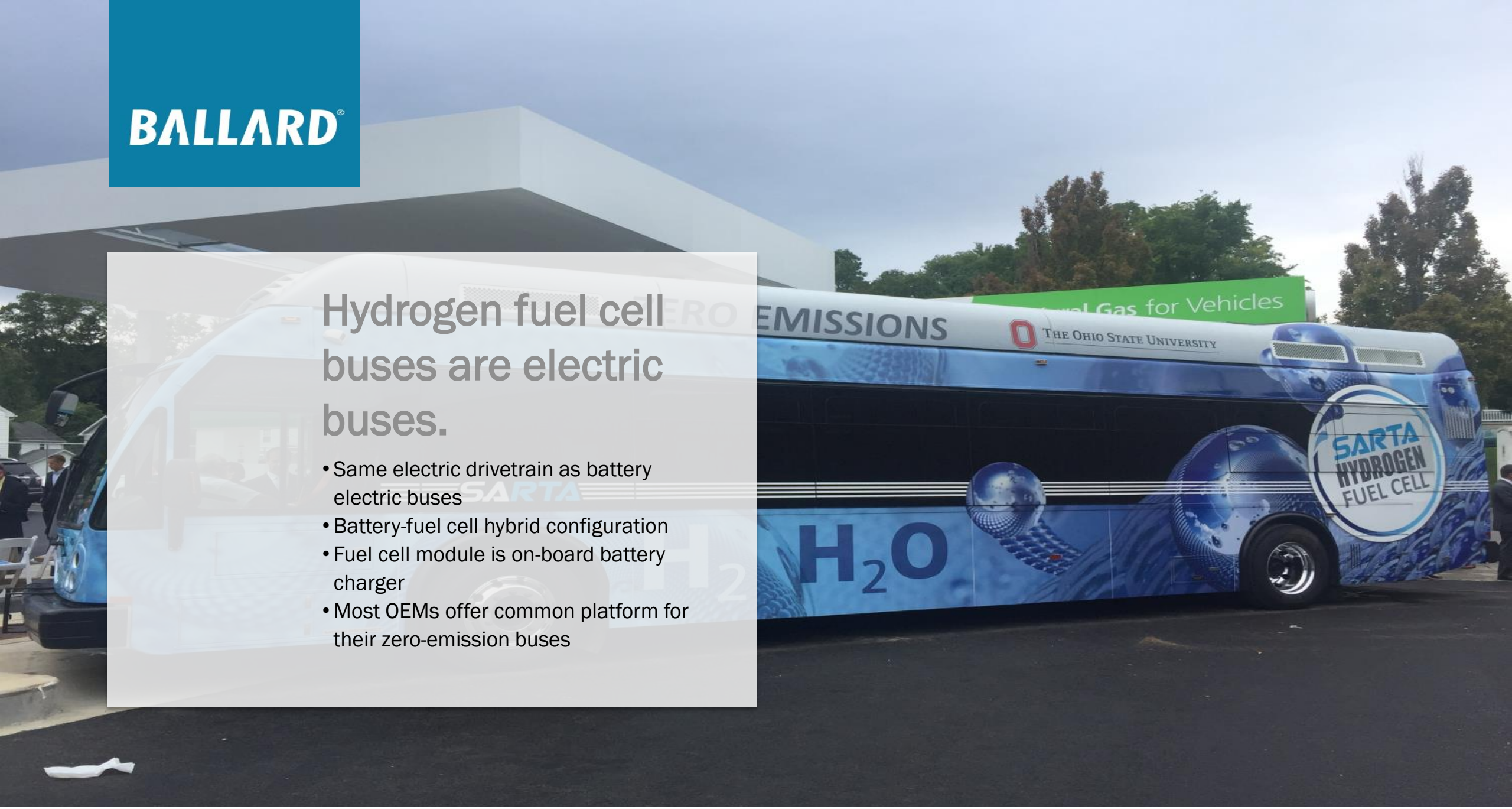
Join us!

www.californiahydrogen.org

BALLARD®

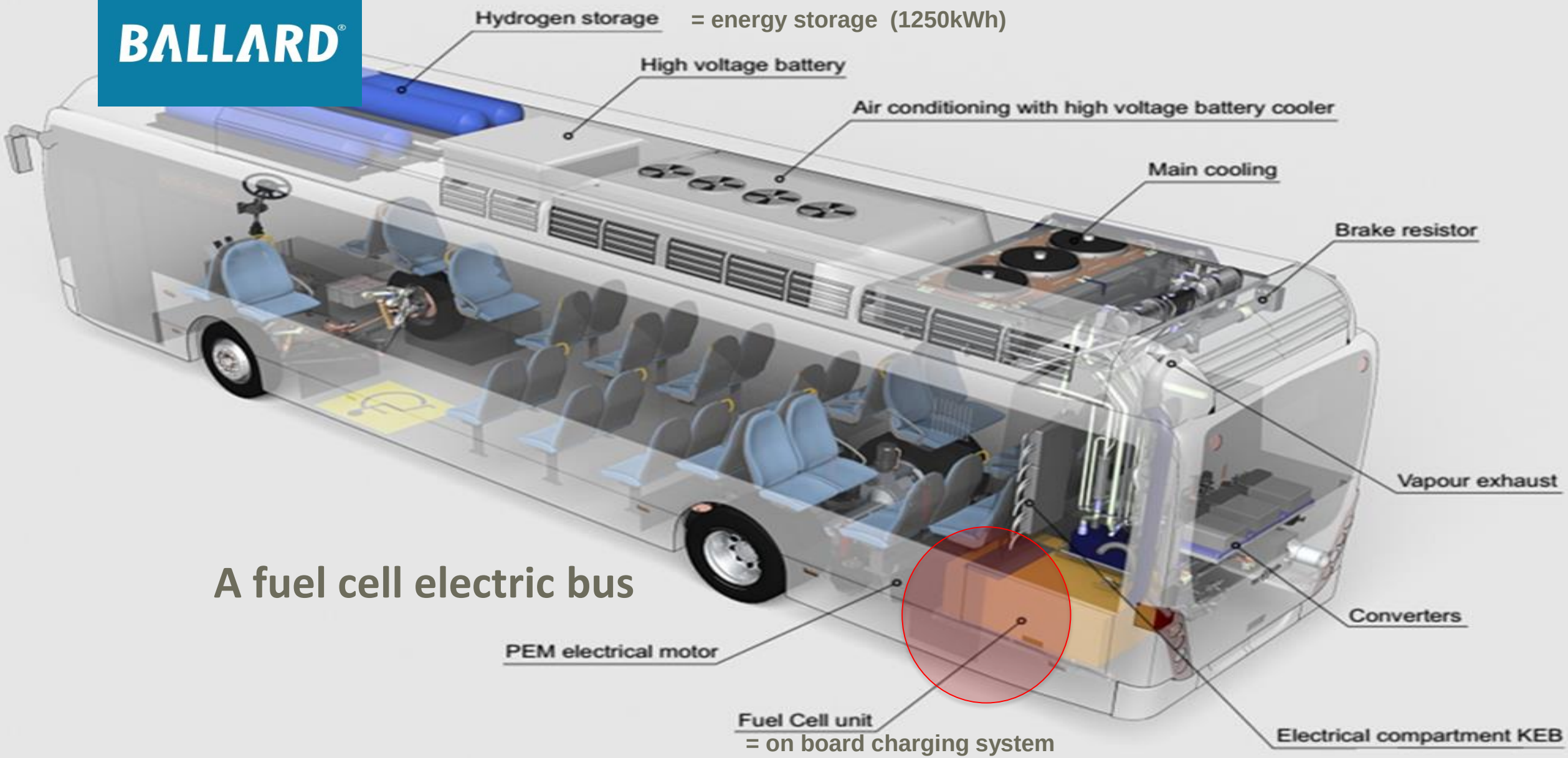
Fuel cell technology for zero-emission electric buses



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

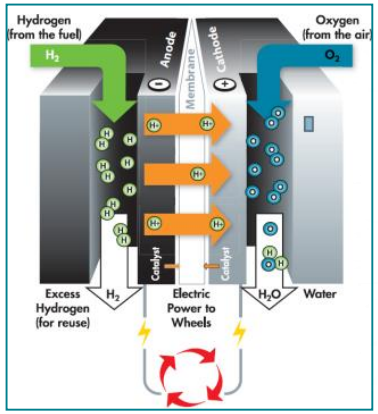
BALLARD®



A fuel cell electric bus

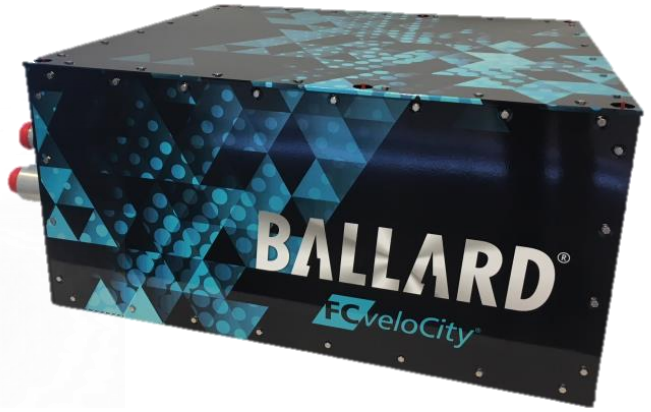
Fuel cell module generates power on board of the bus

- A fuel cell generate DC electricity from air and hydrogen to recharge batteries and power electric drive & auxiliary equipment
- Energy is stored as hydrogen gas (similar to CNG) in tanks



A fuel cell

A fuel cell stack



A fuel cell power module

Fuel cell electric bus program evolution

1991 - 1995
proof of concept
Phase 1 and Phase 2 buses, the first powered by Ballard fuel cells, are demonstrated in Vancouver, Canada

1996 - 1999
phase 3
Chicago Transit Authority and BC Transit (Vancouver) each deploy three Ballard-powered fuel cell buses in revenue service for a demonstration and testing program.

1999 - 2002
phase 4
ZEbus was operated by SunLine Transit Agency, a leader in the deployment of fuel cell electric buses. SunLine now operates 13 buses powered by Ballard.

2002 - 2009
phase 5
Deployment of 30 fuel cell buses in revenue service operating in ten European cities. In addition, three fuel cell buses are deployed in Perth, Australia and three in Beijing, China.

2009 - 2014
phase 6
hybridized fleets
Deployment of 20 Ballard-powered fuel cell buses in Whistler, BC in conjunction with the 2010 Winter Olympics and Paralympic Games. The fleet surpassed one million kilometers in operation in 2011.

2010 – 2020+
European rollout
Europe has led the rollout of FCEBs, with FCH JU support for six major projects. Combined, the JIVE projects will deploy nearly 300 fuel cell buses in 22 cities across Europe by the early 2020s.

2016
rapid market adoption
First 22 of 300 fuel cell buses planned for deployment in the cities of Foshan and Yunfu, China begin operation, marking the beginning of rapid market adoption in China.

Over 10 million kilometers

2017
industry milestone
Ballard becomes the first fuel cell company to power buses for more than 10 million cumulative kilometers of revenue service. Ballard-powered fuel cell buses have now traveled more than 15 million kilometers

TODAY
commercialization
Buses have passed FTA Altoona testing in US

More than 130 fuel cell electric buses powered by Ballard are in operation, with an additional 2,400 planned.

Fuel cell electric buses have demonstrated performance in service

- More than 20 years of road-experience
- Over 9 M miles in service
- FC module availability > 97%
- >30,000hrs stack durability
- Operation in challenging routes and climates

California is leading US deployments

- 50 fuel cell electric buses at 3 agencies (AC Transit, OCTA and Sunline)
- 2 FCEB OEMs: (Altoona tested)
  - New Flyer (40ft & 60ft)
  - ElDorado National (40ft)

BALLARD®

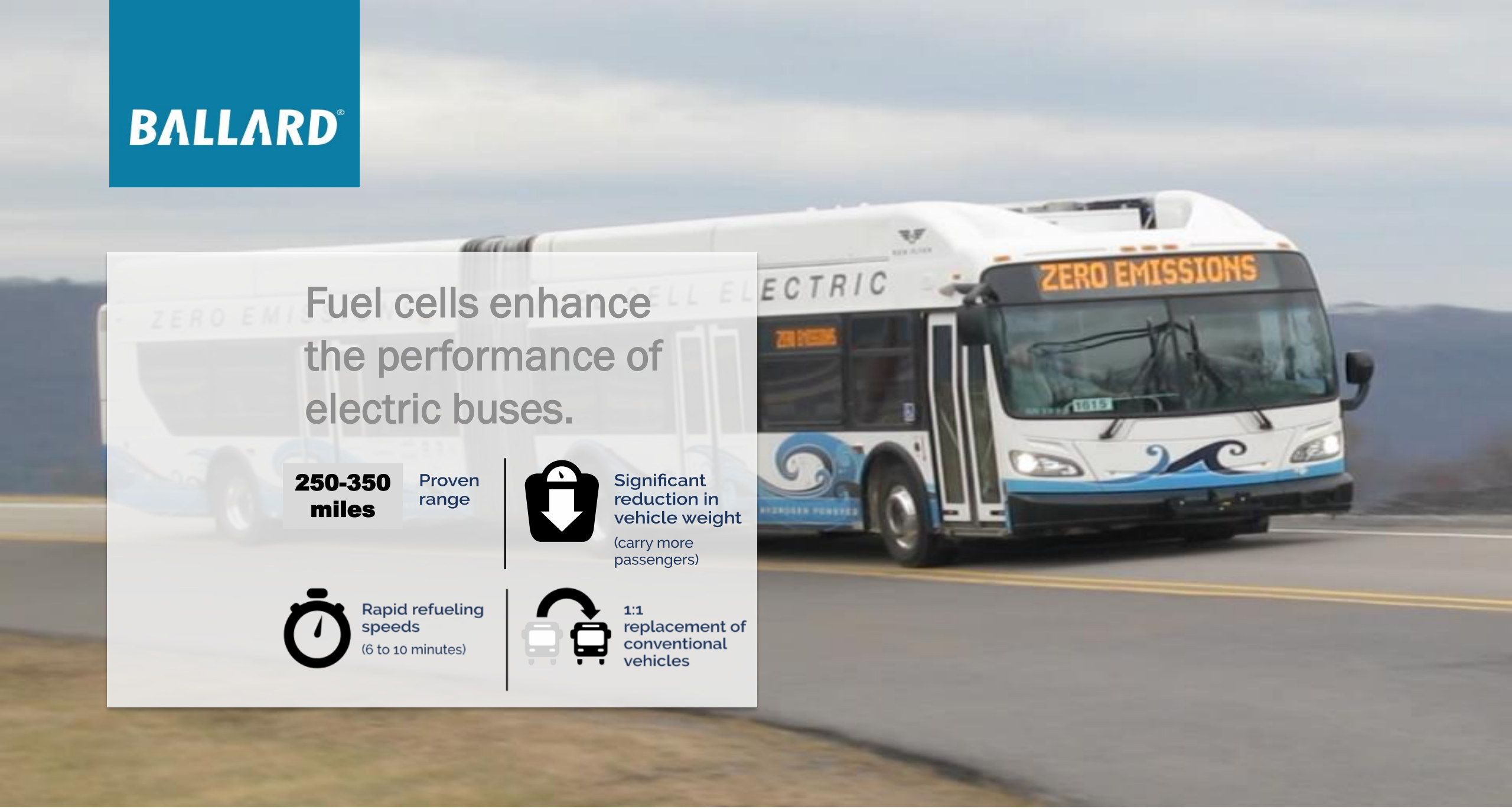
Fuel cells enhance the performance of electric buses.

250-350 miles Proven range

Significant reduction in vehicle weight (carry more passengers)

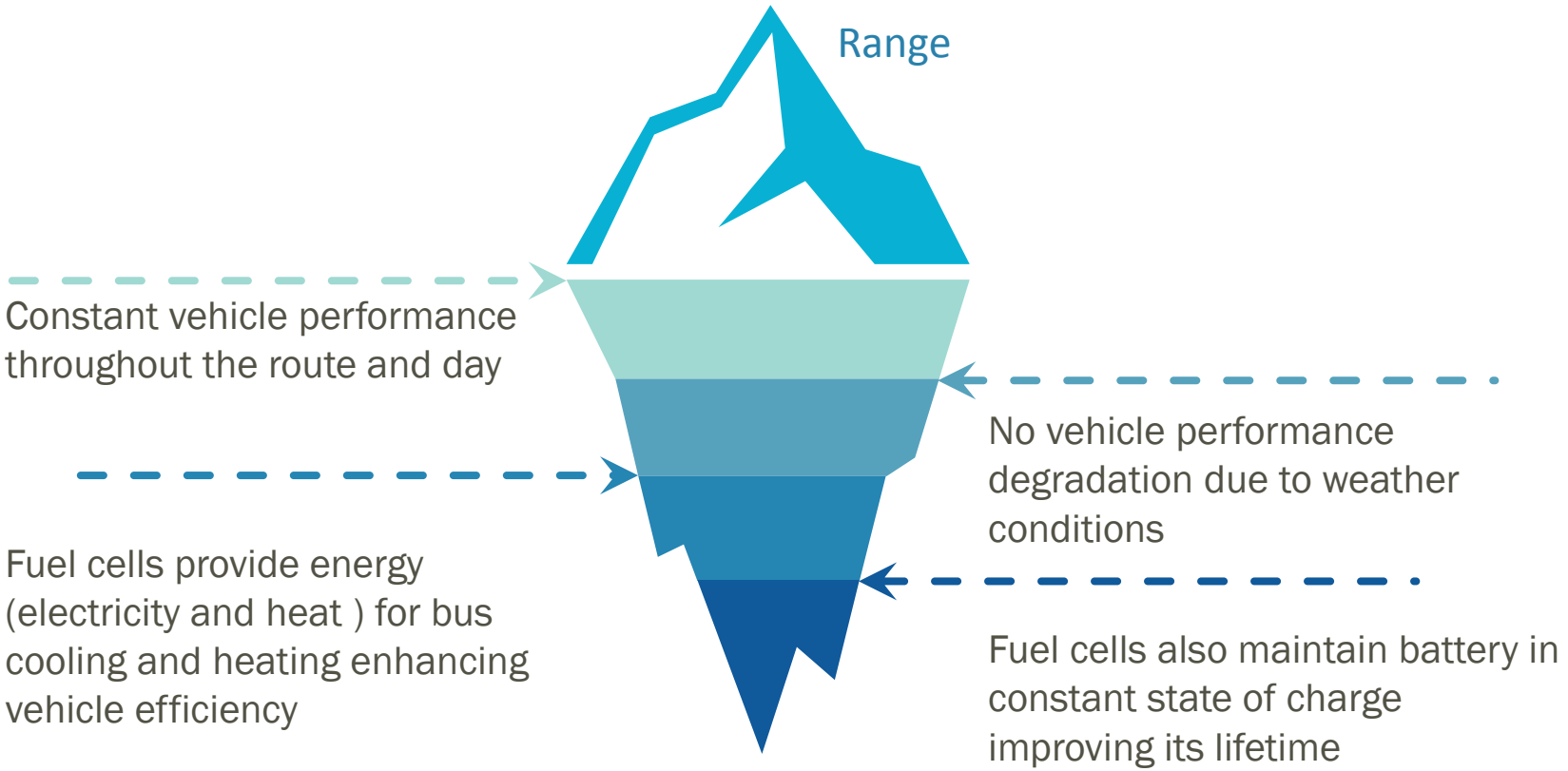
Rapid refueling speeds (6 to 10 minutes)

1:1 replacement of conventional vehicles

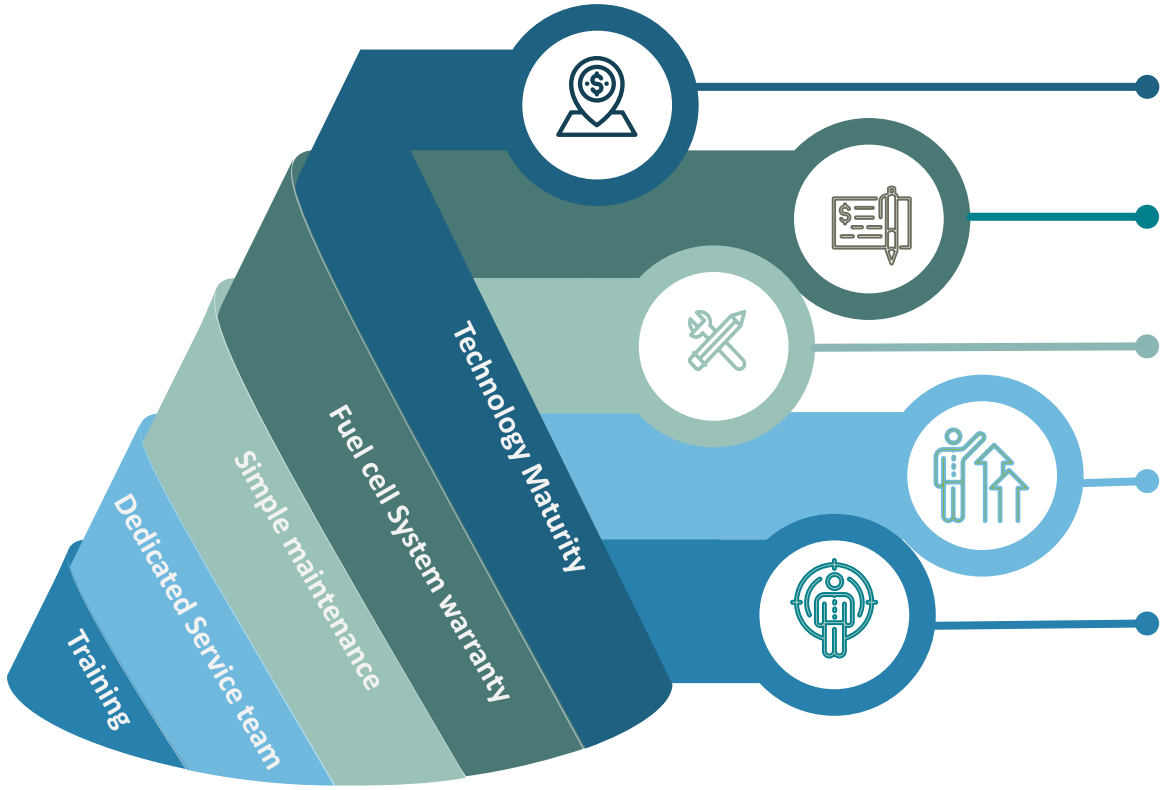


Fuel cells improve performances of electric bus

Fuel cells operate as on-board DC power generator using energy from hydrogen



At scale maintenance cost of fuel cell bus will be comparable to BEB



Technology and supply chain maturity

New generation of BoP components

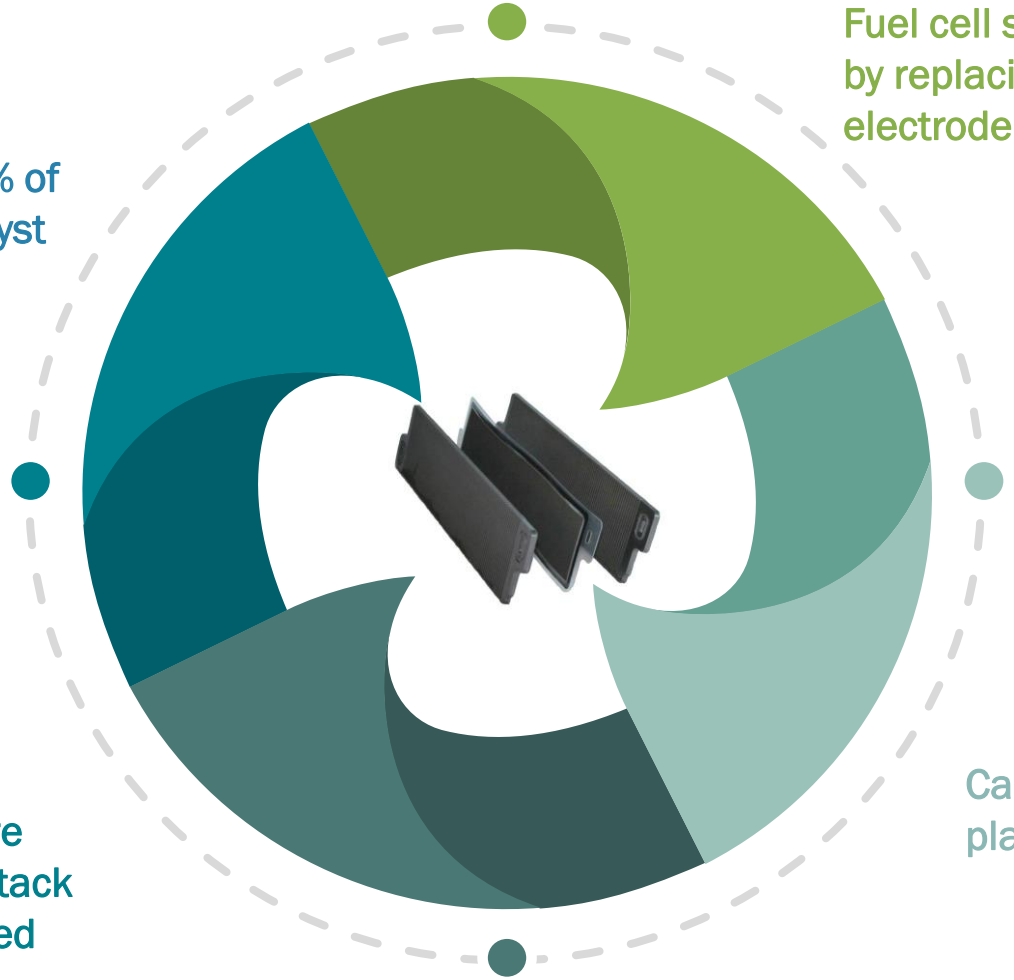
Comprehensive warranty offer 250,000 miles or 6 calendar years

Simple preventive maintenance performed by transit operator

Dedicated service team to provide after-sales services with our bus OEM partners

Knowledge transfer to operator

Fuel cell delivers zero emissions but also sustainable power.



Fuel cell stack are refurbished by replacing the membrane electrode assembly (MEA)

More than 95% of platinum catalyst is recycled

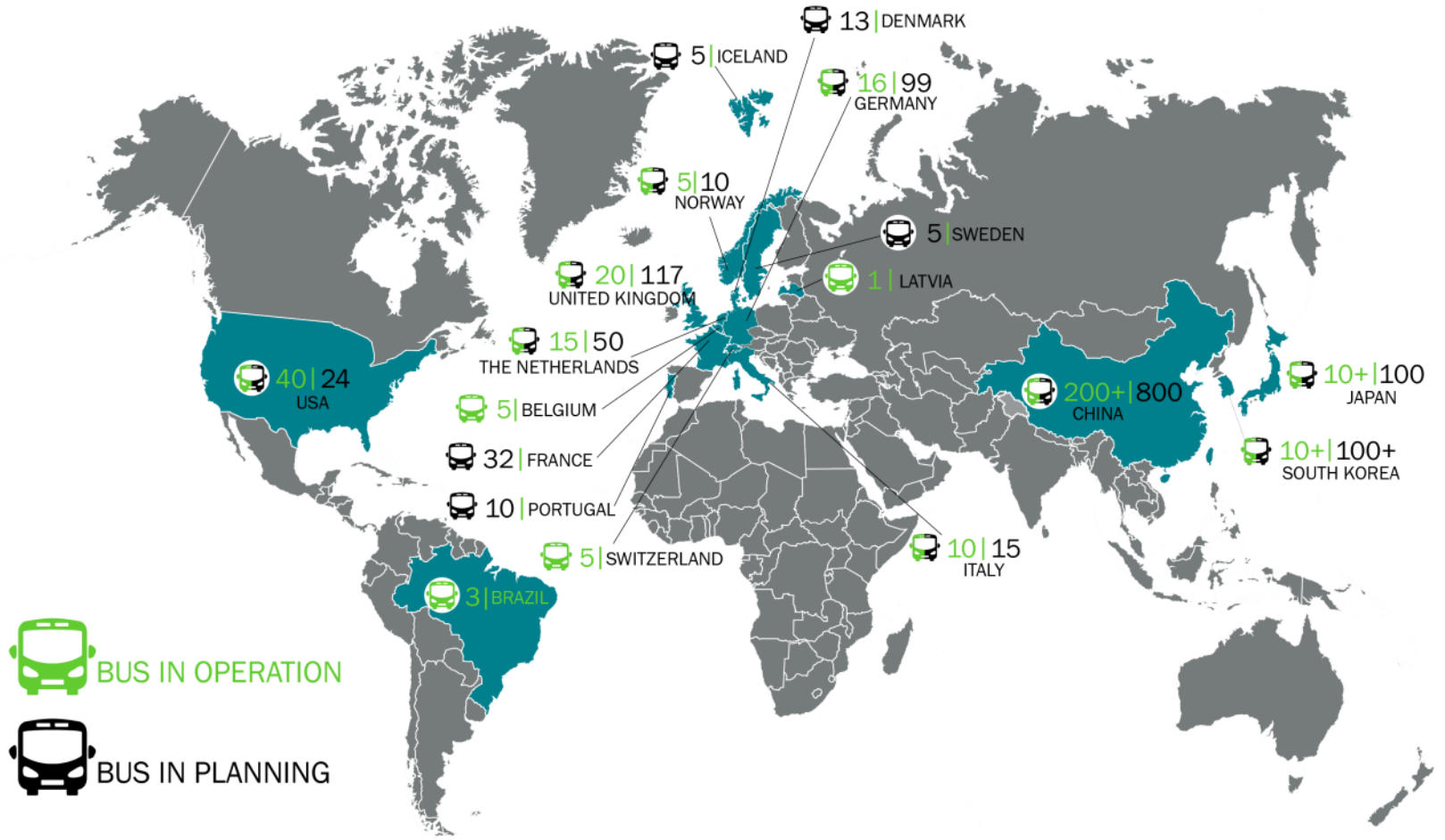
Fuel cell membranes are recycled and stack is re-conditioned

Carbon bipolar plates are re-used

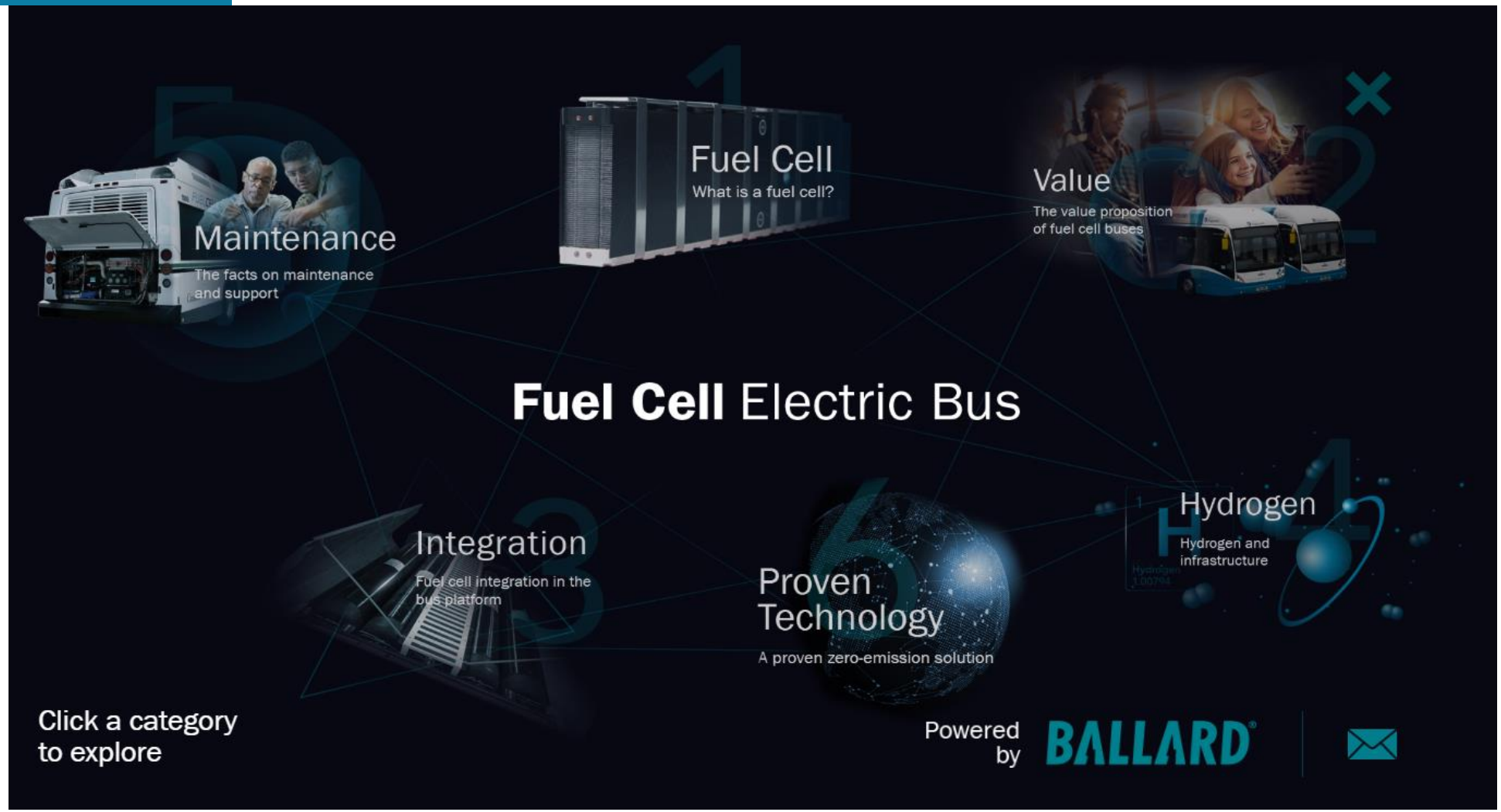
There will be more than 2,000 FCEB on the road by 2020.

FUEL CELL BUSES WORLDWIDE

300+|2000+



Learn more about FCEB
http://zeroemissionbus.org



BALLARD

Committed to sustainable mobility, and clean air for everyone.

www.ballard.com

#theotherelectricbus

Today's Transit for Tomorrow's World

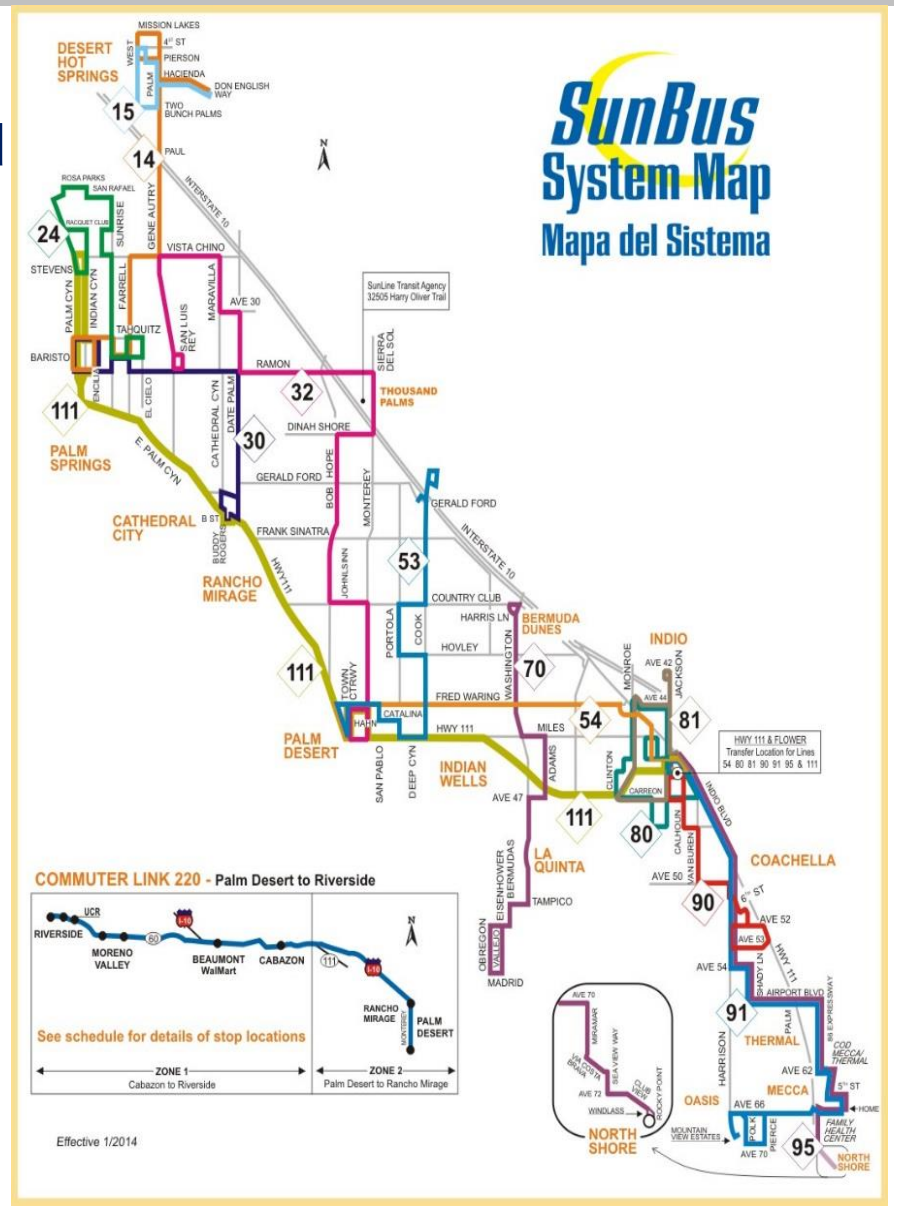
Making the Case For Hydrogen Bus Technology

Rudy Le Flore
Chief Performance Consultant

SunLine Facts

SunLine Operations

- Fourteen (14) local SunBus fixed routes, (1) express line, (1) Riverside Commuter Link, ADA Paratransit
- **68 CNG buses**
- **15 Electric Hydrogen Fuel Cell buses (2 more in production)**
- **4 All Electric Battery BYD buses**
- **39 CNG Paratransit Vehicles**
- Operated 4.3 million revenue miles for 4.5 million passenger trips
- 350 Employees



SunLine's Hydrogen Program

- **Vehicles**
- (9) 40ft El Dorado Axess Hydrogen Electric Fuel Cell buses (FC3,4,5,6 FC8,9,10,11,12) (Low/No)

  BAE/Ballard 150 Kw
- (5) 40Ft New Flyer Xcelsior Hydrogen Electric Fuel Cell buses (NOTE; FC14,15,16,17,18)

  Siemens/ Ballard 85Kw
- (1) 40ft El Dorado Axess Battery Dominant Hydrogen Electric Fuel Cell Bus (NOTE; FC7)

  BAE/US Hybrid 50/60 Kw
- (1) 40ft New Flyer Battery Dominant Xcelsior Hydrogen Electric Fuel Cell bus (**Note: FC13 delivery end of May 2019**)

  Siemens/Hydrogenics 50/60 Kw
- (2) 32ft El Dorado Hydrogen Electric Fuel Cell shuttle buses **(Note: in production, delivery December 2019)**

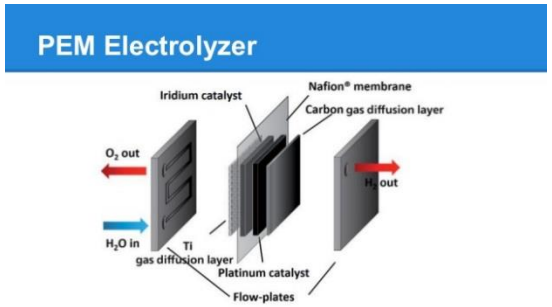
  Us Hybrid 30 Kw

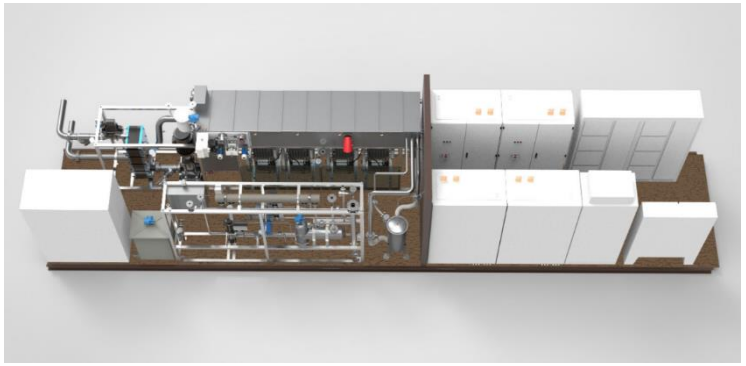
SunLine's Hydrogen Program

- **Current Fueling**
  - Hyradix Reformer
  - 220 Kg per day capacity
  - Natural Gas / Bio Gas (landfill) source fuel
  - 100 Kg use per day
  - Public fueling station – 350 Bar
  - Averages $7 a Kg

SunLine's Hydrogen Program

- **Future Fueling – Funded**
  - Nel PEM Electrolyzer
  - 900 Kg per day production
  - 60% renewable solar electricity
  - 380 Kg use per day
  - 2 dispenser fast fill rate
  - Public Fueling – 700 Bar expansion for future





SunLine's Hydrogen Program

- **Future Fueling Exploration**
  - SunLine is looking to move into liquid Hydrogen as a redundancy component and to reduce the transportation/transmission charges
    - Contracted services for Hydrogen escalate to approx. $30 Kg

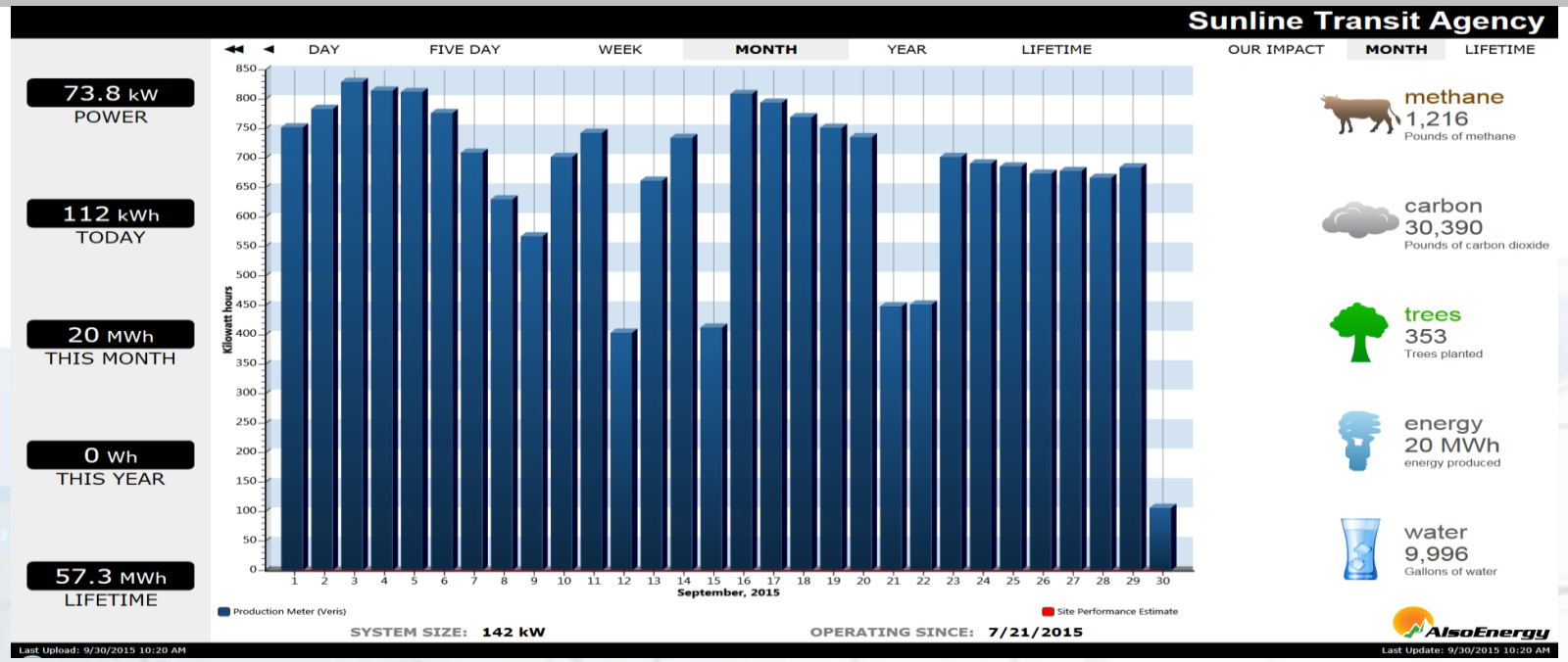
Solar Energy

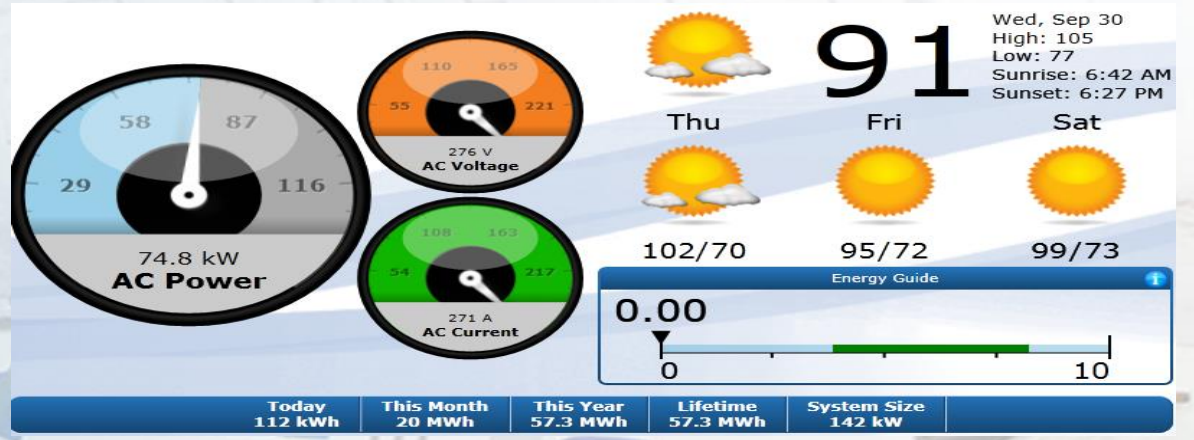
- SunLine produces approximately 33 percent of it's electrical energy power from solar
- FY19 – Second phase under construction now and provide approximately 60 percent of electrical energy usage from solar power
- The goal is to be 100 percent on solar power for energy needs outside of nighttime fueling
- SunLine has a net metering energy agreement/rate with our local municipal provider at about 13 cents a kWh with standard industry demand charges

Phases 1

Phases 2

Solar Collector Dashboard

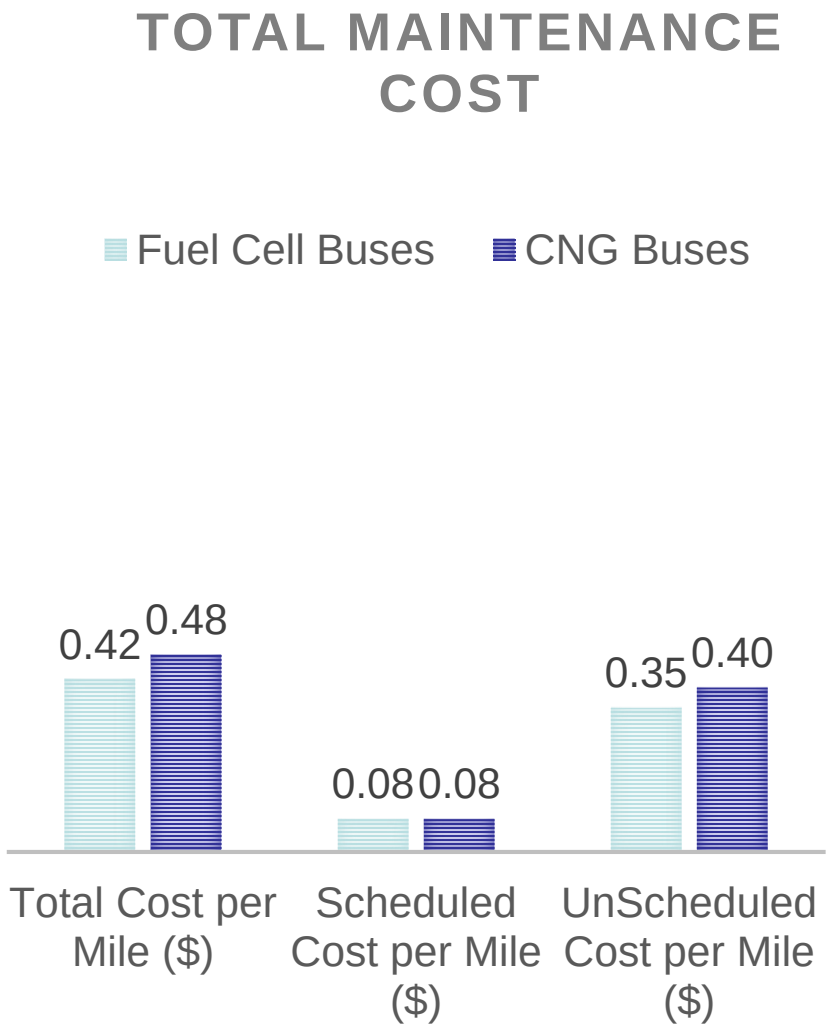


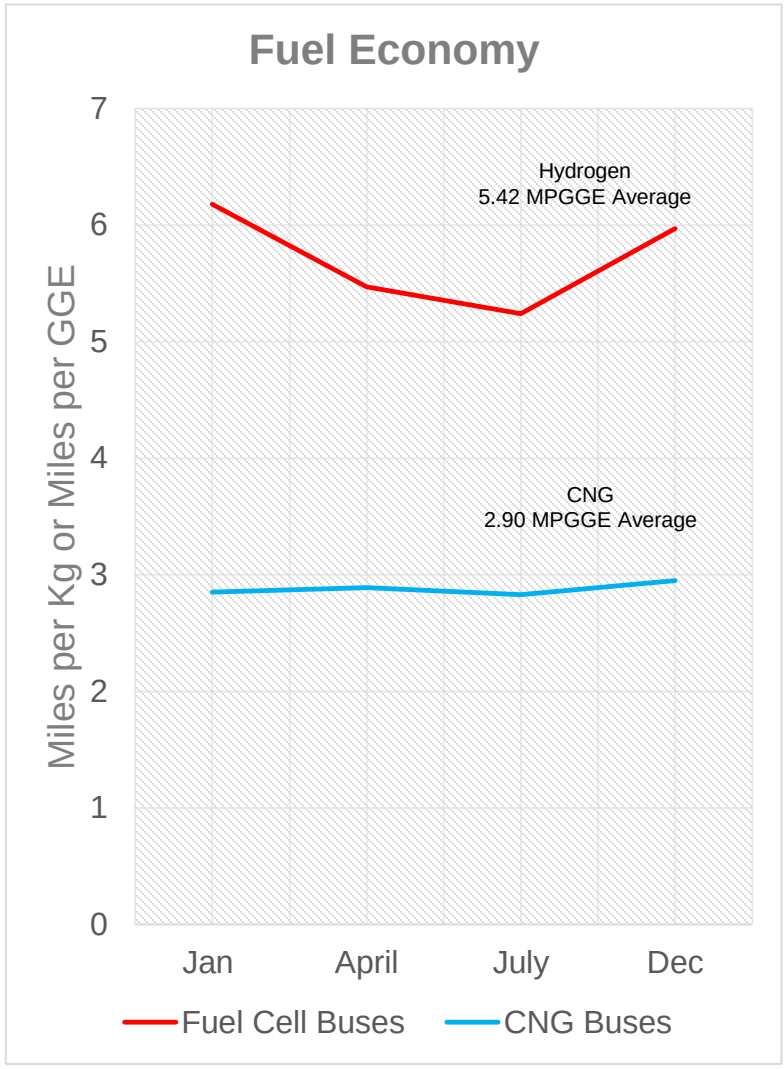


H2 Bus Affordability

FC1	2004	3.25M
FC2	2008	2.75M
FC3	2012	2.4M
FC4,5,6	2014	2.1M
5 buses Newest	2019	1.17M

Maintenance Costs





Infrastructure Costs Comparison

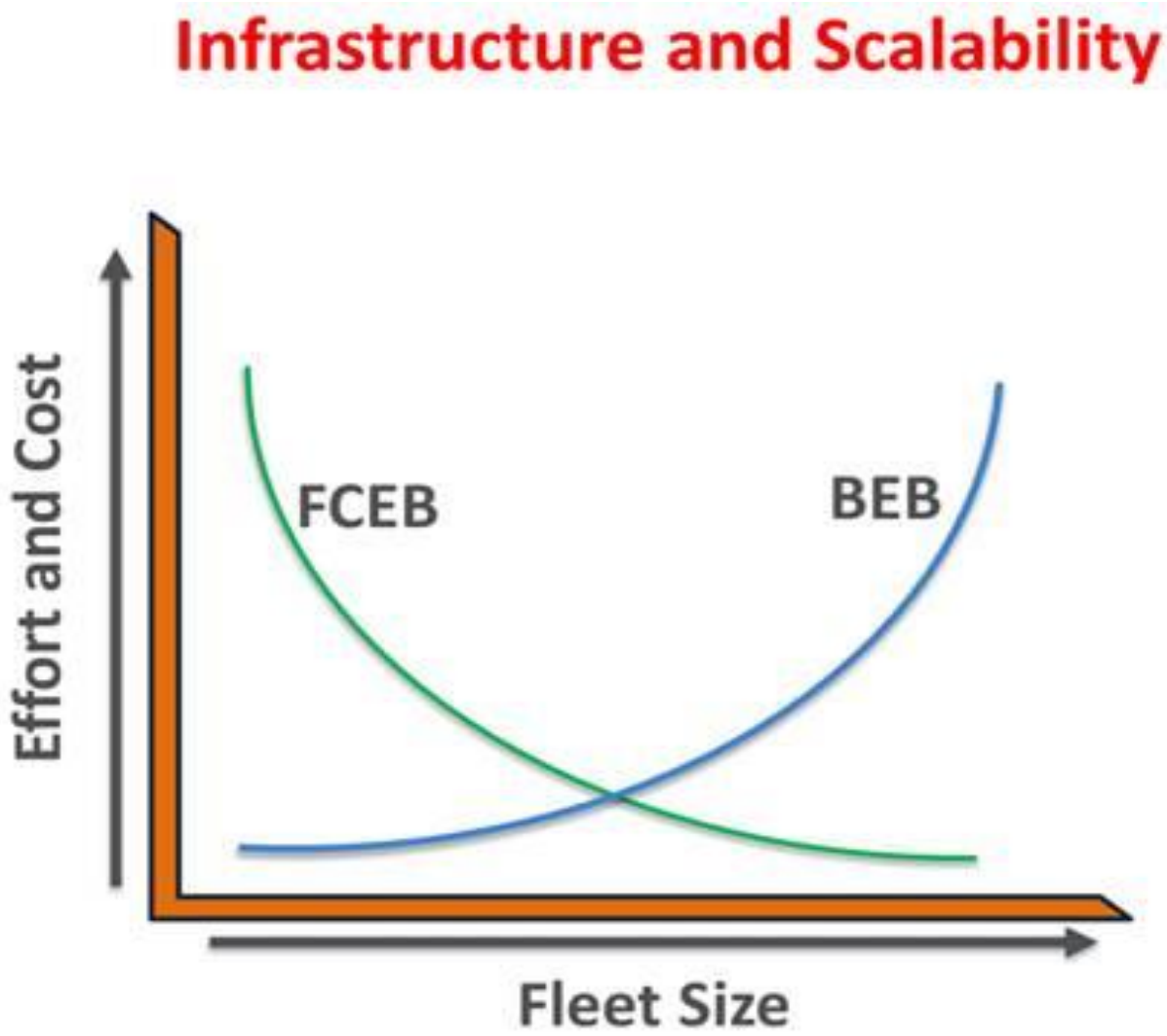


Chart Furnished by The Center for Transportation and the Environment

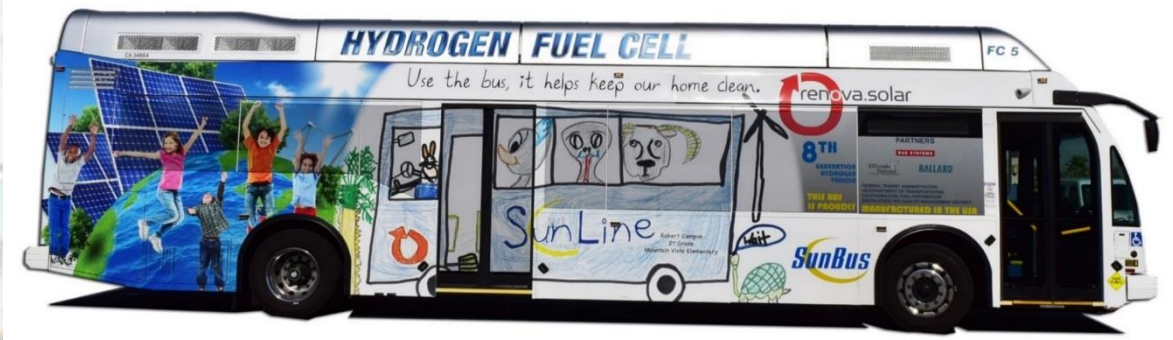
Getting Started

- **What should you do to start a ZEB program?**
  - Create a Board Policy
    - Most Operators assume Hydrogen is too complicated/expensive for their team and their community
  - Develop a mission or focus on ZEB technology
    - Ensure that the agency knows what and why leadership is directing change a in platform
    - Develop internal champions who are emerging leaders and believe in the benefits of piloting new technology
  - Redesign your existing system
    - We have to “stop selling, what riders aren’t buying”
    - Plan your new network using ZEBs
      - Many agencies are looking at more frequent, reduced running times and more productive services
  - Manufacturer/Operator relationships
    - Ensuring all parties understand risk and work together to solve problems

Key Takeaways

- SunLine has made a deep commitment to reducing environmental impacts while delivering world-class transit services
- A strong mission/focus must be developed and delivered from all levels of the organization
- SunLine does not use any solid fuel to deliver transit to the Coachella Valley
- Zero emission technology works
- Don't wait until the funding opportunities sunset to create a renewable energy mission/focus

Thank You



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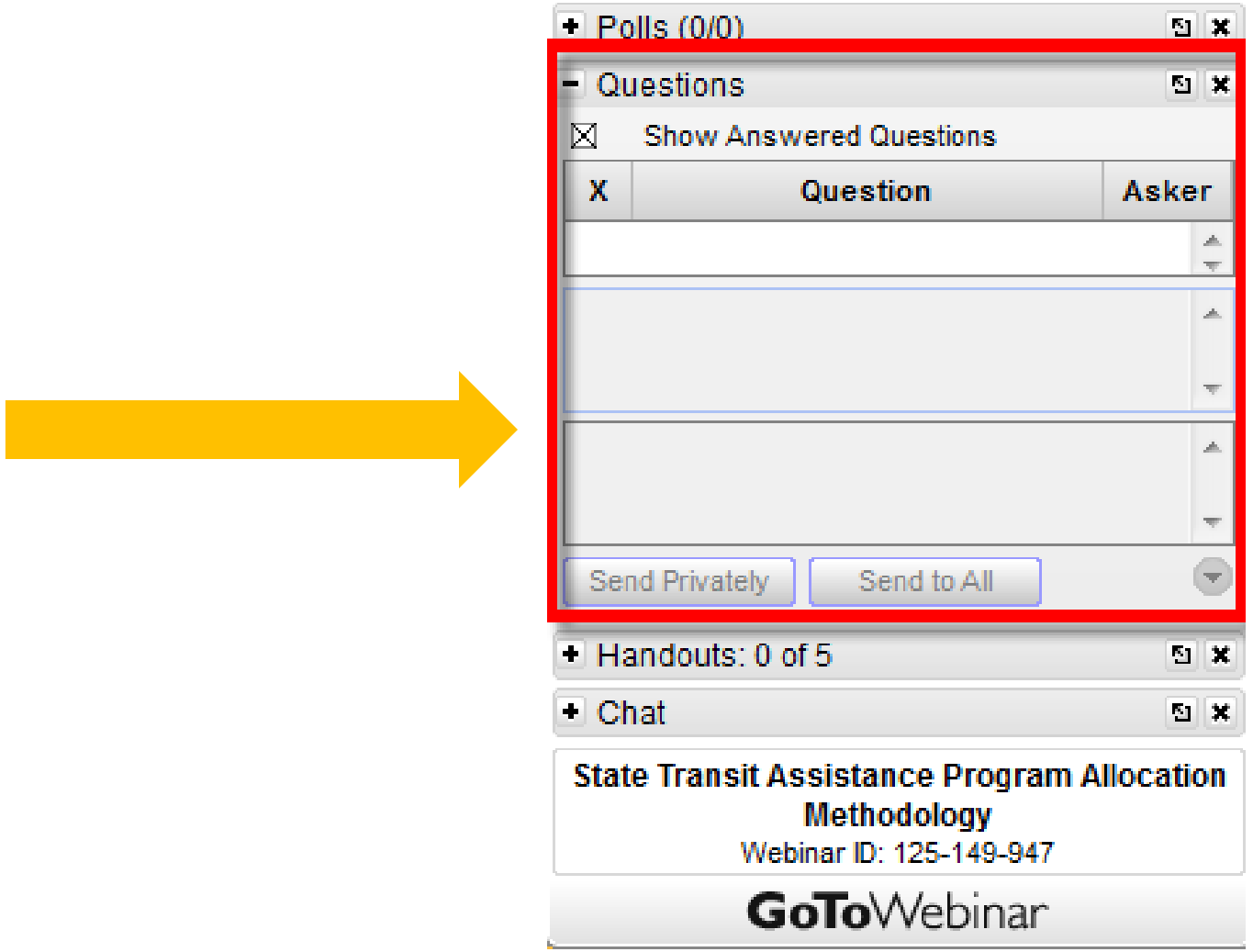

Remember to Register!

- Fuel Cell Electric Bus Technology: Technical Capabilities and Experience (6/13)
- Hydrogen Infrastructure: Scalability and Technical Considerations (TBD)
- Fund the Fleet: Funding Mechanisms to Assist and Accelerate ZEB Deployment (6/27)

Contact Us

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