FCEB Webinar Series 2024:
The Fundamentals of Fuel Cell Electric Bus Deployment

March 14, 2024

Webinar Contributors

Kim Leach
Market Development Manager, Ballard

Moderator

Tim Sasseen
Market Development Director, Ballard

Zero-emission adoption & TCO

Michael McDonald
Operations Manager, New Flyer

New Flyer FCEB case study

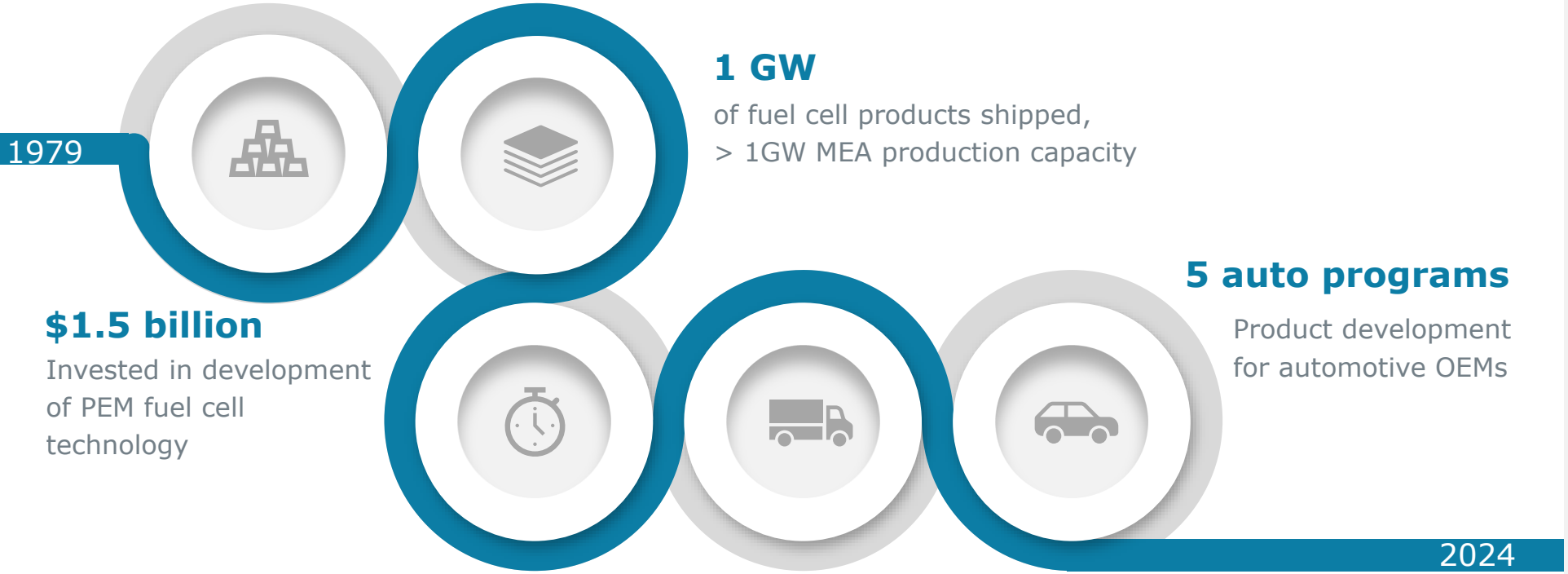
FCEBs Today

Kim Leach

Market Development Manager, Ballard

About Ballard

We have fuel cell expertise and experience with leading technology



$1.5 billion
Invested in development of PEM fuel cell technology

1 GW
of fuel cell products shipped,
> 1GW MEA production capacity

5 auto programs
Product development for automotive OEMs

14 generations
of fuel cell stacks &
8 generations of heavy-duty modules

125m miles Fleet experience
Ballard fuel cells powering bus & truck fleets globally

Ballard Today

3,600+
buses & trucks operating

170+
FCEB on the road in US & Canada

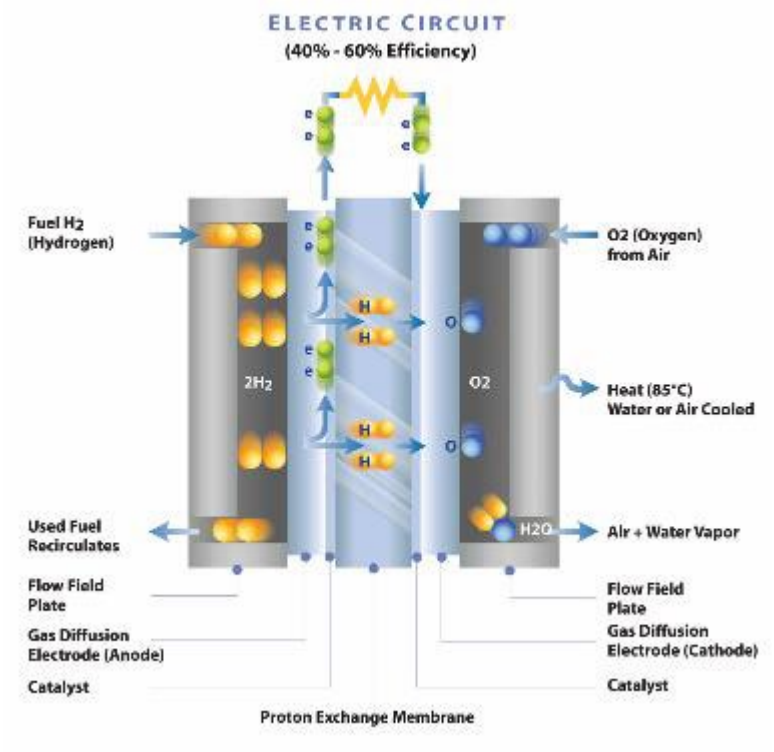
98%
uptime of fuel cell module modules in transit bus

+25,000
hours product lifetime proven in operation

Rigorous technology & product development processes

Fuel Cell Fundamentals

Unit cells combine to convert hydrogen and oxygen into electricity for power with water and heat as by-products: **ZERO-EMISSION**



UNIT CELL:
Flow Plate/MEA

FUEL CELL STACK

FUEL CELL ENGINE

BUS POWERTRAIN

30+ years of experience

Ballard Power Systems has now completed more than 30 years of support, development and optimization for on-road deployments of fuel cell electric buses.

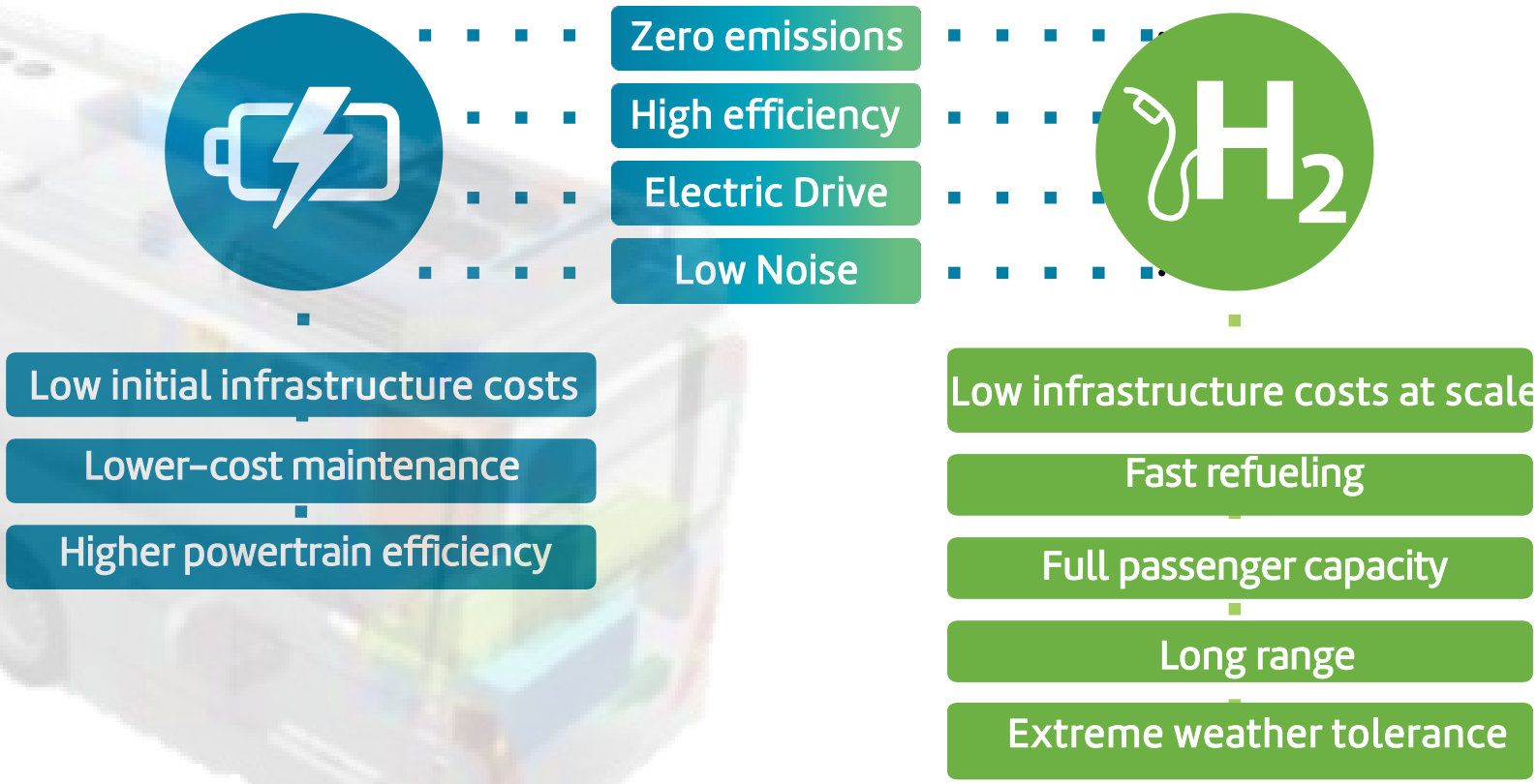
Proof of Concept
1991-1995

Hybridized Fleets
2009-2014

Commercialization
Today

A Hydrogen Bus is an Electric Bus

- Same electric drivetrain as battery electric buses
- Same maintenance and parts – excluding fuel cell power module and gas tanks



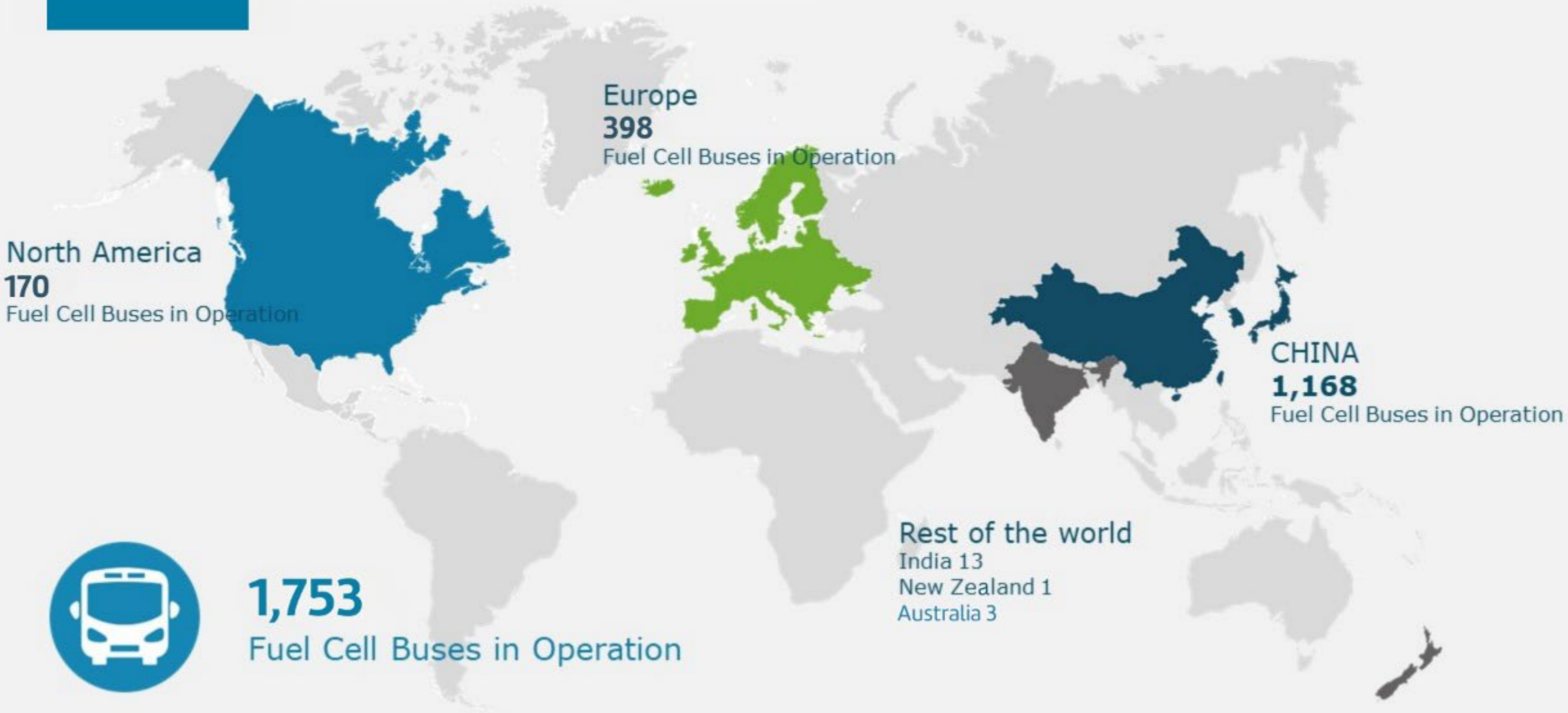
Zero-Emission Bus Comparisons

Category	BEB	FCEB
Promotes positive driver behavior	✓	✓
Refueling/recharging times	✗	✓
Social acceptance – knowledge and perception	✗	✓
Range (550km/350 miles)	✗	✓
Challenging terrain and cold weather performance	✗	✓
Less impact on schedule time and resources	✗	✓
Auxiliary heaters/accessories	✗	✓

Today there are multiple offerings for FCEBs

- More than 20 years of road experience
- Over 8 million miles in service
- Fuel cell module availability >98%
- More than 25,000 hours stack durability
- Operation in challenging routes and climates
- Buses deployed in more than 70 cities globally
- 125 million miles (200m km) on-road experience (heavy-duty vehicles)

FCEBs Worldwide



FCmove® Platform

- Compact innovative design
- Low lifecycle cost
- Engine bay and flat configurations for easy integration
- High performance, robust product with wide operating range
- 70kW and 100kW versions

FCmove® Platform

Complete product portfolio to address all commercial vehicle applications (on and off road)

45kW → **120kW/240kW**

Light duty | **Medium Duty** | **Heavy Duty**

FCmove®

Click for Spec Sheet ▶

FCmove®-HD
70kW

FCmove®-HD+
100kW

FCmove®-XD
120kW | 240kW

FCmove®-HD+
Module

Ballard's **FCmove®-HD+** module is specifically designed for transit buses and medium duty trucks

Specs
- 100kW fuel cell modules
- Roof top and engine bay configuration

Vehicle Types
- Commuter Trains
- Transit buses (12m-18m) including articulated buses and rapid transit buses
- Medium duty trucks (12t-19t), Class 4-6

Product Availability:
Commercially availability: 2023

1. 45kW based on net values

From fuel cell products to solutions & services

Ballard Solutions

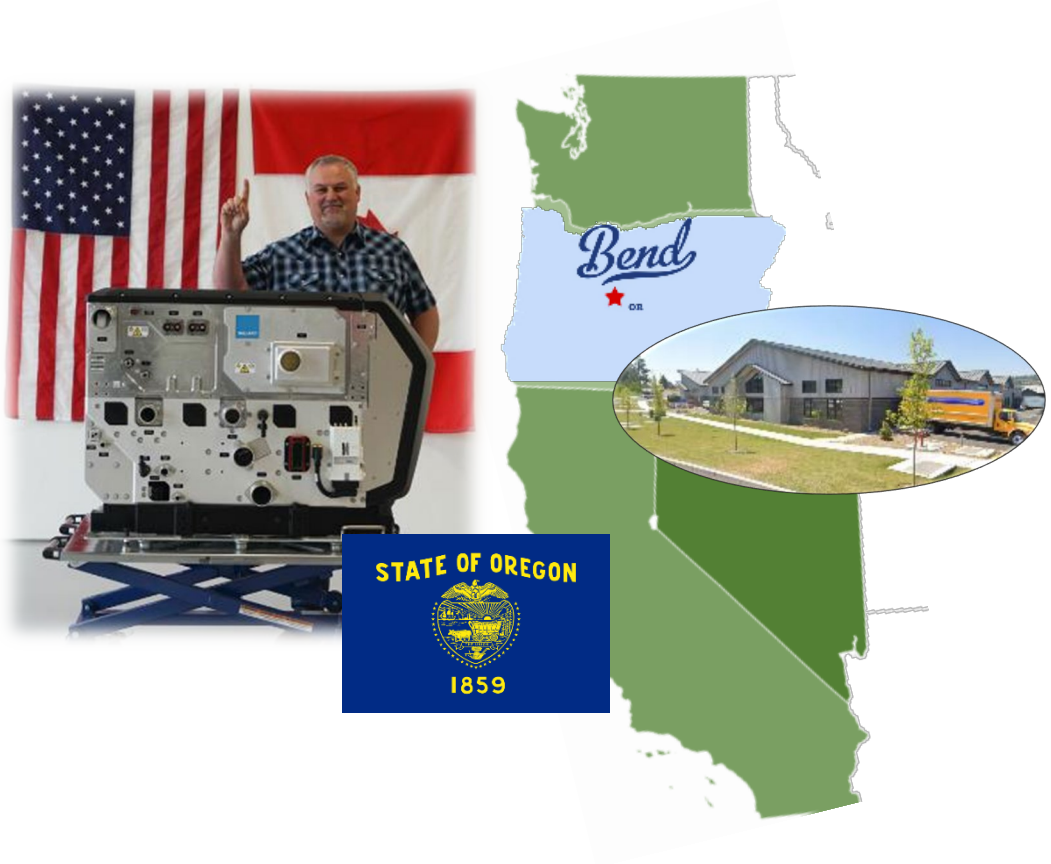
- Battery + fuel cell integration
- Energy System and Powertrain integration
- Technology Solution programs

Ballard Care

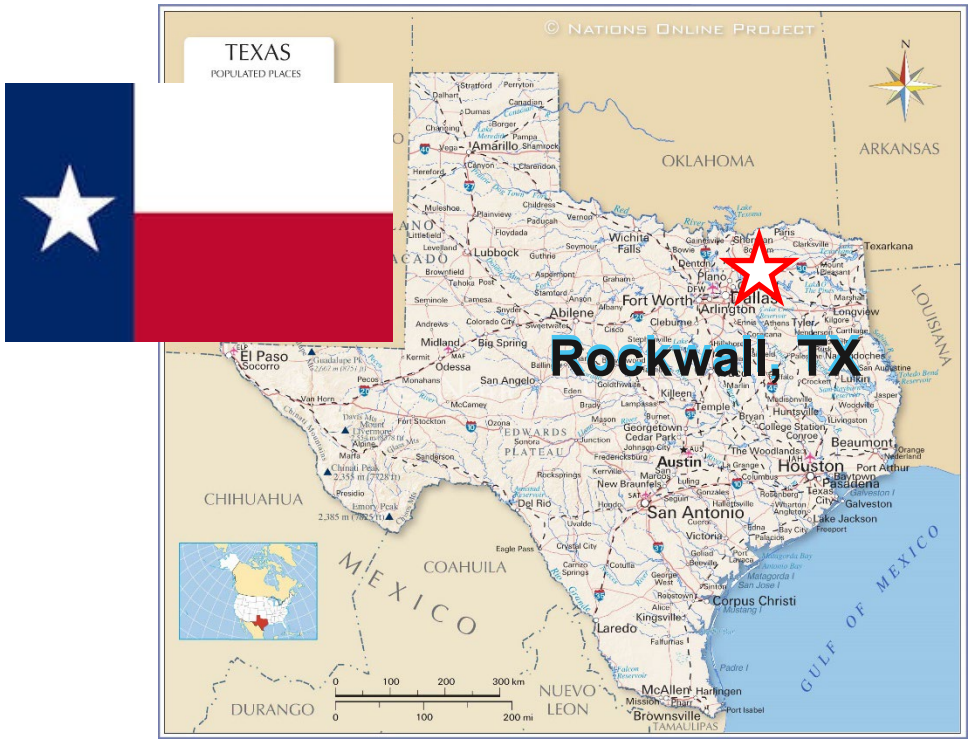
- Application engineering support
- Training
- Extended warranty and service agreement
- Field service support
- Spare part management
- Fleet monitoring

Here for Life in the U.S.:
Bend, Oregon FCmove® Manufacturing Facility
Rockwall, Texas Fuel Cell Gigafactory

2023: U.S. manufacturing of FCmove®-HD+ 100kW fuel cell engines for all North American zero-emission bus customers



2024: Ballard announces $40 million in DOE grants to support build-out of integrated **fuel cell production Gigafactory in Rockwall, Texas**



OEM Partner – New Flyer

- **February 2017**: Ballard commits to provide 20 fuel cell engines to New Flyer's 40ft Xcelsior XHE40 zero-emission buses

- **June 2021**: Ballard announces follow-on order of 20 more fuel cell modules for the Xcelsior

- **September 2022**: New Flyer unveils Xcelsior CHARGE FC, with fuel cell engine provided by Ballard

New Flyer FCEB Case Study

Mike McDonald

Operations Manager, New Flyer

Driving Hydrogen with NFI

Michael McDonald, Ph.D.

Operations Manager, *NFI Vehicle Innovation Center*

Michael McDonald, Ph.D., joined NFI Group (“NFI”) in 2017 and has since assumed the role of operations manager for the Vehicle Innovation Center (“VIC”). Michael lends strategic vision and guidance to VIC programming, outreach, R&D, and electric bus demonstrations. He also speaks regularly on EV technology, sustainability, and infrastructure at industry conferences across the U.S. and Canada

VIC™ | VEHICLE INNOVATION CENTER

- Designed to equip you on your journey to zero-emission mobility
- EV, AV and Infrastructure Technologies
- Manufacturing Innovation Lab
- Interactive Exhibits
  - Electric bus driving simulator
  - Latest technology demonstrations
- Over **400 events** and training sessions have been hosted since opening in 2017.
- More than **7,000 industry leaders** have visited and learned from our VIC experts.
- **+50 years** of experienced manufacturing zero-emission buses.
- More than **140 million EV miles** of experience.

DRIVING INNOVATION

- Largest bus & coach OEM in North America.
- Largest ZEB provider in North America.
- Scalable provider of FCEB in North America.
- FCEB innovation heritage: most proven & advanced FCEB on the market.
- Experienced in-house infrastructure EPC capabilities.
- Proven, continent-wide deployment of BEBs and FCEBs.
- On the assembly line – not a project.
- Made in America!

450 Years

NFI Group and its subsidiaries have a combined 450 years of experience

50+ Years

More than 50 years of experienced manufacturing zero-emission buses.

140+ Million

More than 120 million EV miles of experience.

4 Pillars

NFI's four-pillar mobility solutions.

Buses and Coaches

Infrastructure Services & Support

NFI Infrastructure Solutions™

Workforce Development

NFI Learning Institute | VIC Vehicle Innovation Center

Connected Technology

NFI Connect™

xcelsior CHARGE FC™

EXTENDED RANGE WITH ZERO EMISSIONS

Extended Range

The Xcelsior CHARGE FC™ can travel 370+ miles on a single refueling and requires no off-board electric recharging.

Robust Design

- Built on the proven Xcelsior® platform.
- Features EV industry-proven Tier 1 components.
- Utilizes common battery-electric drive system.
  - **Balanced approach for battery & FC contribution to match transit duty cycle**

Zero Emissions

Only water from the tailpipe.

Incorporates four (4) distinct high-performing technologies:

- Ballard Power Systems new high-performing fuel-cell power module FCmove™-HD+
- New battery packaging designed and developed by New Flyer
- The newest, high-power, rapid-charge batteries
- Siemens new innovative traction drive system, call “ELFA 3”

40'

60'

WHY CHOOSE AN NFI FUEL CELL-ELECTRIC BUS?

- **Zero emissions***
  - Pure, clean water at tailpipe
- **Extended range**
  - Superior energy density of Hydrogen (H2) vs. Li-ion batteries
- **Fast re-fuel**
  - No slow charge or specialized infrastructure for fast charging
- **E-drive**
  - Quiet
  - Smooth, responsive acceleration
  - Efficient (FC, regen)
- **Free heat!**
  - Capture waste like in ICE vehicles
  - Further enhances range in cold
- **Infrastructure**
  - Economic at scale
  - NFI Infrastructure Solutions™
- **Xcelsior® robust, proven platform structure**
- **Only 60' FCEB** manufacturer
  - First 60' fuel cell-electric bus to complete Altoona.
- **Only manufacturer** to offer both a **40' and 60' fuel cell-electric model** that **qualifies for federal funding**.
- **Performs like a diesel**
  - 1:1 bus substitution ($)
  - No reinventing deployment strategy

370+ miles

on a single refueling with no off-board electric recharging.

20+ years

of experience producing fuel cell-electric buses for North American operators.

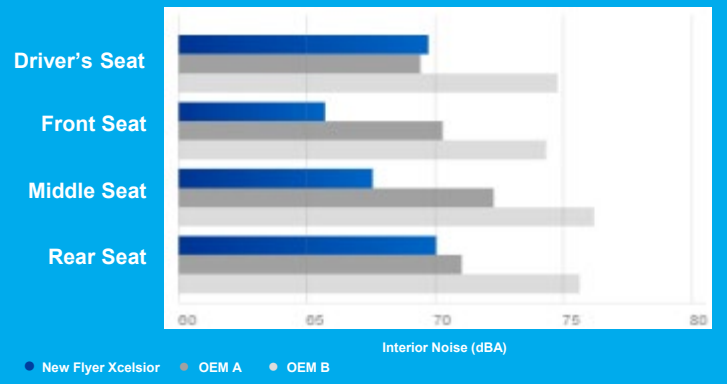
Avoid 85-175 tons

of greenhouse gas per year from tailpipe emissions compared to a diesel bus.

>115M EV miles

of experience.

Sturra (Altoona) Test Results



FUEL CELL-ELECTRIC BUSES BY NFI

TONS OF EXPERIENCE. LITERALLY.

Powered by Fuel Cells

Advanced Battery Packaging

Integration with Battery-Electric Technology

Fully Zero-Emission Solution

Longer Range

Smart City Capable

Smart Refueling

Energy Recovery

1993
Introduced the world's **first** FCEB (with technology partners)

2010
20-bus evaluation program for the 2010 Winter Olympics

2018
Delivered first 60' zero-emission fuel cell bus in North America

2019
Reached 350 miles of range in test demonstration

2019
Launch of Xcelsior CHARGE H2

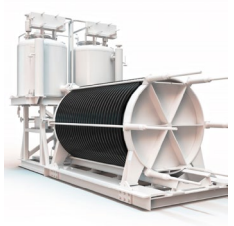
2022
Launch of Xcelsior CHARGE FC™

North American Deployments

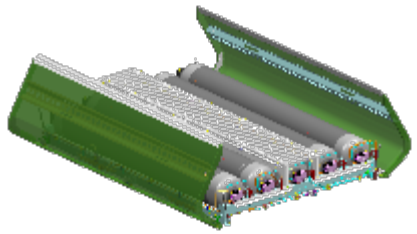
	2018	2019	2020	2021	2022	2023+
Fuel-Cell	6	20	5	28	33	
Agencies	3	3	1	4	3	

The most advanced hydrogen fuel cell-electric bus in North America.

ENERGY FLOW IN E-ARCHITECTURE: FCEB

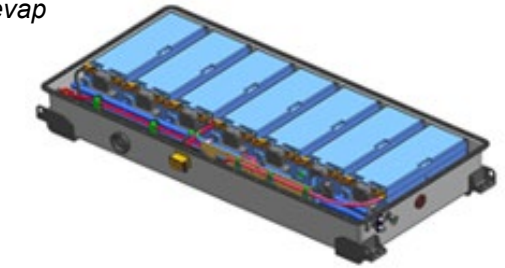






Hydrogen Production → *Electrolysis, SMR* → **Onsite Storage** → *Compressed, LNG + evap* → **Fill Panel** → *350 bar* → **Onboard Fuel**






Traction Motor ← *3-phase AC PEM* / *Regenerative Braking 20-25%* → **Traction Inverters** ← *618 VDC nominal* → **ESS** ← *100 kW* → **FC System**

Brake Resistor / *40 kW* → **Heater** ← *Captured FC waste heat*

Lights, Multimedia, Power Steering

Low Voltage Accessory ← *24 VDC* ← **Auxiliary Inverters** → *230 VAC* → **High Voltage Accessory**

A/C, BTMS, Air Compressor

FUEL CELL E-DRIVE IN TRANSIT

IT'S PHYSICS: POWER VS ENERGY

ENERGY

- Total energy required to satisfy task requirement (regardless of how fast it's utilized)
- e.g., size of water storage on a firetruck

POWER

- *Rate* that energy must be expended to satisfy task requirement
- e.g., hose system pressure on firetruck to expend water tank

ZE TECHNOLOGY: FUEL CELLS

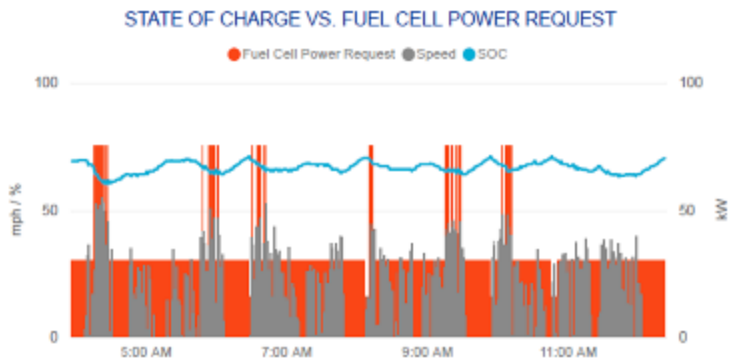
- Hydrogen has high energy density
  - Can store lots of onboard energy
- Fuel cells have poor power density
  - Poor ability to respond with agility to frequent changes in power demand

ZE TECHNOLOGY: BATTERIES

- High power density
  - Good at expending or accepting charge to and from e-drive system
- Modest energy density
  - Unable to make long ranges

The stop-and-go nature of transit = high flux of power demand.

It's a <u>battery application with a need for range boost/recharge.</u>

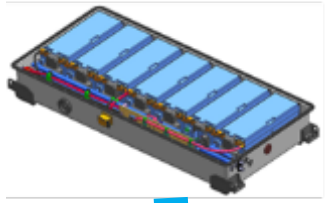


xcelsior CHARGE FC™: WHAT'S NEW

FUEL CELL

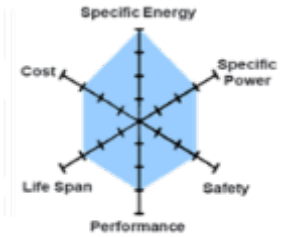
- 85 → 100 kW
- Internal heating
- Smaller, consolidated
- Built for serviceability

ESS PACKAGING



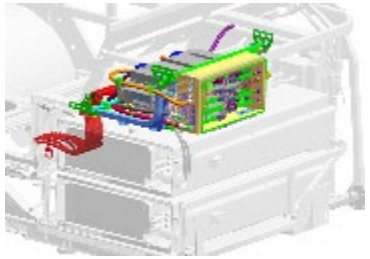
- Composite
- Lighter weight
- IP67
- Built for serviceability

BATTERY CHEMISTRY



- 13% greater energy density
- Latest NMC technology
- Plug-and-play modules
- Built for HD applications

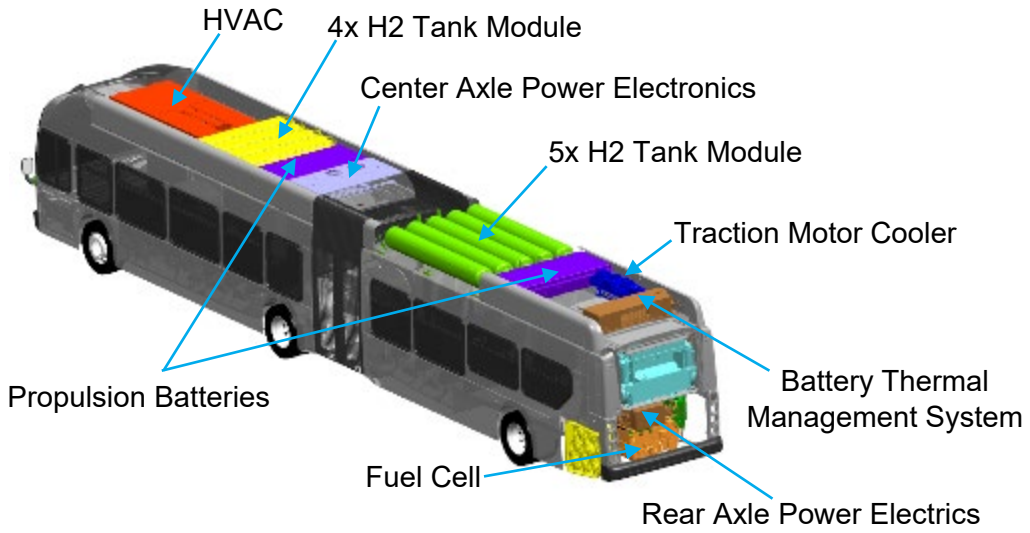
PROPULSION

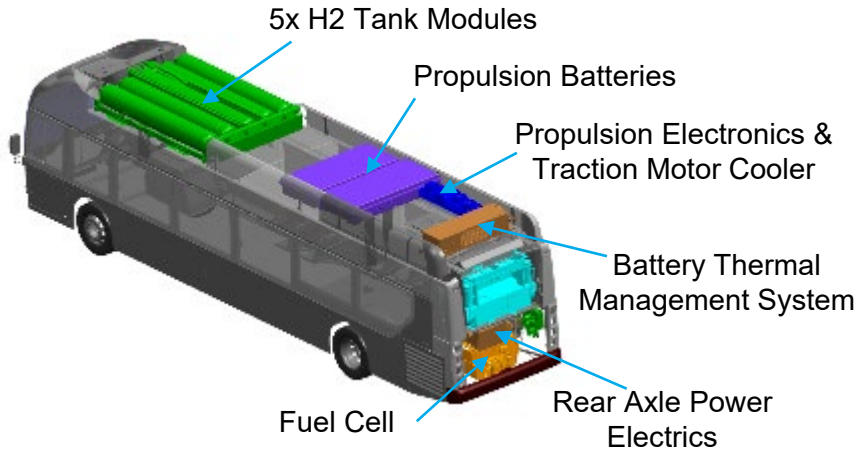


- More power, torque
- Consolidated packaging
- Weight, space reduction
- Powerful control

xcelsior CHARGE FC™

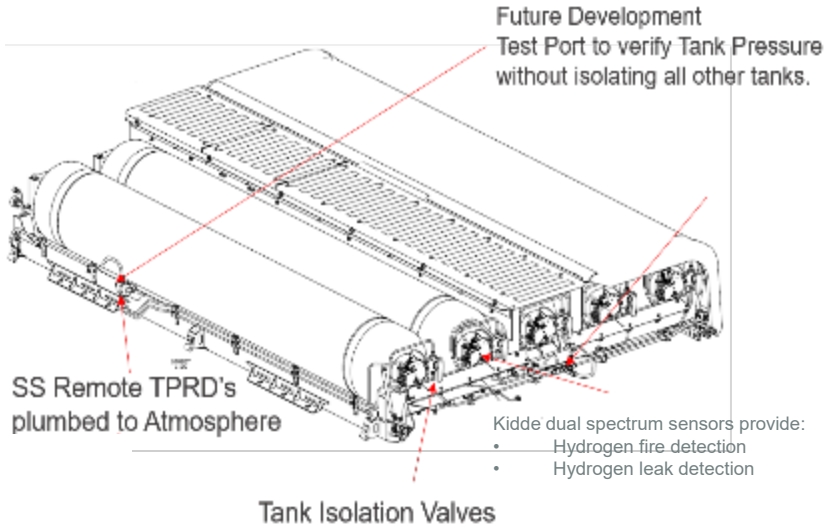
	40’	60’
Fuel Cell	1 x Ballard FCmove™-HD+: 100 kW	
Hydrogen Storage	37.5 kg	56 kg
Battery Capacity	140 kWh	
Equivalent Energy	765 kWh	1073 kWh
Range	370+ miles	
Traction	• PEM T-axle at rear • Optional high gradeability motor	• PEM T-axle at rear (std & high grade) • 2x induction in-wheel motors in center axle
Rated Power	160/230 kW 209/280 kW	410/480 kW 459/530 kW
Rated Torque	1400/3000 Nm 2000/3800 Nm	1885/3485 Nm 2485/4285 Nm

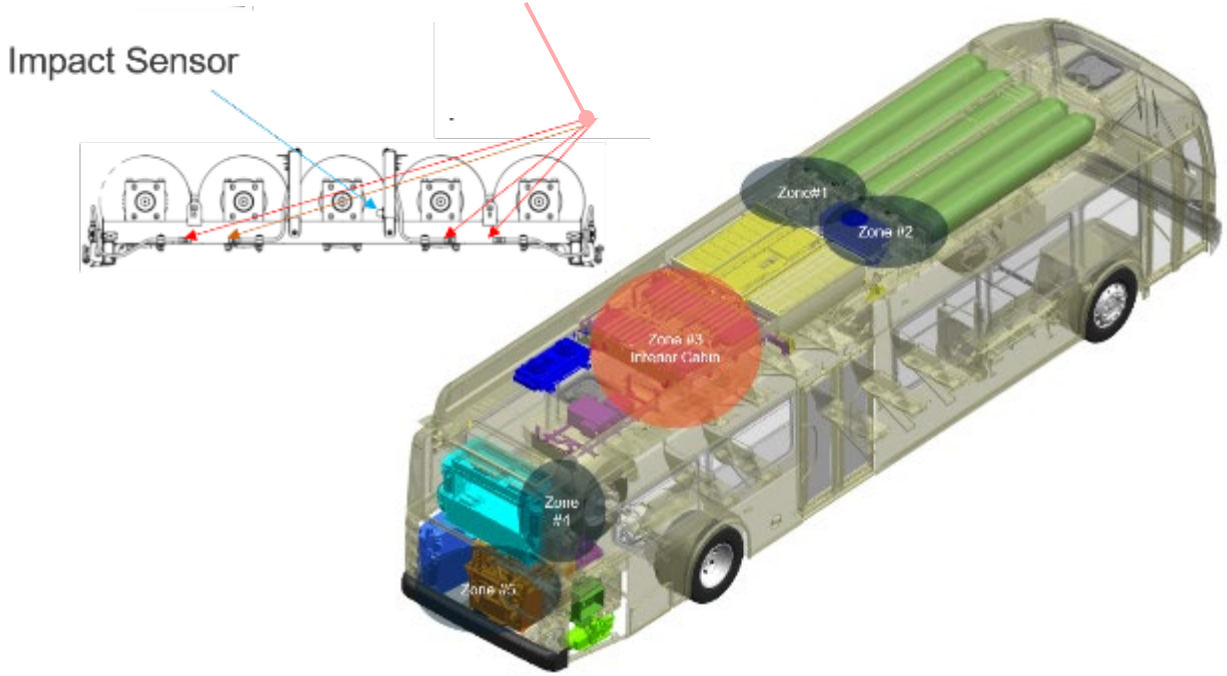




H_2 SAFETY

- **Fire detected** – shut off high voltage, shuts off all flow in the H2 system, turns off fans, turns off the fuel cell, alarm sounds
- **TPRD activated** – vent tank(s) to atmosphere
- **Excess flow valve activated** – tank(s) shut-off
- **Impact detected** – shuts off all flow in the H2 system
- **Proximity switch** – with fill box open ignition is disabled, high pressure hydrogen flow is stopped
- **Tank temperature reported to fill station** – fill station adjusts fill rate





Infrastructure Solutions™

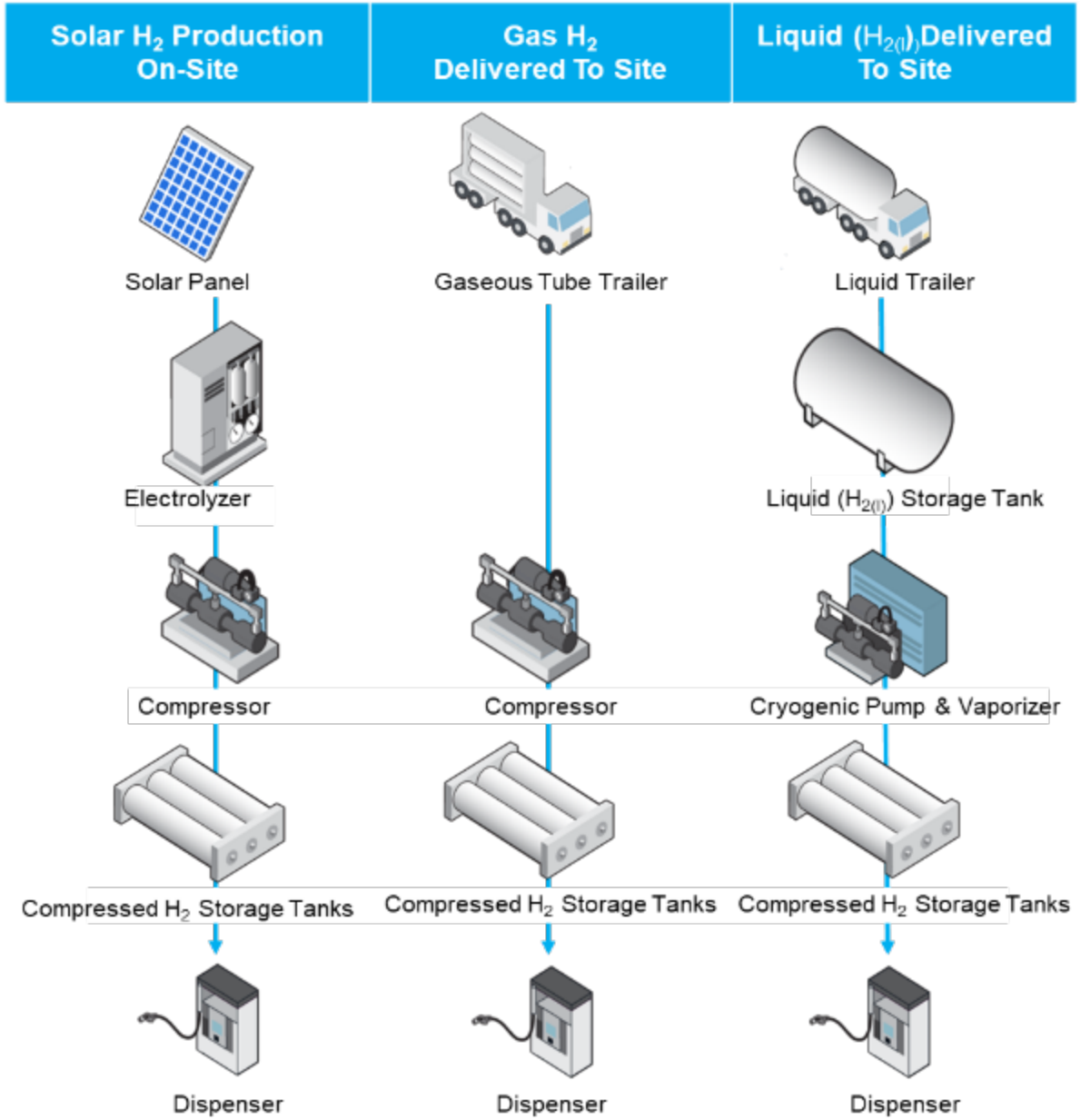
Providing safe, reliable project management for smart, sustainable mobility solutions

- Guide mobility projects start to finish
- Focuses on maximizing energy transfer and usage, as well as infrastructure planning and development
- Provides a cohesive shift to zero-emission electric technology
- Supports all NFI North American electric bus deployments
- Over 411 BEB chargers installed to date
- ***Extending expertise to FCEBs***

Infrastructure Solutions™

Typical Program Phases

Phase 1	Site Visit/Scoping/Quotation
Phase 2	Utility Service Assessment
Phase 3	Design and Engineering Services
Phase 4	Infrastructure Construction
Phase 5	Systems Installation
Phase 6	Testing & Commissioning



Connect™

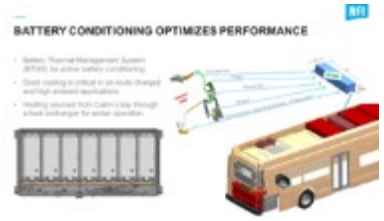
- Exclusive and advanced telematics solution.
- Puts real-time fleet information at your fingertips.
- Delivers daily and actionable information.
- Smarter oversight of your whole operation.
- Improves bus and coach uptime and lowering costs
- Customizable and easy-to-read visual reports.
- Provides insightful assessments of
  - On-board power and energy management.
  - Electric motor propulsion.
  - Accessory loads.
- Easy to deploy, compatible with multiple vehicle platforms, and requires minimal IT infrastructure.
- Connect 360™ is a performance dashboard that provides smart analytic reporting.

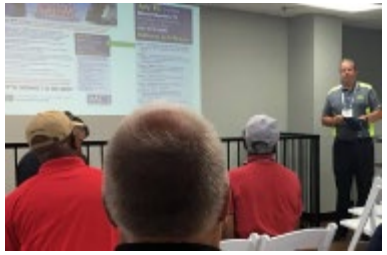
NFI Learning Institute | VIC VEHICLE INNOVATION CENTER

WORKFORCE DEVELOPMENT

- Low-No applicants must identify the proposed use of the workforce development funds in their proposals
- NFI provides world-class training to our customers through customized:
  - In-person Training
  - Virtual Learning Series
  - Hybrid combination of virtual and in-person training
  - Web-based turn-key eLearning Courses available any place, any time.
- Our team of experts will
  - Provide a detailed training plan for you and your teams
  - Design and deliver training to improve existing skill sets
  - Retrain in new skill sets such as electrification and digitization.

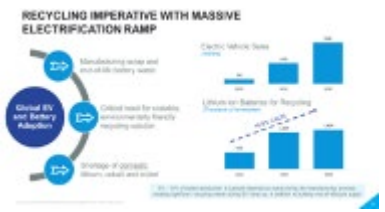












INTEGRATING *CHARGE FC*™ INTO FLEETS

1. **Start Small**
   - Continue piloting ZEBs manageably
     - "Onesie/twosie", or more
   - Strategize, test, collect data, analyze
     - NFI Connect
   - Inform scaling strategy
     - incorporate into transition masterplan
2. **Simple & Scalable Infrastructure**
   - Sourcing is preferred
     - Buy vs produce
   - Use modular equipment, facilities, space
   - Don't worry about carbon intensity (today)
3. **Leverage Your Expertise**
   - Diesel
     - Chemical fuel
     - Long range
     - Fast refueling
   - CNG
     - Compressed, flammable gas
     - Similar safety, handling provisions
   - BEB
     - Electric drivetrain
     - HV battery components
     - Carryover from EV training initiatives

Ballard is the world leader in fuel cell technology

Ballard has been dedicated to PEM fuel cell development, engineering excellence and future-forward zero emissions technologies for over 40 years.

Ballard's Promise

"We at Ballard are here for you. From cradle to grave, our technology experts and customer support networks are here to simplify your life and guide you through this revolutionary shift to a powerful zero emissions future."

BALLARD™
Here for life™

- Next phase in NFI's multi-decade established partnership with Ballard.
- Key component in advancing NFI's leading fuel cell bus offerings.
- Leveraging best practices and generating design, engineering and sourcing synergies.

"We are proud NFI… has chosen Ballard as their committed partner for the next phase of growth in the fuel cell bus market," said David Mucciacciaro, Ballard Chief Commercial Officer. ***"We believe New Flyer is well positioned to deliver deployment scale volumes of fuel cell buses****, particularly in the US market…"*

January 3, 2024, Ballard Press Release

VIC™ | VEHICLE INNOVATION CENTER

Don’t just own the latest technology – get ahead of the curve.

Contact Us To Learn More

www.nfigroup.com/vic

vic@nfigroup.com

www.nfigroup.com/LTC
to sign up for our newsletter

The Vehicle Innovation Center 106 National Drive, Anniston, AL , 36207

Cold Weather Fuel Cell Performance

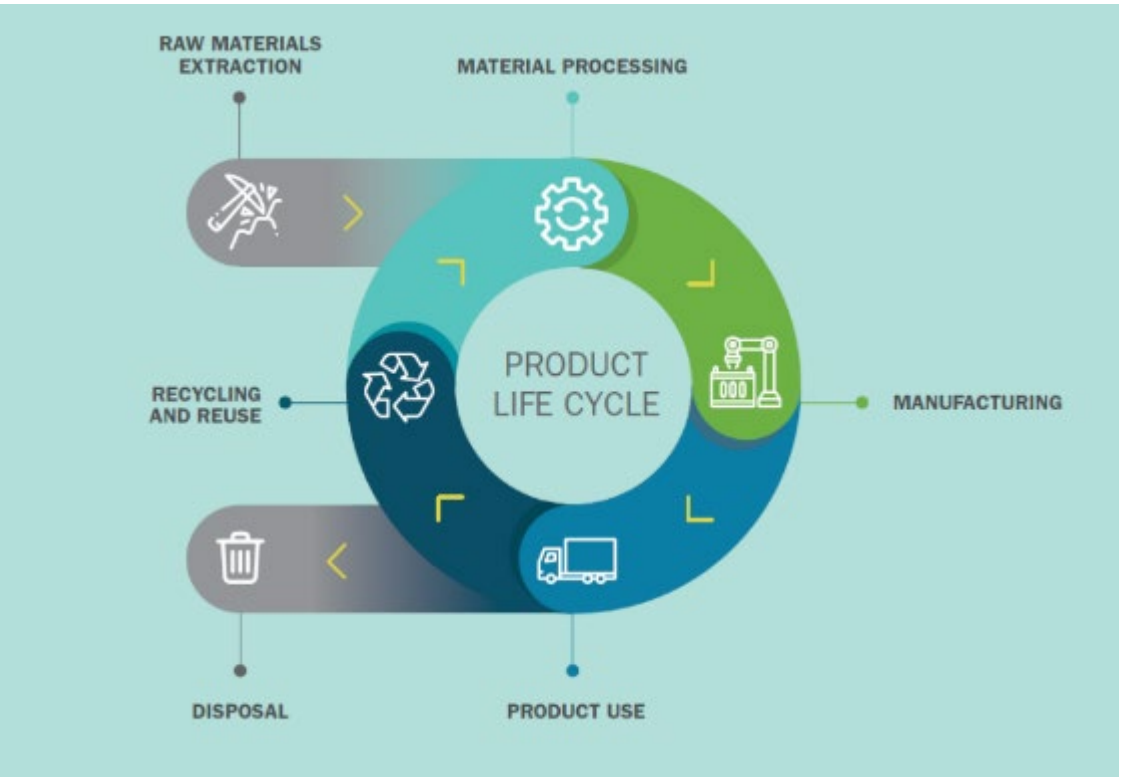
- FCEBs are commercially available today with competitive TCO to other clean transit alternatives
- FCEB can meet winter's challenging operating conditions
- FCEBs complement battery electric buses to enable 100% ZEB fleets
- Low-carbon hydrogen can be produced in every province using local resources at same or better GHG impact as electricity
- Strong eco-system in place
- Deployment of FCEB will pave the way for other heavy-duty applications such as truck, marine, rail

FCEB Economic Value Proposition

Kim Leach
Market Development Manager, Ballard

Timothy Sasseen
Market Development Director, Ballard

Zero-Emission Transit Should also be Sustainable



Fuel cells have a lower impact on the environment

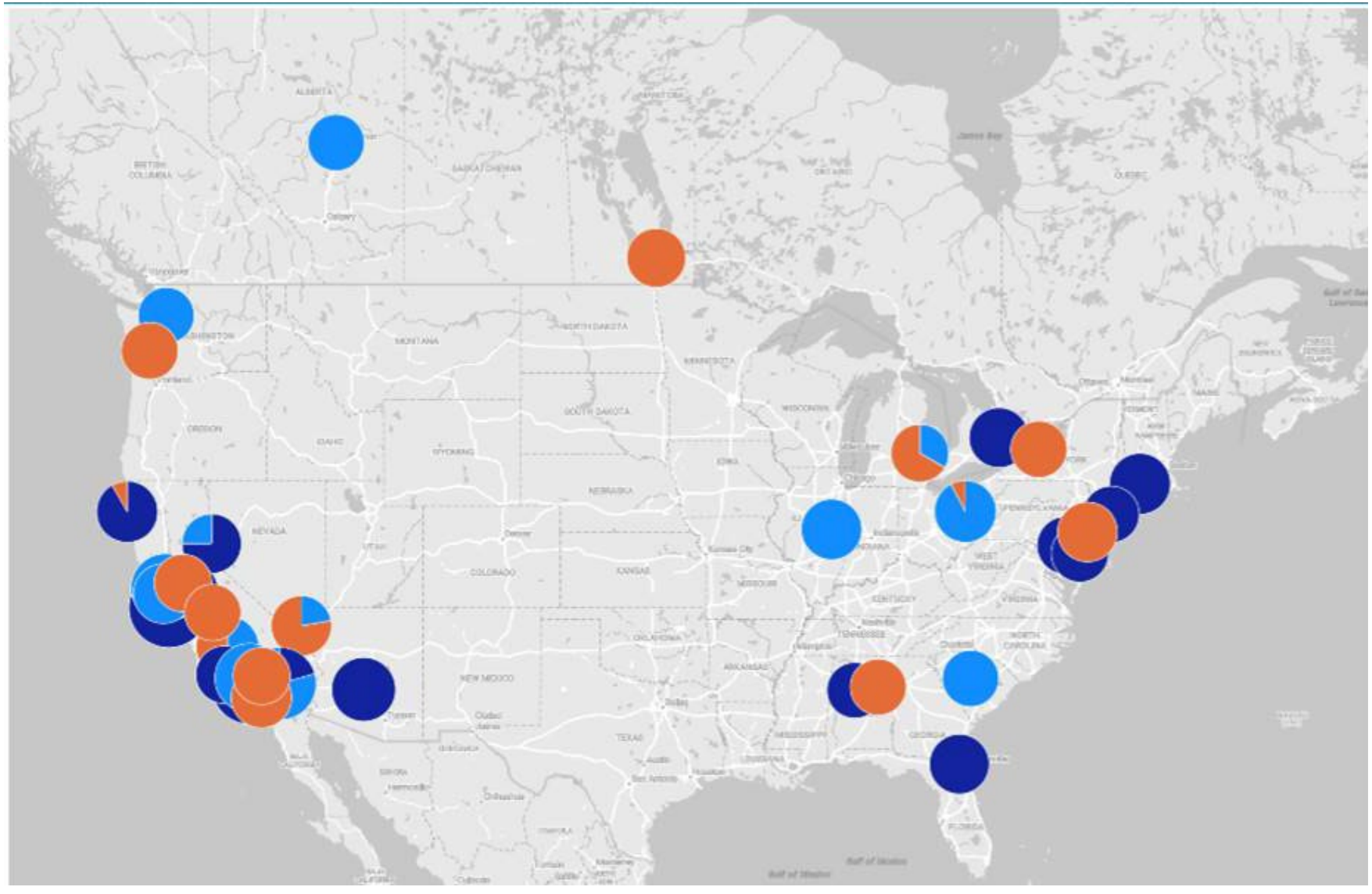
At Ballard we:

- Design our product to minimize carbon footprint
- Refurbish fuel cell stacks at the end of life
- Re-use graphite bipolar plates
- Reclaim 95% of the platinum
- We are committed to be carbon neutral by 2030

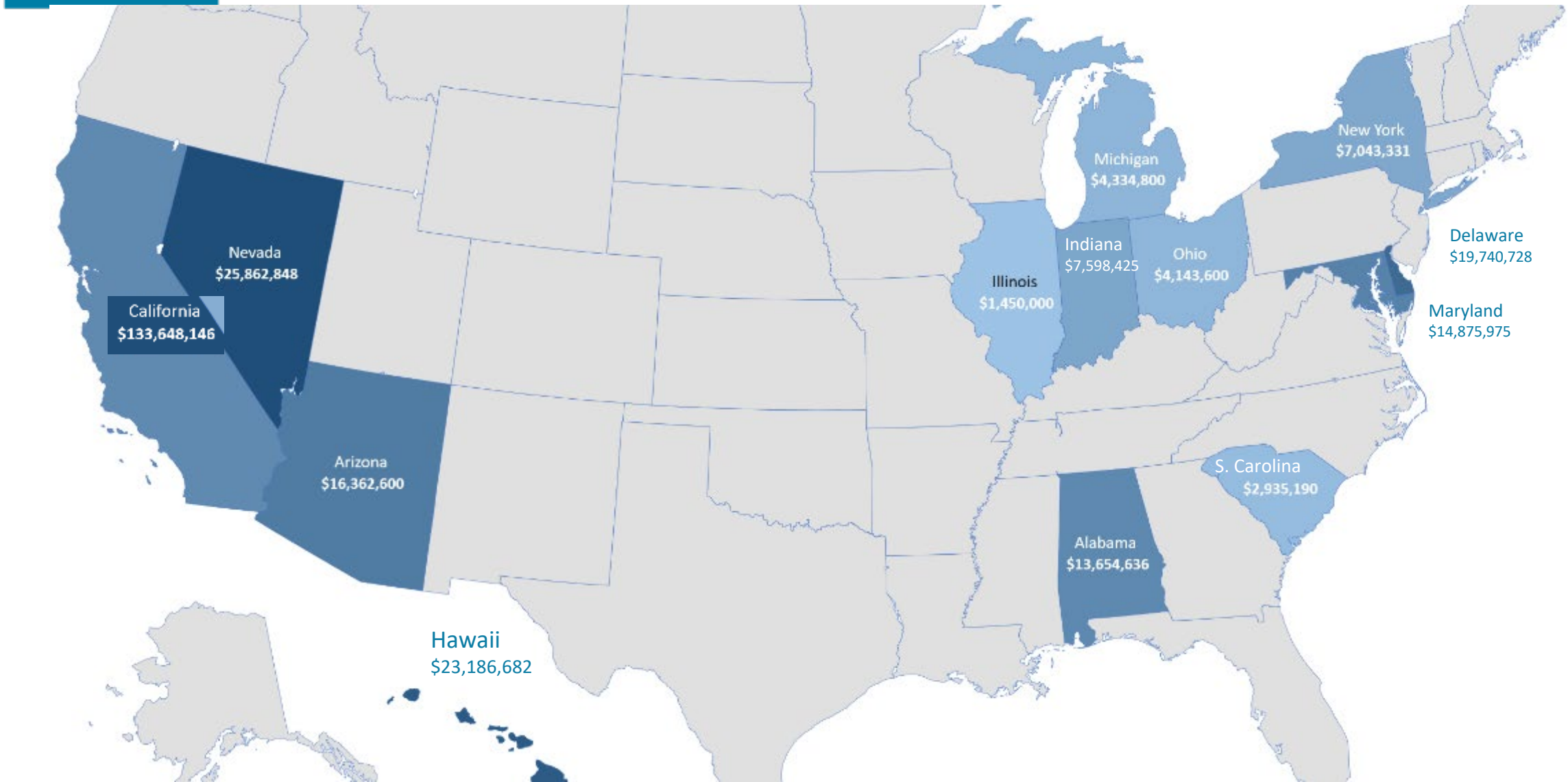
The Demand for FCEBs in North America is Growing - Driven by Zero-Emission Bus Transition

175 FCEBs deployed

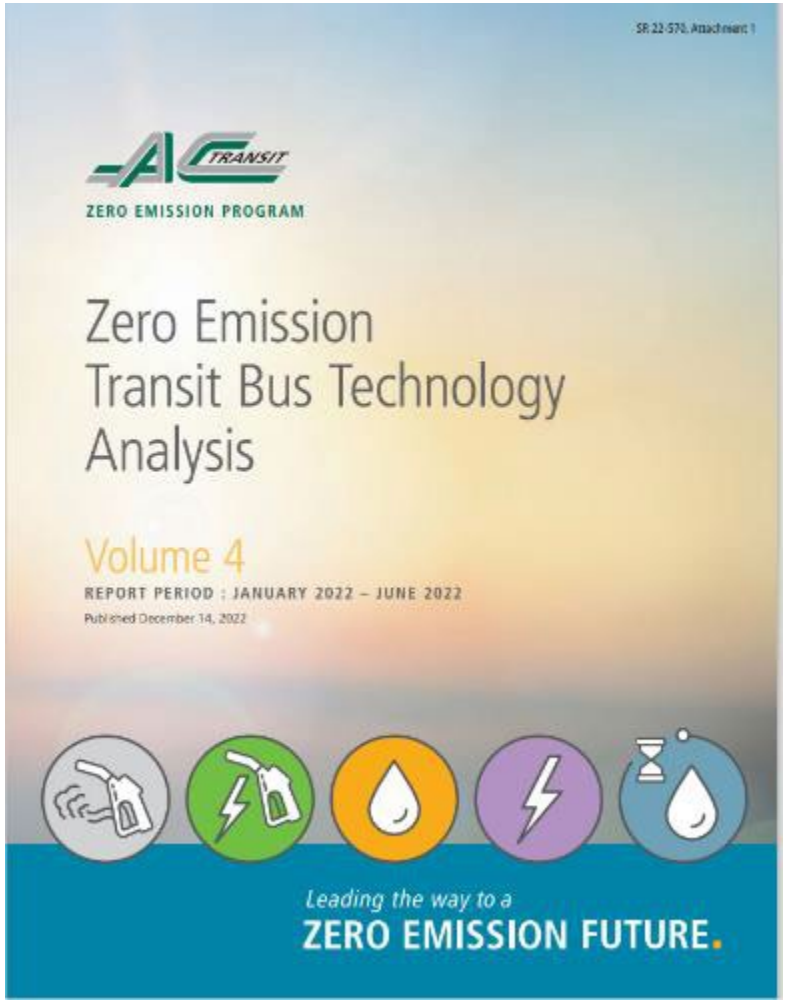
>250 additional FCEBs funded or on order



FTA Hydrogen Fuel Cell Electric Bus Awards



AC Transit 5x5 ZEB Study



FLEET	DIESEL (BASELINE)	DIESEL (HYBRID)	FUEL CELL ELECTRIC	BATTERY ELECTRIC
Technology Type	Diesel	Diesel Hybrid	PEM Fuel Cell	Lithium-Ion Battery
Bus Quantity	5	5	5	5
Bus Year	2018	2016	2019	2019
Length	40ft (12m)	40ft (12m)	40ft (12m)	40ft (12m)
Energy/Fuel Capacity	120 Gallons (454l)	120 Gallons (454l)	38kg	466kWh
OEM Range Specifications	480 miles (770km)	700 miles (1,125km)	300 miles (480km)	200 miles (320km)
Date Summary (June 2020-July 2022)				
Total Fleet Mileage	757,363	1,235,654	452,103	272,046
Operating Cost/Mile (Average)	1.58	2.02	2.03	1.65
Cost/Mile (W/Credits)	1.55	1.98	1.32	0.64
Total Emissions (CO_2)	1,103	622	0	0
Fleet Availability (Average)	92%	68%	75%	58%
Efficiency (Average) DGE	4	5.3	8.4	17.2 (1.4kW/km)
Maintenance Cost/Mile	0.93	1.54	0.97	1.2

Foothill Transit Agency

Servicing the communities in eastern Los Angeles County and surrounding areas, Foothill Transit Agency's fleet of diesel and zero-emission 359 buses covers a route network of 327m². With an annual ridership of nearly 7m passengers, Foothill depends upon reliable and efficient buses that can keep pace with the high utilization rate required by a large transit agency.

[Ballard Blog: Foothill Transit Agency: Leveraging the power of fuel cells]

SEPTA

Southeastern Pennsylvania Transportation Authority (SEPTA) is one of the largest transit systems in the United States and an agency that has explored zero-emission technologies from an infrastructure perspective since 2016.

From SEPTA's analysis, vehicle range is a significant consideration for decarbonizing fleets. Fueling time for a fuel cell electric bus is 10-12 minutes, while range data from other transit agencies shows FCEBs get 250-300 miles from a single fill - both mimicking diesel-hybrid fueling operation.

Conversely, analysis on the battery electric side shows that for a charge of three to four hours, you get 150-200 miles of range.

Ballard blog: SEPTA's journey to deliver zero-emission transit

Champaign-Urbana MTD

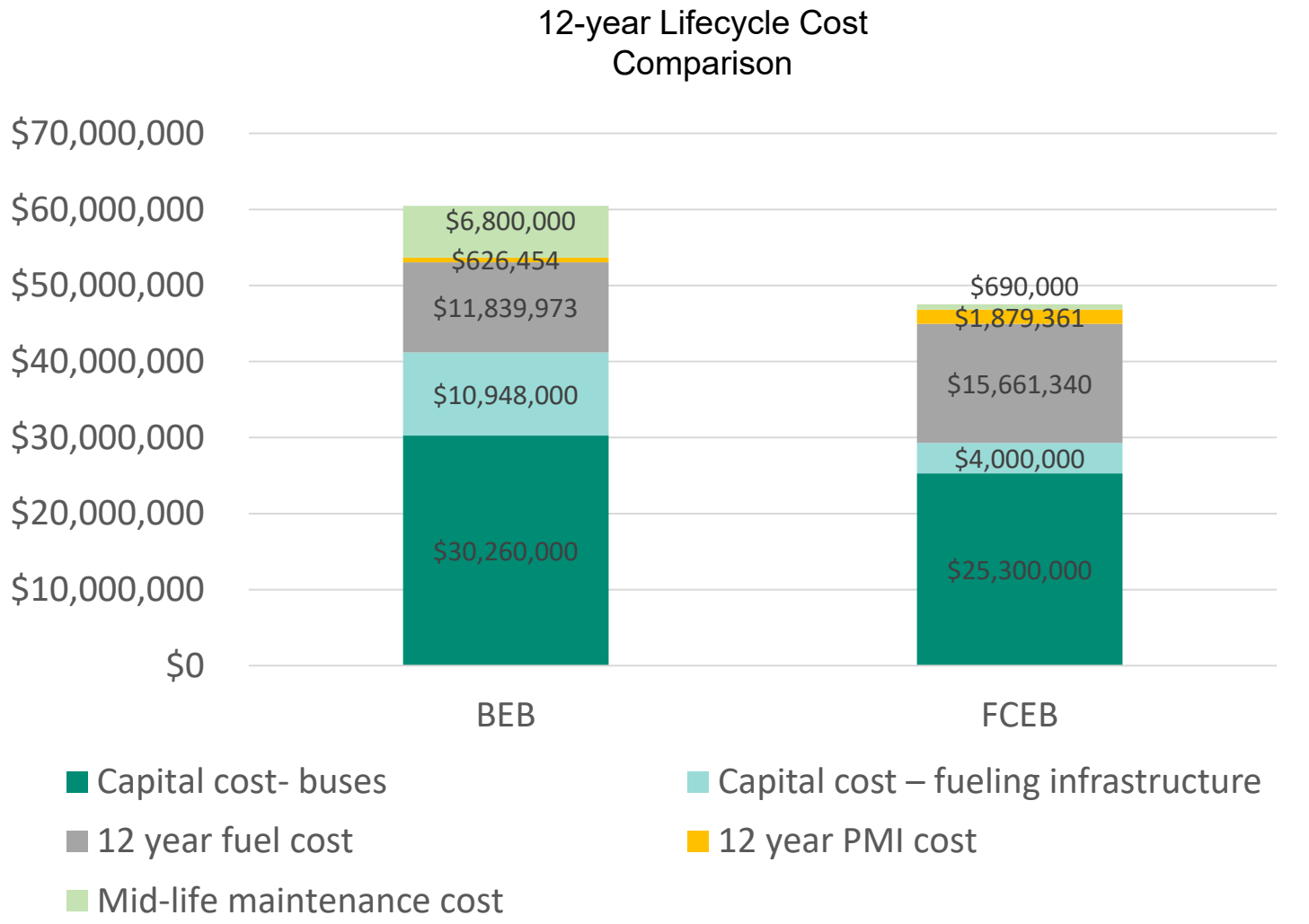
MTD provides all the public transit for the Champaign, Urbana, and Savoy communities, but also the University of Illinois - a large BIG-10 University with over 57,000 students plus faculty and staff, with a lot of community interest in sustainability and environmental impact. As a part of that, MTD has launched a zero-emission fleet program, and are transitioning to hydrogen fuel cell electric buses.

[Ballard blog: Champaign-Urbana MTD: Transit agency transitions to fuel cell buses]

Foothill Transit Study Shows Total Cost of Ownership of FCEBs Lower than BEBs

Foothill Transit's study compares the cost of deploying 20 zero-emission buses on a 42-mile roundtrip route (up to 263 miles per daily block)

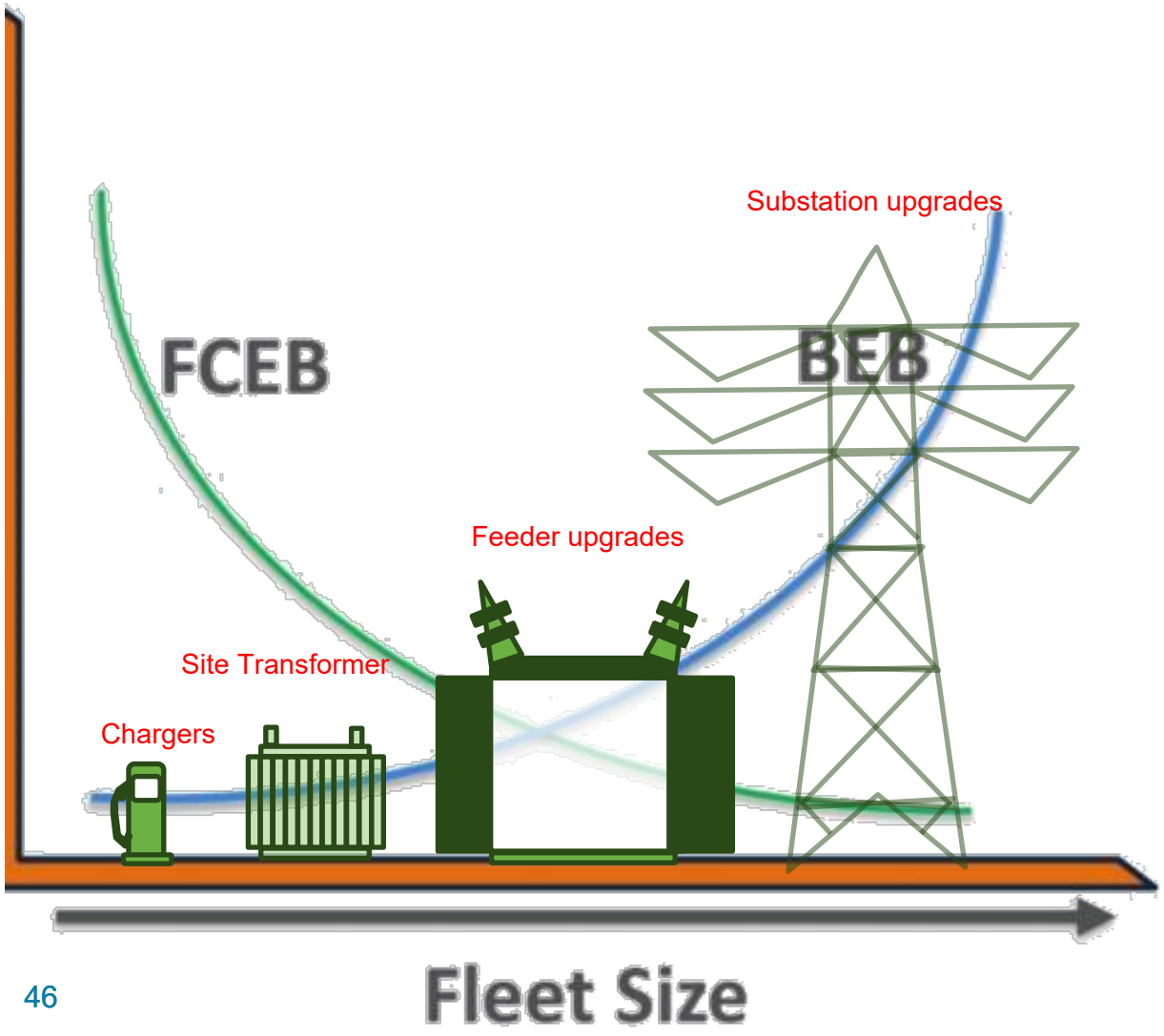
Due to the range limitations of BEBs, it was determined the line will require 34 BEBs vs 23 FCEBs.

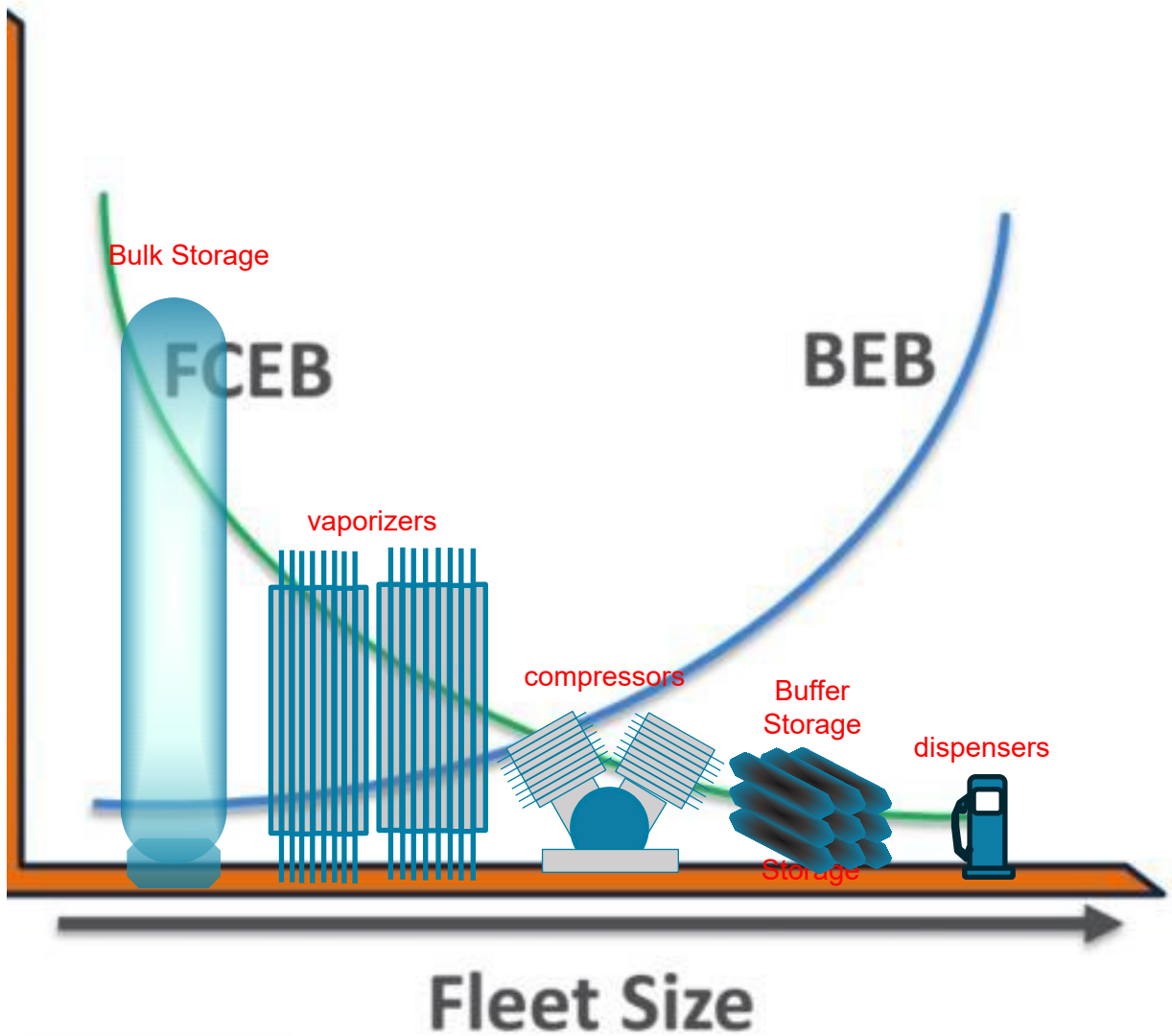


Cost Savings with FCEB: $12,943,726 (20%)

Foothill Transit Executive Board Meeting (July 24, 2020)

Infrastructure and Scalability





Hydrogen – *THE* Grid Alternative

Gridlock is on the horizon

- 95% of the renewables needed in 2035 are backlogged today for transmission
- 20% of planned capacity for utility-scale solar projects was delayed in the first half of 2022
- U.S. transmission's 1% annual growth must **more than double** to an average of about 2.3% to meet federal climate goals

An **alternative** is needed to **capture and distribute** renewable energy which:

- Allows **storage for indefinite periods**
- Can be **readily redirected** to new places at arbitrary times
- Creates **no GHGs** or criterion pollutants
- Captures **remote, intermittent renewable electricity**
- Is **non-toxic**

"Two infrastructures are cheaper than one…"

Source: https://www.nerc.com/AboutNERC

US Federal Hydrogen Cost Reduction Programs

Bipartisan Infrastructure Law - Hydrogen Highlights

U.S. DEPARTMENT OF ENERGY

- **Covers $9.5B** for clean hydrogen:
  - $8B for at least four regional clean hydrogen hubs
  - $1B for electrolysis research, development and demonstration
  - $500M for clean hydrogen technology manufacturing and recycling R&D

President Biden Signs the Bipartisan Infrastructure Bill on November 15, 2021.
Photo Credit: Kenny Holston/Getty Images

- **Aligns with Hydrogen Shot priorities by directing work to reduce the cost of clean hydrogen to $2 per kilogram by 2026**
- **Requires developing a National Hydrogen Strategy and Roadmap**

Performance of FCEBs Powered by Ballard

- ✓ Fuel cell stack durability: **> 25,000 hrs** (proven in service)
- ✓ Fuel cell module availability: **> 97%**
- ✓ FCEB current maintenance cost: <**$0.48/mile***
- ✓ Fuel cell maintenance cost: **<$0.16/mile***
- ✓ Environmental conditions:
  - Fuel cell power operation from **-40°C to +50°C**
  - Freeze start from -**25°c**

Based on fleet of 100+ FCEB monitored by Ballard in 2020/2021

* Depending on operating conditions – FCmove® product

Webinar Q&A

Kim Leach
Market Development Manager, Ballard

Moderator

Tim Sasseen
Market Development Director, Ballard

Zero-emission adoption & TCO

Michael McDonald
Operations Manager, New Flyer

New Flyer FCEB case study

BALLARD™

FCEB WEBINAR SERIES 2024

Webinar 2 : Ballard's Fuel Cell Electric Bus Training and Support

March 28, 2024 10:00 – 11:00 AM P.S.T

Kim Leach
Market Development Manager, Ballard

Kevin Hutton
Team Lead, US Service & After Sales Support, Ballard

Kirt Conrad
CEO/Executive Director, SARTA

Thank you

Tim Sasseen
Director of Market Development and Public Relations, North America

Tim.Sasseen@ballard.com
Tel:+1 805.705.0716

Kim Leach
Market Development Manager, North America

Kim.Leach@ballard.com
Tel:+1 604.218.6626

Mike McDonald
Operations Manager, New Flyer

Michael_McDonald@newllyer.com
Tel:+1 431.278.2709

www.ballard.com

Here for life™