FCEB Webinar Series: Fuel Cell Electric Bus Training & Support

March 28, 2024

Webinar Contributors

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Moderator

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Fuel Cell Electric Bus Maintenance & Service

Kirt Conrad
CEO & Executive Director, SARTA

SARTA Case Study: FCEB Operation & Service in Cold Weather

Tim Sasseen
Market Development Director, Ballard

Q&A

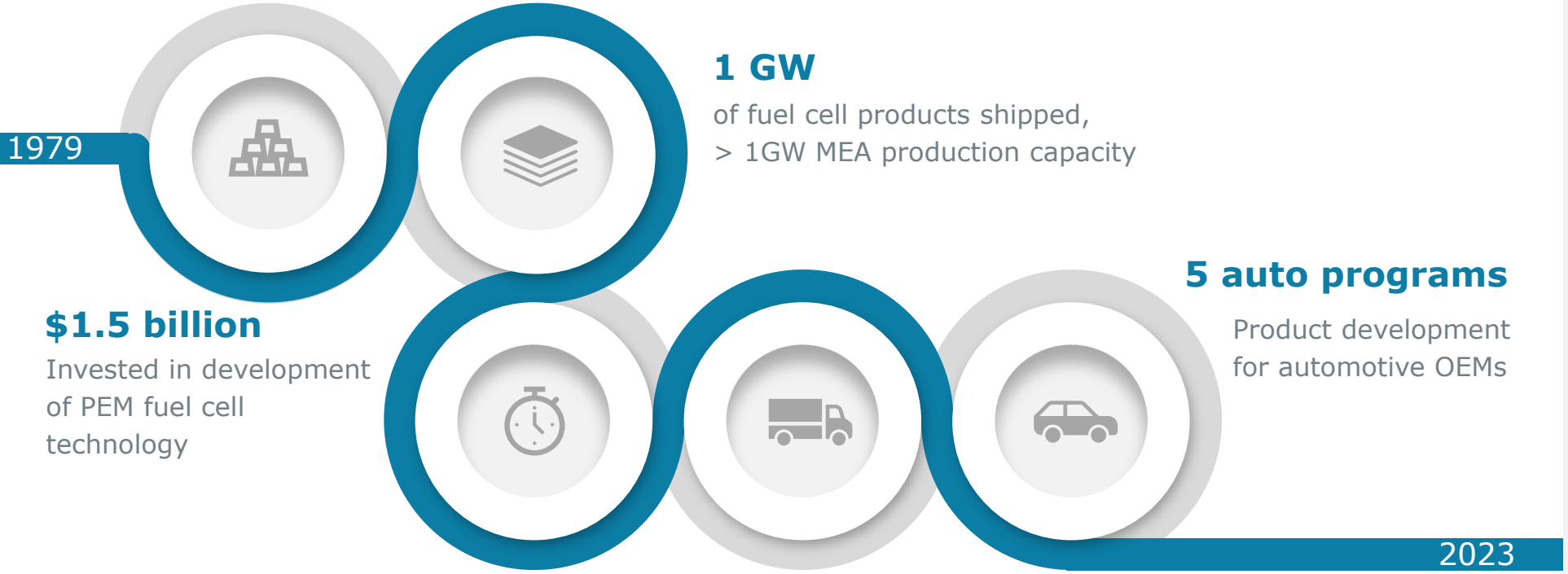
Introduction

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

200M km Fleet experience
Ballard fuel cells powering bus & truck fleets globally

Ballard Today

3,600+
buses & trucks operating

97%
uptime of heavy-duty power modules in vehicles

+30,000
hours product lifetime proven in operation

+4.3 L/kW
power density

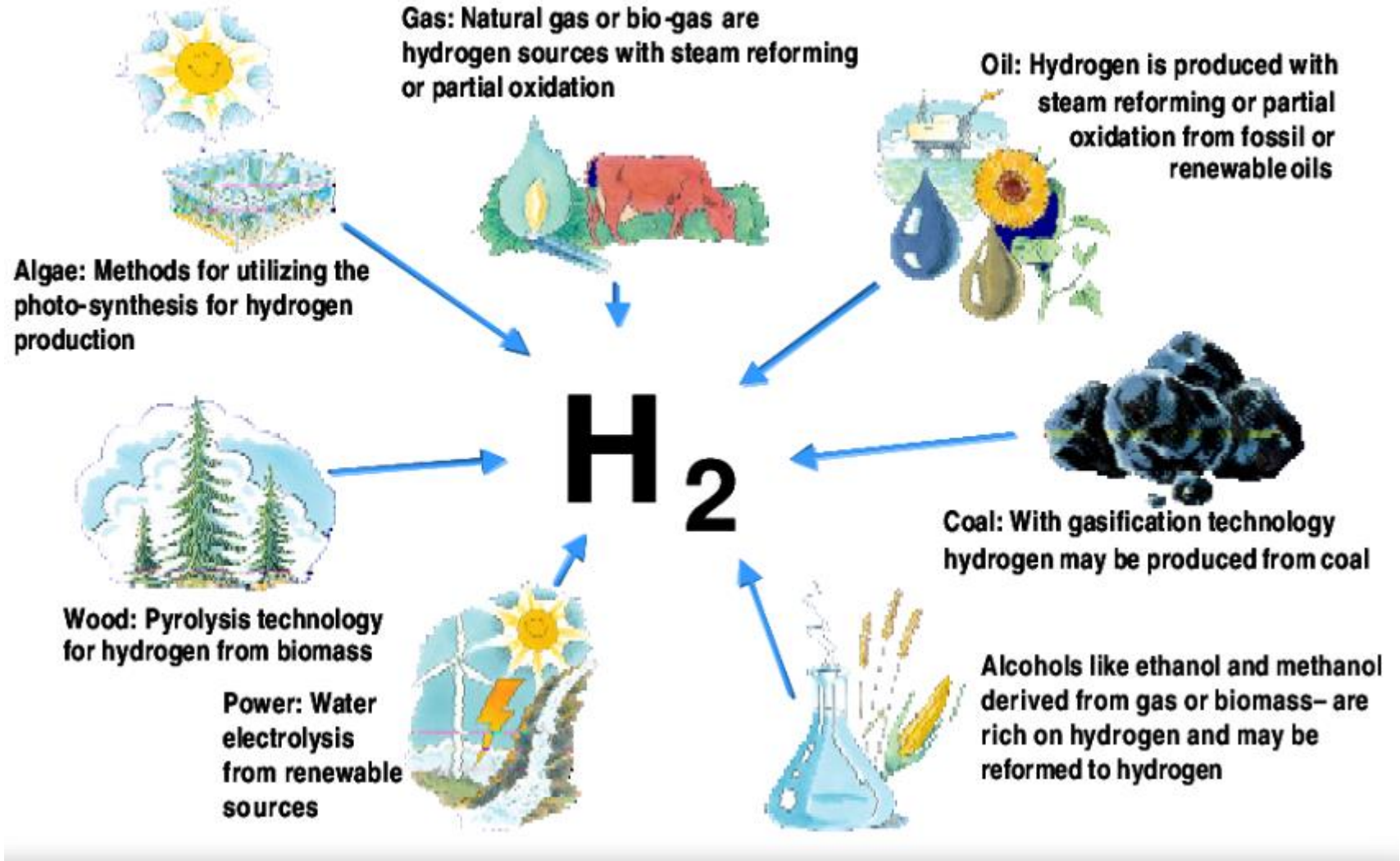
+1,300
patents & applications

Rigorous technology & product development processes

Why Hydrogen?

- Safe and manageable
- Excellent energy carrier
- Non-polluting
- Supplied as compressed gas or liquid
- Economically competitive
  Can also be produced on-site
- Has been used effectively for more than 50 years
- Produced from various sources

Hydrogen Production Pathways



Source Hydro

Why Hydrogen?

The U.S. Department of Energy's (DOE's) Energy Earthshots initiative aims to accelerate breakthroughs of more abundant, affordable, and reliable clean energy solutions within the decade.

ENERGY earthshots
U.S. DEPARTMENT OF ENERGY | Hydrogen

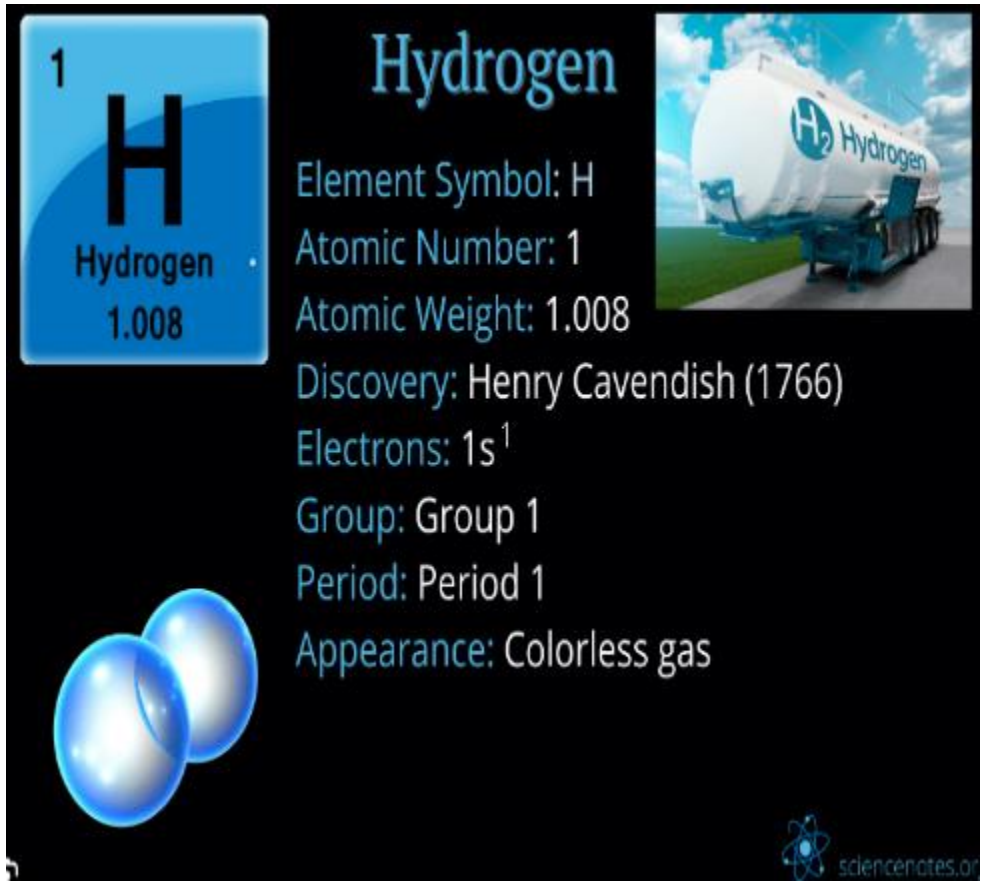
Today there are multiple offerings for FCEBs

- More than 20 years of road experience
- Over 8 million miles in service
- Bus availability >85%
- 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)

FCmove® Platform

1,000,000
KM PRODUCT
WARRANTY

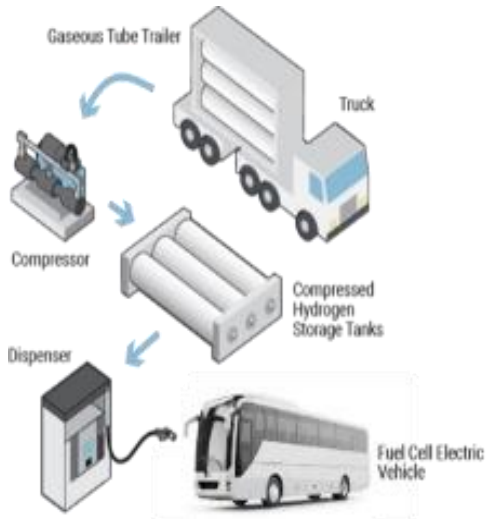
- Compact innovative design
- Low lifecycle cost
- Engine bay and flat configurations for easy integration
- High performance, robust product with wide operating range
- 70kW and 100kW versions



Why is Hydrogen Safer than Fossil Fuels	
Fourteen times lighter than air	✓
Hydrogen disperses quickly	✓
Rises 20 meters per second (at normal temperatures)	✓
Flames emit low radiant energy – less likely to move to surrounding areas	✓
Non-Toxic – leaks and spills don't contaminate the environment	✓
Less combustible than gasoline (gas is 1.4%, hydrogen is 4%)	✓
Hydrogen rises and diffuses	✓

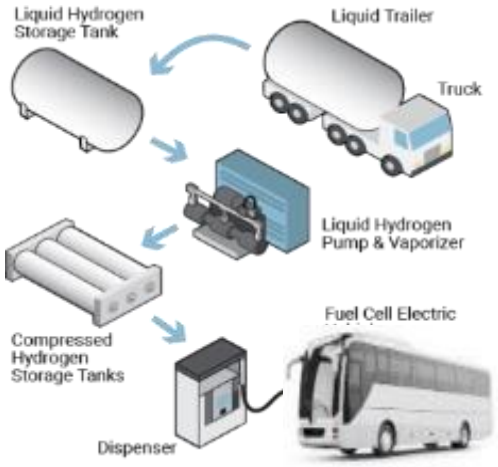
Hydrogen Fueling Options

Compressed Gas Trailer



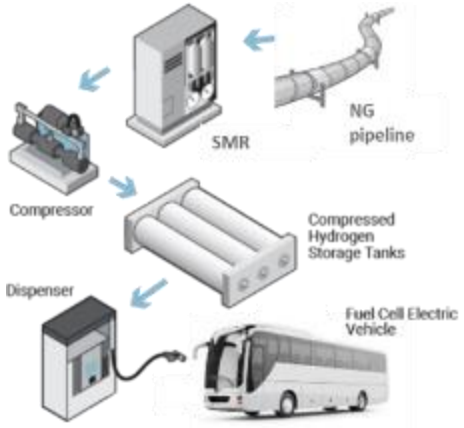
Gas delivery for up to 10 buses

Liquid Hydrogen Delivery



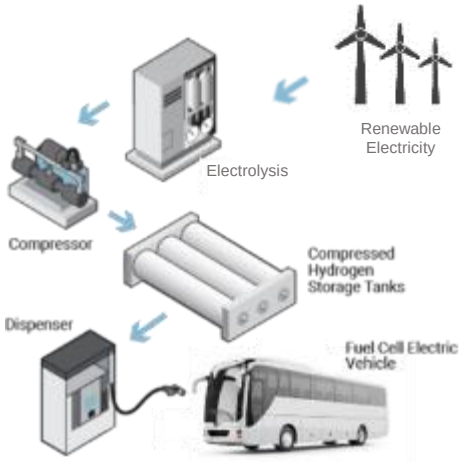
Liquid delivery from 10's to 100+ buses

On-site generation (SMR process)



Scalable process, good for large volumes

Electrolyzer



Scalable process, good for large volumes

FCEB Tank Modules and Fueling Details

Fueling
Tank Modules & Fill Panel

Fill Panel

- Dual H35 fill receptacles – TN1 and/or TN5
  - Inline Check Valves
- Prepared for IrDA communication w/ fill station or hardwired communication for fast fill @ smart stations
- Lower service panel
  - HP Defuel Port
  - LP Sample Port
  - LP Vent to Roof Stack
- HP & LP Analog Gauges & HP Digital Gauge

Tank Modules

- Lightweight Type 4 HGV2 tanks with 95% usable capacity
- All-composite (Hexagon)
- 7.5 kg H_2
- **350 bar** (15 °C)
- 98 kg empty (excluding valve & mounting)
- Ø16.3" x 125" long
- HGV2 / EC79 certified
- 20-year service life

40'	60'
6 – 10 minutes*	12 – 20 minutes*

Hydrogen Safety & Transportation

Richard Cheng

Vice President, Hydrogen, Certarus

CERTARUS

HYDROGEN TRANSPORT SAFETY

March 2024

CERTARUS AT A GLANCE

SAFELY DELIVER LOW CARBON ENERGY SOLUTIONS TO NEW MARKETS AND CUSTOMERS ACROSS NORTH AMERICA

COMPRESSION

- Fixed site & mobile hub designs
- Capacity up to 10,000 MMBtu/d per Hub
- Rapid fill design (~1 hour per MSU)
- Engineered & constructed by Certarus

TRANSPORTATION

- 770+ MSUs in the fleet today
- Canadian wide exclusivity for Titan & Quantum MSUs

GAS DELIVERY & DECANTING

- 350+ Pressure Reduction Systems (PRS)
- Custom gas delivery specification
- Unmanned delivery platform
- Engineered & constructed by Certarus

24 STRATEGIC FACILITIES

770+ MSUs ~50% OF N.A.

50 BCF+ CUMULATIVELY TRANSPORTED

INDUSTRY LEADING LEADING SAFETY RECORD

Integrated Platform

- Sourcing & Compression
- Transportation & Distribution
- Site Delivery & Decompression
- Monitoring & Logistics

CNG

RNG

H_2 Hydrogen

Logistics Platform Addresses 3 Key Energy Transition Fuels

CERTARUS FACILITIES

OPERATING REGIONS

EXPANSION REGIONS

Certarus Hydrogen Trailer Fleet

Smart Store – 400 kg at 250 Bar

Quantum – 800 kg at 250 Bar

Liquid Trailer – 4000 kg at 10 Bar

Titan – 600 kg at 250 Bar

Hydrogen Transport Safety

Trailer Design:

- Transport Canada/ US Dept Of Transportation Approval
- PHMSA Static Rollover Threshold
- ESD Valve
- Fire Protection
- Overpressure Protection
- Whip Checks

Equipment Design:

- ASME B31.12 Piping
- CGA G-5.5 Vent Design
- NEC Class I, Division 2 Group B

Hydrogen Transport Safety

Equipment Layout:

- NFPA 2
- Equipment Grounding/ Bonding
- Hazard and Operability Study (HAZOP)/ Process Hazard Analysis (PHA)

Driver Safety:

- Continued Training
- GPS with accelerometer
- Internal/ External Cameras
- Scorecard

Questions

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CERTARUS

Fuel Cell Electric Bus Maintenance & Service

Kevin Hutton

Team Lead, U.S. Service & Aftersales Support, Ballard

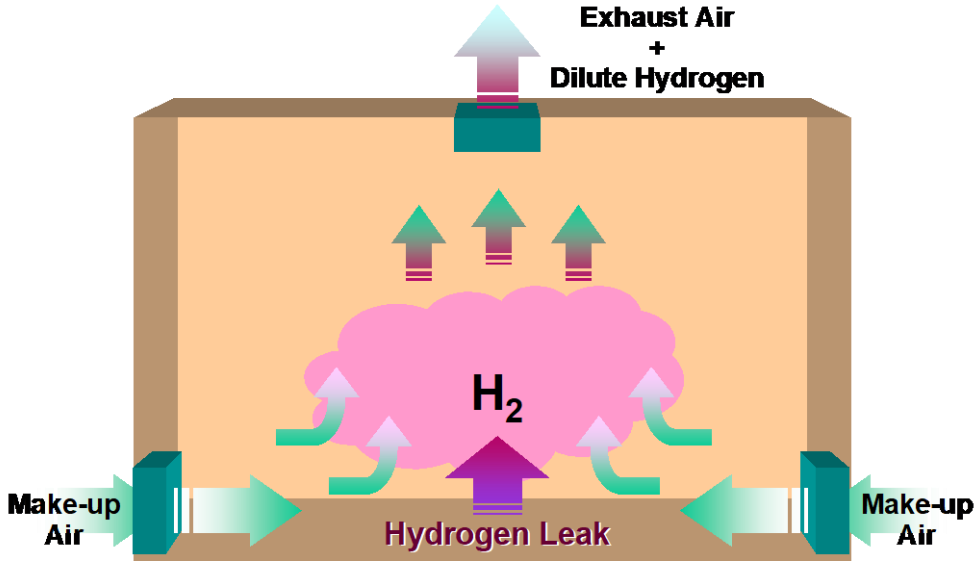
Starting a New FCEB Fleet

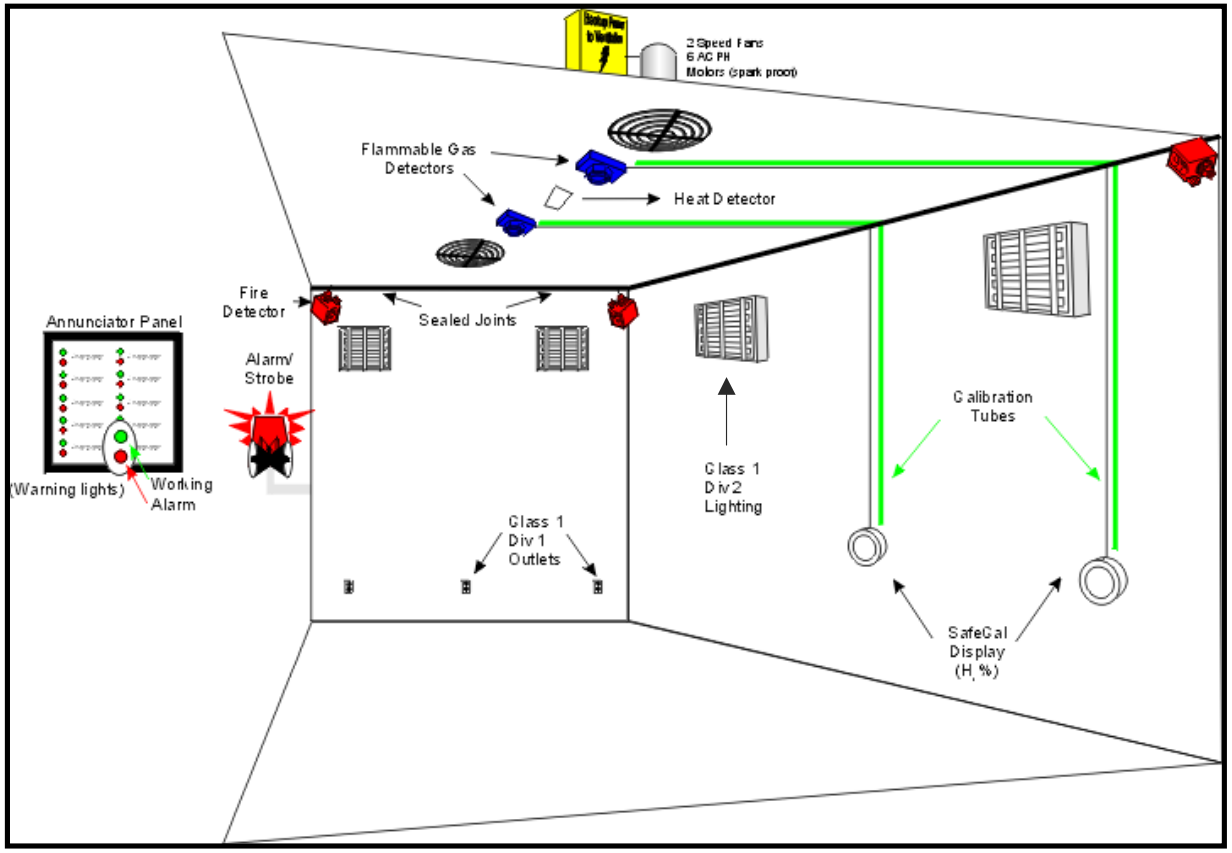
Sequence of Events for a New Fleet

- Preparation of facilities
- Arrival of buses
- Training of technicians
- Customer Portal access
- Expectations for service and support

Maintenance Facility Requirements

- Sensing, ventilation, x-proofing
- FCM workspace
- Recommendations for onsite inventory





Fuel Cell Module Training

Tier 1/2/3 training overview

Tier 1, 2 training
- Duration
- Class size
- Scheduling onsite training

Tier 3 training
- Content
- Prerequisites

When to Train, Relative to Bus Arrival
Training effectiveness vs. technician engagement during warranty period

Daily Operations and Maintenance

- Refueling, Parking, Starting up – Summer, Winter
- Scheduled Maintenance
  - Monthly Checks
  - Scheduled Replacements Over Lifetime

H2 test gas bottles are available in different sizes and with various pressure regulator options.

2% H2 test gas bottles and regulators used by Ballard:

- 5 liter bottle with additional pressure regulator. Filling pressure 200bar.
- 2 liter bottle with small pressure regulator. Filling pressure 200bar.

Besides special tool kit other additional tools are recommended:

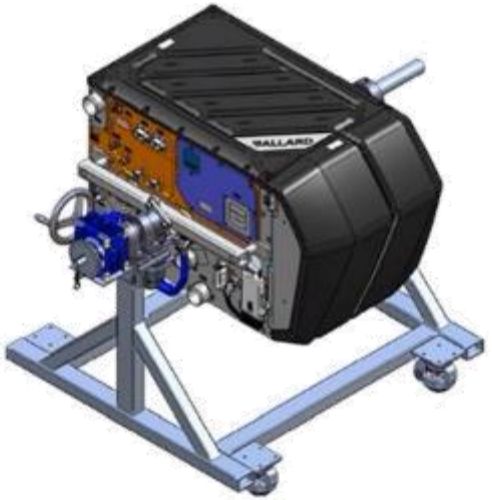
- Tools to lift and move the system components
- Coolant spill containment materials
- 24 V vehicle battery charger
- Digital multimeter
- Computer with Ethernet cable

Smoke detectors are tested using regular smoke detector test gas.

Training Equipment and Systems

Ballard FCM Training Equipment for LowNo Applications

- Operational Training Module
- Control Systems Training Board
- 3D Virtual Module Training Software
- Augmented Reality Technician Communication Tool
- Module Test Stand, Training Posters



SARTA Case Study: FCEB Operation & Service in Cold Weather

Kirt Conrad

CEO & Executive Director,
SARTA

SARTA
HYDROGEN
FUEL CELL

SARTA Key Facts

- Transport 2.8 million passengers
- 212 employees
- $23 million budget
- Operates express routes to Akron and Cleveland (the longest route in Ohio)
- 30 routes and countywide paratransit

Operations

- Range 312 miles
- Operate every day
- 15 minute fill
- Getting about 7 mpg compared to 4 for diesel
- Program evaluated by NREL

Station at Night

Para Transit Vans

Fuel Cell

Fueling Port

Fueling Station

Fueling Dispenser

Outside View

First Public Fueling

Second Truck

Kirt Conrad Q&A

- Having been one of the first to implement a hydrogen fuel cell bus fleet in North America, especially in a colder climate, what did you find to be your largest concern?
- What did you do to convince the city to support the project, and what were the motivating factors for Council?
- What do you feel is the best approach regarding budget recommendations to support a pilot project?
- Times have changed since you started, and climate resiliency and zero-emission mandates have developed 100% even from five years ago - what is the best approach to implementing a journey down the path to a FCEB pilot project?
- Codes and standards had to be developed to support your deployment, who did you rely on for guidance, and what was your best resource?
- Did staff buy-in, or did you leave that to the Fleet Maintenance Manager to oversee? Should an agency look at mandatory training for all technicians or does a more aligned approach identifying 1-5 technicians who will champion the FCEB deployments work best?
- What are the two takeaways you would leave with an agency that is considering a fleet transition?

Webinar Q&A

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Market Development Director, Ballard

Q&A Moderator

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Hydrogen Fuel Cell Bus Council

Interested in touring a transit agency with a hydrogen fuel cell fleet?

Contact the Hydrogen Fuel Cell Bus Council at info@hfcbuscouncil.com.

The Council can connect you with its member agencies to facilitate a tour.

Join the Council to learn more about hydrogen fuel cell fleets and **advocate for Federal resources dedicated to the zero-emission transition!**

Membership is available to transportation agencies, engineering firms, manufacturers, design consultants, fuel suppliers, and any other entity in the hydrogen sector.

Thank you

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FCEB WEBINAR SERIES 2024

Webinar 3 : Steps to Secure Low or No Emissions Grants & Funding

April 11, 2024 10:00 – 11:00 AM P.S.T

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President, Krueger Transit Consulting