Fuel cell electric bus program for Far North transit

May 2022

Presented by Ed KruegerKTC Biz Development Manager for Ballard Fuel Cells North America

Snapshot of Hydrogen and Fuel Cells Applications in the U.S.

Examples of Applications

>500MW
Stationary Power

>35,000
Forklifts

>60
Fuel Cell Buses

>45
H_2 Retail Stations

>8,700
Fuel Cell Cars

Hydrogen Production Across the U.S.

- 10 million metric tons produced annually
- More than 1,600 miles of H_2 pipeline
- World's largest H_2 storage cavern

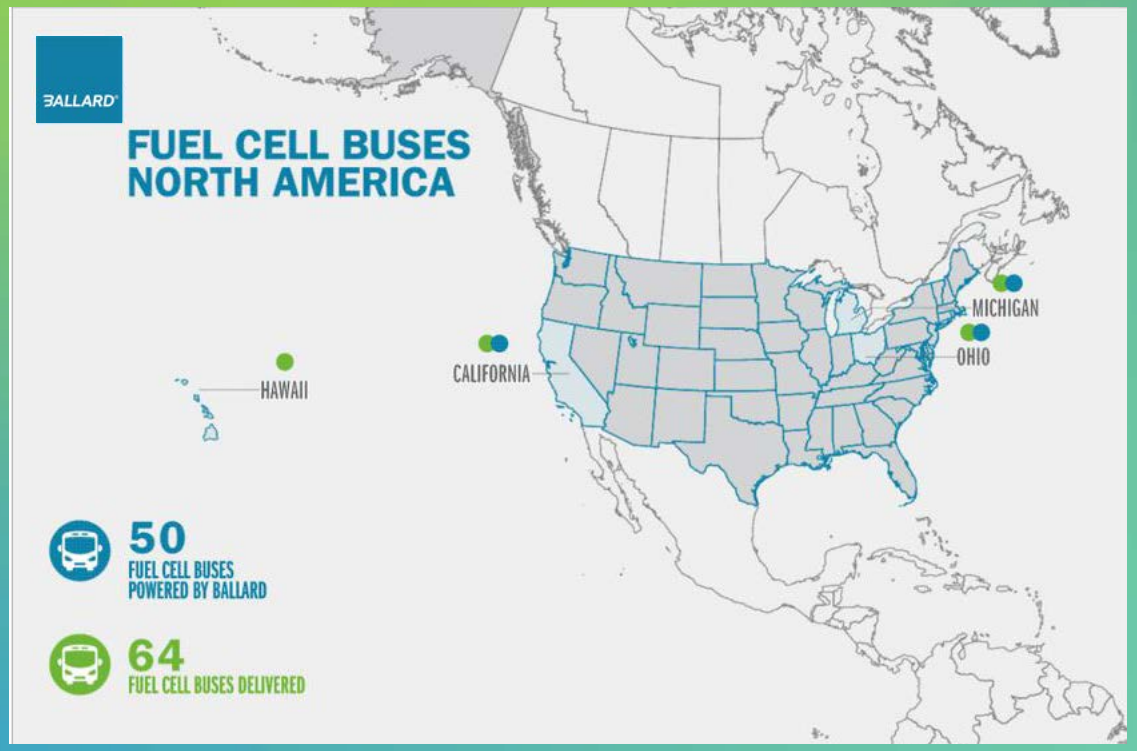
Hydrogen Stations: Examples of Plans Across States

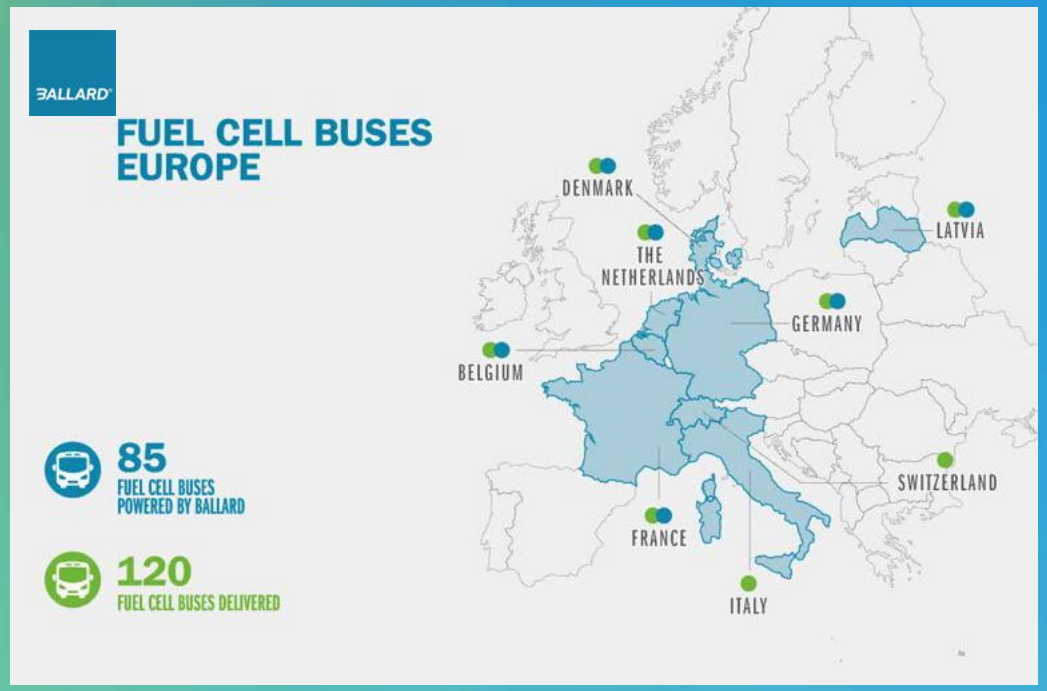
California
200 Stations Planned
CAFCP Goal

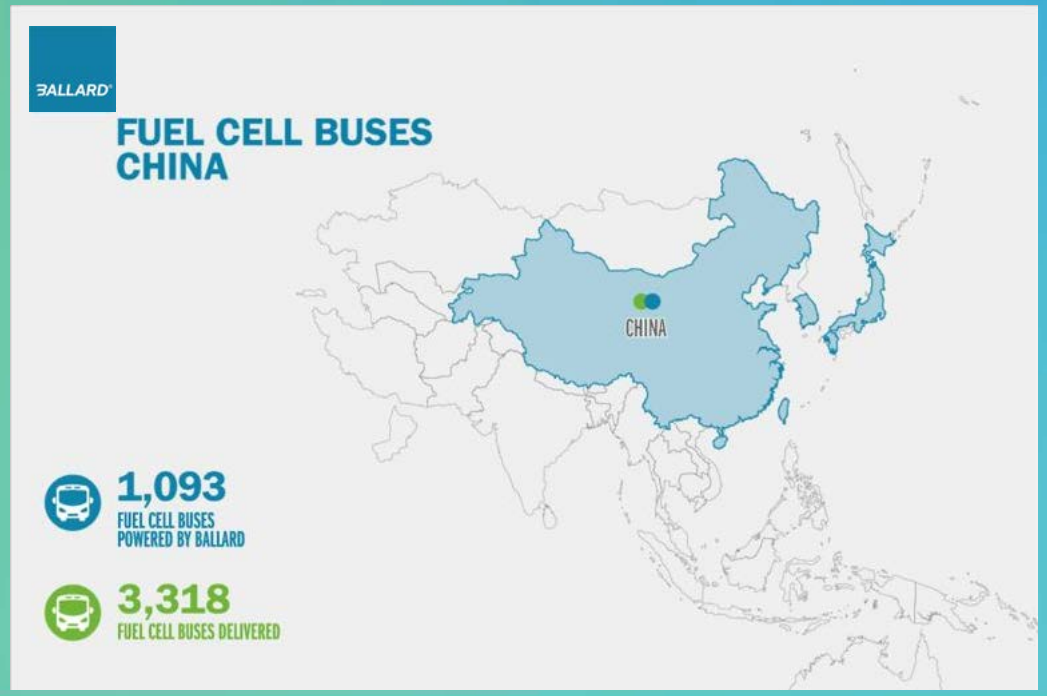
Northeast
12 – 20
Stations Planned

HI, OH, SC, NY, CT, MA, CO, UT, TX, MI
And Others

BALLARD™


BALLARD
FUEL CELL BUSES
NORTH AMERICA
HAWAII
CALIFORNIA
MICHIGAN
OHIO
50
FUEL CELL BUSES
POWERED BY BALLARD
64
FUEL CELL BUSES DELIVERED


BALLARD
FUEL CELL BUSES
EUROPE
DENMARK
THE
NETHERLANDS
LATVIA
GERMANY
BELGIUM
SWITZERLAND
FRANCE
ITALY
85
FUEL CELL BUSES
POWERED BY BALLARD
120
FUEL CELL BUSES DELIVERED


BALLARD
FUEL CELL BUSES
CHINA
CHINA
1,093
FUEL CELL BUSES
POWERED BY BALLARD
3,318
FUEL CELL BUSES DELIVERED

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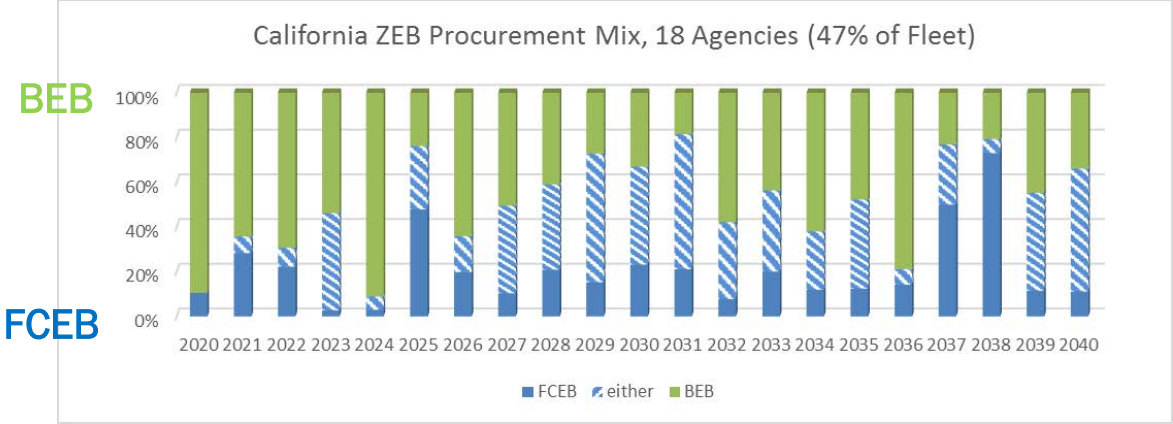
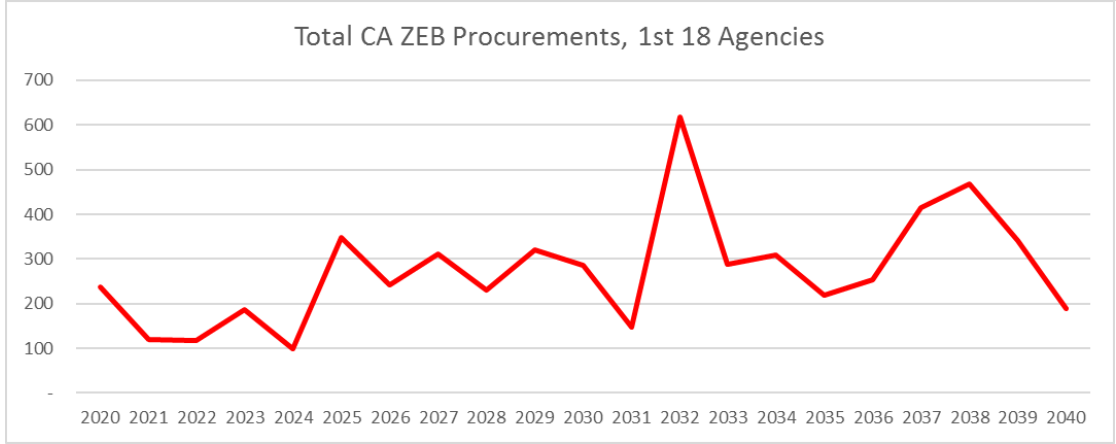
As Result of ICT Planning, there is Growing Demand for FCEBs

1. 66% of the 19 agencies surveyed in California include fuel cell electric buses (FCEB's) in their plans, with more than 50% dedicating part or 100% of their fleet to FCEB's.

2. Report shows an opportunity for 2,800 to 6,500 fuel cell electric buses in service, or 71 to 163 tons per day of renewable hydrogen consumption

Data collected from CARB published ICT roll out plans





Hundreds of millions of dollars already invested to supply California with Hydrogen

Air Products plant in Sacramento, Ca $150 million benefit to the California market. In the same city!

West Coast's largest green hydrogen plant 30 metric tons of liquid green hydrogen daily within about four years. The facility will use a new 300 megawatt zero-carbon solar farm to power 120 megawatts of Plug Power's state-of-the-art PEM electrolyzers, which split water into hydrogen and oxygen through an electro-chemical process, the announcement stated.

Ballard by the numbers

42
YEARS

900
employees

1,400
patents & applications

26 years Nasdaq
28 years TSX
publicly listed Company

WEICHAI
AngloAmerican
NISSHINBO
大洋电机 BROAD-OCEAN
4
strategic shareholders

1,300+
transit buses

2,200+
trucks

6 TRAIN
projects on track

8 SHIPS
in development

HIGH-POWER DENSITY
stack development program

850 MW
fuel cell products delivered

>6.5million MEAs
produced

>88 million
kilometers in operation

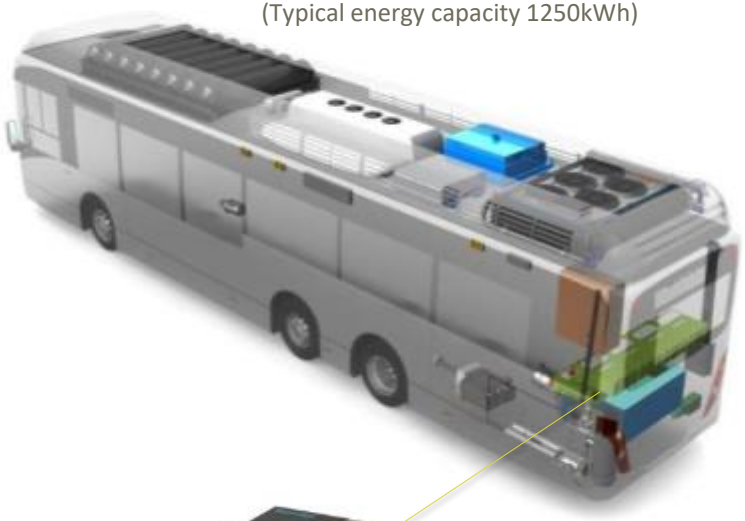
>35,000hours
operation of fuel cell stack

2030
commitment to carbon neutrality

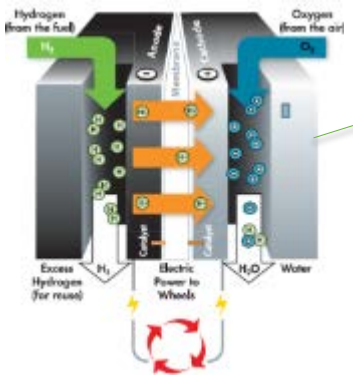
A fuel cell bus is an electric bus

- This is a ZEB POWERHOUSE
- Equivalence of 640kwh of energy through 37.5 kg of hydrogen on roof generating its own power
- Same electric drivetrain as battery electric buses
- Same maintenance and parts apart from the fuel cell power module and gas tanks

Hydrogen gas storage
(Typical energy capacity 1250kWh)



Fuel cell
Solid state DC power generator
Fuel = air and hydrogen



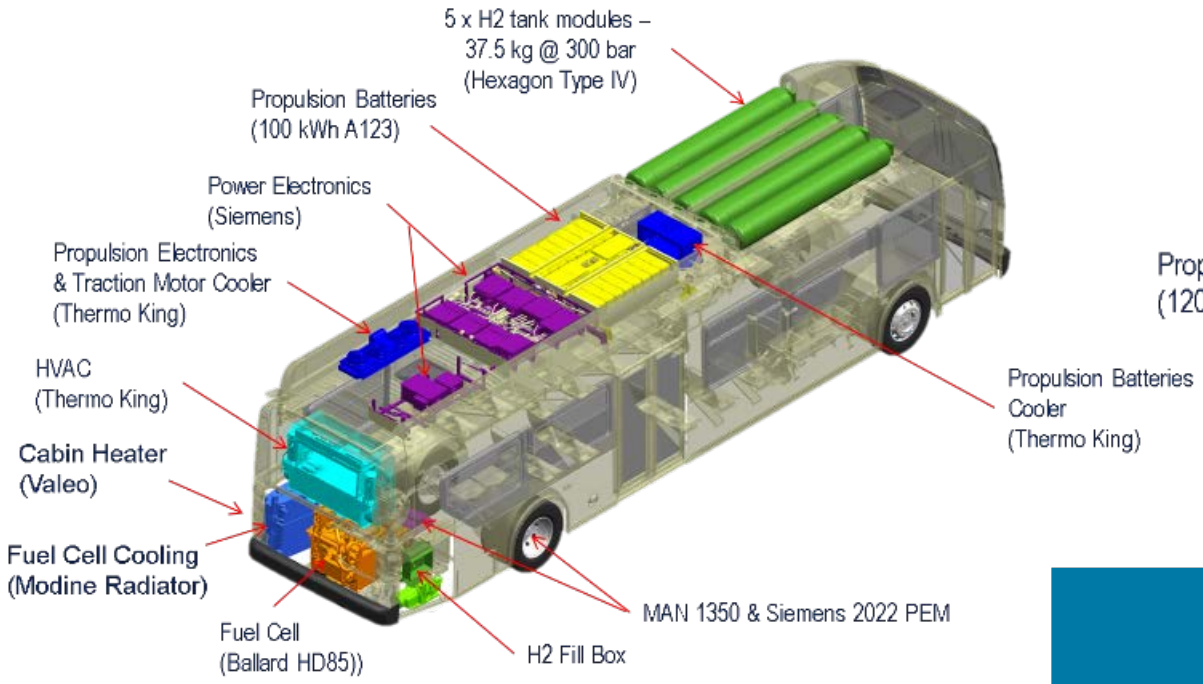
Fuel cell power module

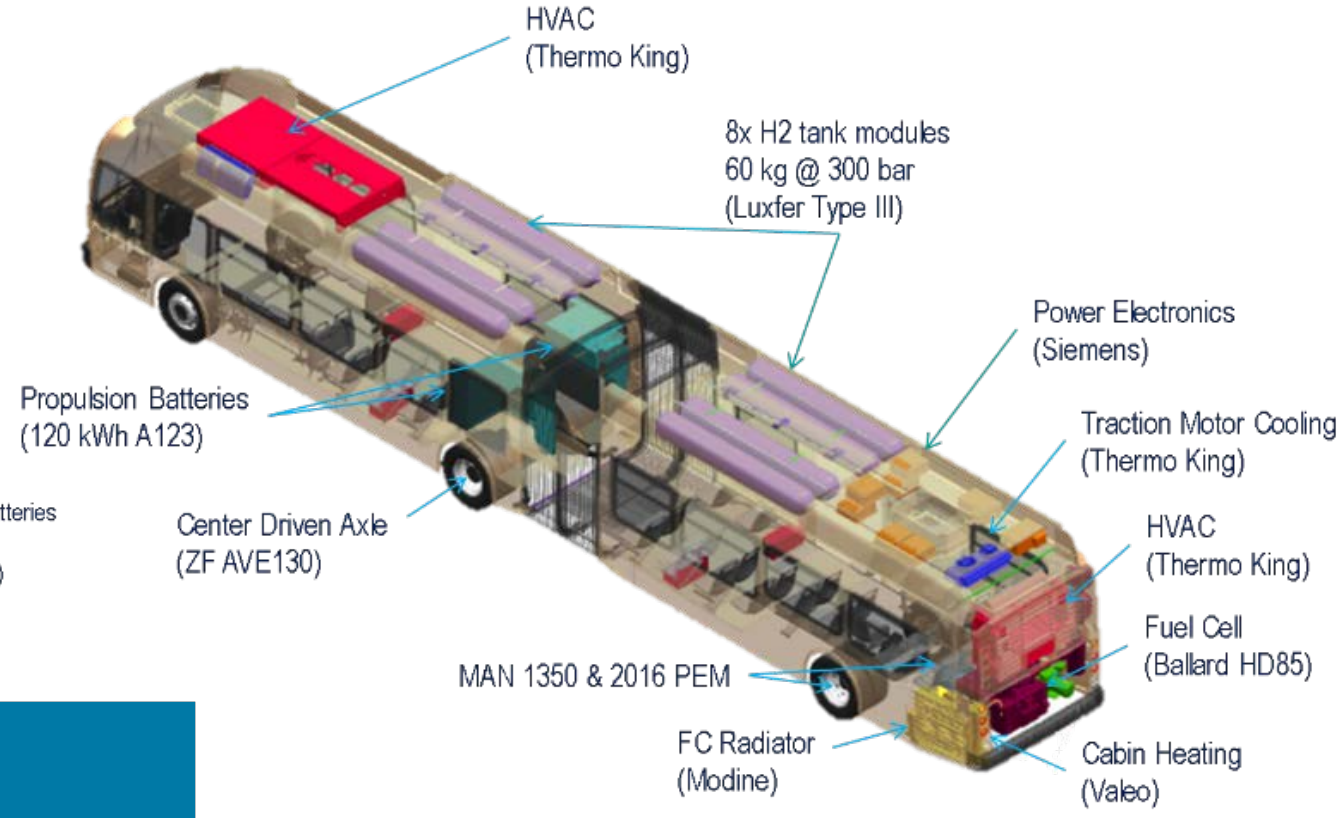
New Flyer Electric Bus Experience

- Over 50 years of experience manufacturing zero-emission buses
- New Flyer actively supports over 41,000 heavy-duty transit buses currently in service, of which 7,300 are powered by electric motors and battery propulsion and 1,600 are zero-emissions
- New Flyer offers all 4 types of electric, and all 3 types of zero-emission propulsion systems:
- Diesel-electric hybrid (low-emission)
- Battery Electric (zero-emission)
- Trolley-electric (zero-emission)
- Fuel cell-electric (zero-emission)

xcelsior CHARGE H2™

60-foot & 40-foot Layouts





BALLARD™

XCELSIOR CHARGE™

- Battery Electric Bus (BEB)
- Eco Friendly
- Robust Design
- Up to 200 mile Range*
- Curb Weight Heavier than FCEB
- 4 Hour typical overnight Charge
- One charger per 2-3 buses

*40-foot on APTA BAC transit duty cycle

Zero-Emission Options

NEW FLYER

xcelsior CHARGE H2™

- Fuel Cell Electric Bus (FCEB)
- Eco Friendly
- Robust Design
- 300+ Range*
- Curb Weight Lighter than a long range BEB
- 6-20 minutes fill time
- Fill station scalable by fleet size
- No secondary Aux heater required for cold climates

BALLARD™

Funding and Sponsorship Provided by Grants Through

CALIFORNIA AIR RESOURCES BOARD

CALIFORNIA CLIMATE INVESTMENTS
Cap and Trade Dollars at Work

FCEB Deployment Status (March 2021)

NEW FLYER

Federal Transit Administration

CALIFORNIA ENERGY COMMISSION

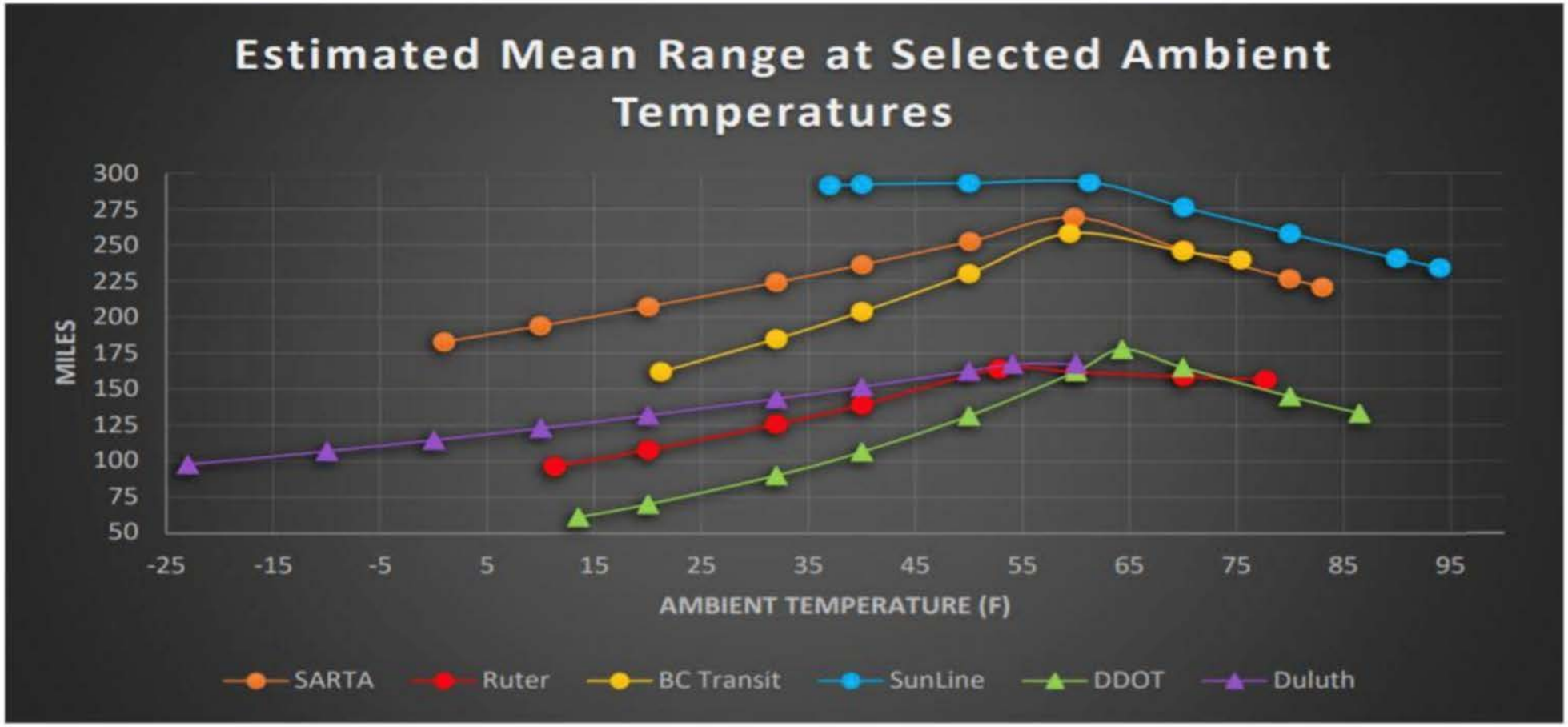
(20) FCEBs at AC Transit (Bay Area)

- With 33 buses to come at Foothill transit

(10) XHE40 FCEBs in service at OCTA (Orange County)

(11) XHE40 FCEBs delivered to SunLine (Thousand Palms)

Figure 9. Range Versus Temperature for Selected Transit Agencies



When grouped together by ZEB type, the decrease in average range going from a temperature interval of 50-60°F to 22-32°F was greater for BEBs (37.8% decrease) than for FCEBs (23.1% decrease) when weighting by miles traveled below base temperature for the respective agencies,

Fuel cell module preventive maintenance plan

Preventive Maintenance (PM)

- Check filters (replace as required)
- Check coolant conductivity
- Check calibration of sensors
- Check smoke detector
- Check ventilation fan
- Minimum interval of 1 month or 5,000 miles

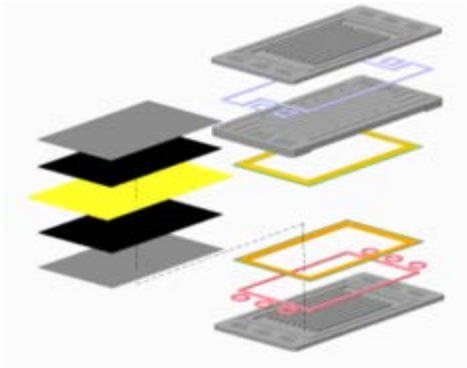
Training

- Provided to transit technicians to be qualified for PM work

PM parts

- Source from Ballard, or
- Source directly from suppliers
- https://www.youtube.com/watch?v=vFIE0We0gx0

We continuously invest in our technology and product development



Unit cell components

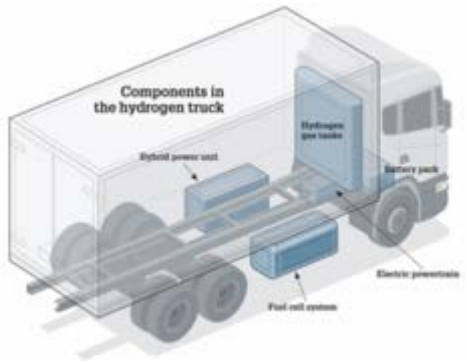
MEA, bipolar plates

Fuel cell stacks

14th generation

Fuel cell modules

8th generation



Fuel cell vehicle integration

application engineering/
after sales service

Humidified and
pressurized system

Freeze-start
from -30°C

IP67
protection

>30,000 hours
life time

Costs are trending down

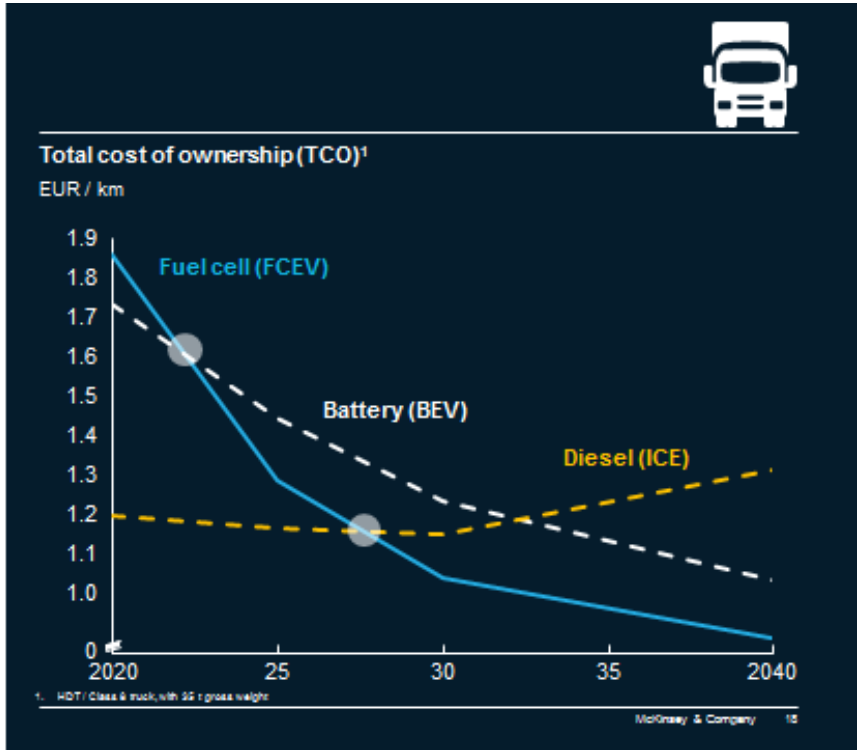
Hydrogen fuel cell transport's path to cost competitiveness with Diesel

- Fuel cell system cost will drop by 70% in 10 years
- Hydrogen distribution & refueling cost will drop by 40% in 10 years

HDT: Commercial heavy duty transport can become cost competitive by 2030

-70%
Fuel cell system

-40%
Distribution and refueling infrastructure



McKinsey - Path to Hydrogen Competitiveness report 2020

"In less than 10 years, it will become cheaper to run a fuel cell electric vehicle (FCEV) than it is to run a battery electric vehicle (BEV) or an internal combustion engine (ICE) vehicle for certain commercial applications."
McKinsey - *Path to Hydrogen Competitiveness* report 2020.

Fueling the Future of Mobility, Deloitte-Ballard 2020 https://info.ballard.com/deloitte-vol-1-fueling-the-future-of-mobility

California is Leading the Move Towards Hydrogen Mobility With Strong Regulations Now In Place

- Executive order directing that all new cars and passenger trucks sold in California be ZEV by 2035
- 8,475 fuel cell cars on the road
- 48 fuel cell buses in service, 67 on order
- More than 20 trucks in operation or in assembly for demonstration projects
- 42 hydrogen refueling stations (HRS) in service and 15 in construction & planning

The West, Midwest and Eastern USA is moving towards H2 as a fuel for Mobility

- Fort Collins has received Colorado's first hydrogen fueling station. They will generate hydrogen on-site by splitting water molecules using renewable electricity.
- Nevada won a $3.8 million dollar Low- no grant to fully fund FCEB and a liquid station with a goal to convert 200 buses to FCEB by 2035.
- Indygo is consider 30 60' FCEB for their BRT line. WMATA is considering hydrogen

Cost Comparison: Battery Electric Buses vs Fuel Cell Electric Buses to be performed for VTA

Foothill Transit's study compares the cost of deploying **20 zero-emission buses on a 42-mile roundtrip route.**

Due to the range limitations of BEBs, it was determined the line will require 34 BEBs vs 23 FCEB, incurring an additional cost of $4.9 million dollars in 11 BEB buses.

Fueling Infrastructure

Fuel cell – 23 buses but can fuel up to 50 buses	$4 million
BEB – Chargers for 34 buses	$11 million

$6 million savings with FCEB

Mid-Life Replacement Cost/Bus

Fuel cell	$30,000
BEB	$200,000

$170K savings per FCEB

Capital Cost

Fuel cell electric bus	$1,100,000
Battery electric bus	$890,000

Fuel Cost/Mile/Bus

Fuel cell	$1.00
BEB/kW	$0.76

Scheduled Maintenance per Mile

Fuel cell	$0.12
BEB	$0.04

Foothill Transit Executive Board Meeting (July 24, 2020)

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The results of Foothill Transit's study show the total cost of ownership of BEBs is higher than FCEBs

12-year Lifecycle Cost Comparison		
	34 BEBs	20 FCEBs
Capital cost- buses	$30,260,000	$25,300,000
Capital cost – fueling infrastructure	$10,948,000	$4,000,000
12 year fuel cost	$11,839,973	$15,661,340
12 year PMI cost	$626,454	$1,879,361
Mid-life maintenance cost	$6,800,000	$690,000
Total	$60,474,427	$47,530,700

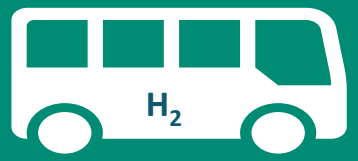
Foothill Transit

Cost Savings with FCEB: $12,943,726

Foothill Transit Executive Board Meeting (July 24, 2020)

Liquid Power Requirements for Zero Emission Bus Fleet at Scale

Fuel Cell Electric Buses



- For a 100 bus fleet, the hydrogen fueling infrastructure will require **750kW of electricity**
- For a 10-15 bus fleet, only 100kW to 200kW of electricity is needed

Battery Electric Buses

- For a 100 bus fleet, the charging infrastructure will require **7,000 to 12,000kW of electricity**
- That's **10 times more power** – could require investment in additional infrastructure (i.e. substation)

Cost Comparison:
Hydrogen vs Charging Infrastructure

King County Metro

- **BEB:** Quoted $60 million per 100 bus base to bring in additional electricity
- **FCEB:** Hydrogen fueling facility was quoted at $8.3 million per 100 bus base
- **Savings of $51.7 million per 100 bus base to go with hydrogen**

Foothill Transit

- **BEB:** $125 million for charging infrastructure for 363 buses
- **FCEB:** $23.4 million for hydrogen fueling infrastructure for same fleet size
- **Savings of $100 million to go with hydrogen**

La Metro

- **BEB:** $ 1 billion for charging infrastructure for 2,200 buses
- **FCEB:** $206 million for hydrogen fueling infrastructure for same fleet size
- **Savings of $794 million to go with hydrogen**

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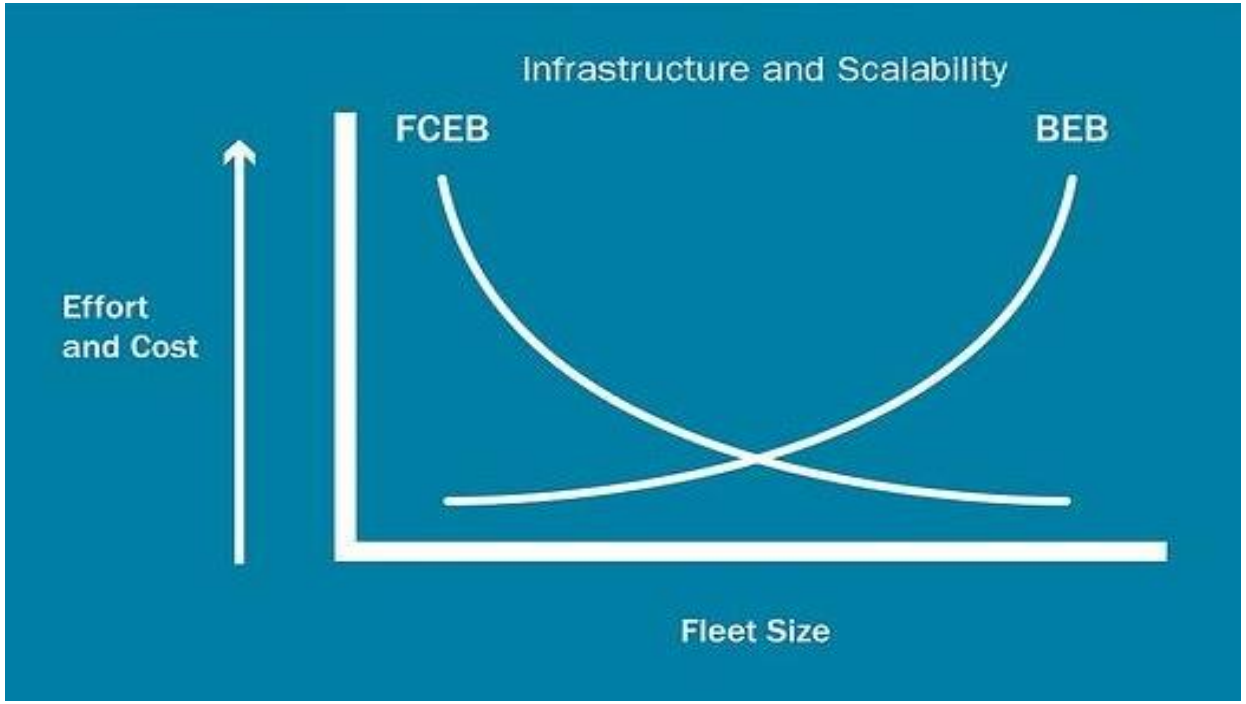
ICT planning studies confirmed that as fleet size increases, cost of hydrogen infrastructure per vehicle decreases



Agency	FCEB	BEB
Foothill Transit	$133k/bus, 30 buses	$322k/bus, 30 buses
Long Beach	$108k/bus, 125 buses	$209k/bus, 100 buses
AC Transit	$90k/bus, 200 buses	$560k/bus, 530 buses

Data collected from CARB published ICT roll out plans

OCTA plans to transition 100% of its 500+ buses to fuel cell vehicles

"The 100 percent FCEBs scenario showed a slightly **lower overall cost** than the mixed technology fleet given current vehicle, fuel, and support infrastructure pricing. …FCEBs offer an **extended range and better match to OCTA's current operating parameters.** In comparison, the current range of BEBs may require more vehicles and drivers to meet similar service levels."

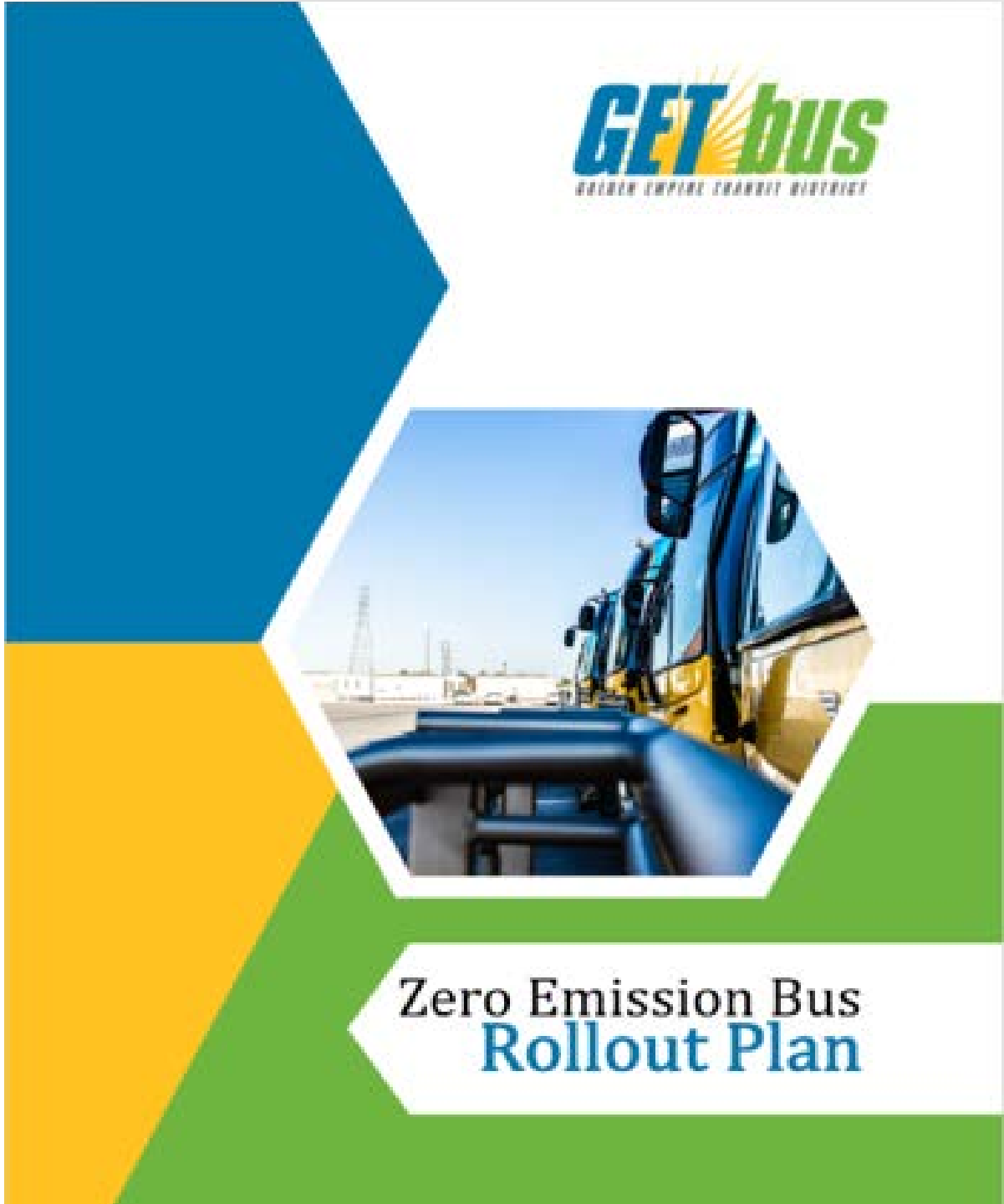
Orange County Transportation Authority

OCTA Zero Emission Bus Rollout Plan

GET Selected 100% FCEBs in their ZEB Rollout Plan

"The final composition of the fixed route fleet will be **100% fuel cell electric buses**. Modelling analysis found that a small percentage of the routes currently operated by GET could be satisfied by battery electric buses as a 1:1 BEB:CNG bus replacement. However, **operating one type of vehicle offers significant benefits** to the agency as all buses can be operated and maintained efficiently and economically. It also means the **buses are interchangeable and can be dispatched on any route as required."**

Golden Empire Transit District



GET Zero Emission Bus Rollout Plan

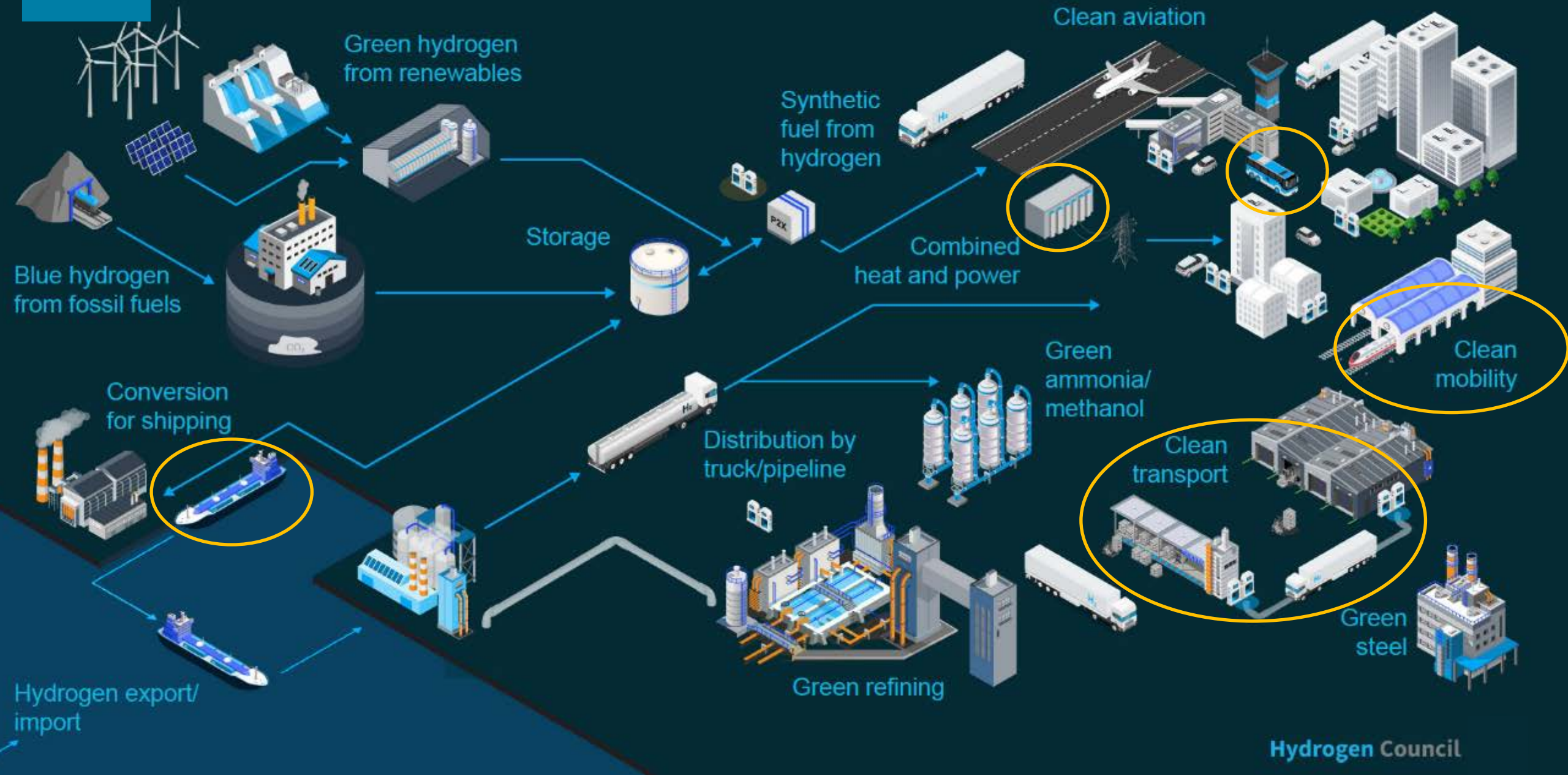
Sunline Transit fleet will be zero emission by 2035 with 85% fuel cell buses

Sunline transit has been operating fuel cell buses since 2000. It now operates 16 hydrogen buses in one the hottest region of the US

The final fleet composition – 67 fixed route fuel cell buses, 18 fixed route battery-electric buses and 39 paratransit fuel cell vehicles – was determined to maximize performance and **minimize cost**

Sunline ZEB roll out plan 2020

Hydrogen can be generated from various sources



NICE America liquid mobile hydrogen trailer

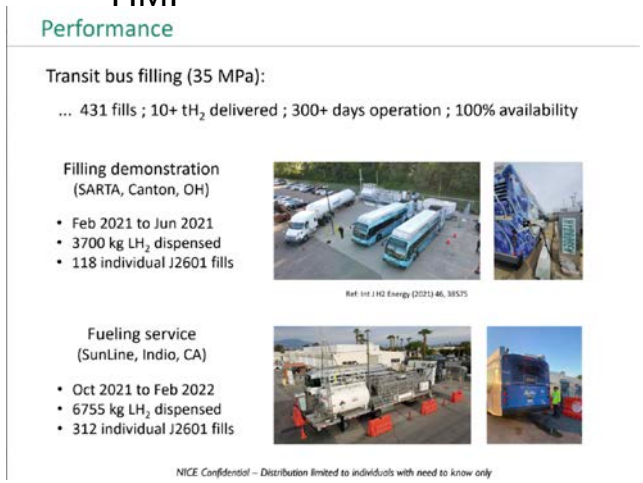
Square Footage: 45’ by 20’

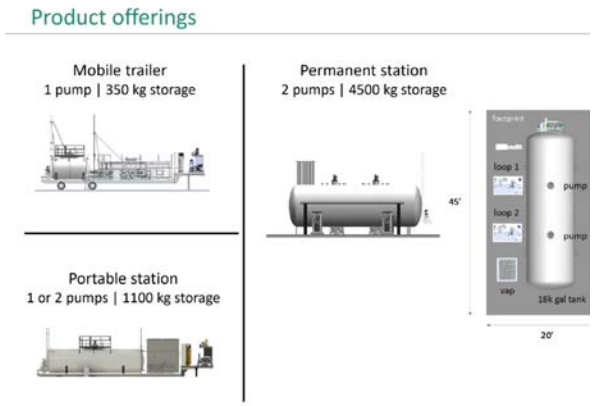
Power requirements: 480V 3 phase 60hz 300A requirement, primarily for our HDU (hydraulic drive unit) to drive the pump

Price- $3.2million

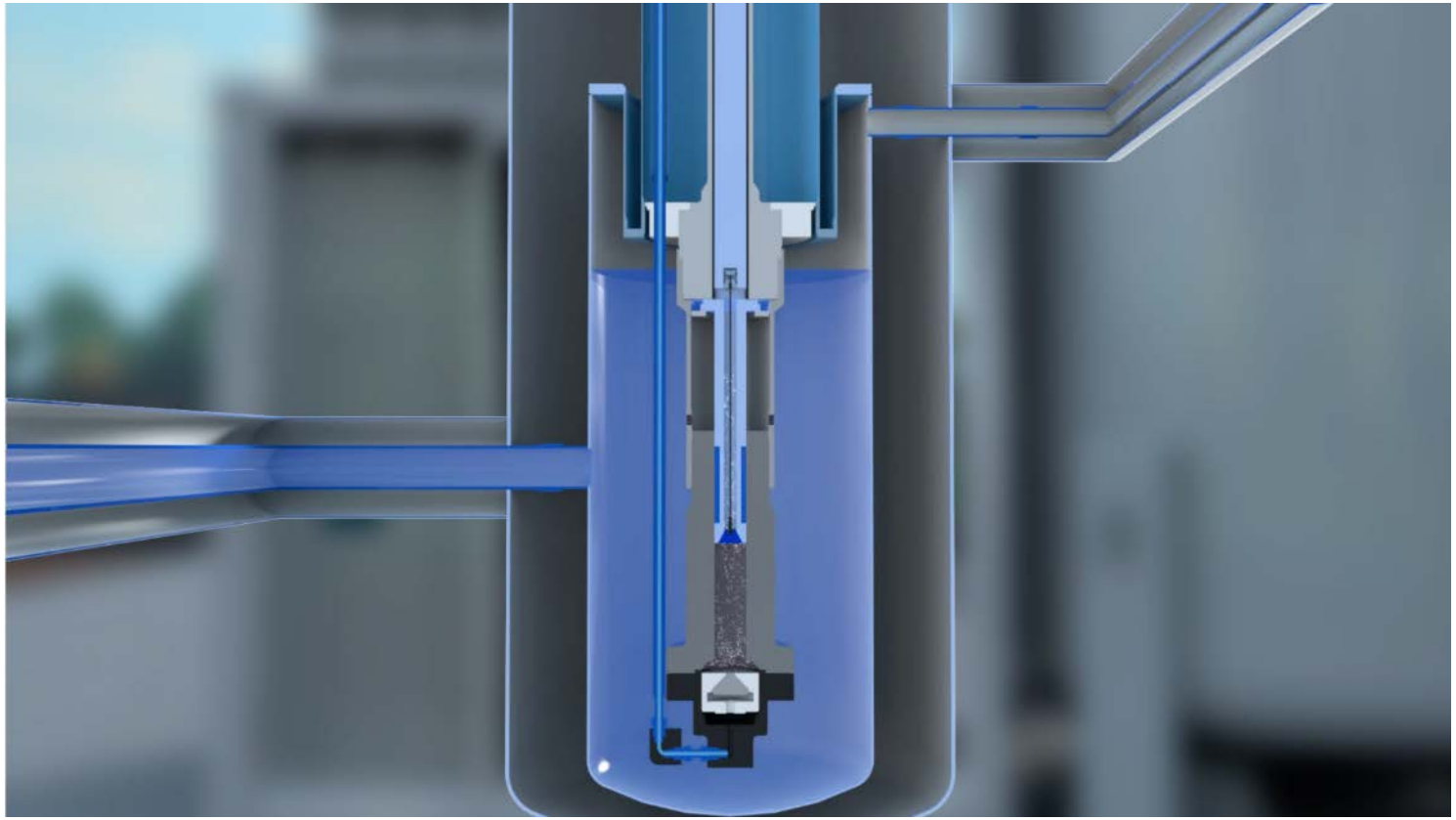
Lead Time- 1 year

Equipment-Fully mobile on wheels Pump in primary LH2 tank, heat exchanger, vaporizer, HDU, dispenser. power electronics/controls HMI





Linde standard hydrogen filling station with the cryopump in their containerized solution

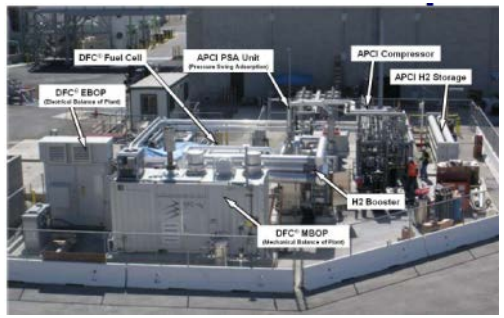


https://www.youtube.com/watch?v=Pjh639S2dek

Equipment delivery:
https://www.youtube.com/watch?v=TRerXAeMOb0&fbclid=IwAR28rnIsLUxtAIsxRNMAaTfgBwN2PW3Mh92TU1iJ6gc2la2TriH2EQ6TGQA

Hydrogen Mobility & Energy Markets

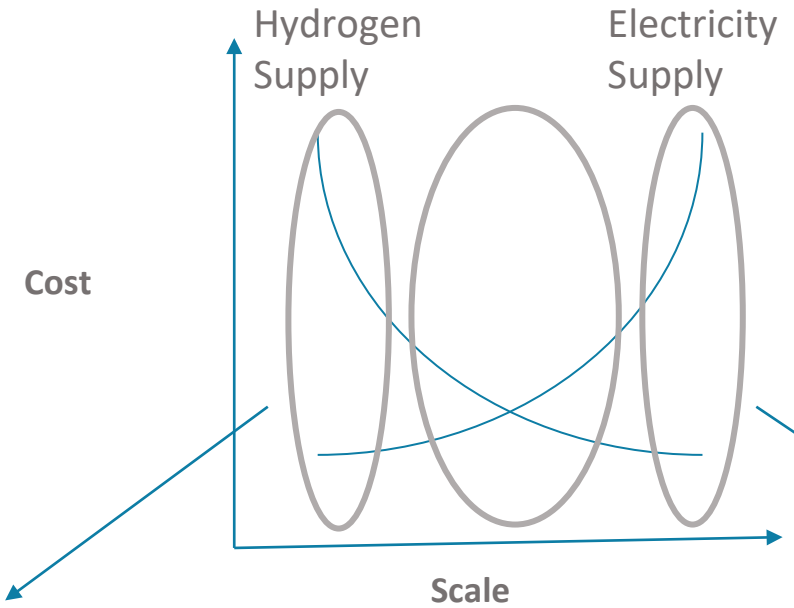
Power Generation



Transportation

Air Products fueling vehicles on these markets in Europe, Asia and US

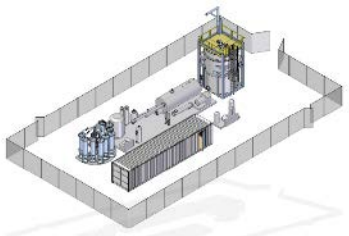
Scaling Comparison and Hydrogen Supply Options



1-2 Buses

5-50 Buses

50+ Buses



2020 Liquid Hydrogen Fueling Station at AC Transit Emeryville Hydrogen station which we could model our Far North transit agencies station after

1. Small Liquid Hydrogen station footprint in AC transits depot

2. 15,000-gallon liquid h2 tank receives delivery 2x month of 4,000kg. They have not missed a delivery in a year

3. Two reciprocating cryogenic liquid pumps. Pumps can handle 130kg/ hour or fill 65 buses in 6 mins in a 12-hour window

4. Pressurized vaporizers transform the hydrogen from a liquid into a gas and distributes it to the dispenser Fueling line is run around 500 feet to separate fuel island with 2 redundant dispensers

Reference #2 – OCTA's Liquid Hydrogen Fueling Station- 60x40 footprint at their depot, built to fuel 50 40' buses. Currently fuels 10 FCEB

Option 1: Liquid Hydrogen Delivery for up to entire fleet

Hydrogen delivered via cryogenic truck and stored on site in tanks

Estimated cost:

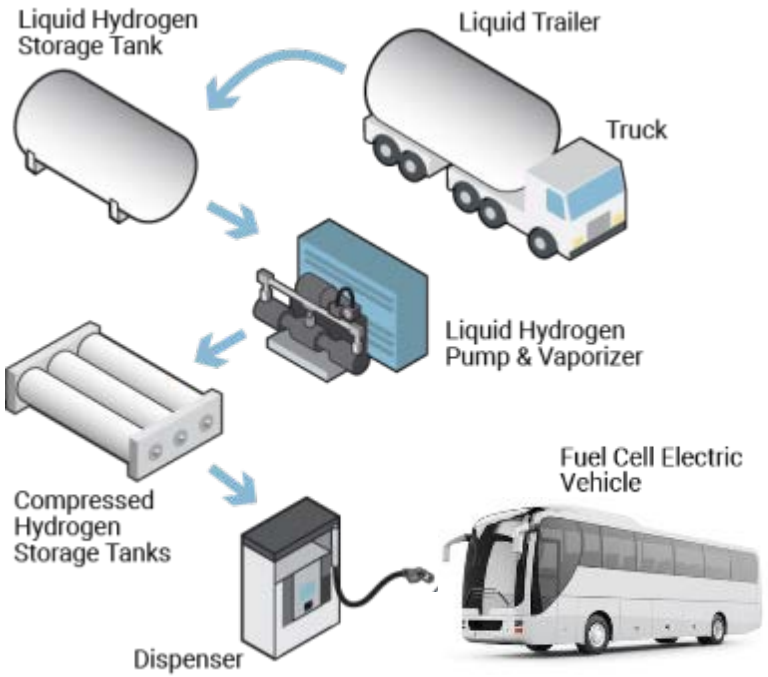
- $1.7 million to fuel 10-15 buses
- $4.7 million to fuel 50 buses
- $8.3 million to fuel 100 buses station $15.1 million for 200 buses

→ **Around $80,000-$100,000/bus and .78 cents per mile or** $7.80-8.60/kg or

- Includes site work, liquid storage, vaporization, compression, gas storage, and dispensing

Optimized footprint:

- 34 ft x 41 ft for 15 bus station
- 30 ft x 60 ft for 50 bus station
- 24ft x 100ft = for 100 bus station

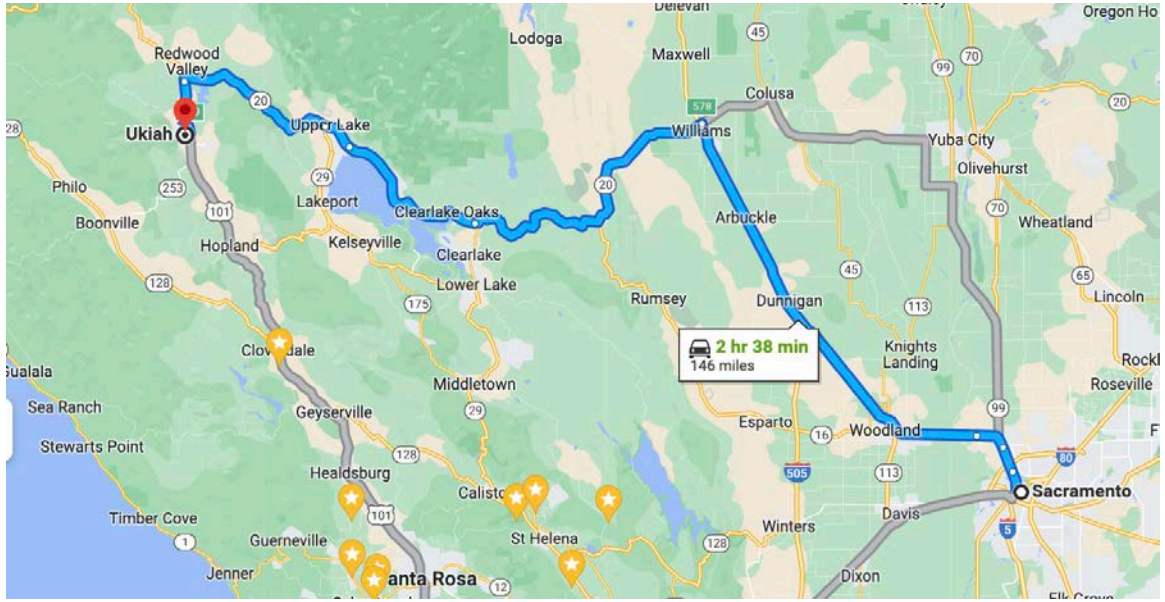


What is the best option supply for Far North transit Agencies?

Options for Hydrogen Supply for Far North

1) Air Products supply from Sacramento is 146 miles

2) Plug Power supply from Fresno is 200 + miles and 100% clean h2



Hydrogen fueling stations: flexible solutions for each depot

Liquid hydrogen delivery

OCTA Station ~ 60’ x 30’ (up to 50 buses)

On Site Reformer

AC Transit – Emeryville

On site H2 production (Electrolyser)

On Site Electrolyser

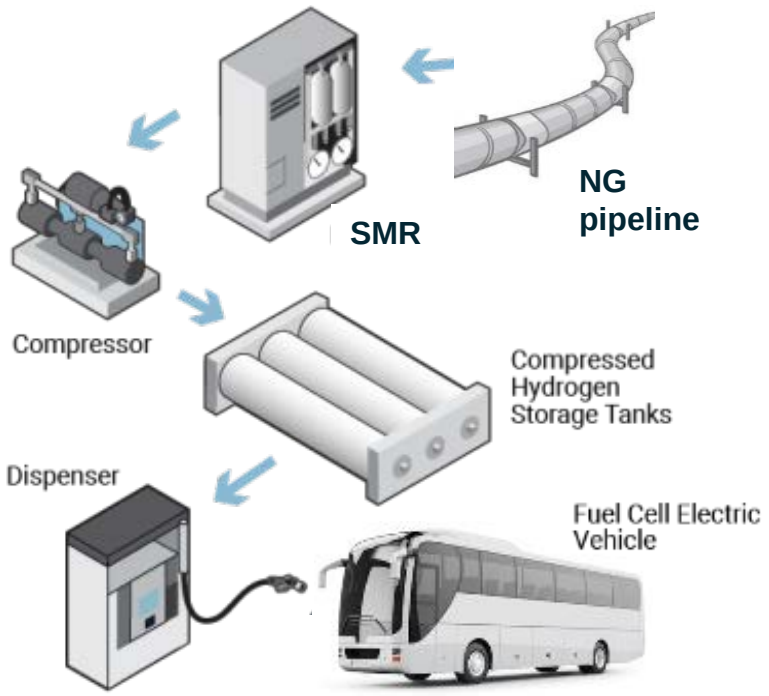
Transit bus depot (Europe)

Hydrogen storage & dispensing area

Compressed H2 delivery

(55”x45” – 20 buses)

Option 2: On-Site SMR



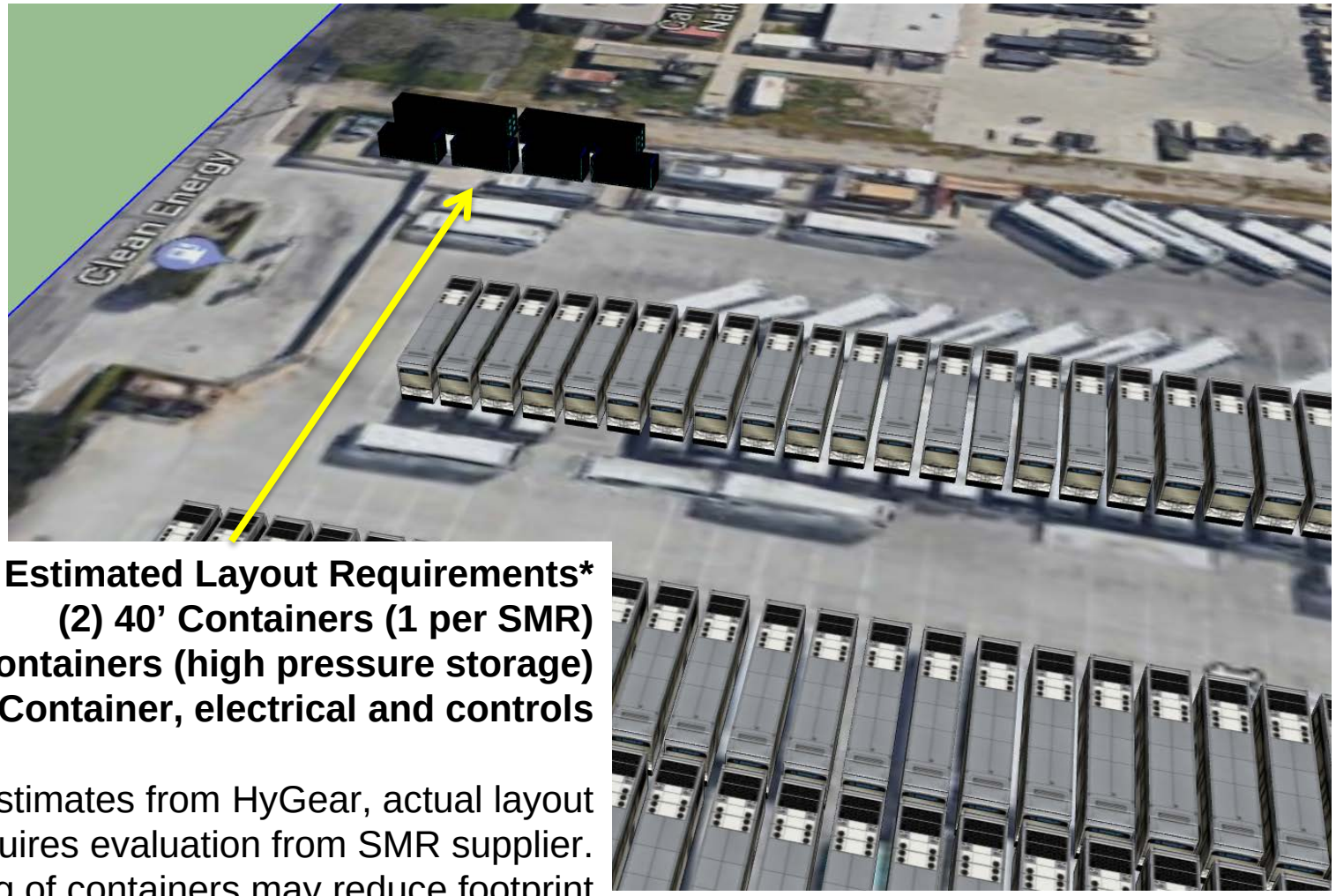
Hy-Gear 150

(2) HyGen 150 SMR – 300 kg to fuel 12 40’ bus	$3.64M
(2) Compressor Skids	$0.7M
(3) H2 Storage Modules	$0.41M
(2) Dispensers	$0.7M
TOTAL =	$5.45M

plus permitting, facility work

Layout: Two 40’ containers (SMR’s) plus four 20’ containers (3 storage + 1 compressor)

Option 2:On-Site SMR Layout, 20 Bus Deployment



Estimated Layout Requirements*
(2) 40’ Containers (1 per SMR)
(3) 20’ Containers (high pressure storage)
(1) 20’ Container, electrical and controls

*Rough estimates from HyGear, actual layout requires evaluation from SMR supplier. Stacking of containers may reduce footprint

Option 2: Onsite Steam Methane Reformer

Hydrogen reformed onsite from natural gas, delivered through existing pipeline

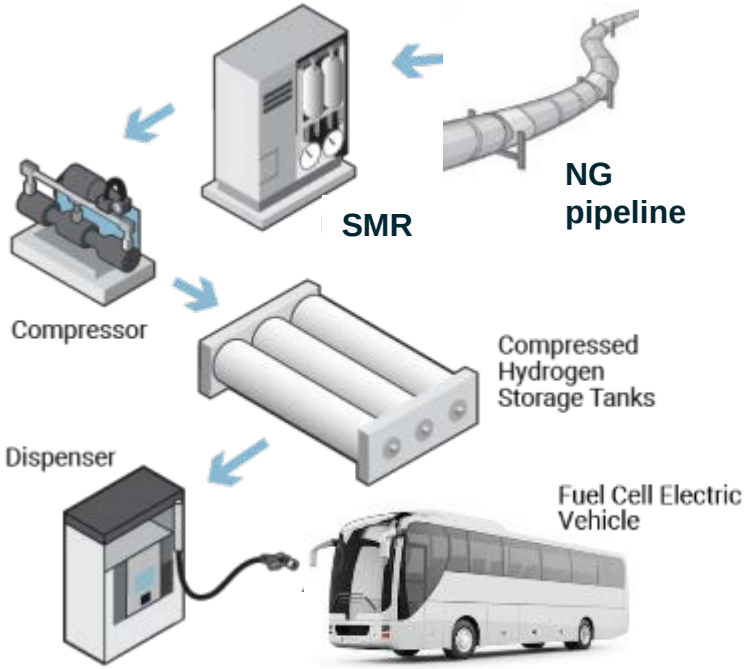
Estimated cost:

→ around $190,000 to $210,000 /bus

Total footprint:

- 4,000ft^2 for reformer, 4,000ft^2 for compression and storage
- Dispensed at existing CNG fueling station

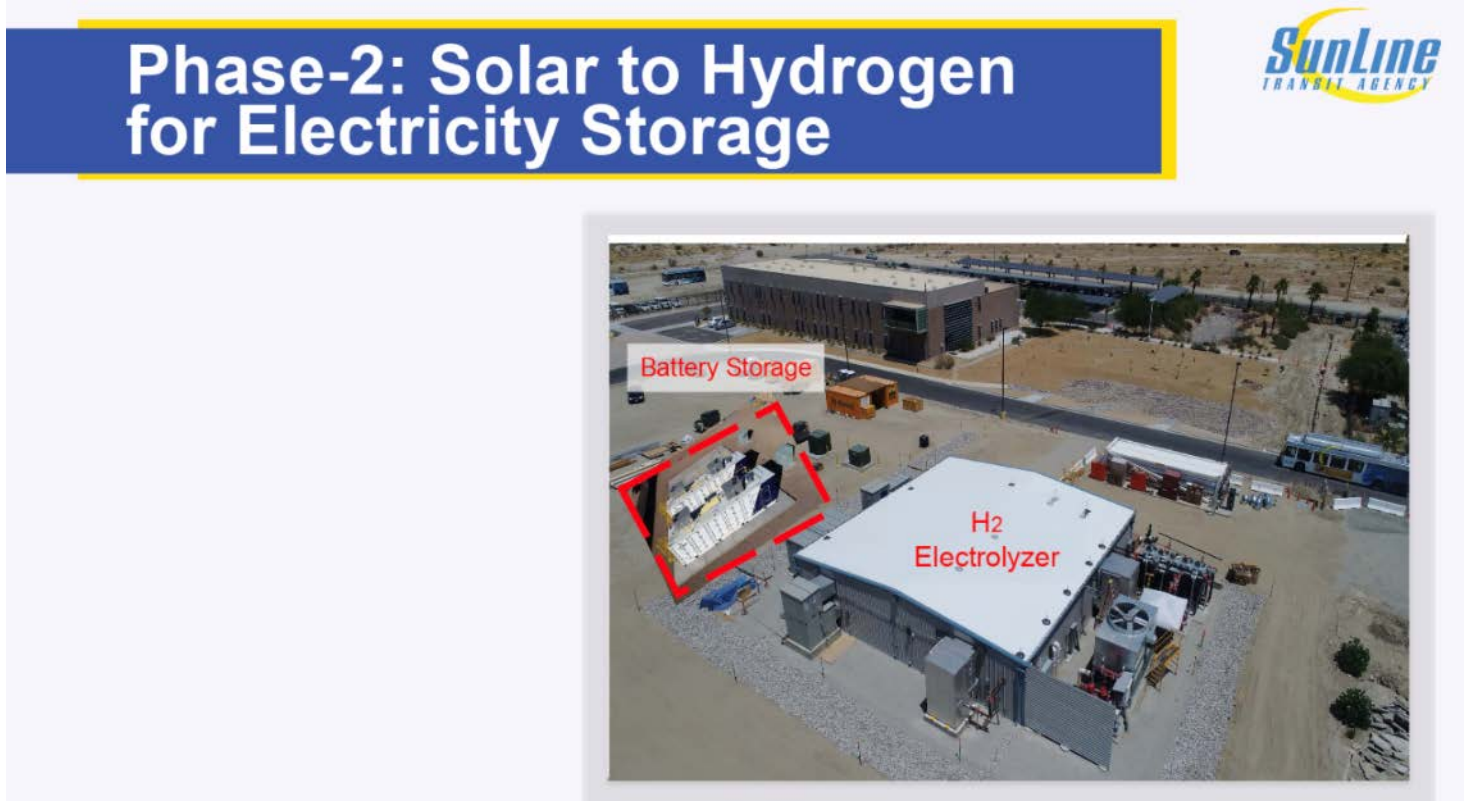
$0.60/therm with 50% renewable natural gas



Option 3: Centralized Electrolysis Production of Renewable Hydrogen

On-site electrolysis

Best way to get 100% renewable hydrogen today is from **centralized production through electrolysis**, powered by wind and solar



Option 3: Centralized Electrolysis Production of Renewable Hydrogen

On-site electrolysis

	Contractor	Total	Funding Sources: Federal	State	Local
Quality Assurance & Inspection, Project Management & Tech. Assistance	CTE	$523,225	-	-	$523,225
Facility Design & Engineering	Fiedler Group	$436,900	-	-	$436,900
Bus Procurement	New Flyer	$3,087,084	$1,080,479	$2,006,605	
Hydrogen Fueling Station	**Trillium**	**$7,918,092**	**$2,771,332**	**$5,146,760**	-
	Total	$11,965,301	$3,851,811	$7,153,365	$960,125
			32%	60%	8%

Option 3: Centralized Electrolysis Production of Renewable Hydrogen

Hydrogen for Buses in California (2019)

nel

Electrolyser and H2Station® for world's largest onsite hydrogen fueling station

- SunLine Transit Agency in Thousand Palms, California.
- Turn-key solution including civil works and permitting.
- Proton® PEM electrolyser for hydrogen production – 900kg/day.
- Two H2Station® for fueling of two busses simultaneously
- Capacity for up to 24 hydrogen fuel cell busses per day.
- Nel conduct operation and maintenance of facility.

SunLine

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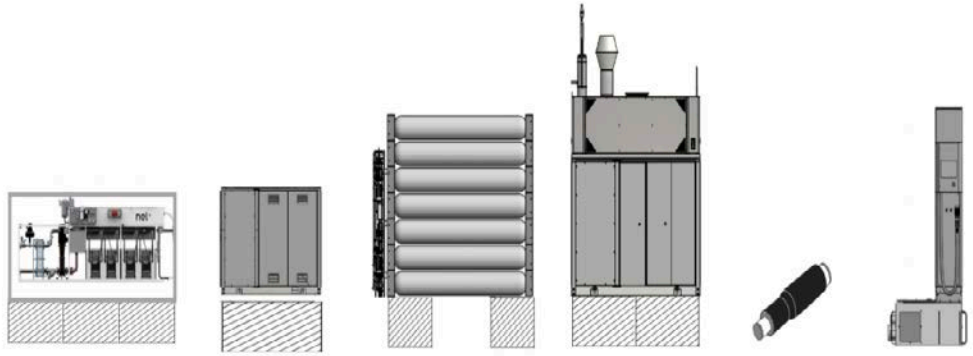
Equipment civil works scope

nel



	Electrolyser (if applicable)	Supply Compressor (if applicable)	Hydrogen Storage	Station Module	Dispenser Pipeline	Dispenser
	Block foundations for equipment enclosures	Block foundation and canopy for compressor skid	Point foundation under storage sleeves	Block foundation for enclosure and compressor	Closed pipeline trench (burial).	Pre-fabricated underground pitbox
	Hydrogen pipe to Supply Compressor and electrical wiring to Station Module	Hydrogen pipe to Hydrogen Storage and electrical wiring to Station Module.	Hydrogen pipe and electrical wiring to Station Module	Control/connects to Hydrogen Storage, Supply Cabinet and Dispenser	Pre-insulated hydrogen pipeline and electrical wiring to dispenser	Connects to Dispenser Pipeline and wiring
	480VAC 3 phase + neutral 60Hz	480VAC 3 phase.		480VAC 200Amps 3 phase 240VAC 20Amps 1 phase Communication / Internet		

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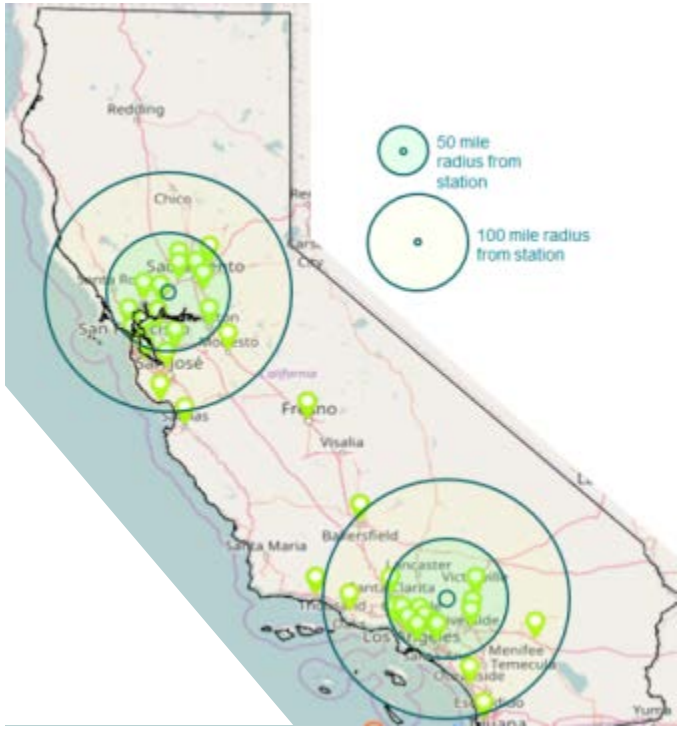
Option 3: Centralized Electrolysis Production of Renewable Hydrogen



On-site electrolysis challenging at scale in CA due to real estate, power costs

Best way to get 100% renewable hydrogen today is from **centralized production through electrolysis**, powered by wind and solar

Compressed hydrogen gas is delivered to the depot from production site (within 120 mi)

Can take advantage of a higher LCFS rebate

- $5.40/kg for renewable hydrogen vs $0.50/kg for hydrogen from natural gas

At scale, this option is a path to reduced cost and 100% zero-emissions well-to-wheel

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World's Largest Green Hydrogen Project to Launch in Lancaster, California

- Will produce 11,000 kilograms per day of green hydrogen
- SGH2's patented Solena Plasma Enhanced Gasification (SPEG) technology gasifies biogenic waste materials
- Five to seven times cheaper than other green hydrogen
- Hopeful for more projects like this to come with the DOE announcement of $5 billion for hydrogen hubs across the US


AC TRANSIT
HYDROGEN FUEL CELL
ZERO EMISSION

Here for life™

Thank you

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