

# *Best Practices in Hydrogen Fueling and Maintenance Facilities for Transit Agencies*



**Ohio Fuel Cell Symposium  
31 March 2017  
Steven Sokolsky, Program Manager**



# CALSTART is a non-profit, clean transportation coalition

## *Mission:*

Support and expand clean transportation tech industry

Tech and fuel neutral

## Goals:

- Create high-quality jobs;
- Clean the air;
- Reduce dependence on foreign oil; and
- Reduce global warming emissions



# CALSTART's 160+ Member Companies and Organizations

(PARTIAL LISTING)

## Making Clean Transportation Happen

The image displays a grid of logos for various member companies and organizations. The logos are arranged in approximately 10 rows and 10 columns. Some logos are larger and more prominent, while others are smaller. The logos include:

- BAE SYSTEMS**
- South Coast AQMD**
- WELLS FARGO**
- BAY AREA AIR QUALITY MANAGEMENT DISTRICT**
- Southern California Gas Company**
- San Joaquin RTD**
- Time Warner Cable**
- NEW FLYER**
- UPS**
- Westport**
- PRICORN INVESTMENT GROUP**
- Union of Concerned Scientists**
- SunEdison**
- chargepoint**
- SEVCON**
- VOLVO**
- AMERICAN POWER GROUP**
- FCA**
- EATON**
- Altec**
- BYD**
- GEN THERM**
- WIND TRUCKS**
- SOUTHERN COMPANY**
- CATERPILLAR**
- MERITOR**
- FedEx Express**
- TOYOTA**
- Ford**
- GM**
- FedEx Ground**
- PG&E**
- Cummins**
- Allison Transmission**
- BLACK & VEATCH**
- FUSO**
- ARC**
- ODYNE**
- FPL**
- Audi**
- GOLDEN GATE PETROLEUM**
- CEW**
- TESLA**
- BALLARD**
- McDonald's**
- NORTH AMERICAN LOGISTICS COUNCIL**
- ENC**
- REG**
- HUMMINGBIRD ELECTRIC VEHICLE**
- QOM**
- KW**
- HARRIS**
- plug power**
- TEREX**
- US Hybrid**
- Sandia National Laboratories**
- UQM TECHNOLOGIES**
- ACTIA**
- UNICELL**
- greencommuter**
- pace**
- US Hybrid**
- WORKHORSE**
- HH**
- XL HYBRIDS**
- ADVANCED VEHICLE MANUFACTURING**
- Parker**
- MOTIV**
- VIA TEC INC**
- ebus**
- ZENITH MOTORS**
- I.A. DWP**
- Los Angeles Department of Water & Power**
- FritoLay**
- WORKHORSE**
- EMPOWER**
- EMPI**
- Cerritos College**
- Purolator**
- EFFICIENT DRIVETRAINS, Inc.**
- emerald automotive**
- Voltronix USA INC**
- ESW America**
- PROTERRA**
- TORRANCE TRANSIT**
- TransPower**
- NUVERA**
- Schneider Electric**
- oberon FUELS**
- Foothill Transit**
- ART**
- AL TRANSIT**
- REAL POWER**
- ADOMANI**
- e-Traction**
- SARTA**
- UTS**
- SunLine**
- MST**
- GENERAL SERVICES ADMINISTRATION COUNTY OF ALABAMA**
- ITRI**
- WAVE**
- TULA**
- SMUD**
- MTD Santa Barbara**
- New Eagle**
- Clean Cities**
- STURMAN INDUSTRIES**
- CONCORD MILITARY Solutions Group**
- I X OAK**
- ORANGE EV**
- TRI DELTA TRANSIT**
- UNITED STATES POSTAL SERVICE**
- AVTA**
- STURMAN INDUSTRIES**
- effenco**
- UTA**
- City of Gardena**
- ace parking**
- SACRAMENTO METROPOLITAN AIR QUALITY MANAGEMENT DISTRICT**
- Cal State LA**
- VTA**
- POWERTRAINS**
- STANFORD UNIVERSITY P&TS**
- LADOT**
- FIRST PRIORITY GREEN FLEET**

# CALSTART Leading National Campaign for Zero Emission Bus (ZEB) Initiative

» CALSTART leading national coalition to create Zero Emission RD&D and procurement program in federal transportation funding measure

- Success to date:
  - » FC costs declined by 50%
  - » Fuel cell life increased by 3X

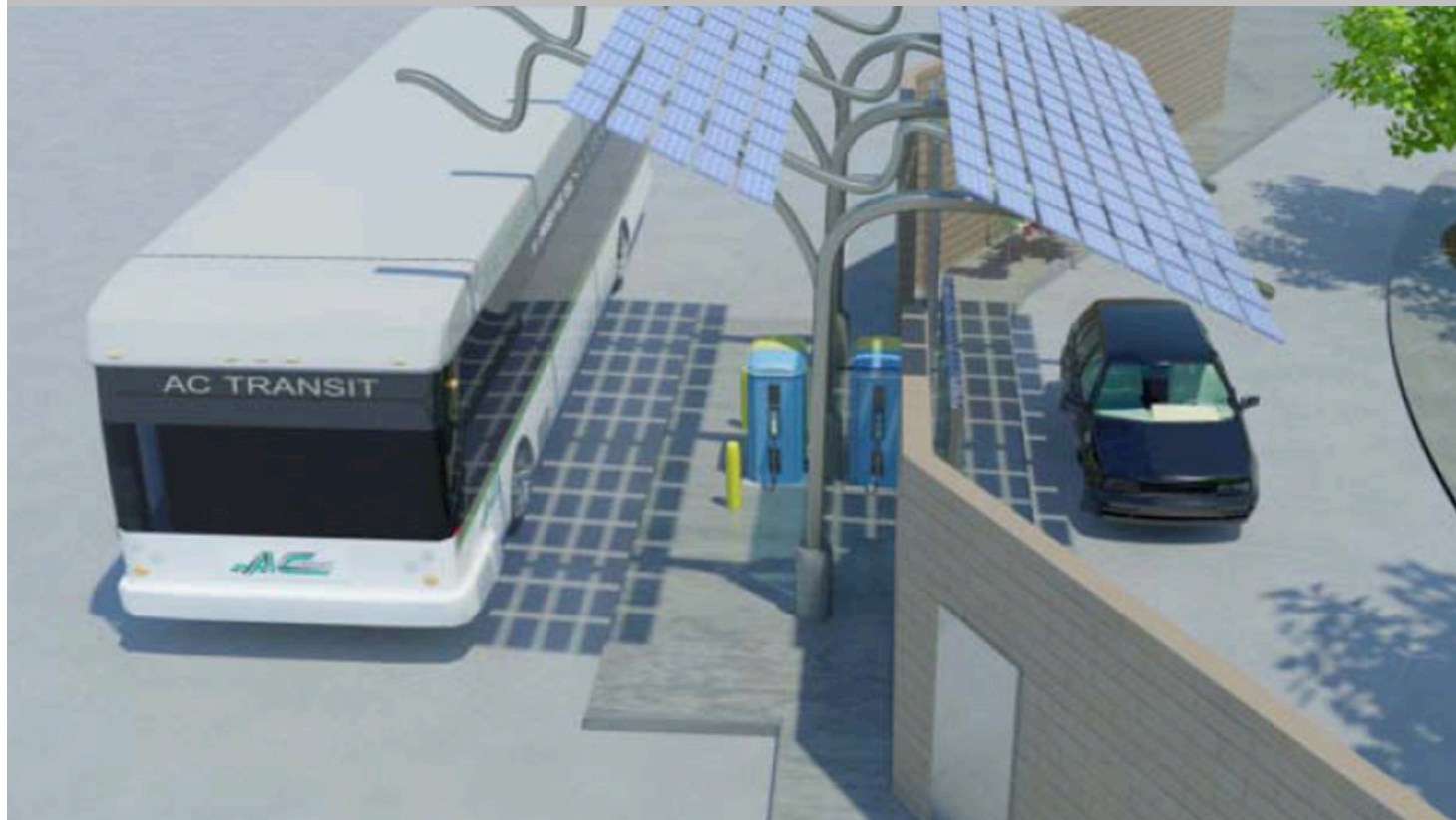


# NFCB Program Objectives and Achievements to Date

PERFORMANCE OBJECTIVE	STATUS
Less than 5X cost of conventional bus	Cost reductions from > \$3.0M in 2006 to ~ \$1.3 million in 2016. Plug-in battery dominant bus < less.
Durability 4-6 years or 20,000 – 30,000 for the FCPS	20,000 hours + achieved on FC bus with durability warranties at 10,000 and 12,000
Fuel economy 2X compared to commercial transit bus	Exceed 1.5X conventional bus, depends on route and bus design
Bus performance equal to or greater than equivalent commercial bus	Operate up to 19 hours/day, good availability, bus miles between road calls at 4,000 (<< than conventional); better acceleration, quieter operation, weight still high
Exceed current emissions standards	Exceeds – zero emissions
Foster competition in FCB technologies	Multiple manufacturers and platforms demonstrating buses
Increase public acceptance for fuel cell bus technologies	Continued progress

# Some Key Transit Agency Survey Feedback

1. Infrastructure is key barrier to adoption.
2. Help envisioning: renditions of different sizes of stations.
3. Space-constraints: installing infrastructure between 5,000 and 20,000 square feet
4. Need to share recommendations with transit executives.





## Transit Agency Needs

“How do I go from zero buses to 1 or 2? From 2 to 10? From 10 to 200?”

No high-level guide available in an easily digestible format.

# Hydrogen Infrastructure Best Practices Guide for Transit Agencies – Now Available

- Report is a **decision-making & planning tool**
- **Enabling activity** to allow transit plan and understand:
  - refueling,
  - safety,
  - maintenance,
  - economics of hydrogen facilities.
- **First comprehensive effort** to develop high-level, easily digestible best practices guidelines
- Report developed & drafted by CALSTART and GTI, funded by FTA and Southern California Gas Company



# Key Issues Covered

1. Generation vs. delivery of fuel
2. On-site electrolysis vs. reformation
3. Balance of station equipment
4. Station ROI
5. Space constraints
6. Codes and standards



# Guidebook Content

- Options for equipment and site design
- Refueling interface and capacity planning
- Refueling economics
- Fuel cell bus maintenance facility requirements
- Training and first responders
- Directory of industry suppliers, vendors, and consultants



# Options for Obtaining H<sub>2</sub>

- » Delivery of liquid H<sub>2</sub>
- » Delivery of gaseous H<sub>2</sub> and/or storage in tube trailer
- » On-site generation through steam reformation
- » On-site generation through electrolyzer
- » Pipeline delivery of H<sub>2</sub>
- » Energy station (combined heat & power)

# Example: Hydrogen Station Selection Factors

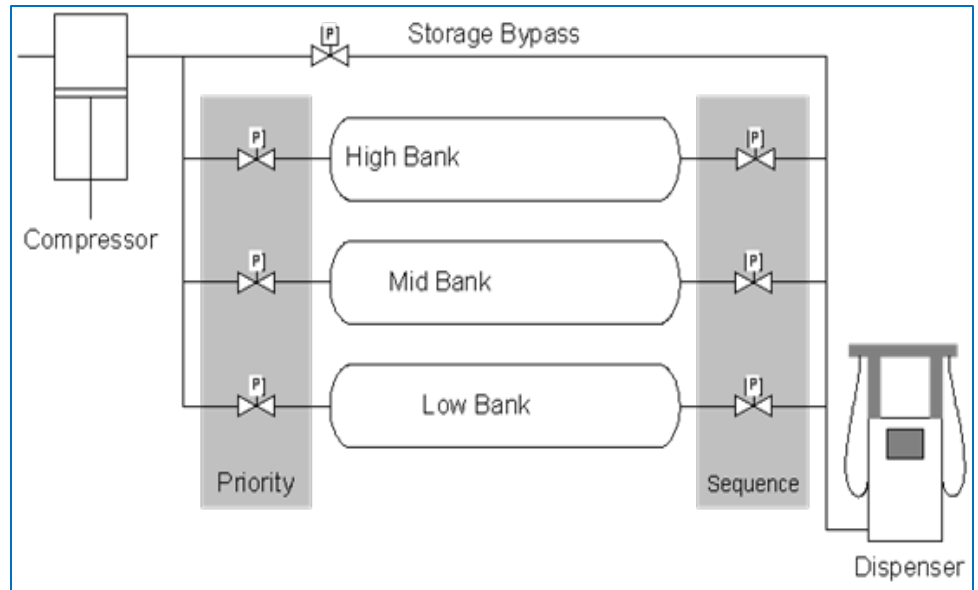
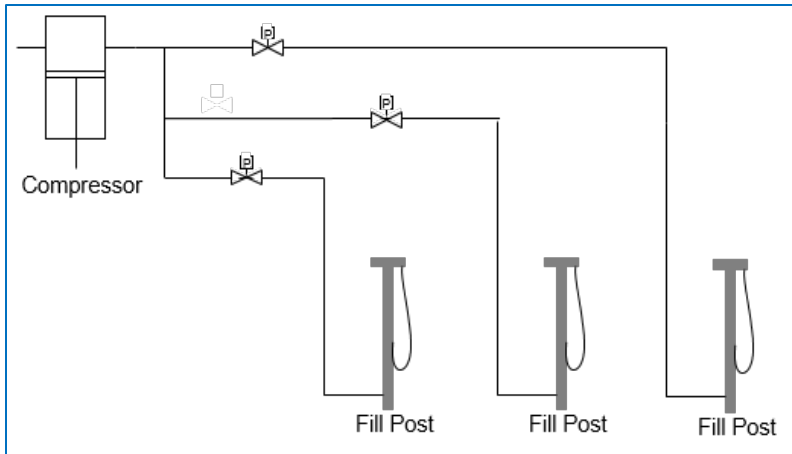
- **H<sub>2</sub> Capacity Factors**
  - ✓ Fleet Size
  - ✓ Fill Rate ⇔ kg/day
  - ✓ Bus H<sub>2</sub> System
  - ✓ Bus Fill Receptacle
- **Site Parameters**
- **Fuel Sourcing**
- **Hydrogen Assets**
- **Operations, Safety**

General Station Type	Typical Capacity (kg/day)
Liquid Delivery	1,000
Onsite Reformation	100 – 1,000
Pipeline Delivery	1,000+
Onsite Electrolysis	30 – 100
Mobile Fueler	50
Energy Station (CHP)	100 - 300

# Estimated Costs for Various Station Types

Station Type	Reformer	Electrolysis	Pipeline Delivered	Reformer	Liquid H <sub>2</sub> Delivered
Capacity (kg/day)	100	100	100	1000	1000
Capital and Installation	\$1,047,927	\$923,039	\$583,141	\$5,137,202	\$2,677,362
Operating Cost	\$92,594	\$202,558	\$79,459	\$456,278	\$901,007
Cost/kg					
Natural Gas	\$1.14			\$1.14	
Electricity	\$0.36	\$8.25	\$0.35	\$0.36	\$0.11
Fixed Operating	\$3.84	\$3.44	\$4.24	\$1.13	\$5.09
Capital Charge	\$5.65	\$4.59	\$2.70	\$3.20	\$1.55
Delivery and Installation	\$2.30	\$2.41	\$1.73	\$0.70	\$0.48
<b>Total</b>	<b>\$13.29</b>	<b>\$18.69</b>	<b>\$9.02</b>	<b>\$6.53</b>	<b>\$7.23</b>

# Time Fill vs. Fast Fill Dispensing



# Equipment for Time and Fast Fill Refueling Stations

<b>Equipment</b>	<b>Time Fill</b>	<b>Fast Fill</b>
<b>Compressor</b>	Small compressor necessary as simultaneous filling occurs over 8+ hrs	Fillings usually occurs sequentially and in minutes, so a larger compressor is required
<b>Gaseous Hydrogen Storage</b>	Small volume of buffer storage required to limit compressor start/stop cycling	Large Buffer storage required to limit compressor start/stop cycling and reduce fill time
<b>Dispenser</b>	One dispensing post required per fueling location	One dispenser for every ~20 buses.
<b>Controls</b>	Controls are very simple for start/stop and safety shutdown	Controls are more complicated to decide whether gas should go to filling bus or filling storage and to determine when to safely terminate the fast fill.

# Possible Time Fill Equipment Configurations

# Buses	H2 Fuel Mass (kg/day)	Filling Time (hrs)	Time Fill Rate (kg/hr)	# Compressors	Compressor Size (kg/hr)	Storage Required (kg)	# Time Fill Posts	Fueler Labor (hrs/day)
1	40	10	4	1	4	3	1	0
4	160	10	16	1	16	12	4	0
20	800	10	80	2	40	60	20	0
40	1600	10	160	3	53	120	40	0
80	3200	10	320	6	53	240	80	0

# Possible Fast Fill Equipment Configurations

# Buses	H2 Fuel Mass (kg/day)	Filling Time (hrs)	Time Fill Rate (kg/hr)	# Compressors	Compressor Size (kg/hr)	Storage Required (kg)	# Time Fill Posts	Fueler Labor (hrs/day)
1	40	1	40	1	40	120	1	1
4	160	2	80	2	40	120	1	2
20	800	7	120	2	60	120	1	7
40	1600	7	240	4	60	240	2	14
80	3200	7	480	8	60	480	4	28



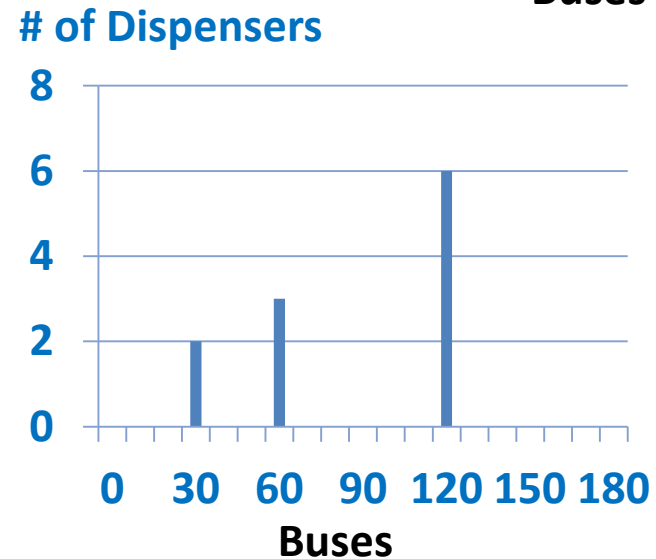
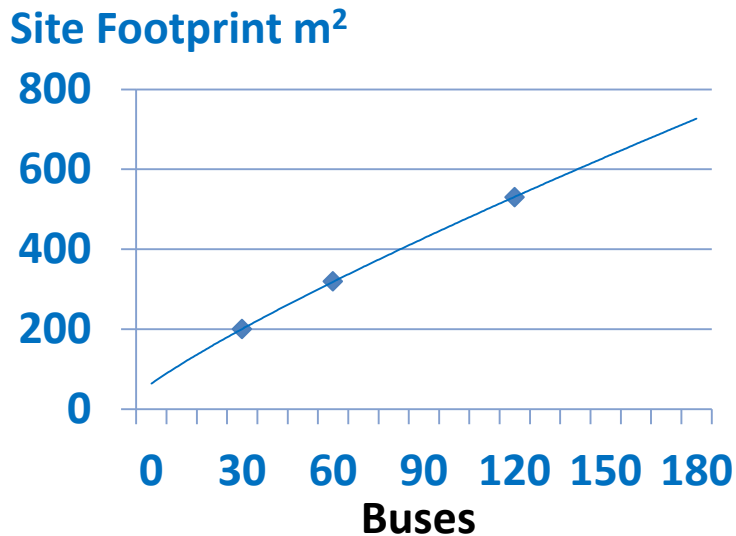
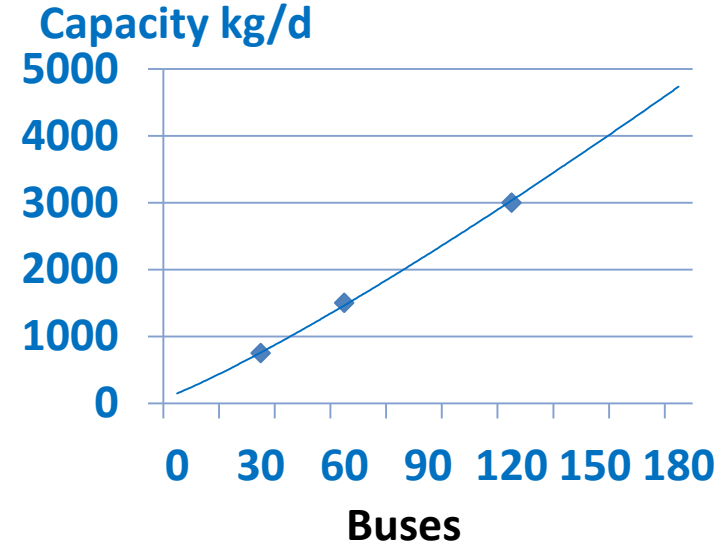
# Common Codes and Standards for Hydrogen Fueling Stations

<b>Construction</b>	<b>H2 Dispensing</b>	<b>FC Vehicle</b>
ICC	SAE	SAE
NFPA	CSA	NHTSA
Local codes		DOT
<b>Electrical</b>	<b>Storage</b>	<b>Fuel Cell Power</b>
NEC/NFPA	NFPA	ANSI
IEEE	CGA	UL
ANSI	ASME	ISO
UL	ANSI	IEC

# The Path Forward

## Growth Path is Important

- » Tube Trailer ➡ More Trailers
- » Liquid H<sub>2</sub> ➡ More Storage /Pumping
- » Tube Trailer ➡ On-site Production



# Guidebook Schedule & Availability

- » Guidebook completed September 2016
- » Final advisory committee review completed
- » Guidebook available at [www.calstart.org](http://www.calstart.org) for more industry/public review
- » Additional transit industry outreach underway

A blue hydrogen fuel cell bus is shown on a city street. The bus features large white circular graphics with the text 'SARTA HYDROGEN FUEL CELL' and 'ZERO EMISSIONS'. The background shows a city street with buildings and a street lamp.

# **SARTA FC Bus Deployment – Customer Acceptance/Voice of the Customer**

- **Survey for Potential Customers Available**
- **Seeking date for workshop to educate users & regulators**



*Making Clean Transportation Happen*

**Leading the Industry  
with Activities in  
Technology Commercialization /  
Policy /  
Technical Analysis / Market  
Acceleration**

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