Best Practices in Hydrogen Fueling and Maintenance Facilities for Transit Agencies

Ohio Fuel Cell Symposium
31 March 2017
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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

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

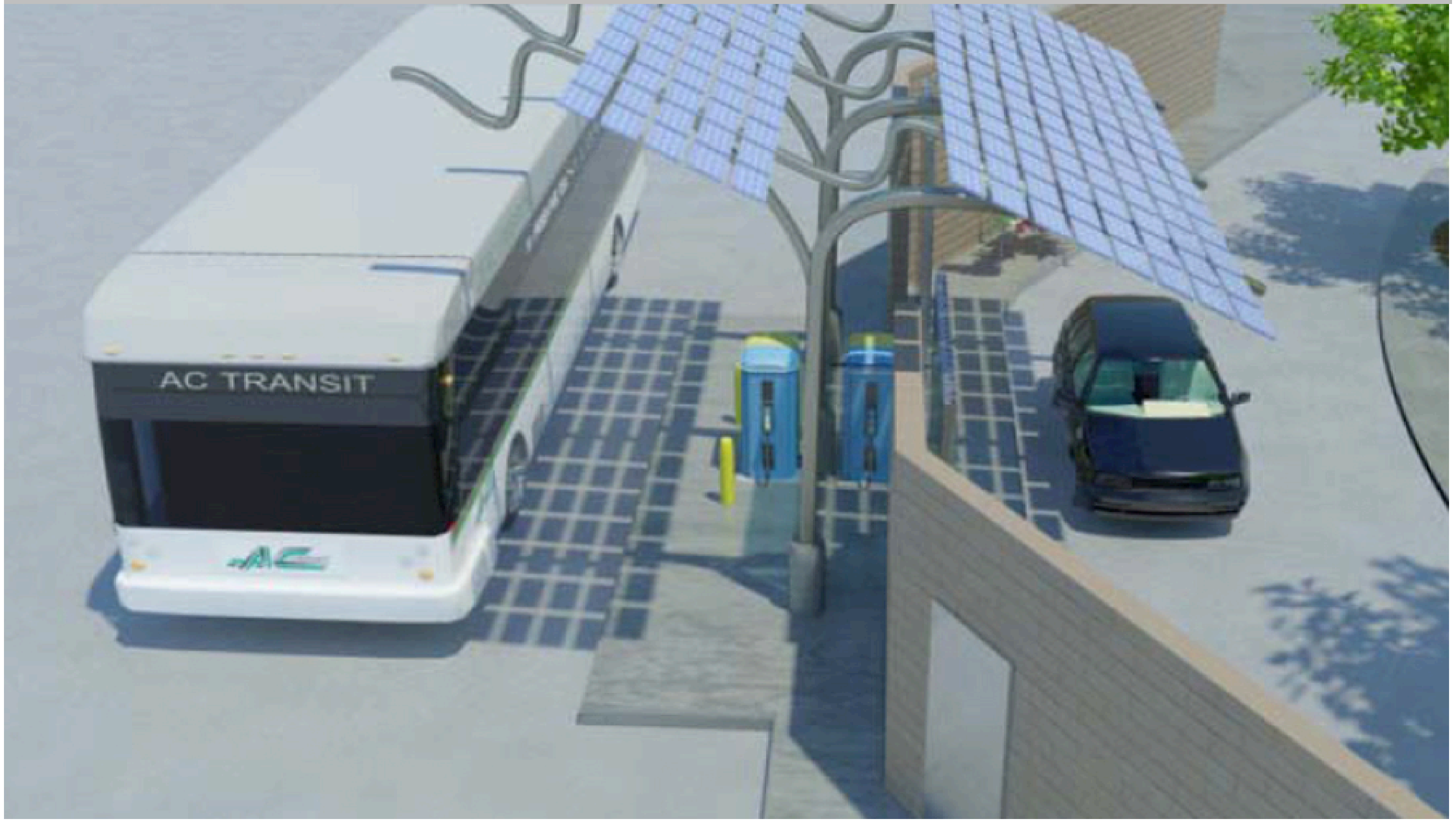
- **CALSTART leading national coalition to create Zero Emission RD&D and procurement program in federal transportation funding measure**
  - **Success to date:**
    - **FC** costs declined by 50%
    - Fuel cell life increased by 3X

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 H2

» Delivery of liquid H2

» Delivery of gaseous H2 and/or storage in tube trailer

» On-site generation through steam reformation

» On-site generation through electrolyzer

» Pipeline delivery of H2

» Energy station (combined heat & power)

Example: Hydrogen Station Selection Factors

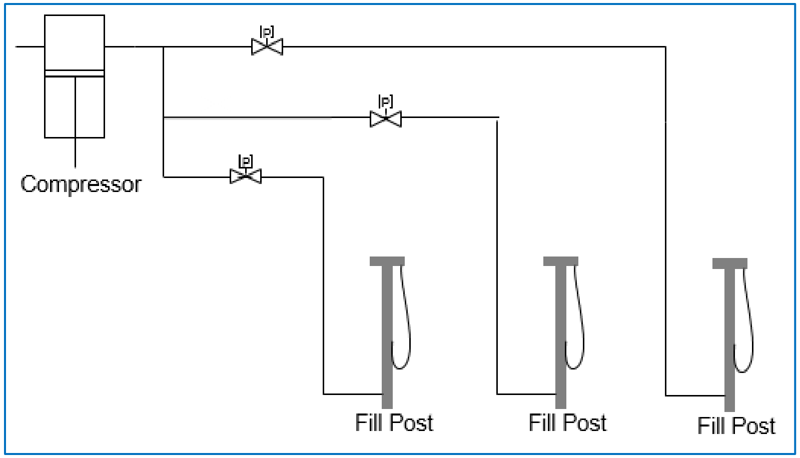
- H_2 Capacity Factors
  - ✓Fleet Size
  - ✓Fill Rate ⇔ kg/day
  - ✓Bus H_2 System
  - ✓Bus Fill Receptacle
- Site Parameters
- Fuel Sourcing
- Hydrogen Assets
- Operations, Safety

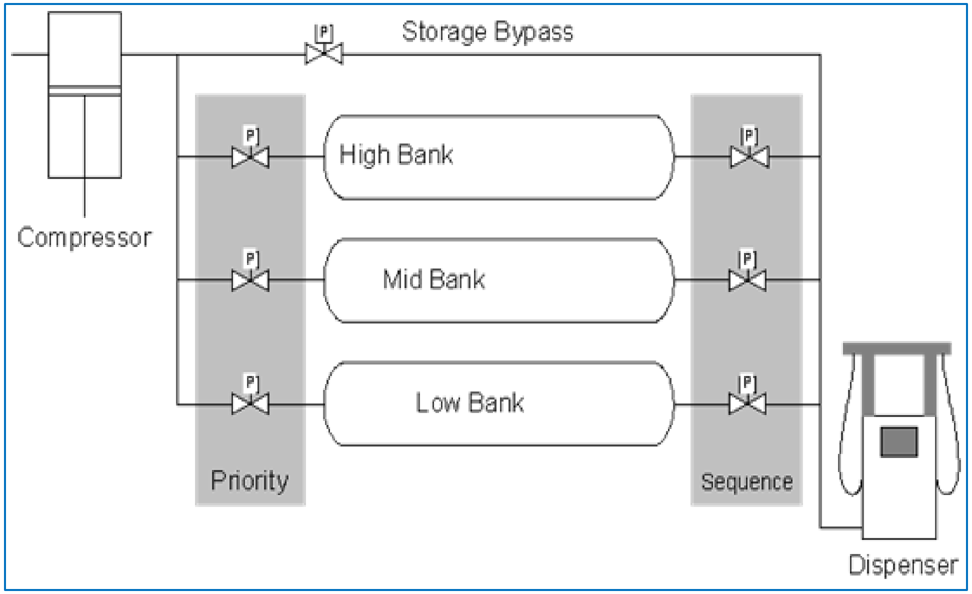
General Station Type	Typical Capacity (kg/day)
Liquid Delivery	1,000
Onsite Reformation	100 – 1,000
Pipeline Delivery	1,000+
Onsite Electrolysis	30 – 100
Mobile Fueler	50
Energy Station (CHP)	100 - 300

Estimated Costs for Various Station Types

Station Type	Reformer	Electrolysis	Pipeline Delivered	Reformer	Liquid H_2 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
Total	$13.29	$18.69	$9.02	$6.53	$7.23

Time Fill vs. Fast Fill Dispensing





Equipment for Time and Fast Fill Refueling Stations

Equipment	Time Fill	Fast Fill
Compressor	Small compressor necessary as simultaneous filling occurs over 8+ hrs	Fillings usually occurs sequentially and in minutes, so a larger compressor is required
Gaseous Hydrogen Storage	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
Dispenser	One dispensing post required per fueling location	One dispenser for every ~20 buses.
Controls	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

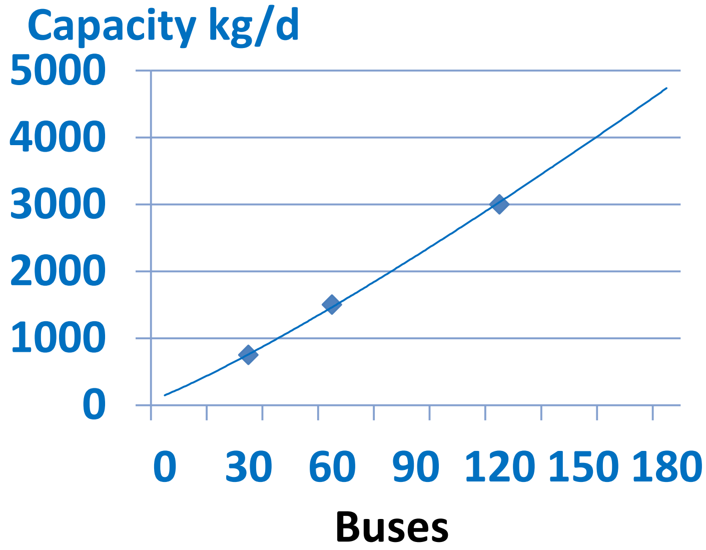
Common Codes and Standards for Hydrogen Fueling Stations

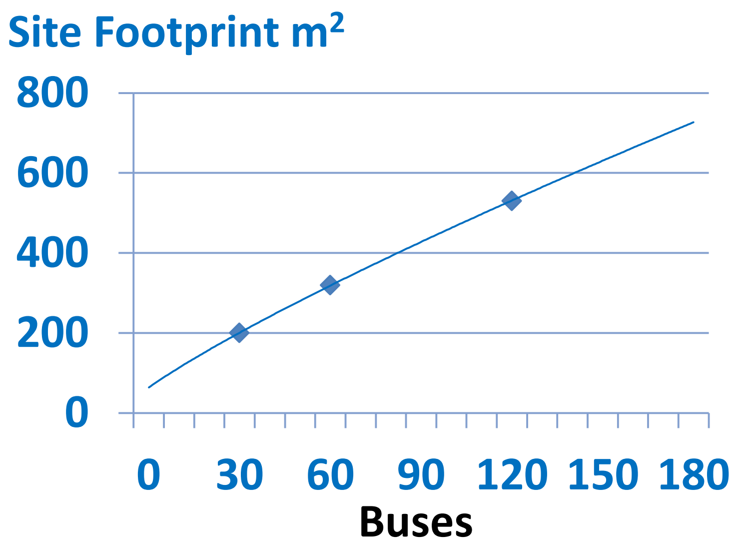
Construction	H2 Dispensing	FC Vehicle
ICC	SAE	SAE
NFPA	CSA	NHTSA
Local codes		DOT
Electrical	**Storage**	**Fuel Cell Power**
NEC/NFPA	NFPA	ANSI
IEEE	CGA	UL
ANSI	ASME	ISO
UL	ANSI	IEC

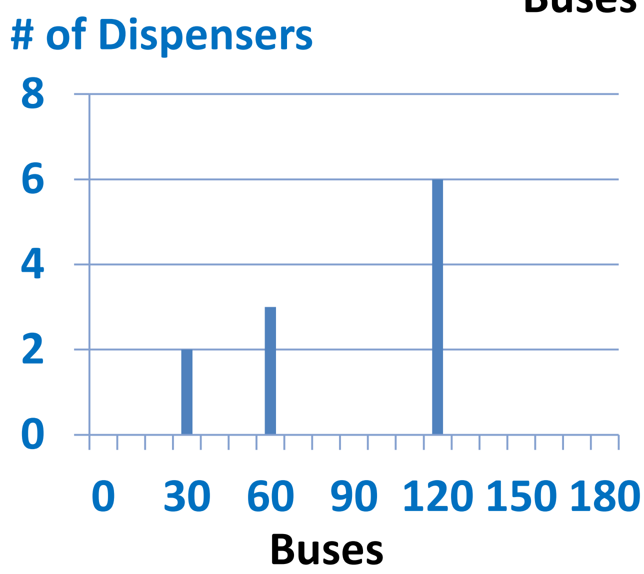
The Path Forward

Growth Path is Important

- » Tube Trailer ➡ More Trailers
- » Liquid H_2 ➡ More Storage /Pumping
- » Tube Trailer ➡ On-site Production







** Hydrogen Bus Infrastructure, Mr. Bachmeier, The Linde Group, Hamburg, October 17th, 2013*

Guidebook Schedule & Availability

- Guidebook completed September 2016
- Final advisory committee review completed
- Guidebook available at www.calstart.org for more industry/public review
- Additional transit industry outreach underway

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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