Building a Commercially Viable National Fuel Cell Electric Bus Program

Fuel Cell and Hydrogen Energy Association

Introduction

In just the last few years, zero-emission, hydrogen-powered, fuel cell electric bus transit has advanced to the point where fuel cell electric buses (FCEBs) are now providing service to hundreds of thousands of passengers. Since 2006, FCEBs have logged over 550,000 miles in the United States alone. At the same time, costs have dropped significantly – and within the next five years, it is projected that the per vehicle price for an FCEB will be less than that of an electric trolley bus. The technology has and is being proven by transit agencies around the world. What remains is to bring down the per-unit cost, which can be achieved with a modest investment in the economies of scale – increasing the number of FCEBs already being operated in revenue service. A broad coalition of industry leaders and public transit providers requests that a $395 million program to establish five regional Centers of Excellence and expand the implementation of this rapidly advancing technology, be included in the Administration's plan for the reauthorization of the transportation bill.

Fuel cell electric bus technology brings with it unique benefits that are unmatched by any other transit bus mode:

1. Completely zero-emission buses with no toxic particulates or other criteria pollutants in city neighborhoods
2. Extremely quiet, smooth, vibration-free, all-electric operation
3. Sufficient electric power to operate a vehicle in excess of 40,000 lbs of gross vehicle weight
4. Better handling and overall driving performance compared to internal combustion engine vehicles
5. Clean and easy maintenance, with no toxic oils or fuels to handle
6. Superb fuel economy in comparison with conventional internal combustion engines, including hybrid-drive engines
7. Complete freedom from petroleum fuels, with the ease of using entirely domestic sources of fuel to help establish true energy independence and price stabilization
8. Significant well-to-wheel reductions in greenhouse gas (GHG) emissions with the potential of eliminating all GHG emissions using carbon-free, renewable sources to produce hydrogen.

Program Goals

Commercialization of FCEBs is at hand, achievable within the next five years. A relatively modest investment in heavy-duty fuel cell transit fleets will lead to significant cost reductions. This clean, affordable, and sustainable transportation technology will serve as the standard for transit fleets nationally and internationally. Additionally, a sizeable addition of green technology jobs will bolster the American economy.

American Industrial Leadership – Given the advances in fuel cell and hydrogen technology within the United States, America has an opportunity to establish itself as a global leader among nations providing sustainable, energy-efficient solutions for the transportation sector. Fuel cell and battery manufacturers, hydrogen fuel providers, hybrid electric-drive suppliers, and transit bus OEMs are prepared to expand production capacity and employment opportunities with the growth of this quickly emerging industry.

Energy Security – Petroleum fuel prices are back on the rise, and at a rapid rate, now exceeding $4 per gallon. Competition worldwide for petroleum, and our over-reliance on imported oil, has created an unstable and unsustainable state of affairs for the United States. Hydrogen and fuel cells are critically important in establishing a long-term diversified and domestically available energy portfolio, and hydrogen for transportation can be produced completely from domestic and renewable sources, insulating us from world events. This is an essential element to the economic security of America. We need to develop and commercialize these technologies now rather than wait until energy inflation creates even bigger financial and foreign affairs crises for America.

Environmental and Community Health Benefits – FCEBs are already delivering on the promise of improved air quality in urban areas (with very large reductions in local criteria emissions affecting community health); enhanced quality of life in America's cities and neighborhoods resulting from quiet, smooth, all-electric heavy-duty drive systems; significant reductions in CO_2 emissions (40% to 50% using hydrogen from methane reforming, and zero carbon using solar, wind, and biomass to generate hydrogen), and significant reductions in America's dependency on petroleum fuels due to the high efficiency of fuel cell engines and the extensive diversity of locally produced hydrogen. The goal is to expand these benefits by investing in fleet expansion.

Progress to Date

In 2006, five heavy-duty, 40' FCEBs (gross vehicle weight in excess of 40,000 lbs.) began operating in three geographic regions of the United States – the San Francisco Bay Area, southern California, and the Northeast. These five buses alone have accumulated more than 400,000 miles of passenger service, carrying in excess of 800,000 people. Smaller scale FCEB demonstrations have also been staged in Chicago, Columbia, South Carolina, and Burbank, California.

Performance – Fuel economy has consistently been at least 60% better than comparable diesel buses (and as high as two times better fuel economy for buses serving higher-speed commuter routes), and fuel cell durability has reached more than 9,000 hours of continuous operation without any failures, repairs, or a reduction in rated power. Employee and passenger acceptance has been exceedingly high. In a FTA-sponsored survey of nearly 500 passengers, between 70% and 80% of respondents ranked the

FCEB program positively. Drivers prefer these buses over conventional internal combustion engine (ICE) propulsion systems because of major improvements to the overall vehicle performance and enhanced handling characteristics. Mechanics find FCEBs cleaner and easier to maintain, since these all-electric drive vehicles have many fewer moving parts and do not use petroleum fuel or oil-based products except for lubricating grease. Steady improvements in the reliability of the hybrid-drive systems, batteries, and fuel cell durability have been made over the last few years, and component manufacturers continue to aggressively pursue commercial targets for reliability and durability.

Program Expansion – An advanced demonstration fuel cell program has recently been initiated in the Bay Area among five large transit operators. AC Transit, Golden Gate Transit in Marin, San Francisco Muni, Samtrans in San Mateo, and VTA in San Jose are working in partnership to operate and maintain 12 third-generation FCEBs and two advanced hydrogen fueling stations. An additional four buses of the same design are operating on the east coast by CT Transit in Hartford, with the possibility that one of these buses will be operated by the New York City Transit Authority. These buses carry as many as 58 people, operate on demanding heavy-duty urban transit routes, yet they are 5,000 lbs. lighter than the first-generation vehicles and feature improved fuel cells, hybrid-drive systems, and state-of-the-art lithium-ion batteries to efficiently capture regenerative braking energy.

International Competition – International programs vying to take the lead in clean mass transit are rapidly expanding, illustrating the worldwide progress being made toward commercialization of fuel cell technology. In Whistler, B.C., Canada, 20 FCEBs began operating at the winter Olympics in early 2010 and continue to provide local community service. After a two-year FCEB demonstration program with 30 buses in ten European cities, a second phase program sponsored by the European Union – featuring more advanced vehicle and station designs – is about to launch in London (eight buses), Hamburg (ten buses), Oslo (five to six buses), Italy (five buses), Belgium (five buses), and Sweden (five buses). Japan, China, and Korea have all developed advanced FCEB programs, with the intent of introducing commercially viable fuel cell technology within their respective public transport sectors. Without strong federal support, the United States could be left behind in providing clean, efficient mass transit.

Program Objectives – Building a Business Case

An expanded national FCEB deployment program will lead to technology enhancements for vehicles and fueling infrastructure, better well-to-wheel performance, and significant reductions in purchase price and life cycle costs. A complete transformation of the transit industry is at hand, and this program promises to propel the commercialization of fuel cell technology at an accelerated rate, which is a critical and necessary complement to other alternative fuel technologies.

Industry leaders representing bus OEMs, fuel cell manufacturers, hybrid-drive companies, battery/energy storage firms, and hydrogen fuel providers have developed a set of realistic performance and cost targets to justify an infusion of deployment capital by the federal government to help drive costs down by ramping up demand. Return on investment will be reflected in enhanced product reliability and durability and in price reductions based on targeted production quantities for vehicles and fuel station suppliers. The technology is at a critical stage, requiring a relatively modest investment to jump-start large-scale production that will make fuel cells commercially affordable. The integrated technology inherent in fuel cell designs lends itself to significant economies of scale through highly efficient manufacturing processes. Mass, size, and cost of fuel cells continue to decrease as power, reliability, and durability improve – a critically important inverse relationship that is difficult to realize with other heavy-duty propulsion technologies.

Green Jobs – An October 2009 study prepared for the American Public Transportation Association by the Economic Development Research Group projected that for every $1 million of capital investment in public transit more than 23.8 new direct, indirect, and induced jobs would be generated, resulting in a total number of 9,000 jobs associated with this fuel cell initiative.[1]

Economies of Scale – All emerging technologies, from cell phones to flat screen TVs, benefit from economies of scale as they enter commercialization. FCEBs are no exception. Just since 2005, FCEBs have seen tremendous reductions in cost, accompanied by significant improvements in performance. Industry leaders have every reason to believe this trend will continue – and will be amplified by increasing volumes of production.

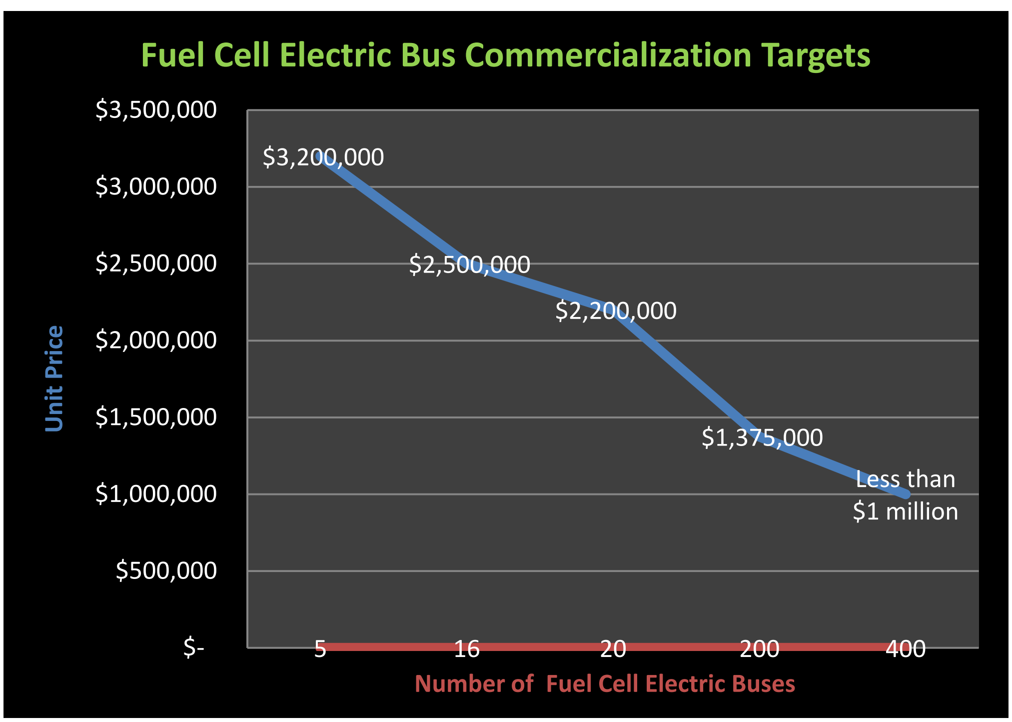
Vehicle Price and Production Targets

Category		Price	Production Quantities	Schedule
1st Bus Actual	1. **Actual Purchase Price of 1st Demonstration Buses**	$3.2 to $3.25 million each	Six	2005
	2. **Fuel Cell Warranty – 1st Bus**	4,000 hours/two years	Six	2005
2nd Bus Actual	3. **Actual Purchase Price of 2nd Demonstration Buses**	$2.2 to $2.5 million each	12 to 20	2010
	4. **Fuel Cell Warranty – 2nd Bus**	10,000 to 12,000 hours/three years	12 to 20	2010
3rd Bus Projection	5. **Projected Average Purchase Price of Deployment Buses** (@ 40% to 50% of 2010 prices)	$1.35 million each	50 units per year over 4 years (200)	2013 to 2016
	6. **Fuel Cell Warranty – 3rd Bus**	15,000 hours/four years	50 units per year over 4 years (200)	2013 to 2016

[1] Glen Weisbrod, Economic Development Research Group, Inc. and Arlee Reno, Cambridge Systematics, Inc., "Economic Impact of Public Transportation Investment," October 2009, http://www.apta.com/resources/reportsandpublications/Documents/economic_impact_of_public_transportation_investment.pdfv.

	Category	Price	Production Quantities	Schedule
3^{rd} Bus Extended Warranty Projection	**7. Extended warranty and replacement parts for fuel cells, batteries and hybrid-drive components, 5^{th} through 12^{th} year**	$500,000 per bus (30,000 hours/eight years)	Service and parts for 200 FCEBs over eight years	2017 to 2028
2017/2018 Bus Projection	**8. 2017/2018 Fuel Cell Bus Price**	At or Under $1 million (less than electric trolley bus and competitive with other all-electric-drive buses)	400 (2^{nd} phase deployment program)	2017 and later

Unit Price At or Under $1 million – An expanded FCEB program would put the industry firmly on the road to further per-unit price reductions. Following the production of 200 buses under this proposed deployment program, an industry projection shows that FCEBs priced at or under $1 million is achievable with annual production quantities of at least 400 FCEBs beginning in 2017 or 2018. This could constitute a second phase deployment program that would result in an entirely zero-emission bus that is competitive with electric trolley buses and other all-electric-drive, heavy-duty transit buses.



Expansion Strategy

Centers of Excellence – An investment of $395 million would establish five regional Centers of Excellence on the east and west coasts, the mid-west, and the south or southeast, building upon existing experience and core competencies. Each center would operate 40 buses targeted at $1.35 million each (a 40% to 50% reduction in price since 2010), at least one fueling station at $4 million each (includes up to $1 million for site improvements and local jurisdiction use requirements), and a maintenance/storage service facility for hydrogen-fueled buses at $1 million each. With the latest technology advancements in infrastructure supply, hydrogen can be delivered at a fuel consumption price competitive with petroleum fuels.

Fuel Efficiency Cost Comparison of Hydrogen to Diesel		
Hydrogen Price per Kilogram	**Inner City Route[1,3]** [Equivalent Diesel Price/Gallon]	**Commuter Route[2,3]** [Equivalent Diesel Price/Gallon]
$4.00	$2.71	$2.26
$4.50	$3.05	$2.54
$5.00	$3.39	$2.83
$5.50	$3.73	$3.11
$6.00	$4.07	$3.39
$6.50	$4.41	$3.67
$7.00	$4.75	$3.96
$7.50	$5.09	$4.24
1) On inner city routes fuel cell buses achieve 60% better fuel economy than conventional diesel buses		
2) On commuter routes fuel cell buses achieve double the fuel economy of conventional diesel buses		
3) Price difference accounts for 13% higher energy value per gallon of diesel than kilogram of hydrogen		

Grants would also provide funds to upgrade fuel cell, battery, and hybrid-drive components on FCEBs as may be required in years five through twelve. This program would put a fleet of 200 FCEBs in passenger service for 12 years and prove the commercial viability of hydrogen fuel and FCEBs for widespread adoption of the technology by transit operators.

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Fleet Infrastructure Development Targets

Category	Target	Production Quantity	Schedule
1. **Capital Cost** of station to fuel 40 buses – Assumptions: • 30 kg per day per bus • Two full functioning fueling dispensers capable of fueling two buses at the same time • Each bus to be fueled within five to six minutes and all buses to be fueled consecutively within a three- to four-hour window • Latest technology advances reduce or eliminate the need for compression systems to fuel buses • 1,200 kg per day minimum	$3,000,000 per station per location	One to two stations per year; total of five stations, one station in each region	2013 to 2016
2. **Site Improvement Costs**	$1 million per station	One to two stations per years; total of five stations	2013 to 2016
3. **Annual Operating Cost;** incurred by transit agencies	$200,000/station /year	N/A	N/A
4. **Hydrogen Price/Kilogram**; incurred by transit agencies	$4/kilogram to $7/kilogram,* depending on location and access to production facilities	1,200 kg per day per station minimum	N/A
5. **Maintenance Facilities per Agency**	$1 million per agency	One to two facilities per year; total of five facilities	2013 to 2016

* This is equivalent to a range of $2.26 to $4.75 per gallon of diesel fuel, taking into account 1.6 to 2 times better fuel economy of a FCEB over a diesel bus.

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Centers of Excellence will accomplish four principal objectives in pursuit of commercialization:

1. Apply limited grant funds to larger scale demonstration programs that can adequately test and develop technologies commensurate with large fleet operations
2. Utilize resources more efficiently and effectively under the stewardship of a selected group of well-managed program teams
3. Expand operational experience across major regions of the United States to expose each region to the real-world operating characteristics and benefits of the technology
4. Develop a bigger technology program with more units to realize production and supply chain economies of scale that will drive down production costs and purchase price.

DOT/FTA would prepare a competitive, performance-based solicitation for a four-year deployment program. Competitive team proposals would be made up of bus OEMs, fuel cell suppliers, and hybrid-drive and battery suppliers, and each team proposal would include a consortium of five-transit agencies. Infrastructure would be competitively bid through a separate solicitation tied to facilities at each transit agency designated to receive buses resulting from the first solicitation.

$395 Million Fuel Cell Electric Bus Deployment Program Budget – 5 Urban Regions		
Expense Categories	**Total Budget**	**Allocation per Region**
Buses ($1.35 million per bus; 200 total; 40/region)	$ 270 million	$54 million
Fuel Cell, Battery, and Hybrid-Drive Upgrades/Replacements after initial four-year warranty (years 5 through 12)	$100 million	$20 million
H2 Fueling Stations (5 stations; one per region)	$20 million	$4 million
Maintenance and Storage Facilities (5 facilities; one per region)	$5 million	$1 million
TOTAL CAPITAL PROGRAM	**$395 million**	**$79 million**

Conclusion

FCEBs have been proven to reduce emissions, increase energy security, and achieve significantly greater fuel economy than diesel. With centralized fueling facilities, public transit fleets present an obvious opportunity to expand implementation. Expanding the nation's fleet of FCEBs will promote domestic industrial leadership while reducing the per-vehicle price to the point where this technology is cost-competitive with other zero-emission modes of transit.

The energy security and environmental benefits of DOT's initiative would be substantial, as reflected in the table below that shows the extent of petroleum and emissions reductions achievable.

Fuel Cell Electric Bus Deployment: Petroleum and Emissions Reductions[1]						
Categories	% Reduction	Number of Buses and Geographic Region				
		DOT Single-City Deployment	DOT 5-City Deployment	National Expansion	National Expansion	National Expansion
		40 Buses	200 Buses	500 Buses/Year	1,000 Buses/Year	5,000 Buses/Year
Diesel Fuel Saved in Gallons per Year	60% to 100%	380,952	1,904,762	4,761,905	9,523,810	47,619,048
NOx						
Reduction Using Methane to Reform H_2 (**Tons/Year**)[2]	91%	4.22	21.09	52.72	105.43	527.15
Reduction Using Renewables (**Tons/Year**)	100%	4.65	23.26	58.15	116.30	581.50
Particulates (PM)						
Reduction Using Methane to Reform H_2 (Tons/Year)[2]	83%	1.16	5.78	14.46	28.92	144.58
Reduction Using Renewables (**Tons/Year**)	100%	1.39	6.95	17.38	34.76	173.79
Greenhouse Gases (GHG)						
Reduction Using Methane to Reform H_2 (**Tons/Year**)	43%	2,160	10,800	27,000	54,000	270,000
Equivalent Number of **Acres of Fir Trees/Year**[3]		417	2,084	5,211	10,422	52,110
Equivalent Number of **Square Miles of Trees/Year**		0.65	3.26	8.14	16.28	81.42
Reduction Using Renewables (**Tons/Year**)	100%	5,040	25,200	63,000	126,000	630,000
Equivalent Number of **Acres of Fir Trees/Year**[3]		973	4,864	12,159	24,318	121,590
Equivalent Number of **Square Miles of Trees/Year**		1.52	7.60	19.00	38.00	189.98

1) Source: California Air Resources Board (CARB) GREET Analysis; In comparison to a 40' heavy-duty diesel transit bus with a 2010 EPA-compliant engine.

2) NOx and PM emissions are from fuel production (assumes liquid H2 is transported 100 miles one-way by truck with 2010 EPA-compliant engine; no emissions from bus.

3) Source: EPA Greenhouse Gas Equivalencies Calculator (http://www.epa.gov/cleanenergy/energy-resources/calculator.htm)