PROMISING TRANSIT APPLICATIONS OF FUEL CELLS AND ALTERNATIVE FUELS

William P. Chernicoff
Aviva Brecher
Kevin Green
Volpe National Transportation Systems Center, U.S. DOT
Cambridge, MA 02142

ABSTRACT
For over a decade, the Volpe Center has been providing technical support to the Federal Transit Administration (FTA) Office of Research, Demonstration and Innovation towards the development, deployment, field test and safety evaluation of advanced transit vehicles and technologies. Of special interest is the cooperative DOT and DOE Fuel Cell Transit Bus research and demonstration program. This paper will briefly highlight policy, environmental, fuel economy, cost and other issues that are being addressed in developing the consensus standards and guidelines and policies for fuel cell buses, electric and hybrid-electric buses and associated technology and infrastructure. The development and adoption of safety standards based on performance specifications and of industry best practices are essential to early deployment. Public acceptance of alternative powertrains and fuels hinges on the successful demonstration of their safe, efficient, environmentally sound, and cost-effective in-service operation. Captive fleets such as buses typically utilize centralized fueling and maintenance facilities, and are well-suited to early demonstration programs. Insofar as transit buses typically operate in specific geographic areas under stop-and-go conditions, are very visible to the public, and may be able to share refueling facilities with other heavy and medium fleets, they represent an attractive transitional niche market for alternative fuels and for emerging "green" propulsion technologies. Flexible refueling and support infrastructure could help to provide cleaner fossil fuels, while at the same time supplying hydrogen to any potential fuel storage device. For example, an on-site reformer could be added to a CNG refueling facility thereby providing hydrogen for emerging vehicles that might rely on that fuel. Some environmental, infrastructure, technology and industrial base implications of different alternative fuel pathways are briefly reviewed.

Background and Introduction
The Federal Government plays a significant role in supporting public transit. In particular, the U.S. applies roughly one dollar of every five collected through fuel taxes to public transit[1], even though private vehicle owners pay the majority of those taxes. The Federal Government currently funds significant research and development (R&D) relevant to fuel cells and alternative fuels and propulsion systems for transit buses. The Federal Transit Administration (FTA) continues to provide (under Sec. 5309, Capital

[1] Current federal gasoline tax of 18.3 cents/gal consists of 15.44 cents/gal for roads and 2.86 cents for transit, i.e. a transit share of 15.6%.

Investment Program) Capital Grants for new alternative fuel buses (AFB), design of new or modifications to existing storage and maintenance facilities, fueling stations, etc. The FTA transit bus R&D programs focus on advanced battery technology development, guidance for transit operators regarding the safe use of alternative fuels, bus testing, the development and demonstration of electric propulsion systems, and test and evaluation of fuel cell transit buses. FTA has also funded the development of the Advanced Technology Transit Bus (ATTB)—a prototype lightweight, low floor, low emissions, user-friendly transit bus concept using advanced technologies. This vehicle was never put into production, but several technologies tested have been implemented in production vehicles.

This R&D is complemented by several other Federal research initiatives, such as the Department of Energy's (DOE's) sponsorship of R&D related to alternative fuels and advanced technologies for both light-duty and heavy-duty highway vehicles. The DOE "Clean Cities" program and related EPA incentive programs for pollution abatements have also encouraged transit authorities to test, evaluate, share lessons learned and sometimes deploy electric, hybrid or other AF buses. DOD (Army, DARPA, Navy) have also funded fuel cell partnerships with industry and universities, and several military bases have tested electric and hybrid shuttle fleets. The FAA co-funded electric-powered ground vehicles and shuttle bus fleets at several major airports to mitigate aviation emissions at these facilities.

Since the 1991 ISTEA legislation, which was extended by the 1998 Transportation Equity Act for the 21st Century (TEA-21), the EPA and DOT have jointly required State Implementation Plans (SIP)s and Transportation Improvement Plans (TIP)s to detail strategies for achieving compliance with and maintenance of air quality standards. Transportation Control Measures (TCM) have included introduction of cleaner transit (electric transit and AFB) options to avoid funding cuts for highway transportation projects in areas cited for non-attainment. TEA-21 created a Clean Fuels Formula Grant program to help polluted areas attain the National Ambient Air Quality Standards (NAAQS). The Clean Fuels program is designed to support emerging technologies. The legislation defined "clean fuel vehicles" as those powered by compressed natural gas (CNG), liquefied natural gas (LNG), biodiesel and clean diesel, alcohol-based fuels, as well as hybrid electric, electric batteries, fuel cell, and other low or zero emission propulsion technologies that reduce harmful emissions. TEA-21 authorized up to $200 Million annually towards the purchase or lease financing of clean fuel buses and facilities, but the program has not yet been funded by the Congress.

Technology development, test, and evaluation efforts sponsored by FTA have focused on electric to fuel cell buses, such as the Advanced Technology Transit Bus (ATTB) and implementation of the clean fuels program, including the safety issues associated with Alternative Fueled Vehicles (AFV) and Hybrid Electric Vehicles (HEV). In addition, the Advanced Vehicle Technologies Program (AVP), transferred by TEA-21 to DOT from the Defense Advanced Research Program (DARPA) and DOE, has focused on medium and heavy-duty vehicle improvements and enabled seven nationwide consortia to evaluate the in-service performance of novel electric, hybrid and alternative fuel buses.

The Volpe Center prepared for the National Science and Technology Council (NSTC) a strategic plan for medium and heavy-duty vehicles (DOT 2000), and assisted the DOT Center for Climate Change with technical studies towards reducing the greenhouse gases contributed by the transportation sector. As part of an ongoing Volpe Center study characterizing market performance of “advanced technology vehicles” (ATVs), available lifecycle modeling tools, technologies and fuels for improved environmental performance and fuel economy of conventional light and heavy-duty Internal Combustion Engine (ICE) vehicles, HEV and Fuel Cell Vehicle (FCV) technology options were evaluated. Some advanced technology emerging for multi-modal heavy vehicles (buses, commercial freight trucks, locomotives, ferries, bulk tankers) included use of hybrid power-trains, electronic engine control, advanced transmissions, lighter weight materials, improved aerodynamics and tires, etc.

Presenters on “*Propulsion and Fuel Systems*” topics at the 2001 Volpe Center Symposium-3 on “*Enabling Technologies and Transportation Innovation*” reviewed the major challenges to introduction of alternative fuels in transportation: need for new supply infrastructure, potential safety hazards to be resolved, higher cost, and lifecycle environmental aspects, and need to utilize renewable energy resources. For fuel cells, the barriers to be overcome include: size, durability, reliability and cost; the need for on-board fuel storage; fuel availability and purity; thermal management (cold start-up times); the need for codes and standards for design, performance and system integration; and customer acceptance of an unfamiliar technology. Even for hybrid power-trains, recognized as a key transitional option, there are substantial cost premiums, improvements needed in system integration, robustness and cycle life; and understanding how their fuel economy depends on the duty cycle.

Current transit buses and infrastructure

According to recent BTS and APTA statistics, in 2001 there were about 700,000 buses in the US (including private and government fleets), of which only about 60,000 were publicly operated transit buses used by about half a Billion (448,500) urban commuters. In addition, there are over 440,000 school buses on the roads, mostly aging diesel buses, which were not built to modern safety and health standards (UCS, 2002).

Alternative fueled buses (AFB) are now a small, but growing, fraction of the urban fueled fleet: the GAO 1999 report on the use of AF in buses found that a total of 6,000 AFBs operated in the US in 2000. AFBs today account for about 25% of all new 40-foot transit bus purchases[i] Though the AFB fraction increased (from 2% in ‘92 to 7% by ’97), the majority (75%) used compressed natural gas (CNG) and a very small number of electric and hybrid-electric buses were in operational testing.

Over the past decade both the size and cost of fuel cells have decreased, while power and performance have improved, largely thanks to vehicle bus testing (a platform that was large enough to accommodate the bulky early fuel cells). Because about 5,000 new buses are produced each year in the U.S., with an operating life expectancy of 12-15 years; hence renewal of the entire bus fleet and of associated fueling and maintenance infrastructure can be accomplished faster than for the nation's automotive fleet. Other environmental, infrastructure, technology and industrial base, as well as fuel economy policy rationale for, and challenges in, using advanced technology transit buses as a transition path towards cleaner fuels leading to a potential hydrogen economy will be briefly reviewed.

Transit Environmental Footprint

The 1999 modal share of key air pollutants indicate that diesel-fueled on-road vehicles contribute most of the particulates load and about 40% of the NOX burden. Since diesel buses comprise a very small fraction (0.02%) of all on-road vehicles in the U.S., so their proportional pollutant emissions share is much lower than that from trucks, medium and light vehicles.

In 1998, transit buses consumed about 700 million gal of diesel fuel, but only 50 million gal of non-diesel fuels (LNG, methanol, propane) and 31million gal. of CNG. Since buses represent a very small fraction (0.02%) of the heavy-duty vehicles in the U.S., it is unlikely that they are a major source of air pollution, except in urban centers. Although the small number of AF, hybrid and electric buses operating now have environmental promise, the EPA currently qualifies only heavy-duty engines (HDE) for emissions now, and not the whole vehicle under a realistic downtown driving cycle. (Final Emissions report, NAVC 2000). Furthermore, a lifecycle analysis of environmental impacts is needed to ensure that mobile pollution sources now certified as LEV or ZEV are not replaced by pollution at the source, due to the electricity generation needed to produce hydrogen by electrolysis or by stripping natural gas (or other hydrocarbon) and compressing it, or to compress and liquefy natural gas and petroleum gas.

Most buses run on diesel fuel and have historically exhibited relatively high emission rates. An average diesel bus emits about 420 lbs/yr/bus of smog and 13.7 lbs/yr/bus of soot (In 2000, a typical heavy- duty vehicle, like a diesel bus, emitted about 2.2 g/mi of HC, 11.5 of CO and 11.25 of NOX (the smog precursor) based on EPA data.); while a newer "clean diesel" with after-treatment emit, respectively 320 and 5.6; and a CNG bus emits about 215 and 0.5 lbs/yr/bus (thus reducing soot output by over 80% and NOX by about 50% when compared to the old diesel buses now operating). Figure 1 and 2 illustrate the total energy consumption for medium- and heavy-duty vehicles and the energy intensity for automobiles and buses. The two charts demonstrate the need to develop energy efficient and environmentally sustainable vehicles, and the value that "clean" public transit can offer by replacing automobiles.

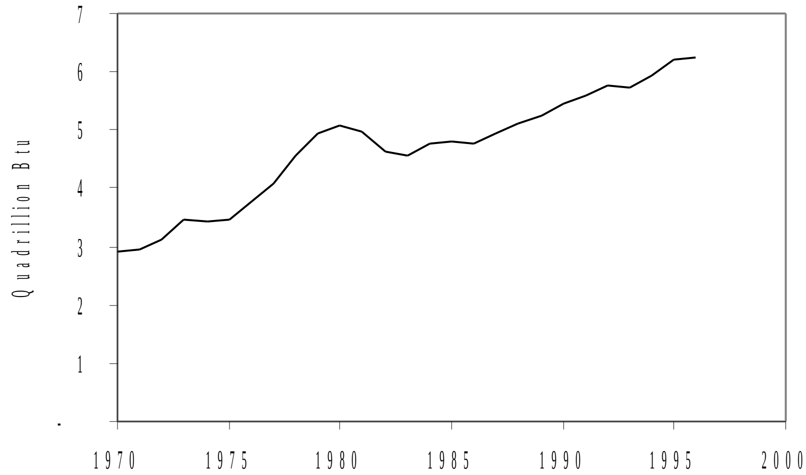

Figure 1. U.S. Energy Consumption by Medium- and Heavy-Duty Vehicles (NSTC, 200)

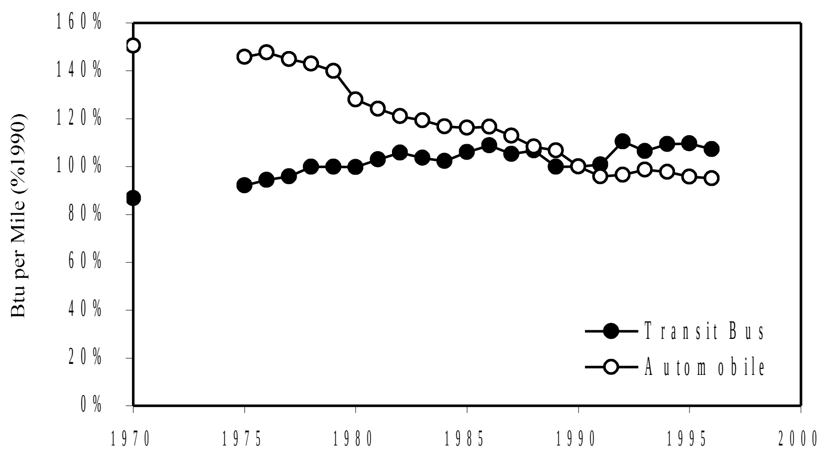

Figure2. Energy Intensity of Automobiles and Transit Buses (NSTC, 2000)

EPA Tier 2 emission standards for NOX and PM are being phased in for all vehicles between '04 and '09, but compliance is more problematic for diesel- fueled vehicles. In the past decade (88-98) stricter EPA emission standards for diesel bus engine exhaust have lowered NOX levels by 63% and particulates by 83%. According to a Consent Decree by EPA, the heavy-duty diesel engine manufacturers agreed to produce by the fall of 2002 engines that meet the stricter 2004 standards.

New and stricter EPA tailpipe emission standards, requiring that diesel trucks and buses release 90% less soot and 95% less smog, will be phased in by 2007. The EPA air quality improvement projections are based on technology improvements in the whole system, comprised of low sulfur diesel fuels and on internal combustion heavy-duty engine (HDE) and emission controls (particulate traps, recirculated exhaust combustion, and tailpipe after-treatment). Although the use of "Best Available Technology" (BAT) in HDE offers incremental benefits to health, and environment, it does not improve fuel efficiency and energy dependence on imported oil. In contrast, expanded transportation use of alternative fuels (like natural gas), and of hybrid-electric and fuel cell technologies offer potentially radical improvements in air quality in addition to other tangible benefits that include a reduction in foreign oil dependence.

Transit authorities, from California to New York, have been replacing their diesel buses with alternative fuel and propulsion fleets. School districts in 17 states are now using CNG buses, taking advantage of financial incentive programs (e.g., DOE, DOT, EPA and CARB).

Health Impacts

There is considerable scientific evidence that diesel exhaust has adverse health effects. The California Air Resources Board (CARB) and the International Agency for Research on Cancer (IARC) have classified diesel exhaust as a probable carcinogen. California, which leads the national trends, classified diesel particulate as a "toxic air contaminant" (TAC) in 1998. The EPA 2000 draft Health Assessment for diesel exhaust for air toxics and hazardous air pollutants (HAP) spells out the evidence for adverse health effects, and supporting technical documents to the EPA rulemaking state the expected costs and benefits of health based standards and pollution abatement requirements. The toxic chemicals in diesel exhaust are associated with lung cancer, immune system and respiratory and circulatory problems; the ozone in smog injures the lungs, while the fine soot particles contribute to asthma, bronchitis, circulatory and heart problems, and to lung cancer.

Cost of Fueling and Maintenance Infrastructure, and Operating Costs

A flexible, multi-fuel national fueling and support structure may be critical to support petroleum-powered cleaner vehicles (e.g., bus with low-sulfur diesel, particulate traps and NOX reduction catalyst), while at the same time supplying hydrogen to any potential fuel storage device. For example, a CNG fueling facility can also have an on-site reformer and supply hydrogen as well. GAO's 1999 survey and the 2001 testimony on use of AFs in transit indicated that CNG buses not only cost more, 15-25%, or $45-$65K per bus, but also requires costly fueling and maintenance depot infrastructure: $1.5-20M if new, and potentially higher costs if upgraded or retrofitted. In addition, NG buses have lower fuel efficiency than diesel (by about 30%). Several transit operators have reported higher fuel, operating and maintenance costs; other transit operators, have claimed lower fuel, operating and maintenance costs. The improvements necessary to meet the applicable codes and standards to ensure safety of handling, storing and dispensing multiple fuels, especially hydrogen, at dispensing stations may add significant costs to the infrastructure.

Technical Challenges

Alternative fuel and propulsion technologies each present several technical and environmental challenges that must be addressed if a functional, and environmentally benign system is to be implemented. Technical goals of the U.S. DOT Medium- and Heavy-Duty Vehicle R&D Strategic Plan (DOT, 2000) are summarized in Table 1.

Vehicle Type	Year	Fuel Economy	Emission Reduction Targets[2]

	Base	Goal	Target	NOx	PM	GHG
Transit Bus	2000	2010	+200%	-90%	-90%	-67%
Freight Truck	2000	2010	+100%	-90%	-90%	-50%
Freight Locomotive[3]	2000	2020	+67%	-90%	-90%	-40%
Marine Vessel	2000	2020	+67%	-90%	-90%	-40%

Table 1. Goals for Medium– and Heavy-Duty Vehicle R&D Strategic Plan

The environmental benefit occurs when the technology is best suited for or adapted to the given operational demands. The successful introduction and use of any of these technologies is dependant on the proper use and application of codes and standards. Early development requires unrestricted development that may result in incompatible unique systems; however, market demands and trends require or force a consensus set of standards and platforms that can be widely and universally utilized. A number of lifecycle models for advanced technology vehicles have been developed (by MIT, Carnegie Mellon's "Green Design" team, UC Davis and others). For example, the DOE Argonne National Laboratories (see ORNL, 2001)has developed a full fuel cycle model, "GREET," which provides a basis for consistent comparison of the energy and emissions properties of different combinations of fuels, fuel feedstocks, and vehicle technologies.[4] Some of the barriers to early deployment of advanced vehicles are briefly reviewed below, in the context of transit bus demonstrations.

Economics of New Production and Distribution Infrastructure

The sunk cost of existing petroleum-derived fuels production and distribution infrastructure is enormous. There is approximately 2 trillion dollars of petroleum infrastructure in use. In 1999, there were over 180,000 gasoline and diesel refueling stations in use in the U.S., vs. fewer than 6,000 AF refueling stations, thus making it difficult to achieve the range and convenience objectives for AFV users.

Infrastructure development for alternative fuels and especially for hydrogen is a major issue. The capital investment for some alternative fuels (assuming a 100% replacement) could exceed the cost of existing infrastructure. This is a challenging investment for an industry that will have little early demand and must be able to maintain a profitable operation. Some fuels, such as biodiesel, can be used with little or no infrastructure changes. Fleet use, specifically buses, rely on centralized infrastructure and can operate from a single facility, thereby reducing the need for widespread availability.

Fuel Economy

For diesel hybrid bus concepts, improvements in fuel economy vs. 1990 on the order of 50-100% appear to be feasible by 2005, whereas methanol and/or hydrogen FCVs are likely to achieve 100% improvements by 2010 for either methanol or for hydrogen feedstock fuel.

---

[2] Full life-cycle and fuel-cycle basis under identical operating conditions, using prevailing global warming potential (GWP) factors for different greenhouse gases.

[3] These departmental energy and environmental goals for freight locomotives are in addition to goals—railroad safety and HSGT advancement—that are the focus of current R&D managed by the Federal Rail Administration.

[4] Available on the Internet at <http://greet.anl.gov>.

Safety Issues

Early alternative fuel and propulsion endeavors were largely unregulated. In response to an increasing interest and use of alternative fuel and propulsion systems, and subsequent problems, the Volpe Center prepared for FTA and transit operators resource handbooks (FTA, 1995-2002) which examined the safety, health and environmental issues associated with the storage, distribution, fueling, handling and maintenance of alternative fuels, including CNG, LNG, propane, alcohol fuels, and hydrogen. Electric and hybrid-propulsion are currently being developed, and older documents are scheduled to be revised. In-service data had to be obtained from demonstration buses and limited revenue service operations, so that safety guidelines (both design and performance) could be developed, and best practices publicized. The underlying goal of these guidelines is to provide fundamental knowledge and guidance in the implementation of clean propulsion vehicles and infrastructure. Many of these recommended practices resulted from incident investigation and lessons learned, as transit operators rebuilt facilities and initiated operation of AFBs. While they do not provide all of the answers, FTA and the Volpe Center provided methodology for addressing many of the safety, performance, and environmental issues associated with alternative fuel buses and infrastructure. Because these newer fuels and associated vehicle subsystems and facilities are less commonly used in transit, and there was less operating experience, safety and health hazards (fires, explosions, cryogenic temperatures, fuel toxicity and environmental effects of spills and leaks) were a major concern and a barrier to their adoption. While these issues still remain, FTA's involvement has provided a centralized means of addressing them.

Costs of Advanced Technology Buses

The costs of HEV buses remain higher, but the 50-70% increase in fuel economy relative to diesel buses may offer lifecycle advantages. In 1999 the New York City Transit Authority (NYCTA) purchased several demonstration HEV buses at a unit price of $575K, nearly twice that of conventional diesel buses, but economies of scale in ordering, and technology advances reduced the unit cost to $380K in 2000, and $329K in 2001.

Hybrid Propulsion Challenges

The incremental cost of using a hybrid propulsion system vs. a conventional fuel system is significant. The system integration of the energy storage system and the internal combustion engine (ICE) should be improved to maximize both the fuel economy and emissions reduction, and also to insure the full life of the on-board energy system (batteries).

Battery life, particularly on heavy-duty buses has proven to be short, on the order of 2-2.5 years, and has been less in some instances. Lead-acid batteries are currently the dominant choice, with nickel-metal hydride batteries an increasing option along with Li-solid polymer electrolyte and other less common types of batteries and energy storage devices such as ultra-capacitors. These batteries may pose a significant environmental risk of handling, disposal, and recycling if it is not done properly.

Natural Gas
Natural gas (NG), which contains a significant percent of methane (minimum 88%), poses a significant up-front infrastructure costs for fleets. Vehicle and fuel system safety has been well engineered, and although the fuel poses some additional risks, it may be considered as safe, if not safer than that of conventional fuels. NG is however, a powerful greenhouse gas, with over 20 times the potency as CO_2. NG systems should therefore be engineered to not leak and insure a near 100% combustion of the fuel. This is a particular problem for Liquid Natural Gas (LNG) systems, which continuously volatilize the fuel, and may be forced to vent the unused NG.

Fuel Cells
A true understanding of the well-to-wheels fuel and environmental cycle for FCs is necessary to comprehensively understand the environmental impact. With the exception of direct methanol FCs, (which also produce hydrogen for feed in a FC), all other FCs need a direct and pure source of hydrogen. The dominant type of FC is the Proton Exchange Membrane, which requires a 99.9999% purity of hydrogen to function properly. Hydrogen can be produced from one of several streams, each with its own set of environmental implications. Production of hydrogen via water electrolysis is a common production means; but it is very energy intensive. More energy will be put into producing the hydrogen than can be stored, and even less that is utilized. Unless the electricity is produced with a zero-emission renewable resource there are displaced associated emissions with this energy source. If the electrical power plant is not “green”, pollution at the point-source could replace that which was on the road. However, FC is the only propulsion technology discussed in this paper that can be zero emission, and its implication for urban air quality is significant. Even if clean renewable energy is used, it is argued that this electricity is now no longer available for the grid and therefore cannot replace “dirtier” electricity. Reformation of NG (or methanol) is a common choice, but this process still results in carbon emissions, and can be energy intensive.

Current FC configurations, and future configurations will still require some amount of on-board energy storage, and therefore must consider similar storage and system integration issues that face a conventional hybrid vehicle. All FC vehicles face the fundamental challenge that hydrogen must be produced on-board or off-board and this process can be energy intensive, and has associated environmental impacts.

Codes, Standards, and Best Practices for Electric and Hybrid Buses
Within the past 5 or so years, the transit community (government, operators, suppliers, etc.) has become increasingly interested and active in developing standards to facilitate the introduction of new technologies and ensure their smooth system-integration, safety, operability and reliability. Current technologies are regulated and/or governed by industry or professional associations codes, standards, and guidelines developed over decades of operational use and development. New fuels and technologies require a new set of codes, standards and best practices to foster confidence and interoperability.

Codes, Standards, and Best Practices serve a valuable role in implementing safe, functional and successful vehicle deployment, operation, and infrastructure development.

Specifically, they can help address the many technical challenges of a specific technology. Each serves a distinct and unique function and role. Codes specify what type of systems and equipment must be used, in what manner they may be used, and tells the user what specifically must be done. Codes can be adopted by Federal, state, and local regulatory bodies and may be legally enforced. A standard provides a set of performance criteria that should be met, but does not prescribe the manner in which this is achieved. Best/Recommended practices are also non-enforceable, but provide recommendations on how best to achieve benchmarks set by standards, and may cover other recommendations on the current state-of-the-art. These best practices are often culminated from operational experience. The underlying motivation of the best and recommended practices, and some of the standards is to insure not only the safe use of the alternative fuel technology, but the successful use of the technology, with out which any environmental gains would be set back for a generation of vehicles as a result of the publics aversion to a perceived failure. The National Renewable Energy Laboratory presents a strong case for the adaption of best practices, and a strong commitment to a fuel, as critical for successful operations in a study on natural gas bus operations entitled: Natural Gas In Transit Fleets: A review of the Transit Experience.

Distinct organizations and government agencies have assumed responsibility for developing the codes, standards, or best practices. The following Table outlines the structure and relationship between various organizations and government entities within the U.S. In addition to the federal government, local, county, and state fire and building codes, the environmental boards also have jurisdiction. The U.S. DOT and its modal agencies may develop standards, may support the development of standards and best practices, or may adopt existing codes and standards.

DOT (Modal Agencies)
FHWA: Federal Highway Administration
FMCSA: Federal Motor Carrier Safety Administration
FTA: Federal Transit Administration (Guidelines and recommended/best practices)
NHTSA: National Highway Transportation Safety Administration (Federal Motor Vehicle Safety Standards)

Industry/Management:
APTA: American Public Transportation Association (vehicle and facility best practices)
CTAA: Community Transportation Association of America
TSC: Transit Standards Consortium
ITSA: Intelligent Transportation Society of America
AASHTO: American Society of State Highway and Transportation Officials

Standards Development Organizations
IEEE: Institute of Electrical and Electronic Engineers
SAE: Society of Automotive Engineers (Vehicle)
ITE: Institute of Traffic Engineers
ASCE: American Society of Civil Engineers

ASME: American Society of Mechanical Engineers NFPA: National Fire Protection Association (Infrastructure) NGVC: Natural Gas Vehicle Coalition (Vehicle)

Some regulatory agencies may use codes and enforceable standards that appear to conflict or may be confusing. Best practices help to address this potential confusion by providing guidance on how to best enact codes and standards, and in some instances may provide recommendations that exceed those required or recommended in a code or standard, but which may be critical for a safe, cost-effective, and environmentally sound system.

Bus Fleet Utilization

While fleet use, particularly buses, pose some challenges to utilizing environmentally friendly fuel and propulsion technologies; it also poses some intrinsic benefits. These benefits include mitigated safety risks (by removing public operation), highly-trained and easily accessible maintenance staff, the ability to use a single or centralized refueling infrastructure, and the potential existence of a fall-back fleet. The added performance and image that a clean propulsion bus fleet offers may also help attract new riders and expose them to the benefits and safety of alternative fuels and propulsion systems.

Conclusions and Recommendations

In conclusion, despite their promise, alternative fuels face significant technical, economic, political, and other challenges to deployment and market penetration. However, they are a key to achieving energy security and a sustainable future. Transit buses and other heavy and medium vehicle fleets (for airports, school districts, US Postal Service, National Park Service, paratransit vans) are an important platform for the demonstration, evaluation and improvement of "green" fuel and vehicle technologies. These bus fleets provide a substantial niche market and floor on purchases for an emerging industry, and can bring about unit cost reduction through economies of scale. Urban, airport, interurban and school buses must also be improved to comply with stricter EPA standards and avoid non-attainment penalties

Forecasters agree that transit buses in the U.S. will probably rely primarily on improved diesel engines and low-sulfur diesel fuel in the foreseeable future, and that incentives and taxation Federal policies would be needed to support significantly greater use of fuel cells and/or alternative fuels. A variety of policies could be helpful toward that end, such as:

- Funding for related research and development
- Cost-shared funding for related infrastructure development in partnership with industry and State/local authorities
- Subsidies for fuel cell purchases
- Subsidies (including reduced tax rates) for alternative fuels
- Requirements regarding the purchase of fuel cells and alternative fuels
- Phase-in strategies, which take into consideration transition issues and times for industrial base and market penetration.

Of course, one reason alternative fuels still account for a relatively small share of the total energy used for transportation is that conventional gasoline and diesel fuel are both cheaper and supported by the established production and distribution infrastructure. In general, differential taxation rates can provide an incremental incentive to use alternative fuels. However, because public transit providers do not pay Federal Highway User Taxes, this approach is of limited relevance for transit buses.

Along with broad trends, industry decisions, and policies at the State and local level, Federal policies have helped to significantly increase the role of alternative fuels and advanced technologies in transit buses during the past decade. For example, at least twenty percent of all new bus orders are for CNG buses. California is an important trend-setter to the nation: in 1998, CARB determined that diesel exhaust particulates are a Toxic Air Contaminant (TAC); in 2000, CARB adopted stricter emission standards for both transit and school buses; and mandated the phase-in "clean diesel" fuel by July, 2002. Other states are considering similar approaches.

Overall, diesel remains the primary fuel for transit buses. Current projections suggest that the real price of diesel fuel is likely to remain relatively stable for the next two decades. EIA projects that even doubling of the crude oil prices would not affect significantly the small market share for AFVs, given that they are more expensive to produce and that conventional vehicles and infrastructure operate at low cost and high volumes. To the extent that fuel cells and alternative fuels are important as means of achieving broad policy goals related to energy markets and the environment, this underscores the importance of continued policy support for the development and utilization of these technologies.

The EIA near term energy utilization forecasts indicate that petroleum based fuels will continue to be the mainstay of transportation vehicles, albeit improved conventional vehicle technologies and cleaner fuels will enhance fuel efficiency and control the growth of the environmental burden.

Although regulations regarding bus emissions of criteria pollutants, in particular nitrogen oxides (NO_X) and particulate matter (PM), could increase the attractiveness of fuel cells and some alternative fuels, it currently appears likely that, given significant reduction in diesel fuel sulfur content, diesel engines will be able to meet those requirements.
The EPA 2000 HDE requirements and supporting documentation for reducing environmental emissions emphasize that the "clean diesel" system (low sulfur fuel and advanced technology engines) can alone achieve desired pollution reduction levels, the adoption of fuel cell and electric-hybrid HED options promise added benefits: environmental preservation, a more diversified energy production and utilization base, improved fuel economy and energy independence, and technological leadership with possible global market penetration.

Alternative fuel (such as natural gas, biodiesel, and propane) and propulsion technologies (such as hybrid and Fuel Cell) offer multiple benefits Reduction on foreign oil dependency by expanding use of renewable or alternative fuels and introduction of advance vehicle technologies, will also lead to economic and environmental improvements. A strategy of targeted federal incentive programs for RDT&E, and public-private partnerships for infrastructure and manufacturing base creation is desirable. At present, a negative feedback loop exists because the scarcity of AFVs makes it unprofitable to produce them at higher volume and lower cost, and precludes development of manufacturing, storage and distribution infrastructure, in spite of federal R&D policies and economic incentives. The gradual integration and utilization of advanced bus and other vehicle technologies and fuels, using selected test platforms targeted to niche markets to test and assess the viability of options which rely on natural gas and renewable sources for electricity production, can help smooth the transition to a more sustainable transportation system.

Public Transit Buses serve as a platform for test and improvement of key bridging technologies, on the path towards a hydrogen economy. Hybrid-propulsion vehicle technology with various types of configurations and with or without an on-board reformer, is a bridge to evaluating options for fuel cell technology, electric propulsion and on-board energy storage. A major challenge is development of the industrial infrastructure for producing, storing and distributing hydrogen fuel. Though many potential and viable fuel streams exist (hydrogen from electrolysis, natural gas reformation, on-board methanol reformation, liquid hydrocarbon reformation, and others) the entire well-to-wheels life cycle cost and emissions must be considered, as well as fuel abundance and cost. Natural gas, a domestically available and abundant fuel can address these issues. It also has the benefit of an existing and widespread infrastructure. Development and use of NG vehicles then also serve as an interim solution: NG facilities can also serve as a platform for hydrogen production and delivery. This hydrogen can be utilized as gaseous or liquid hydrogen, or may serve as a hydrogen feedstock for other storage technologies such as sodium boro-hydrate. Gasoline and diesel may also serve as a feedstock for reforming, but only goes so far in addressing environmental and energy security concerns.

References

APTA 2001 Transit Vehicle Data Book (www.apta.com)

BTS 2001 Transportation Statistics (http://www.bts.dot.gov)

Brodrick, C, D. Sperling and H. Dwyer, “Clean Diesel: Overcoming Noxious Fumes”, pp. 16-25, in Fall 2001 “Access”, No 19.

California Air Resources Board (CARB) postings on diesel fuel toxic byproducts: www.arb.ca.gov/toxics/diesel/diesel.htm

Chernicoff and Mora, Bus Industry Standards, Codes, Best Practices, and Related Complexities, Proceedings 2002 APTA Bus and Paratransit Conference.

DOT Advanced Vehicle Technologies Program on Medium and Heavy Vehicles for the 21st Century, http://scitech.dot.gov/partech/nextsur/avp/ and the Consortia links.

DOT, 2000: "Medium and Heavy- Duty Vehicle R&D Strategic Plan", prepared by the Volpe Center for the NSTC Transportation Subcommittee, April, 2000.

EPA Heavy-Duty Highway Engines (HDE (Truck and Bus Emissions standards) web page postings at www.epa.gov/otaq/hd-hwy.htm

EPA, 2000a: EPA 40CFR Parts 69,80 and 86, June 2, 2000, Control of Air Pollution from New Motor Vehicles: Heavy Duty Engine and Vehicle Standards; Highway Diesel Fuel Sulfur Control Requirements; Proposed Rules; and Final Rule (Oct.6, 2000)- Control of Emissions of Air Pollution from 2004 and Later Model Year Heavy-duty Highway Engines and Vehicles", Fact Sheet

EPA, 2000b: "Health Assessment Document for Diesel Exhaust" EPA/600/8-90/077E, July 2000, SAB Review Draft

EPA, 2000c: "Technical Support Document: Control of Emissions of Hazardous Air Pollutants from Motor Vehicles and Motor Vehicle Fuels", EPA420-R-00-023, Dec. 2000

EPA, 2000d: "Regulatory Impact Analysis: Control of Emissions of Air Pollution from Highway Heavy Duty Engines", EPA420-R-00-010, July 2000

FTA Fuel Cell Transit Bus Program,
www.fta.dot.gov/research/equip/buseq/fucell/fucell.htm

FTA, 95: "Clean Air Program: Summary Assessment of the Safety, Health, Environmental and System Risks of Alternative Fuel", Volpe Center for FTA, DOT-FTA-MA-90-7007-95-1, Aug. 1995

GAO, 1999: "Mass Transit: Use of Alternative Fuels in Transit Buses", GAO/RCED-00-18

GAO, 2001: "Alternative Motor Fuels and Vehicles- Impact on the Transportation Sector", Testimony GAO-01-957T

Hormandiger wt al, 2001, "An Evaluation of Economics of Fuel Cells in Urban Buses", Imperial College, London, UK www.e-sources.com/fuelcell/econpap.html

NSTC 2000, Medium- and Heavy-Duty Vehicle Strategic Plan (Draft), Volpe National Transportation Systems Center Transportation Strategic Planning and Analysis Office. Cambridge, MA.

NorthEast Advanced Vehicle Consortium (NAVC) website web-postings and links to other Advanced Vehicle Consortia, Hybrid Transit Bus Demonstration and Deployment, www.navc.org/HDdemo.html

NAVC, 2000: "Hybrid-Electric Drive Heavy-Duty Vehicle Testing Project- Final Emissions report", by Northeast Advanced Vehicle Consortium, M.J. Bradley &Assocs. , and West VA University, posting at www.navc.org

National Renewable Energy Laboratory (NREL), "Natural Gas in Transit Fleets: A Review of the Transit Experience" and Alternative Fuels Data Center at http://www.afdc.nrel.gov/

ORNL, 2001: Oak Ridge National Laboratory "Transportation Energy Data Book- Ed. 21", by Stacy Davis, ORNL-6966

Union of Concerned Scientists (UCS), http://www.ucsusa.org/index.html see Clean Vehicles and Cleaner Transit Campaigns information and **"Pollution Report Card: Grading America's School Bus Fleets**", 2002 report

Volpe Center National Symposium on Transportation-3, "Enabling Technologies and Transportation Innovation", "Propulsion and Fuel Systems" papers posted at: www.volpe.dot.gov/ourwork/symposia01/three-schedule.html

- John German, Honda America, "Hybrid Drive System Engineering & Integration";
- Rodica Baranescu, NAV-International, "Clean and Green Transportation in the 21st Century- the Potential of the Diesel Engine Technology";
- Peter Teagan, A. D. Little, "Hydrogen Fueling Options".

WorldWatch, 2001: "Hydrogen Futures: toward a Sustainable Energy System", WorldWatch paper 157, by Seth Dunn, Aug. 2001

i