Transit on the Cutting Edge of Clean Technology

INTRODUCTION

This white paper reviews the substantial progress that transit agencies have made in investing in innovative clean technologies and fuels, such as electricity, hybrid vehicles, electric storage, biofuels, natural gas, and hydrogen fuel cells. Transit, in fact, has often been on the cutting edge of adopting these clean technologies, driven in part by a range of federal and state policies, programs, and incentives.

TRANSIT'S LEADERSHIP ON CLEAN ENERGY, ENERGY EFFICIENCY, & CLEAN FUELS

Transit agencies have historically relied on diesel buses and other long-standing technologies to move their passengers. Transit agencies have begun to move away from those technologies and to adopt cleaner, more efficient ones. These include:

- *electric vehicles and diesel-electric hybrids* – vehicles that rely in whole or in part on electric motors to provide propulsion.
- *regenerative braking and energy storage* – systems that capture and systems that store the energy generated by trains' braking systems.
- *biofuels* – fuels created from living or recently living matter (e.g., ethanol, biodiesel).
- *natural gas vehicles* – vehicles that run on compressed natural gas (CNG) or liquefied natural gas (LNG).
- *hydrogen fuel cell vehicles* – vehicles that run on electricity generated by compressed hydrogen fed into a fuel cell.

As Ray LaHood, Secretary of Transportation, has explained, federal research on "alternative fuels and high efficiency vehicles has yielded the introduction of hybrid-electric buses, hydrogen fuel cell buses, and other low emissions technologies" into the mainstream of public transit. He further noted that "[t]ransit vehicles make ideal demonstration vehicles because of their high visibility and centralized maintenance."[1]

Even though buses and other transit vehicles are typically kept in service for many years, meaning only a small portion is replaced each year,[2] transit agencies have taken the lead with a range of cleaner technologies and fuels. For instance, the percentage of buses on the road powered by alternative fuels rose from 2% in 1992 to 36.6% in 2011;[3] for comparison, the percentage of cars capable of being powered by alternative fuels in 2011 was about 3.2%, most of which consisted of ethanol "flex fuel" vehicles.[4]

Electric Vehicles & Hybrids

Electric and hybrid vehicles have received lots of media attention in the consumer market, but transit agencies have been at the forefront of adopting hybrid buses– usually diesel-electric hybrids, though sometimes gasoline-electric hybrids – and utilize a large number of pure electric vehicles as well.

According to the Transit Cooperative Research Program, diesel-electric hybrid buses can have 14% to 48% better fuel efficiency than conventional diesel buses while significantly reducing tailpipe emissions.[5] Hybrid buses started to catch on in the late 1990s,[6] but before 2005, less than 0.5% of transit buses were hybrids. In 2005, that figure rose above 1% for the first time, as more than 40 North American transit agencies had hybrid buses in service. By 2011, about 9% of buses were diesel-electric or gasoline-electric hybrids, and more than 60 agencies had such buses in service.[7] According to APTA's 2011 Public Transportation Vehicle Database, hybrids accounted for about 17% of the new buses on order by transit agencies.[8]

New York City was among the leaders in utilizing hybrid-electric buses. MTA started using 10 hybrid-electric buses in 1998, ordered 125 more in 2001, and as of 2009, had 850 hybrids in its fleet.[9] By the start of 2011, MTA had more than 1,600 active hybrid buses in its almost 5,900 bus fleet (about 28%), the largest hybrid bus fleet of any U.S. city.[10] Other transit agencies have also been taking action, including:

- Philadelphia's Southeastern Pennsylvania Transportation Authority (SEPTA) bought 440 hybrid buses between 2009 and 2012 (40 of which were purchased with $17.8 million in federal grants under the 2009 stimulus bill) and plans to add 285 more by 2015 – which means more than half of SEPTA's 1,400 bus fleet will be hybrids by mid-decade.[11]
- The Washington Metropolitan Area Transit Authority (WMATA) in DC has replaced more than 400 of its older diesel buses with hybrids, and as of August 2011, had 548 hybrid buses in its 1,492 bus fleet (almost 37%).[12]
- Other agencies that have hybrids accounting for sizable portions of their fleets include Ann Arbor (MI) Transportation Authority (*more than half*), San Joaquin (CA) Regional Transit District (*about 46%*), Baltimore's Maryland Transit Administration (*nearly one third*), and Minneapolis Metro Transit (*about 15% by the end of 2012*).[13]

Many transit agencies utilize fully electric vehicles as well. All heavy rail and almost all light rail, trolleybuses, and commuter rail self-propelled cars are powered by electricity, while only a small percentage of buses and commuter rail locomotives are.[14] Foothill Transit in California is one of the few transit agencies pioneering electric buses (bought with $6.5 million in federal funding from the 2009 stimulus bill).[15] Washington State's King County Metro received a $5 million federal grant to design and build at least one all-electric demonstration bus, is exploring fast-charging batteries for its trolleybuses (which connect to overhead wires), is employing hybrid technology in its buses, and is investing in all-electric vehicles for its vanpool.[16] In spring 2011, King Country Metro added 256 new hybrid buses to its fleet (funded partly by a $35.8 million federal grant from the 2009 stimulus bill), complementing the existing 285; combined with its 159 electric trolleys, King County thus has more than half of its fleet as hybrid-electric or fully electric.[17] In Ohio, the Greater Cleveland Regional Transit Authority's entire fleet is powered by electricity and clean diesel (i.e., electric rail cars and clean diesel and hybrid-electric buses).[18]

Transit agencies have been at the forefront of adopting plug-in hybrid technology as well, though plug-in hybrids are still far from widespread. In 2006, the Kansas City Area Transportation Authority in Kansas City, MO began piloting a plug-in diesel-electric hybrid paratransit (demand response) van.[19] Thunder Bay Transportation Authority in Michigan received more than $2.5 million in federal stimulus funding in 2009 to replace four diesel buses with four plug-in hybrid buses (and collect data for two years).[20]

Regenerative Braking & Energy Storage

Transit agencies have been using regenerative braking technologies – which capture the energy generated by trains' braking systems – for many years to reduce the energy needs of their electric rail vehicles. WMATA, for instance, has been using regenerative braking since 1983,[21] while Portland, Oregon's TriMet has incorporated regenerative braking on its light rail trains since 1997.[22] With regenerative braking, the energy generated from braking electric rail vehicles generally is fed back into the power supply and distribution network for other vehicles on the system or other power needs drawing power at the same time. NYC Transit's New Technologies subway cars, for instance, feed braking energy back into the Third Rail.[23] Amtrak, which uses regenerative braking in about 80% of its electric fleet (in the Northeast Corridor), returns electricity to the power grid through overhead wires.[24] Amtrak's use of regenerative braking has reduced its energy consumption by up to eight percent.[25] In late 2010, Amtrak arranged to buy 70 new electric locomotives with regenerative braking systems for the Northeast and Keystone Corridors that will replace much older locomotives that lack such systems.[26]

One challenge with regenerative braking is that if other vehicles or other power needs are not drawing power at the exact same time the power is generated, the regenerated energy dissipates and is lost.[27] For TriMet, this meant that only about 70% of the regenerated energy was utilized;[28] Philadelphia's SEPTA estimates that only 30-50% of the regenerated energy is used.[29] In recent years, therefore, transit agencies have focused increased attention on coupling regenerative braking technologies with energy storage devices (e.g., batteries, supercapacitors, flywheels) so that the regenerated energy can be stored and used (or sold back to the grid) whenever needed.[30] In transit systems, energy storage can be located either on board the vehicles or alongside the tracks.[31]

Some transit systems are already initiating projects with energy storage:

- Los Angeles MTA received a $4.5 million federal grant in 2009 for a flywheel-based wayside energy storage substation at one of its metro stations; testing during this demonstration project is expected to show a 48% reduction in energy consumption.[32]
- San Francisco Bay Area Rapid Transit (BART) is researching on-board energy storage that will allow the vehicle generating the energy to use it any time it needs, whether immediately or in the future.[33] BART has estimated that installing on-board ultracapacitors to capture and store the energy from regenerative braking could reduce electrical consumption by almost 83 million kWh per year, reduce demand by more than 19,000 kW, and yield cost savings of about $8.7 million per year.[34]
- Philadelphia's Southeastern Pennsylvania Transportation Authority (SEPTA), funded by a grant from the Pennsylvania Energy Development Authority, is piloting a wayside energy storage system that involves a large lithium-ion battery being installed in a SEPTA substation to store energy from regenerative braking. The energy in the battery can help trains accelerate, reduce electricity consumption, or be sold back to the grid.[35]

- Oregon's TriMet received a $4.2 million federal grant in late 2010 to install twenty on-board energy storage units (capacitors) on its light rail vehicles, saving an additional 70,000 kWh each year for each equipped train. [36]
- New York MTA is partnering with the New York State Energy Research and Development Authority (NYSERDA) on pilot projects to field test a giga-cell battery for wayside energy storage and model the potential for on-board energy storage using ultracapacitors.[37] MTA also received a $4 million federal grant in 2010 to incorporate wayside energy storage into the subway system, using nickel metal hydride battery technology.[38]

Other transit systems exploring wayside energy storage include ones in Long Island, NY and Sacramento, CA.[39]

To help the transit industry assess the potential of wayside energy storage and consider future smart-grid implications, APTA and the Electric Power Research Institute (EPRI) in 2009 formed a consortium of transit agencies, representatives of the electric power industry, Sandia National Laboratory, and other interested parties.

Biofuels

Transit agencies have also taken a leading role in utilizing biofuels such as biodiesel and ethanol, with at least 40 agencies in North America utilizing buses running on biofuels.[40] For example:

- The San Francisco Municipal Transportation Agency (SFMTA) has the largest municipal biodiesel fleet in the United States – 512 vehicles – including both biodiesel and biodiesel-hybrid buses. SFMTA has been using B20 (a 20% biodiesel blend), but meeting San Francisco's greenhouse gas goals will require B50.[41]
- The Central Florida Regional Transportation Authority's LYNX system was the first transit agency in the U.S. to build and operate its own biodiesel fueling station, in May 2009; LYNX uses a B20 blend – nearly 4.2 million gallons per year - in its 269 bus fleet.[42]
- The Roaring Fork Transportation Authority (RFTA) in Aspen, Colorado replaces about 100,000 gallons of gasoline or diesel with biofuels every year. RFTA tested B5 (5% blend of biodiesel) in 2004 and B10 in 2006 and now uses B20 in all of its diesel buses and E10 (10% ethanol blend) in all of its gasoline trucks during the summer.[43]
- The St. Louis and Kansas City, MO transit systems participated in field tests in 2009-2010 to evaluate the real-world performance of B20 (blend of 20% biodiesel and 80% ultra-low sulfur diesel) in existing buses and engines, in cooperation with the National Biodiesel Board and the National Renewable Energy Laboratory.[44]
- Many other agencies across the country have tested and/or are still utilizing biodiesel blends include SunTran (Tucson, AZ), the Utah Transit Authority, and the Ames Transit Agency (Ames, IA).[45]

As of 2011, biodiesel fueled about 8% of buses (up from about 6.5% a couple of years earlier) and about 5.5% of demand response vehicles.[46] According to APTA's 2011 Public Transportation Vehicle Database, biodiesel vehicles accounted for about 7% of the new buses and more than 14% of the new demand response vehicles on order by transit agencies.[47]

Natural Gas

Use of natural gas (compressed natural gas, liquefied natural gas, or blends) in transit bus fleets started taking off in the late 1990s, growing from 2.8% of buses in 1996 to 18.6% in 2011.[48] More than 40 North American transit agencies now use buses powered by compressed natural gas (CNG) or a CNG blend, and at least 7 agencies use

buses powered by liquefied natural gas (LNG).[49] According to APTA's 2011 Public Transportation Vehicle Database, CNG and CNG-blend buses accounted for about one-third of the new buses on order by transit agencies.[50] Among the many transit agencies currently or soon to be utilizing natural gas are:

- The Los Angeles County Metropolitan Transportation Authority, which relied heavily on CNG to eliminate diesel buses entirely from its fleet in 2011, becoming the first major U.S. transit agency with a fleet 100% equipped with alternative fuel technologies. Taking delivery of its first natural gas buses in 1995, MTA now has more than 2,000 buses powered by CNG, plus one electric bus and six gasoline-electric hybrids.[51]
- The Sacramento Regional Transit District, which started operating CNG buses in 1993 and was among the first U.S. transit agencies to undergo a major CNG conversion. Sacramento runs its entire 182 bus fleet on CNG.[52]
- The Dallas Area Rapid Transit (DART), which is expecting one of the nation's largest CNG bus orders – 459 buses – to begin arriving later this year to replace its current fleet of LNG and clean diesel buses; the fleet should be fully converted by 2015.[53]
- The Metro Regional Transit Authority in Akron, OH, which runs about half of its buses on CNG, and the Central Ohio Transit Authority, which has tested a range of alternative fuels and plans to start buying CNG buses as early as 2013.[54]

Hydrogen Fuel Cells

Several U.S. transit agencies use buses or other vehicles powered by hydrogen fuel cells, most built within the past few years.[55] For example:

- Oakland, California's AC Transit is integrating 12 hydrogen fuel cell buses into its 680 bus fleet (and in April 2012 unveiled a large-scale, publicly accessible hydrogen production and dispensing station).[56]
- The Mass Transportation Authority in Flint, MI, became in May 2012 the first transportation agency in the Midwest with a hydrogen fuel cell bus – and plans to issue a request for proposals within the next year to buy more hydrogen vehicles. The hydrogen fuel cell bus joins MTA's new propane autogas paratransit vehicles and its anticipated new CNG vehicles, all of which will be housed and maintained at MTA's new Grand Blanc Alternative Fuel Facility.[57]
- As of late 2010, Connecticut Transit had 5 buses powered by hydrogen fuel cell hybrid-electric technology.[58]

POLICY DRIVERS OF TRANSIT LEADERSHIP

The leadership of the transit community in testing and implementing clean technologies and fuels has been driven in no small measure by federal and state policies, funding, and incentives.

Federal Policy Drivers

There are a wide range of federal policies, programs, and incentives that have driven clean fuels and vehicle technologies.[59] Federal support for cleaner fuels and technologies in transit is nothing new. For example, the Alternative Motor Fuels Act of 1988 directed the Secretary of Energy (in conjunction with other relevant federal agencies) to help state and local agencies test the environmental and safety aspects of alcohol and natural-gas powered buses in urban settings.[60] Other federal policy drivers include, but are in no way limited to, the following:

- The American Recovery and Reinvestment Act of 2009 (the stimulus bill) provided significant funding for clean transit purchases and projects around the country, including many of those described earlier. One of the key programs initiated under ARRA (but continued on beyond ARRA) is the Transit Investments for Greenhouse Gas and Energy Reduction (TIGGER) Program, which works directly with and provides grants to public transportation agencies to implement new strategies for reducing greenhouse gas emissions and/or reduce energy use within transit operations.[61] The TIGGER program has been a critical driver of clean fuel and clean technology adoption by transit agencies over the past few years,[62] distributing more than $360 million in grants, but it was not renewed in the fiscal 2012 budget deal and may not receive funding in the 2013 appropriations bills.[63]
- The Clean Air Act Amendments of 1990 created a Clean Fuel Fleet Program, which requires cities with air quality problems to promote vehicles that meet a strict set of emission standards. The Program applied to all fleets of 10 or more vehicles. Section 7554 of the Act set emission standards for urban buses beginning with model year 1994.[64]
- The Clean Fuels Grant Program allowed the FTA to support emerging clean fuel and advanced propulsion technologies for transit buses in areas that are maintenance or non-attainment for ozone or carbon monoxide.[65]
- Under the Fuel Cell Bus Program, the FTA provides grants to promote hydrogen fuel cell buses.[66]
- The FTA is helping to lead an Electric Drive Strategic Plan to guide federal research efforts on bus electric propulsion technology.[67]
- DOE's Clean Cities Program is a voluntary initiative with a national network of nearly 100 Clean Cities coalitions that bring together stakeholders in the public and private sectors to share information and resources, educate the public, help craft public policy, and collaborate on projects that deploy alternative and renewable fuels, idle-reduction measures, fuel economy improvements, and emerging transportation technologies. Many transit agencies are members of Clean Cities coalitions and are eligible for technical assistance and funding opportunities.[68]

Going forward, the new transportation bill (MAP-21) includes a "deployment" program focused on low- and zero-emission public transportation vehicles, providing grants for acquiring such vehicles (and related equipment), constructing facilities for such vehicles, and rehabilitating existing facilities to accommodate the use of such vehicles.[69]

State and Local Policy Drivers

State and local governments also have various policies, programs, and incentives that promote clean fuels and technologies in public transportation.[70] These also are not new. For instance, Texas law required use of lower emission technologies in transit agency vehicles by September 1991.[71] Other state and local policy drivers include, but are in no way limited to, the following:

- As noted earlier, Philadelphia's SEPTA is piloting a wayside energy storage system funded by a grant from the Pennsylvania Energy Development Authority.[72]
- As noted earlier, the New York State Energy Research and Development Authority (NYSERDA) is partnering with and funding New York MTA on pilot projects to field test a giga-cell battery for wayside energy storage and model the potential for on-board energy storage using ultracapacitors.[73] NYSERDA also has a Clean Fueled Bus Program that provides funds to state and local transit agencies, municipalities, and schools for up to 100% of the additional cost of a clean-fueled bus and for associated infrastructure projects; NYSERDA has awarded $24.5 million for 520 buses including CNG, electric, and diesel-electric hybrid.[74]

- California has a Fleet Rule for Transit Agencies that aims to reduce air pollution from urban buses and transit fleet vehicles by requiring them to use either clean diesel or alternative fuels and by promoting zero-emission bus demonstration projects and acquisitions.[75]
- New Jersey law requires NJ Transit, from fiscal year 2007 onward, to purchase only buses either with improved pollution controls or that are powered by alternative fuels (e.g., CNG, hybrids, fuel cells, biodiesel).[76]
- Ohio runs a Diesel Emissions Reduction Grant Program that has enabled, for instance, the Toledo Area Regional Transit Authority to replace 33 old diesel buses with new ones that are able to use biodiesel and that may enable the Central Ohio Transit Authority to purchase the CNG components of 30 new transit buses. (The grants are supported with federal Congestion Mitigation and Air Quality funds distributed to Ohio by the Federal Highway Administration.) [77]

CONCLUSION

Transit agencies have been leaders in investing in innovative clean technologies and fuels.

Agencies such as those in New York City and Ann Arbor have been at the forefront of adopting hybrid-electric buses – which now account for about 1 out of every 6 new buses that transit agencies have on order – and a few agencies are pioneering plug-in electric hybrids and all-electric buses as well. Agencies such as those in Washington, DC and Portland, OR have utilized regenerative braking technologies on their electric rail vehicles for years, and leaders like those in Philadelphia and Los Angeles have initiated projects to store and deploy that regenerated energy. Dozens of agencies, from central Florida to Utah, now power their buses in whole or in part with biofuels. Natural gas buses are booming around the country, from Dallas to Akron, and now account for 1 out of every 3 new buses on order. Agencies in Oakland, CA and Flint, MI are leading the way in using buses powered by hydrogen fuel cells.

Transit agencies' leadership in this area has been driven in no small part by a range of federal and state policies, programs, and incentives. These policies should be maintained and expanded to enable transit agencies to continue their leadership in transforming their fleets to clean fuels and technologies.

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Prepared by David Gardiner & Associates, LLC, *August 2012*

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The American Public Transportation Association (APTA)

The American Public Transportation Association (APTA) is a nonprofit international association of more than 1,500 public and private member organizations, engaged in the areas of bus, paratransit, light rail, commuter rail, subways, waterborne services, and intercity and high-speed passenger rail. This includes: transit systems; planning, design, construction, and finance firms; product and service providers; academic institutions; transit associations and state departments of transportation. APTA members serve the public interest by providing safe, efficient and economical transit services and products. More than 90 percent of the people using public transportation in the United States and Canada ride APTA member systems.

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