Alternative Fuels Study:

A Report to Congress on Policy Options for Increasing the Use of Alternative Fuels in Transit Vehicles

United States Department of Transportation
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Acronyms

1992 EPAct	**Energy Policy Act of 1992**
2005 EPAct	**Energy Policy Act of 2005**
APTA	**American Public Transportation Association**
B100	**neat biodiesel (100%)**
B20	**20% biodiesel, 80% petroleum diesel**
CBD	**central business district**
CMAQ	**Congestion Mitigation and Air Quality Improvement Program**
CNG	**compressed natural gas**
CO	**carbon monoxide**
CO_2	**carbon dioxide**
CSHVC	**City Suburban Heavy Vehicle Cycle**
DOE	**Department of Energy**
DOT	**Department of Transportation**
DPF	**diesel particulate filters**
E85	**ethanol (85% by volume)**
EGR	**exhaust gas recirculation**
EPA	**Environmental Protection Agency**
FHWA	**Federal Highway Administration**
FTA	**Federal Transit Administration**
GAO	**Government Accountability Office (formerly General Accounting Office)**
GHG	**greenhouse gas**
HC	**Hydrocarbons**
LNC	**lean NO_x catalysts**
LNG	**liquefied natural gas**
LSD	**low sulfur diesel**
M85	**Methanol**
NAVC	**Northeast Advanced Vehicle Consortium**
NMHC	**non-methane hydrocarbons**
NO_x	**oxides of nitrogen**
NREL	**National Renewable Energy Laboratory**
NTD	**National Transit Database**
O_3	**Ozone**

OC	**oxidation catalysts**
OEM	**original equipment manufacturer**
PM	**particulate matter**
SAFETEA-LU	**Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users**
SCR	**selective catalytic reduction**
SECAT	**Sacramento Emergency Clean Air and Transportation**
SEP	**State Energy Program**
SO_x	**sulfur oxides**
STP	**Surface Transportation Program**
TERP	**Texas Emissions Reduction Plan**
TRB	**Transportation Research Board**
ULSD	**Ultra-low sulfur diesel**
VEETC	**Volumetric Ethanol Excise Tax Credit**
VOC	**volatile organic compounds**
WMATA	**Washington Metropolitan Area Transit Authority**
WVU	**West Virginia University**

Results in Brief

This report presents the results of a study required by Section 3016(c) of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). That section directed the Secretary of Transportation to conduct a study of the actions necessary to increase the use of alternative fuels in public transportation vehicles, including buses, fixed guideway vehicles, and ferries. The study considered the environmental and other benefits expected from increased use of alternative fuels, barriers that discourage the purchase of alternative fuels, available opportunities that encourage the purchase of alternative fuels, including those that require no capital improvements to transit vehicles, and the levels and type of support necessary to encourage greater use of alternative fuels in public transportation vehicles.

Environmental Benefits

Greater use of alternative fuels in public transportation vehicles would yield environmental benefits, in comparison to continued reliance upon diesel fuel, primarily in reduced tailpipe emissions of air pollutants harmful to public health, reduced risk of soil and water contamination from diesel spills, and quieter operation. Engines operated on most alternative fuels emit lower levels of non-methane hydrocarbons (NMHC), oxides of nitrogen (NO_x), and particulate matter (PM) than current diesel engines in all kinds of transit vehicles. This is especially true for alternative fuel comparisons involving ferryboats and locomotives, which typically have few if any diesel emission controls on their engines.

The Environmental Protection Agency (EPA) requires that emissions from diesel engines produced to the 2007 standard must be substantially lower than those meeting the 2004 standard for diesel engines. The result may be that future diesel engines will be as clean as alternative fuel engines available today. Beginning in 2007, diesel engines will be required to operate on ultra-low-sulfur diesel fuel and use particulate filters and exhaust treatment technologies to reduce emissions of hydrocarbons (HC), carbon monoxide (CO), NO_x, and PM. Diesel engines used in locomotives and ferries will soon face tougher emissions standards also. As these new diesel engines are phased in, the relative advantage of using alternative fuels to achieve emissions standards will be diminished. Some alternative fuels will continue to compare favorably with this new diesel baseline when all pollutant emissions are considered.

In the longer term, depending on the source of the hydrogen, vehicles powered by hydrogen in fuel cells or internal combustion engines may ultimately be cleaner than other alternative fuel or diesel engines. Further, electric transit vehicles offer performance and noise reduction benefits and emit no exhaust gases, but their net environmental benefit depends on controlling emissions from the fuel used to generate electricity. Finally, hydroelectric, wind and solar generation of electricity produces no emissions, and so may become the optimal power source for hydrogen fuel cells or electric vehicles of all kinds.

Although not a direct environmental benefit, substituting domestically produced alternative fuels for diesel would yield energy-security benefits through reduced reliance on imported petroleum and reduced risks of price volatility and supply interruptions. Quantifying these external benefits, however, may be challenging.

Alternative fuels that can be used in diesel engines, such as biodiesel, Fischer-Tropsch diesel and certain alternative diesel blends, will continue to offer emissions rates lower than the diesel baseline. Renewable fuels can also significantly reduce greenhouse gas emissions from transportation.

Why Use of Alternative Fuels Has Been Growing

Agencies operating public transportation systems have seized opportunities that encourage the purchase of alternative fuels by purchasing increasing numbers of alternative fuel vehicles and supporting equipment since the mid-1990s. Reasons for choosing alternative fuels instead of diesel include:

- Complying with Federal air quality regulations in non-attainment or maintenance areas;
- Reducing tailpipe emissions of particulate matter and toxic gases;
- Voluntarily adopting clean fuel buses by state, regional, or local public transportation agencies in an effort to improve local air quality;
- Improving public perception of transit to attract new riders;
- Utilizing Federal or State legislation offering higher levels of financial assistance for purchase of clean fuel buses;
- Favorable public response to new rail systems (New Starts) powered by clean and relatively inexpensive electricity;
- Recent price increases in oil used to produce diesel fuels, as compared with electricity or alternative fuels made from agricultural commodities;
- Reducing dependence on foreign oil by substituting domestically produced renewable fuels, such as biodiesel and ethanol, or natural gas;
- Promotion by industry groups advocating specific fuels, such as natural gas and biodiesel; and,
- Achieving local priorities such as increasing use of fuels derived from local sources (e.g., corn or soybean crops or natural gas production).

Barriers Facing Alternative Fuels

Every alternative fuel reviewed in this study imposes some combination of increased capital costs, operating costs, technical challenges, or institutional issues as compared to diesel fuel. Barriers that have inhibited greater use of alternative fuels in public transportation vehicles include:

- Higher capital costs of alternative fuel vehicles and supporting facilities, especially natural gas facilities and electrification of routes for trolley buses or commuter rail lines;
- Higher operating costs for items like the alternative fuels themselves and maintaining vehicles and equipment using them;
- Unproven reliability and durability of early production models of new alternative fuel vehicles that could affect transit service dependability;

- Limited availability of new alternative fuels;
- Risk of interruptions in fuel delivery;
- The need to develop, adopt and enforce codes and standards for alternative fuel performance and stability, comparable to those used in specifying diesel fuel quality;
- Higher logistics costs of adding a duplicative inventory of components and spare parts peculiar to the alternative fuel vehicles; and,
- Costs of developing new operating and maintenance procedures for handling alternative fuels and conducting special training for mechanics and vehicle operators.

Policy Options

SAFETEA-LU directed the Secretary to recommend regulatory and legislative alternatives that will result in the increased use of alternative fuels in transit vehicles. Accordingly, this report recommends consideration of the following policy options to increase the use of alternative fuels in transit: (1) Defer Action, (2) Mandate the Use of Alternative Fuels, and (3) Create New or Enhance Existing Incentive Programs. Each option has associated risks.

Defer Action. Rely upon existing regulations and statutes, as well as market conditions, to indicate where the alternative fuels market is going. This option has the greatest risk of achieving no results, since some current incentives are set to expire and the marginal environmental benefits that have driven the increased use of alternative fuels will soon diminish significantly as cleaner diesel engines become available. If high oil prices persist and tax advantages to manufacturers and fuel producers expire, transit agencies may decide to increase use of biodiesel blends[1] that do not require expensive engine modification in their existing fleets. Modest environmental or operational benefits of other alternative fuels would then appear too expensive to pursue by comparison with biodiesel blends.

Mandate the Use of Alternative Fuels. Congress has the discretion to legislate a requirement for some or all of the U.S. transit vehicles to operate on specific alternative fuels. This option has a low risk of achieving no results, but leaves the barriers identified in this study unaddressed. It would be politically controversial as an unfunded mandate. It also has a high risk of unintended consequences, such as mandating an inherently high-cost fuel or technology, thus leading to a decline in the level of transit service in many areas nationwide, especially in smaller localities that have few resources for, and little experience in, working with alternative fuels. It risks slowing down the replacement of transit vehicles, leaving older, dirtier vehicles on the road longer and making public transportation less attractive to choice riders.

Create New or Enhance Existing Incentive Programs. Congress could provide additional funding or a higher Federal matching ratio, in addition to continuing various existing incentives, to encourage increased development and use of selected alternative fuels in transit. This option, if carefully designed to address the barriers identified in this study, has a higher likelihood of

[1]Some biodiesel blends produce more energy output than others for the same input (i.e., soy or sawgrass fuel vs. corn-based fuel), so their proportional price differential with regard to petroleum based fuels may decline over time. However, this will not happen if the fuels do not reach market-efficient production levels before the expiration of Federal and other incentives.

achieving results than the “Defer Action” option and a lower likelihood of unintended consequences than the “Mandate” option. And, since the heavy trucking industry uses the same basic engines as transit buses, advances adopted and proven in transit use may be implemented more easily for freight operations.

Stakeholders, who have expressed their opinions through focus groups and surveys found in the literature on this topic, favor the third option. In their input on the issue, they made recommendations for how to structure grant programs and non-financial incentives to achieve the greatest effect with the fewest disruptions. Stakeholders called for flexible grant programs and extensions of current tax incentives to address capital and operating costs. They also recommended education, information sharing, and testing programs that address the technical challenges and institutional issues associated with alternative fuels use.

Significant changes in Federal programs and policies affecting use of alternative fuels in transit vehicles were put into place in August 2005, when SAFETEA-LU and the Energy Policy Act of 2005 were enacted. Congress could choose to await results of evaluation of experience implementing the new provisions before considering new legislation. Meanwhile, the three Federal agencies whose actions most affect decisions to use alternative fuels in transit vehicles, the DOT, DOE and EPA, could continue to provide current information and technical assistance needed by transit agencies planning future vehicle purchases.

Introduction

This report presents the results of a study required by the National Research and Technology Programs heading (Sec. 3016) of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) enacted in 2005. The study focused on the incentives necessary to increase the use of alternative fuels in public transit vehicles, including buses, fixed guideway vehicles and ferries, and considered the following aspects of alternative fuels:

1. Environmental benefits of increased use of alternative fuels in transit vehicles;
2. Opportunities currently available to transit system operators that encourage the purchase of alternative fuels for transit vehicle operation;
3. Existing barriers to transit system operators that discourage the purchase of alternative fuels for transit vehicle operation, including situations where alternative fuels that do not require capital improvements to transit vehicles are disadvantaged over fuels that do require such improvements; and,
4. Levels and types of support necessary to encourage additional use of alternative fuels for transit vehicle operation.

Alternative Fuel Definitions

For the purposes of this study, the following fuels — designated by the Energy Policy Act of 1992 (1992 EPAct) or the Department of Energy after that date — are considered alternative fuels:

- Alternative diesel (including biodiesel, Fischer-Tropsch and diesel blends);
- Methanol, ethanol, and other alcohols;
- Liquefied petroleum gas (propane);
- Blends of 85 percent or more of alcohol with gasoline;
- Coal-derived liquid fuels;
- Fuels (other than alcohol) derived from biological materials;
- Natural gas and liquid fuels domestically produced from natural gas;
- Hydrogen; and,
- Electricity.

In addition to vehicles powered exclusively by these alternative fuels, this study considered electric-drive hybrid vehicles, which can use these fuels, as well as diesel or gasoline, to generate electricity on board. Electric-drive hybrids offer environmental, energy conservation and performance benefits and should serve as an important precursor to electric-drive buses powered by hydrogen fuel cells. They are also eligible to receive alternative fuel cost offsets.

Alternative Diesel is the name for a variety of non-petroleum fuels and petroleum diesel blends that can be used in diesel engines. Some examples include biodiesel, Fischer-Tropsch diesel, and ethanol/diesel blends. Each promises emissions benefits compared to neat petroleum diesel. Petroleum diesel blends, though they contain alternative fuels, are not considered alternative fuels according to the Energy Policy Act definitions above.

- ***Biodiesel*** is a fuel derived from vegetable oils or animal fats. It is typically blended with petroleum diesel at a concentration of 20 percent biodiesel (known as B20) as this blend represents a good balance of emission benefits, cost and risk of field problems.. B20 is commonly used in diesel engines with no modifications.
- ***Fischer-Tropsch diesel*** is a synthetic diesel fuel made from coal, natural gas, or biomass feedstock via the Fischer-Tropsch process. The fuel has the same properties regardless of the feedstock. No engine modifications are required to use Fischer-Tropsch diesel, whether alone or blended with petroleum diesel.
- ***Diesel/Alcohol blends***, also called diesohol or oxygenated diesel, are petroleum diesel blends containing up to 15 percent ethanol or methanol. These fuels are marketed under names such as O_2Diesel™ and E-Diesel™. Diesel blends with low concentrations of ethanol can be used in existing engines without modifications.

Ethanol is also known as ethyl alcohol or grain alcohol. It is primarily fermented from grains, such as corn or other agricultural products. The form of ethanol typically used in transportation is known as E85 and contains 15 percent gasoline. All flex-fuel light-duty vehicles are designed to use E85. During the 1990s, the Los Angeles County Metropolitan Transportation Authority operated an ethanol bus fleet.

Methanol, also called methyl alcohol, is a clear, odorless liquid typically made from natural gas, though it can also be made from coal, wood or various grains. In heavy-duty vehicles, methanol is typically used unblended, though it is also sold as M85, which contains 15 percent gasoline. Methanol powered transit vehicles were used in significant numbers in the 1990s, when the Los Angeles County Metropolitan Transportation Authority operated more than 300 of them.

Liquefied petroleum gas, also called propane or LPG, is a by-product of petroleum refining and natural gas processing. In the U.S., most propane comes from natural gas processing plants. Propane is gaseous at room temperature and atmospheric pressure but liquefies easily at moderate pressure (120 psig).

P-series, one of the alternative fuels designated by Department of Energy, is a proprietary gasoline substitute derived from approximately 70% renewable biomass for use in light and medium-duty vehicles. Since it is not a fuel suitable for the heavy-duty engines used in most transit vehicles, it was not considered further in this study.

Natural gas comes in two forms: compressed (CNG) and liquefied (LNG). If the gas is compressed, it typically comes through a utility pipeline. If the gas is liquefied, it is typically delivered by tanker truck.

Hydrogen is a developmental fuel. Like natural gas, it may be compressed or liquefied. Its use has been restricted to research and demonstration projects of buses with hydrogen internal combustion or fuel cell engines. A test fuel made of a hydrogen/natural gas blend is undergoing evaluation, and Section 1823 of the 2005 EPAct requires a DOE report to Congress regarding commercialization of Hythane, a proprietary mixture of hydrogen and natural gas. Fuel cell buses may be powered by hydrogen derived from fuels such as methanol if the bus is equipped with an on-board hydrogen reformer.

Electricity is delivered in one of two ways: directly, through a catenary wire or third rail, or indirectly, through a battery that must be charged offline or filled with chemicals that create an electric potential when combined. Electric-drive hybrid vehicles use batteries, but they are not purely electric vehicles. In electric-drive hybrid propulsion systems, diesel, gasoline or an alternative fuel is used by an engine or fuel cell to generate electricity to drive the wheels. The electricity is stored in a battery, and regenerative braking is typically used to capture kinetic energy otherwise lost in stop-and-go urban driving. The engine or fuel cell may also provide a direct mechanical drive.

Fuel Use in Public Transportation

Within the transportation industry, including trucks and delivery vans, transit vehicles account for less than 2% of the total fuel consumed.[2] Diesel is the most commonly used transit fuel. Use of other fuels, known as alternative fuels, is limited but growing. Table 1, based on a January 2006 survey of 300 transit agencies by the American Public Transportation Association, shows the dominance of petroleum diesel fuel use in transit vehicles of various types.

Table 1. Survey of U.S. Transit Vehicles by Power Source and Type of Vehicle (2006)

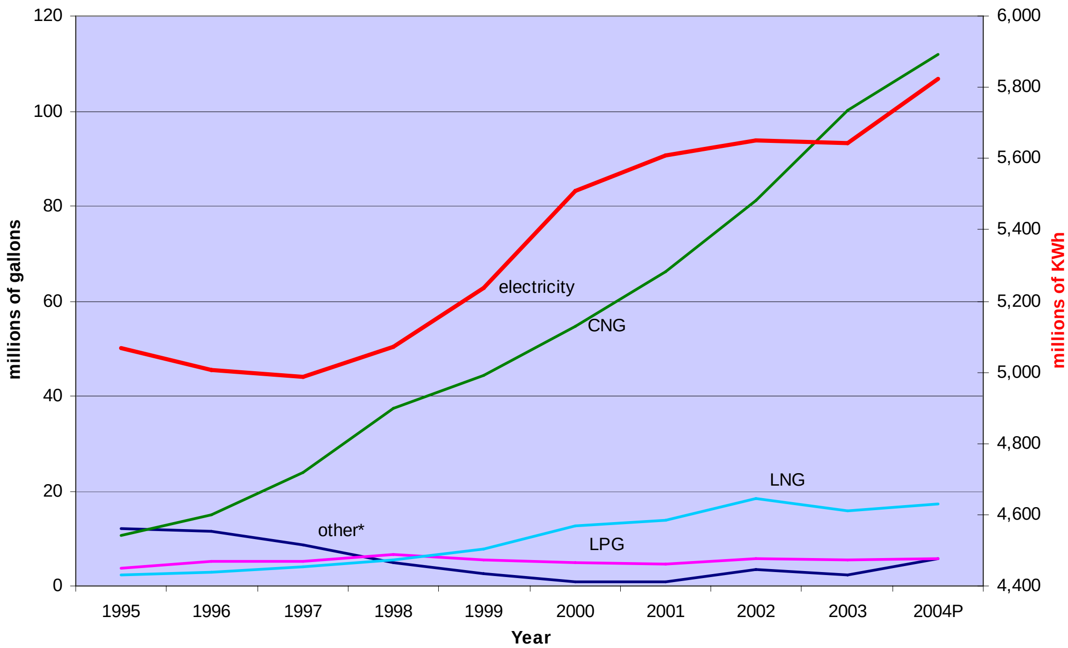
Power Source	Bus	Commuter Rail Car	Commuter Rail Locomotive	Heavy Rail	Light Rail	Paratransit	Trolley Bus	Other	Subtotals	Percent
Diesel	46,266	18	639		24	7,714		286	54,947	57.9
Ultra-Low Sulfur Diesel	618					207			825	0.3
Gasoline	336					3,498		3,969	7,803	8.2
Liquefied Natural Gas	1,092					38			1,130	1.2
Propane	310					161			471	0.5
Compressed Natural Gas	7,488					311		30	7,829	8.3
CNG Blends	169					2			171	0.2
Electric & Diesel	750						26	28	804	0.8
Electric & Other	211							15	226	0.3
Electric Third Rail or Catenary		3,008	79	11,151	2,046		686	144	17,114	18.0
Other [3]	376					39			415	0.4
Unpowered		3,044		3				49	3,096	3.3
Totals	**57,616**	**6,070**	**718**	**11,154**	**2,070**	**11,970**	**712**	**4,521**	**94,831**	**100.0**

[2] Source: National Transit Database fuel use in 2004, with FHWA MF-27 table, 2004.
[3] Includes bio/soy fuel, biodiesel, hydrogen and propane blends.

Electricity is widely used in rail and trolley bus operations, but battery electric buses are used relatively little because of continuing technical challenges.[4] Only diesel fuel is used in ferryboats, and only diesel or electricity is used in rail vehicles.

As Figure 1 illustrates, the use of alternative fuels in transit vehicles has been growing steadily, especially use of compressed natural gas. This is due primarily to effective marketing by the bus engine manufacturers and the Natural Gas Vehicle Coalition, which represents suppliers of natural gas. The marketing effort followed implementation of Clean Air Act Amendments passed in 1991, tightening the emission standards for heavy duty bus engines.

Figure 1. Annual Alternative Fuel Consumption by Transit Vehicles, 1995-2004 – millions of gallons (diesel equivalent) or kilowatt-hours



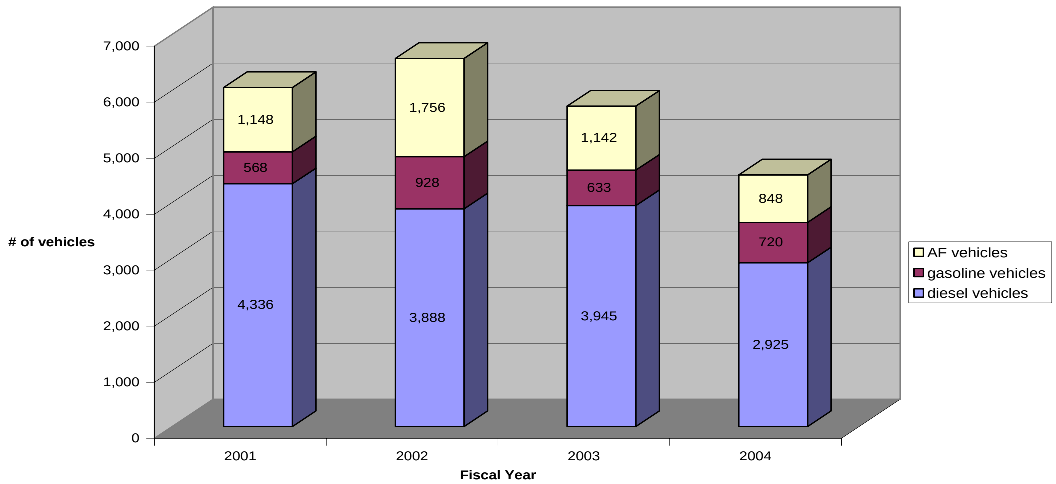
other* = includes biodiesel, bio/soy fuel, hydrogen, jet fuel and propane blends
2004P=preliminary estimate

Source: National Transit Database, fuel consumption table.

FTA has been awarding grants for purchase of increasing numbers of alternative fuel transit buses and vans. Figure 2 shows the numbers of transit buses using diesel, gasoline or alternative fuels that were included in grants awarded by FTA during fiscal years 2001 through 2004. During fiscal year 2004, of the $746 million in FTA grant assistance for bus purchases, $244 million (33%) was for alternative fuel buses.

[4] Eudy, L.N. et al. Challenges and Experiences with Electric Propulsion Transit Buses in the United States. NREL. DOE/GO-102003-1791. November 2003.

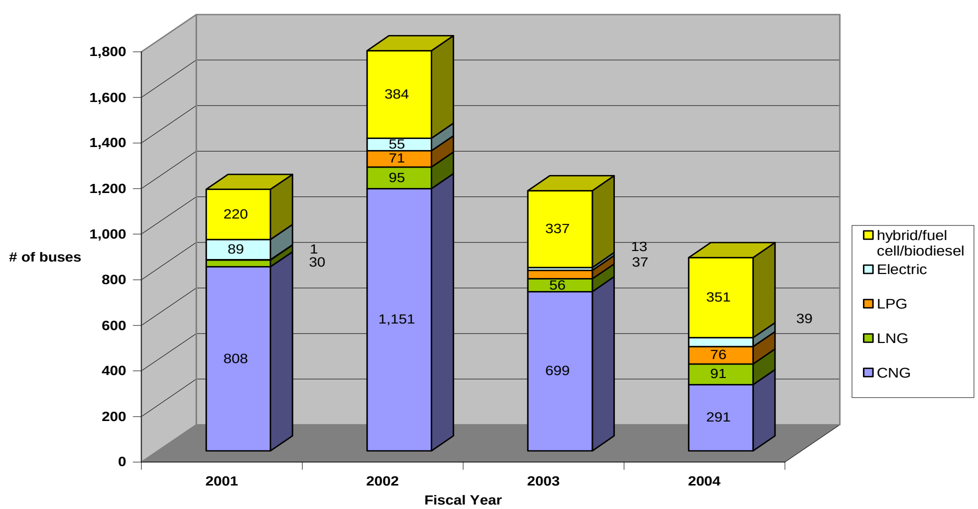
Figure 2. FTA-Funded Transit Buses, Fiscal Years 2001-2004



Source: FTA Statistical Summaries, Grant Assistance Programs, 2001-2004

Figure 3 breaks out the type of alternative fuel used in grants for transit buses awarded by FTA during fiscal years 2001 through 2004.

Figure 3. FTA-Funded Transit Buses by Type of Alternative Fuel Used, FY 2001-FY 2004



Source: FTA Statistical Summaries, Grant Assistance Programs, 2001-2004

This study considers transit operations using alternative fuels both in pure form and in petroleum diesel blends. Fischer-Tropsch diesel and biodiesel may be used in a pure form in unmodified diesel engines, although some engine tuning may be required, and some diesel blends are also compatible with existing diesel engines.

Much of the information presented in the report pertains to buses. Buses today represent over 50 percent of the transit vehicle fleet; they also use a large variety of alternative fuels. Not surprisingly, most reliable data and information on the topic of alternative fuel transit vehicles pertain to buses. Where appropriate, bus-specific conclusions or issues that may differ for ferryboats or rail vehicles, are noted.

Both conventional drivetrains and hybrid electric drivetrains are analyzed. Hybrids using batteries for regenerative braking in stop-and-go urban traffic achieve substantially improved fuel economy and lower emissions per mile, as well as quieter operation, than conventional diesel buses. Hybrids are not specific to alternative fuels but are considered an enabling technology for some promising alternative fuels, such as hydrogen. Hybrids using hydrogen internal combustion engines or fuel cells are in the developmental stage.

Most transit agencies operate heavy-duty vehicles – i.e., buses - in revenue service, though they may use light and medium duty vehicles (such as vans and modified chassis vehicles) for paratransit, demand-response, security, and other operations. This study is limited to heavy-duty vehicles because they consume most of the fuel used by transit agencies.

Environmental Benefits

Reduction of tailpipe emissions is the single greatest environmental benefit of alternative fuels use in public transportation vehicles. Diesel exhaust is particularly hazardous to breathe, even at emission levels equivalent to alternative fuels. Alternative fuel engines typically offer lower emission rates for PM, NO_X, and NMHC than diesels in all kinds of transit vehicles.

New EPA emission regulations applied to all bus engines will require major reductions in emission rates, especially for diesels, in model year 2007 and again in 2010. Rail vehicles and ferryboats will soon be subject to tightened emission regulations as well.

The new regulations could equalize the diesel baseline emissions of regulated pollutants with those of alternative fuels like ethanol, methanol, propane, CNG, and LNG. Alternative fuels that can be used in diesel engines, such as Fischer-Tropsch diesel and certain alternative diesel blends, will continue to offer emissions rates lower than the diesel baseline.

Transit vehicles using hydrogen and electricity are not affected by the new EPA regulations because they produce zero or near-zero tailpipe emission rates. With respect to other environmental considerations, quiet electric motors generate far less noise than internal combustion engines using diesel or other fuels.

While using alternative fuels to reduce emissions from transit vehicles improves local air quality, controlling the sizes and types of vehicles used in transit operations could make an even greater difference. Managing a fleet to minimize cumulative emissions throughout the day, for example, by using smaller buses in low-density service areas and off-peak periods, could reduce emissions and energy use per vehicle-mile of operation.

Compared to other fuels' emissions, diesel exhaust is particularly hazardous to breathe, even at equivalent emission rates. Diesel also generates larger amounts of life-cycle greenhouse gas emissions than nearly every other fuel reviewed. Finally, spills and leaks of most alternative fuels, unlike those of diesel or diesel alternatives, vent or evaporate without long-term damage to soil or groundwater.

Pollution Effects

Air pollution associated with transit fuels comes from several sources, including fuel production (e.g., petroleum refining or electric power generation), fuel transportation, evaporative emissions, and tailpipe emissions from transit vehicles. In communities where transit vehicles operate frequently, tailpipe emissions make the greatest impact on air quality. Exhaust tends to accumulate around localized hotspots such as transit bus depots and railroad stations. Therefore, this study focused on air pollution from transit vehicles' tailpipe emissions.

Table 2 describes the four pollutants subject to U.S. EPA motor vehicle emissions standards – particulate matter (PM), oxides of nitrogen (NO_X), hydrocarbons (HC), and carbon monoxide (CO) – and their environmental and health effects. The table shows that PM exhaust can be toxic and that NO_X and NMHC can form ground level ozone, a principal component of smog. Because of high concentrations of soot, ozone, and smog in many urban areas, these emissions are of primary concern. Diesel vehicles are not a major source of CO.

Table 2: Regulated Pollutants in Diesel Exhaust and their Health and Environmental Effects

Pollutant	Source	Description	Environmental and Health Effects
Particulate Matter (PM)	Product of fuel or lubricating oil combustion	Tiny carbon particles (soot or smoke) with sometimes-toxic organic compounds attached	PM can affect respiratory health and carry toxic substances into the lungs and bloodstream. PM finer than 10 microns in diameter (PM10) is absorbed by the lungs causing lung damage. The core carbon of PM may not be the primary culprit of adverse health effects. Instead, compounds, when bonded to the tiniest carbon particulates, penetrate deep into the lungs and are suspected of triggering a cascade of effects in many body systems.
Oxides of Nitrogen (NO_X)	Reactions between oxygen and nitrogen in the engine's combustion chamber	Gases including NO (nitric oxide) and NO_2 (nitrogen dioxide). As emitted directly from the tailpipe, NOx consists mainly of nitric oxide (NO) (90% NO + 10% NO_2) although vehicles equipped with certain types of aftertreatment systems can emit as much as 35% nitrogen dioxide NO_2).	NO_2 is an oxidizing gas, which in concentrations higher than 0.2 ppm, irritates and damages lung tissue. NO_2 also combines with water to form nitric acid, which is damaging to plants. NO_2 is a precursor in the formation of ground level ozone (O_3) and smog and contributes to global warming. NO is non-toxic and does not promote the formation of ozone. However, NO is rapidly converted to NO_2 in the atmosphere.
Hydrocarbons (HC) and Non-Methane Hydrocarbons (NMHC)	Unburned or partially burned fuel, fuel spills	Hydrocarbons contain both reactive species, called volatile organic compounds, and non-reactive species, such as methane.	Hydrocarbons are ozone precursors. In the presence of sunlight, reactive hydrocarbons react with NO_2 in the atmosphere to produce ozone. Methane, the principal HC constituent in CNG engine exhaust, while not photochemically reactive, is a powerful greenhouse gas.
Carbon monoxide (CO)	Incomplete combustion of carbon-containing fuels	Highly toxic gas	CO is hazardous in high concentrations because it binds with hemoglobin in the blood, impairing its ability to transport oxygen to the brain and other vital organs.

Source: Environmental Protection Agency, http://www.epa.gov/otaq/invntory/overview/pollutants/index.htm.

Diesel Exhaust Emissions Standards

With respect to regulated engine emissions, today's diesel transit buses are the cleanest in history, and they will become increasingly cleaner through 2010. A timeline of urban bus emissions standards appears in Table 3. The standards are given in grams per brake-horsepower-hour (g/bhp-hr), a measure of how much of the pollutant is emitted during an hour of operation against a one-horsepower load. The table clearly shows the dramatic reduction in PM, NO_X, and NMHC emission rate limits for urban buses since the early 1990s. In 2006, the combined NO_X and NMHC limit is 60 percent lower than in 1991, and the PM limit is over 90 percent less. CO standards have not changed since 1985, but heavy-duty vehicles are not a major source of this pollutant.

Table 3. Federal emissions standards for transit bus engines (g/bhp-hr)

Model Year	PM	NO_X	NMHC	CO	NMHC+NO_X
1974-1978	-	-	-	40	16
1979-1984	-	-	1.5	25	10
1985-1987	-	10.7	1.3	15.5	-
1988-1989	0.60	10.7	1.3	15.5	-
1990	0.60	6.0	1.3	15.5	-
1991-1992	0.25	5.0	1.3	15.5	-
1993	0.10	5.0	1.3	15.5	-
1994-1995	0.07	5.0	1.3	15.5	-
1996-1997	0.05	5.0	1.3	15.5	-
1998-2004	0.05	4.0	1.3	15.5	-
2004-2007 (option 1)	0.05	-	1.3	15.5	2.4
2004-2007 (option 2)	0.05	-	0.5	15.5	2.5
2007-2010 + (phased in)	0.01	0.20	0.14	15.5	-

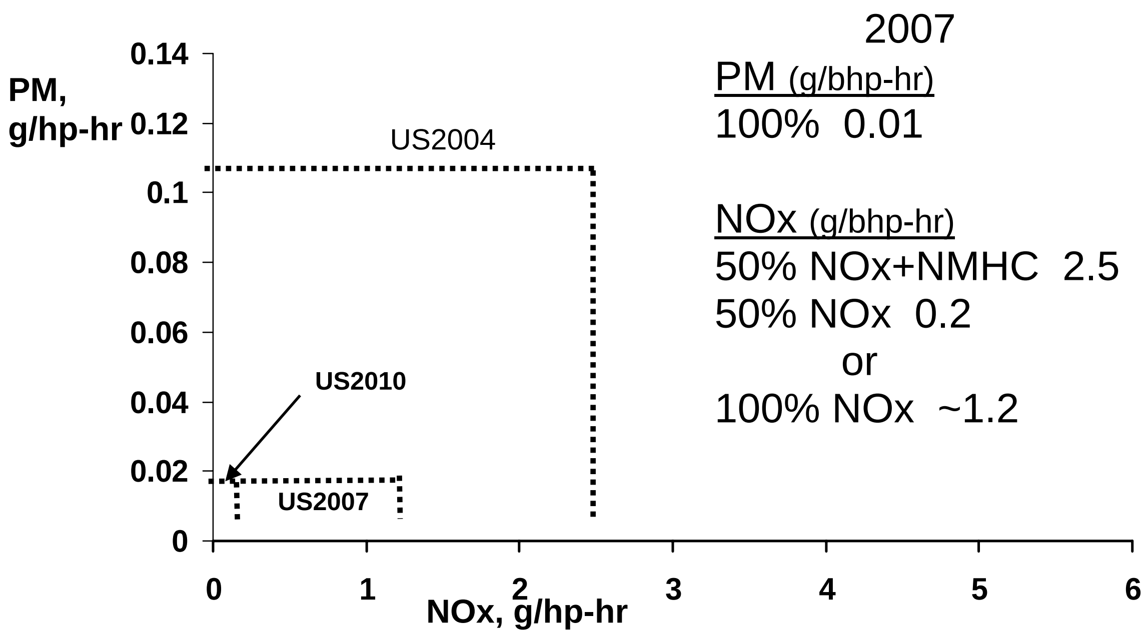
Source: Environmental Protection Agency, Heavy Trucks, Buses, and Engines website, http://www.epa.gov/otaq/hd-hwy.htm and related links.

Emissions standards continue to tighten. New bus engine standards will take effect in the 2007 model year, with 80 to 89 percent reductions in PM and NMHC emission limits and similar reductions for NO_X. Nearly all manufacturers will choose to meet NO_X standard incrementally – first by meeting an interim standard in 2007 and then by meeting the full standard by 2010. (Otherwise, the rule requires 50 percent of engine sales to meet the full standard in 2007.) The PM emission standard takes full effect in 2007, but the NMHC standard will phase in between 2007 and 2009 (50 percent of sales each year).[5]

The reduction in emission limits for PM and NO in 2007 and 2010 is shown graphically in the EPA chart in Figure 4.

[5] Manufacturers can choose to meet an interim NO_X standard of approximately 1.2 g/bhp-hr during the phase-in period, and all surveyed by EPA in 2004 planned to do so. Thus, the 1.2 g/bhp-hr limit is referred to in this report as the 2007 NO_X standard and 0.2 g/bhp-hr limit as the 2010 NO_X standard. Source: EPA 2005 Manufacturer Guidance Letter CCD-05-06, "Averaging Calculations for Model Year 2007 Through 2009 Heavy-duty Highway Diesel Engines", March 17, 2005, http://www.epa.gov/otaq/cert/dearmfr/ccd0506.pdf

Figure 4. EPA PM and NOx Emission Standards for 2007 (Averaging) and 2010 (Final) – g/bhp-hr



Source: Byron Bunker, presentation, “US EPA Heavy-Duty 2007 Emission Regulations.” Environmental Protection Agency, Washington, DC. May 2006.

Table 4. Federal emissions standards for diesel rail and marine vehicles – g/bhp-hr[6],[7]

Category	Duty cycle	NMHC	CO	NO_X	NO_X + NMHC	PM
Locomotive Tier 0: Original manufacture 1973-2001	Line haul	1.00	5.0	9.5	-	0.60
	Switch	2.10	8.0	14.0	-	0.72
Locomotive Tier 1: Original manufacture 2002-2004	Line haul	0.55	2.2	7.4	-	0.45
	Switch	1.20	2.5	11.0	-	0.54
Locomotive Tier 2: Original manufacture 2005 and later	Line haul	0.30	1.5	5.5	-	0.20
	Switch	0.60	2.4	8.1	-	0.24
Marine Category 1: Engine size less than 5 Liters/cylinder[8]		-	3.73	-	5.37-5.60	0.149-0.299
Marine Category 2: Engine size less than 30 Liters/cylinder		-	3.73	-	5.82-8.21	0.373
Marine Category 3: Engine size at least 30 Liters/cylinder		-	-	7.31-12.7	-	-
Non-road diesel engines (applies to rail multiple diesel units), Tier 1-3		1.0	2.6-6.0	6.9	3.0-7.8	0.15-0.75

[6] U.S. EPA, Regulatory Announcement: Final Emissions Standards for Locomotives. 1997.
[7] U.S. EPA, Regulatory Update: Overview of EPA's Emission Standards for Marine Engines. 2004
[8] Calculated from standards set in g/kWh using 1 kWh = 1.34 bhp-hr.

Current transit rail vehicles and ferryboats must meet far less stringent emissions standards than today's buses. They must meet one of three sets of emissions standards: locomotive (e.g., commuter rail), marine (e.g., ferryboats), or non-road diesel (e.g., self-powered diesel rail vehicles). Rail and marine vehicle emissions standards are listed in Table 4. Compared to 2010 bus standards, NO_X emission rate limits are 4 to 15 times higher; PM limits are 15 to 60 times higher, and NMHC limits are 2 to 15 times higher.

Rail and marine transit vehicles may soon be subject to tight emissions standards modeled after the heavy-duty bus standards. In 2008, Tier 4 standards take effect, requiring up to 90 percent reductions in PM and NO_X for nonroad diesels. These standards will be phased in through 2015. EPA is considering tightened standards for new marine and locomotive engine emissions. The new standards for NO_X and PM could be introduced as early as 2011.

Emissions from Alternative Fuels

Below is a summary of heavy-duty bus emissions, focusing on PM, NO_X, and NMHC emissions (heavy-duty vehicles are not a major source of CO). Each fuel has its own emissions profile, which is described in detail. Most alternative fuels have lower emissions than today's diesels but must achieve significant reductions to meet 2010 emissions standards. Other alternative fuels offer zero or near-zero emissions performance today.

Although this section focuses on emissions that may cause air pollution, it is important to point out that alternative fuels are less likely to have the same environmental impact on soil or water as diesel fuel in the event of a spill or leak of fuel, such as could occur in the area surrounding a transit fueling or maintenance facility. Spills of diesel fuel and Fischer-Tropsch diesel can contaminate soil and groundwater because they are not biodegradable. In contrast, most liquid alternative fuels, including methanol, ethanol, and biodiesel, are biodegradable over a short period of time (several months). Liquefied fuels like propane, natural gas, and hydrogen, vaporize quickly when released but present explosive hazards unless promptly vented.

Ultra-low Sulfur Diesel: As Table 3 shows, EPA has tightened PM, NO_X, and NMHC diesel bus emissions standards dramatically in recent years. Simultaneously, EPA reduced the allowable sulfur content of diesel fuel, most recently for highway vehicles to 15 parts per million (called ultra-low sulfur diesel or ULSD). Engine manufacturers and suppliers have developed highly effective emission controls that require ULSD. The new fuels and emission controls are sometimes referred to by industry as clean diesel technology controls or emissions controlled diesel.

In model year 2006, seven EPA-certified diesel urban bus engine models are available. On average, they produce 0.026 grams per brake horsepower-hour (g/bhp-hr) PM, 2.36 g/bhp-hr NO_X, and 0.11 g/bhp-hr NMHC emissions.[9] These engines are equipped with emission control

[9] NO_X and NMHC emission values are estimated. EPA reports 2006 diesel bus NO_X and NMHC emission rates as a combined value with an average of 2.47 g/bhp-hr. This report assumes an average NMHC emission rate of 0.11 g/bhp-hr based on reported data from model year 2006 heavy-duty diesel engines certified for non-bus, on-road applications. The NO_X rate is simply the difference of the two, or 2.36 g/bhp-hr.

systems including engine modifications, electronic controls, charge air cooling, exhaust gas recirculation (EGR), particulate traps, and oxidation catalysts (OC). One engine is equipped with a catalyzed diesel particulate filter (DPF), described later in this section.

Alternative Diesel: The diesel bus engines described above can operate on certain alternative diesel and alternative diesel blends. Four such fuels – oxygenated diesel, B20, B100, and Fischer-Tropsch diesel – can be used in existing diesel engines with few or no modifications.

- *Oxygenated diesel*: The California Air Resources Board (CARB) certifies that use of O_2Diesel™, a petroleum diesel blend that contains 15 percent ethanol, reduces the PM emission rate by 20 percent, the NO_X rate by 1.6 percent, and the NMHC rate by 25 percent compared to the diesel baseline.

- *B20 (20% Biodiesel)*: EPA estimates that use of B20 results in a 10.1 % decrease in the PM emission rate, a 2.0 percent increase in the NO_X rate, and a 21.1 percent reduction in the NMHC rate compared to the diesel baseline.

- *B100 (100% Biodiesel)*: EPA estimates that use of pure biodiesel results in a 47 percent reduction in the PM emission rate, a 10 percent increase in the NO_X rate, and a 67 percent reduction in the NMHC rate compared to the diesel baseline.

- *Fischer-Tropsch diesel*: The National Renewable Energy Laboratory (NREL) estimates that use of Fischer-Tropsch diesel fuel results in an 11 percent reduction in the PM emission rate, a 6 to 20 percent reduction in the NO_X rate, and a 22 percent reduction in the NMHC rate compared to the diesel baseline.

Ethanol: No EPA-certified ethanol transit bus engines are available in the 2006 model year, and no transit agencies today operate ethanol vehicles. When ethanol engines were available in the 1990s, they offered about the same PM emission rate as diesels and a 25% lower NO_X rate. In 1996 NREL emission tests, NMHC rates were 3.4 to 4.7 times as high as similar diesel bus engines at that time. If an ethanol bus engine were manufactured today and equipped with modern emission controls, it would probably achieve the same emission rates relative to today's diesel baseline.

Methanol: No EPA-certified methanol transit bus engine is available in the 2006 model year, and no transit agencies currently operate methanol vehicles. When methanol engines were available in the 1990s, they offered about the same PM emission rate as diesels and a 50% lower NO_X rate. In 1996 NREL emission tests, NMHC rates were highly variable, but the newest bus engines performed about as well as similar diesels. If a methanol bus engine were manufactured today and equipped with modern emission controls, it would probably achieve the same emission rates relative to today's diesel baseline.

Propane: No EPA-certified propane transit bus engine is available in the 2006 model year, but one medium heavy-duty diesel engine, the Cummins B Gas Plus LPG, is certified for other uses.[10] This engine is used today only for mid-size and smaller transit buses. The engine is equipped with a relatively simple emission control system including engine modifications, electronic controls, and oxidation catalysts. It is certified at a 62 percent lower PM emission rate, a 50 percent lower NO_X rate, and a 3.5 times higher NMHC rate than the diesel baseline. Further emissions reductions are expected for propane engines with today's emission controls.

Compressed Natural Gas: In model year 2006, three EPA-certified natural gas urban bus engine models are available. These engines are equipped with relatively simple emission control systems, including engine modifications, electronic controls, oxidation catalysts, and oxygen sensors. On average, they are certified at a 77 percent lower PM emission rate, a 47 percent lower NO_X rate, and an 18 percent higher NMHC rate than the diesel baseline.[11] Further emissions reductions could be achieved with more sophisticated emission controls. To meet 2010 standards, natural gas engine manufacturers expect to use cooled exhaust gas recirculation or other charge dilution technology, similar to the expected 2007 diesel NO_X emission controls.

Liquefied Natural Gas: Liquefied natural gas is vaporized before it enters the engine, so LNG combustion is indistinguishable from CNG combustion. Thus LNG buses have the same emissions characteristics as CNG buses.

Hydrogen: Hydrogen can power two types of bus engines: internal combustion engine (ICE) or fuel cell. Exhaust from a hydrogen fuel cell engine contains only water vapor. A hydrogen ICE produces trace amounts of PM and NMHC emissions from engine oil ingestion. Hydrogen ICEs can be tuned for very low NO_X emission rates.

Electricity: Electric buses, including battery-electric and trolley buses powered by overhead catenary wires, have no tailpipe emissions.

Alternative Fuel Conclusions

The emissions data presented in this section were used to estimate average PM, NOx, and NMHC emission rates for each alternative fuel. Table 5 below shows the estimated emission rates in grams per brake horsepower-hour.[12] In the table, emission rates that meet 2007 or 2010 heavy-duty diesel emissions standards are in boldface. Each alternative fuel reviewed in this study offers some combination of emissions benefits compared to the 2007 and 2010 EPA emission standards for diesel technology.

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[10] Six other engines are certified on the heavy-duty gasoline engine cycle, but gasoline engines and similar engines were not considered in this study.

[11] An average NMHC emission rate of 0.11 g/bhp-hr is estimated based on reported data from model year 2006 heavy-duty diesel engines certified for non-bus, on-road applications; this was used to estimate the NO_X rate from the given NO_X + NMHC rate.

[12] For any emissions reductions presented as a range of percentages, the midpoint was used to calculate a single rate.

Table 5. Comparison of bus engine emissions with 2007-2010 EPA emissions standards. (Levels meeting or exceeding 2010 standards shown in italics).

Fuel	PM (g/bhp-hr)	NO_X (g/bhp-hr)	NMHC (g/bhp-hr)
2007-2010 EPA Standards	*0.01*	*0.2*	*0.14*
Current diesel (baseline)	0.026	2.36	*0.11*
O_2Diesel™	0.021	2.32	*0.083*
B20	0.023	2.41	*0.087*
B100	0.014	2.60	*0.036*
Fischer-Tropsch	0.023	2.15	*0.086*
Ethanol	0.026	1.77	0.45
Methanol	0.026	1.18	*0.11*
Propane	*0.01*	1.18	0.5
CNG	*0.006*	1.24	*0.13*
LNG	*0.006*	1.24	*0.13*
Hydrogen ICE	*Trace*	*Low*	*Trace*
Hydrogen Fuel Cell	*0*	*0*	*0*
Electricity	*0*	*0*	*0*

Source: EPA engine certification data, available at www.epa.gov/otaq/certdata.htm

Fuels such as CNG and LNG nearly meet 2007 diesel bus emission standards for all three pollutants (CO was not considered). Engines burning these fuels use less sophisticated emission controls than today's cleanest diesel engines. Methanol and propane meet the standards for two out of three pollutants. Clean diesel and alternative diesel meet only the NMHC standards, so more effective emission controls are required for the 2007 model year and beyond. Hydrogen and electricity offer zero or near-zero tailpipe emissions.

With the new EPA regulations, all heavy-duty bus engines must soon meet the same standards. These standards are so stringent that they require improved emission control strategies for every diesel and alternative fuel engine except for those using hydrogen and electricity. Engine manufacturers have announced that they will continue to offer dedicated alternative fuel bus engines, like CNG, LNG, and propane, that offer lower emissions of PM and NOx compared to diesel engines. For instance, manufacturers are planning to offer CNG bus engines in the 2007 model year that meet 2010 NOx standards three years early. Model year 2006 CNG, LNG, and propane emissions are already below the 2010 standards for PM and NMHC.

Manufacturers have also indicated that, in 2010, engines designed for alternative fuels will offer further NO_x emissions reductions, so they will "beat" the 2010 NOx standards by an unspecified amount. The exact emissions benefits of alternative fuels compared to 2010 and later diesels will remain uncertain until 2010 engines are certified. Alternative fuels might even offer reduced emission rates of PM and NOx compared to diesels, just as they do today. For instance, CNG test engines equipped with exhaust gas recirculation have demonstrated emissions below the 2010 EPA standards.[13]

The mix of diesel and alternative fuel bus engines to be offered by major heavy-duty engine manufacturers in 2010 and beyond is not known precisely. Key engine manufacturers have indicated that they plan to produce diesel and natural gas bus engines in 2010 and beyond. Also, it is very likely that electric drive motors will be available in production quantities. However, it is unclear whether other dedicated alternative fuel bus engines (such as propane, ethanol, and methanol) will be mass produced.

Alternative diesels are compatible with the new emission control devices on 2007 and later diesel engines. Thus, alternative fuels like Fischer-Tropsch, biodiesel, and diesel blends, because of their cleaner burning properties, will likely continue to offer reduced emissions compared to petroleum diesel. The exact emissions benefits will not be known until the new engines are tested with these fuels. Still, emission reductions on a percentage basis compared to the diesel baseline are not expected to change significantly even as the diesel baseline becomes much cleaner.

To meet the 2007 NO_X and PM standards, new diesel engines will be equipped with new emission controls enabled by the recent availability of ULSD fuel. To control NO_X emissions, manufacturers will use a number of design features that include high-flow, cooled EGR plus combustion, fuel injection system, and control system upgrades. To meet PM standards, manufacturers will equip all bus engines with diesel particulate filters. To meet 2010 NO_X standards, a number of aftertreatment devices are in development. These include NO_X adsorber catalysts and selective catalytic reduction.

Emission reduction technologies can be applied to many alternative fuels to achieve emission reductions below that of 2007 or 2010 diesels. However, the effect of the standards is to encourage manufacturers to produce engines with the same emissions regardless of fuel type. Today's CNG and propane buses are equipped with less effective emission controls because they can meet the standards without them; this pattern is likely to continue as there is little incentive for manufacturers to outperform the emissions standards. This phenomenon will be discussed more deeply in Section 2.

For locomotives, marine vessels, and other non-road transit vehicles, no alternative fuel engines are EPA certified for model year 2006 (EPA does not certify electric motors).[14] These engines have few if any diesel emission controls. The use of alternative fuels in these vehicles would have a greater impact on emissions levels than is shown for buses above, whose sophisticated emission controls reduce the gap between diesel and some alternative fuel emissions (e.g., CNG). Fuel cells and electricity have zero tailpipe emissions in any vehicle application.

[13] Southwest Research Institute, "Southwest Research Institute (SwRI) News: SwRI Develops low-emission natural gas truck engine." http://www.swri.org/9what/releases/2005/lowemis.htm.
[14] Marine vessel, locomotive, and non-road diesel emissions certification data are available at www.epa.gov/otaq/certdata.htm.

Toxic emissions: Diesel combustion tends to produce high rates of mobile source air toxics (MSAT). MSATs are toxic substances from vehicle exhaust or other mobile sources that are known or suspected to cause cancer or other serious health or environmental effects. EPA has identified diesel exhaust and diesel particulate matter as urban hazardous air pollutants. EPA has announced its intent to regulate gasoline fuel, vehicles, and gas cans to reduce MSATs starting in 2010. EPA's exhaust emissions standards targeting NMHC and PM emissions and the 2006 ULSD fuel requirement were also intended to control MSATs.

These toxic substances may be contained in the fuel, formed during incomplete combustion, or formed in the atmosphere from other pollutants. Alternative fuels are inherently cleaner than conventional diesel because they do not contain toxics such as benzene. In addition, they are made of simpler chemical compounds which may yield lower levels of complex combustion by-products such as 1,3-butadiene.

Emission control devices like diesel particulate filters successfully reduce the emission rate of diesel PM and other substances, but no emission controls can completely eliminate the characteristics that make diesel exhaust and diesel PM two particularly hazardous urban air pollutants.[15]

Greenhouse gas emissions (GHG): Important greenhouse gases in transit vehicle exhaust include carbon dioxide and methane. Unlike toxic VOCs or regulated emissions, GHG emissions do not directly affect air quality; however, they are a cause of public concern because of their effect on climate and the potential consequences of global climate change. Relative to alternative fuels, diesel and clean diesel produce high levels of CO_2 tailpipe emissions. Methane is a major a component of natural gas vehicle exhaust. Methane traps about 21 times more heat per molecule than does CO_2. Even considering methane's potency, greenhouse gas emissions from natural gas buses in recent tests were lower than those from diesel.

Comparisons of "well-to-wheels" emissions of greenhouse gases and air pollutants depend upon the processes used in producing fuels or generating electricity and the emissions, if any, involved in delivering the fuel or power to end-use vehicles. Although the complexity of such analysis puts it beyond the scope of this study, "well-to-wheels" emissions and energy consumption are important conceptual considerations in choosing fuel sources for transit vehicles. For example, using the GREET modeling program developed and maintained by DOE's Argonne National Laboratory, the EPA's Office of Transportation and Air Quality estimates that replacing one gallon of petroleum diesel with biodiesel would reduce GHG emissions by 70%. Since very little petroleum is used for growing the feedstocks or producing biodiesel, the net reduction of oil consumption would be 92% for each gallon of diesel displaced, taking into account that biodiesel has about 90% of the energy of diesel from petroleum.[16] In contrast, the CO_2 generated in producing Fischer-Tropsch diesel from coal, unless sequestered, adds to total GHG emissions on a well-to-wheels basis.

[15] A complete list by fuel entitled "Master List of Compounds Emitted by Mobile Sources" is available at http://www.epa.gov/otaq/toxics.htm.
[16] Byron Bunker, Environmental Protection Agency, message, "Review of draft Report to Congress on increasing use of alternative fuels in transit vehicles," July 7, 2006.

Summary

Technologies soon to be common on 2007 and later model diesel buses reduce emissions of the four main criteria pollutants – NMHC, CO, NO_X, and PM – to levels consistent with today's most popular alternative fuel buses powered by CNG. To achieve this level of emissions performance, clean diesel buses must use a combination of sophisticated emission controls and ultra-low sulfur diesel known as clean diesel technology. Some buses running on alternative fuels with relatively simpler emission controls can meet the 2007 standards today. Buses, whether using diesel or alternative fuels, will require even more sophisticated emission control equipment to meet 2010 emissions standards.

Alternative fuel buses will continue to appeal to a number of transit agencies due to their relatively simpler exhaust treatment and potential for even greater emissions reductions. For instance, test CNG engines equipped with exhaust gas recirculation have demonstrated emissions far below the 2010 EPA standards.[17] Tailpipe emissions from hydrogen, electric, and fuel cell buses can be close to zero. Also, diesel exhaust contains relatively high amounts of mobile source air toxics, its lifecycle greenhouse gas emissions are the highest of any fuel considered, and it is more likely to cause harm to soil and groundwater if spilled or leaked than most alternative fuels.

For rail vehicles, locomotives, and ferries, alternative fuels offer more pronounced emission benefits compared to diesel. The diesel engines used in these vehicles have few if any emission controls, so their use of alternative fuels is likely to offer greater emission reductions than for buses. However, no alternative fuel engines (except electric motors) are available for these vehicles in 2006.[18]

[17] Southwest Research Institute. "Southwest Research Institute (SwRI) News: SwRI develops low-emission natural gas truck engine." http://www.swri.edu/9what/releases/2005/lowemis.htm

[18] News reports indicate alternative fuel technologies are being tested for locomotives and ships, but the technologies are not readily available in the marketplace. For examples, see www.sierrarailroad.com/powertrain/loc_emissision.pdf, www.acta.org/Releases/ November%202005%20Bd%20release.pdf, http://www.telegraph.co.uk/news/main.jhtml?xml=/news/2005/03/13/nboat13.xml&sSheet=/news/2005/03/13/ixhome.html

Why Use Is Growing

Various opportunities, already available to transit system operators, have encouraged the purchase of alternative fuels for transit vehicle operation.

Since the 1990s, transit system operators have purchased hundreds of alternative fuel vehicles and constructed related fueling and maintenance facilities. For example, APTA data show that the portion of the national transit bus fleet using alternative fuels increased from 3.8% in FY 1995 to 13.8% in FY 2003. During fiscal years 2001-2004, FTA awarded grants for purchase of 4,894 alternative fuel buses (including 2,859 CNG buses), 2,849 gasoline buses and 15,094 diesel buses. An FTA-funded study of the viability of the bus market found that production by domestic manufacturers of alternative-fuel and hybrid-electric 40-foot buses rose from 759 in 2000 to 1,018 in 2004, as shown in Table 6.

Table 6. Number of 40-ft Buses Produced Annually by Five Domestic Manufacturers (2000-2004)

	Calendar Year				
	2000	**2001**	**2002**	**2003**	**2004**
Diesel	2,705	2,578	2,020	2,451	1,749
CNG	693	1,229	583	317	528
LNG	61	210	4	23	52
Hybrid	5	2	15	9	438
Total	5,465	6,021	4,624	4,803	4,771

Source: APTA Fact Book, 2006

Reasons for considering alternative fuels most frequently mentioned in industry and government publications include:

- Complying with Federal air quality regulations in non-attainment or maintenance areas;
- Reducing tailpipe emissions of particulate matter and toxic gases;
- Voluntarily adopting clean fuel buses by state, regional, or local governments and public transportation agencies in an effort to improve local air quality;
- Improving public perception of transit to attract new riders;
- Utilizing Federal or state legislation offering higher levels of financial assistance for purchase of clean fuel buses;
- Favorable public response to new rail systems (New Starts), powered by clean and relatively inexpensive electricity;
- Recent price increases in oil used to produce diesel fuels, relative to the prices of electricity and alternative fuels made from agricultural commodities;
- Reducing dependence on foreign oil by substituting domestically produced renewable fuels, such as biodiesel and ethanol, or natural gas;
- Promotion by industry groups advocating specific fuels, such as natural gas and biodiesel; and,

- Achieving state and local priorities, such as increasing use of fuels derived from local sources (e.g., corn or soybean crops or natural gas production).

In 2005, NAVC reported, in its analysis for FTA of electric-drive technologies, that emissions reduction was the primary driver for transit agencies who have adopted electric-drive bus technology as an alternative to conventional diesel, as is the case for adoption of other diesel alternatives like CNG, LNG or biodiesel. The increase in oil prices since 2005 has heightened the importance of enhanced fuel economy offered by hybrid electric drives that capture and regenerate braking energy in stop-and-go city traffic.

The decision to choose alternative fuel vehicles is most often made at the upper levels of management in each agency or by their elected or appointed board of directors. In 2002, the NREL interviewed several high-level managers to determine their reasons for choosing natural gas. The most common reason given was environmental concern, not just compliance with regulations such as those of the South Coast Air Quality Management District in California.

Federal and State Grant Programs

A variety of Federal and State programs can provide funds for investing in and using alternative fuel vehicles. Some programs reduce capital or operating costs of alterative fuels relative to diesel through subsidies or tax incentives; others make targeted funds available for alternative fuel vehicles and facilities.

An up-to-date source of information on Federal and state programs can be found at DOE's Clean Cities website: www.eere.energy.gov/cleancities. A searchable database on the site allows transit agencies to find Federal, State, and local opportunities for which they may qualify.

FTA Grant Programs: Current laws authorize the U.S. Department of Transportation (DOT) to award grants to public transportation agencies for transit systems, vehicles and equipment. The FTA administers a number of programs that allow for the purchase of transit vehicles. These include:

- Urbanized Area Formula Grants;
- Formula Grants for Other than Urbanized Areas;
- Clean Fuels Grants;
- Capital Investment Grants:
    - Major Capital Investment Grants (New Starts),
    - Capital Investment Grants less than $75,000,000 (Small Starts),
    - Fixed Guideway[19] Modernization, and
    - Buses and Bus-Related Facilities and Equipment;

[19] The term "fixed guideway" means a public transportation facility that uses and occupies a separate right-of-way or rail for the exclusive use of public transportation and other high-occupancy vehicles, or uses a fixed catenary system and a right-of-way usable by other forms of transportation (49 USC 5302(a)(4)). These include light rail, rapid rail (heavy rail), commuter rail, automated fixed guideway systems (such as a "people mover"), and busway/high occupancy vehicle (HOV) facilities. See http://www.fta.dot.gov/17861_17880_ENG_HTML.htm.

- Formula Grants for Special Needs of Elderly Individuals and Individuals with Disabilities;
- Job Access and Reverse Commute Formula Grants;
- New Freedom Program; and,
- Alternative Transportation in Parks and Public Lands;

FTA grants, in general, offer 80 percent Federal funding for capital expenses. This is increased to 90 percent for clean fuel or alternative fuel vehicle-related equipment needed to comply with the Clean Air Act (interpreted as 83 percent of the cost of an entire bus).

A 50 percent Federal share for operating expenses is available to formula grant recipients in rural and small urban areas. Capital Investment Grants for buses and bus-related facilities include funds for testing of new bus models, ferryboat projects and a competitive National Fuel Cell Bus Demonstration program intended to advance different fuel cell technologies, including hydrogen-fueled and methanol-powered liquid-fueled fuel cell technologies. Recipients must agree to share data and information gathered during the fuel cell program with other agencies.

Using formula-based programs (Urbanized Area Formula Grants, Formula Grants for Other than Urbanized Areas, Formula Grants for Special Needs of Elderly Individuals and Individuals with Disabilities, and Job Access and Reverse Commute Formula Grants) to acquire alternative fuel vehicles and equipment does not, however, increase the amount apportioned to a State or Urbanized Area. Because alternative fuel buses and facilities are typically more expensive than diesel, transit operators must decide if acquiring fewer buses with each year’s apportionment, thus retarding the replacement rate for aging buses, is worth the benefits of converting to clean fuels.

The FTA programs defray the extra costs of alternative fuels use in a few important ways. As indicated above, purchases of vehicles, fueling facilities and maintenance facilities for purposes of complying with the Clean Air Act are eligible for capital grants with a higher Federal share (90 percent for clean-fuel subsystems and equipment or 83 percent for complete clean-fuel buses, instead of the usual 80 percent Federal share). By statute, Clean Fuels Grant funding must be used for clean fuels buses, including hybrid-electric buses, recharging facilities and other facilities needed to accommodate clean fuel buses; not more than 25 percent may be used for clean diesel buses. The National Fuel Cell Bus Technology Development Program applies only to alternative fuels that are compatible with fuel cell engines.

The Clean Fuels Grant program and the National Fuel Cell Bus Technology Development Program offer the clearest incentives for alternative fuels. They both address capital costs, and the Fuel Cell program also addresses certain operating costs, technical issues, and institutional issues for fuel cell vehicles. The National Fuel Cell Bus Demonstration Program funding is limited to three recipients and offers a 50 percent Federal share. Although Section 5308 provides that only transit agencies located in nonattainment or maintenance areas as defined by the Clean Air Act are eligible for Clean Fuels Grants, the Congress may, as it did for FY 2006, earmark Clean Fuels funds for specific projects and make them eligible through a general provision in the appropriation law.

CMAQ and STP Grants: Two additional DOT programs provide states an opportunity to use Highway Trust Funds for transit as well as highway project funding. One is the Surface Transportation Program (STP), which can provide funds for capital costs in transit projects, plus transit research and development and technology transfer programs. The second program is the Congestion Mitigation and Air Quality Improvement Program (CMAQ), which can provide funding for emissions reduction projects and programs. The funds can be used for new and expanded public transit service. CMAQ funds cover capital costs for new transit facilities and new vehicle purchases plus operating costs. For both the STP and CMAQ programs, the Federal share is typically 80 percent.

CMAQ projects receive funding priority based on expected emissions reductions in CO, ozone precursors, and PM. As a result, installation of alternative refueling infrastructure and transit fleet conversions to cleaner fuels are popular CMAQ projects.

The CMAQ program has several limitations. CMAQ funds may be used only in air quality nonattainment and maintenance areas for ozone, CO, and PM. The funds may be applied to clean diesel as well as alternative fuels if an emissions reduction can be expected. There is little incentive for alternative fuels that do not reduce PM, NOx, HC, and CO emission rates. Funds may be applied to transit projects only if a resulting increase in transit ridership can reasonably be expected. Operating cost subsidies are limited to new transit service and expire after three years.

EPA Grant Programs: The U.S. Environmental Protection Agency (EPA) funds most alternative fuel activities through its diesel emissions reduction program, the Clean Diesel Campaign. This program, expanded by the Energy Policy Act of 2005 (2005 EPAct)), provides grants and low-cost loans for technologies that significantly reduce emissions on buses, marine engines, locomotives, and other vehicles and engines. Technologies must be an EPA-certified engine configuration, verified technology, or emerging technology. Up to 10 percent of the funds may be used for emerging technologies. The Clean Diesel Campaign provides 30 percent of its funding to state-administered emissions reduction programs.

The program provides some incentives for using alternative fuels that offer emissions reductions over diesel. Like the CMAQ program, EPA makes its funding decisions based on expected emissions reductions, and clean diesel is eligible. EPA, however, considers a broader range of pollutants than CMAQ does, including mobile source air toxins, thus favoring programs involving substitution of alternative fuels for diesel.

The EPA program, unlike the DOT programs, is not focused on transit and is subject to budgetary constraints. Although the 2005 EPAct authorized $200 million for this program for each of the years 2007 through 2011, the President's FY 2007 Budget request could accommodate only $50 million.

DOE Grant Programs: The U.S. Department of Energy (DOE) provides grants to the states through the State Energy Program (SEP) to design and carry out their own renewable energy and energy efficiency programs. Two goals of the program are to develop alternative and renewable energy resources and to reduce the nation's reliance on imported oil. SEP funding to the states includes both grants and DOE's Office of Energy Efficiency and Renewable Energy program funding to deploy emerging renewable energy and energy efficiency technologies, which are called Special Projects. DOE's Clean Cities Program has awarded states funding for hundreds of Special Projects. SEP has been used to fund alternative fuel transit vehicles, refueling stations, and other costs, in places such as Tucson, AZ, and elsewhere.[20]

Clean Cities also administers the Advanced Vehicle Demonstrations and Pilot Program. A transit agency may compete for one of thirty grants authorized under the 2005 EPAct, which may be used for alternative fuel vehicles, including fuel cell vehicles, ULSD vehicles, fueling infrastructure, and operation and maintenance costs. A total of $200 million is authorized for this program.[21]

Both the SEP and the advanced vehicle program offer some incentives for alternative fuels. Funding from both projects can be applied to vehicles, fueling infrastructure, and operations and maintenance, all of which are costly for most alternative fuels. Both programs may also apply funds to clean diesel projects, and neither program is transit focused. The SEP program is limited to 30 recipients and requires a 50 percent local cost share.

State and Local Grant Programs

State and local funding sources often provide funding for the local share in the Federal grant programs described above. They provide funding for projects that do not qualify for Federal support or exceed the formula allocations, and help offset transit operating costs not covered by fare revenues. Hundreds of state and local programs can be found by searching the database located at DOE's Clean Cities website, www.eere.energy.gov/cleancities.The two largest state programs, in California and Texas, address both capital and operating costs.

Carl Moyer Memorial Program: California's Carl Moyer Memorial Air Quality Standards Attainment Program was the first successful statewide diesel emission reduction grant program. Since 1998, more than $150 million in awards have been granted to California-based recipients in the public and private sectors. Moyer Program funds can be used for heavy-duty vehicle and equipment replacement, re-powering, or retrofits with low NMHC, PM, or NO_X technology. Transit buses, marine vessels, and locomotives are among the vehicles and equipment eligible for funding. State funds can be used to cover two-thirds of project costs and may be used for capital costs only. Local matching funds may be used for operating costs.

The program creates incentives for use of alternative fuels with PM, NO_X, and NMHC emission rates that are lower than diesel. From 1998 to 2002, the Moyer program funded a large number of transit bus projects, most of which specified alternative fuels. The program also funded a number of non-road vehicles like locomotives and ferries; most grants were used for low-emission diesel engines.

[20] www.eere.energy.gov/cleancities/ccn/pdfs/afn3-4.pdf
[21] www.eere.energy.gov/cleancities/

However, the program does not specifically focus on alternative fuels or transit vehicles; heavy duty vehicles like trucks may apply. Funding may be applied to clean diesel as well as alternative fuels projects. Since eligible projects are subject to a cost-effectiveness threshold for NO_X reductions, program terms may favor clean diesel rather than more effective but more expensive technologies – especially as diesel engines using ultra-low sulfur diesel become available. Because project costs must include some capital expense, use of alternative diesel in existing engines is not eligible. Though state funds can be used for capital improvements to vehicles, only matching funds can be applied to fuel purchases. Moyer funds may not be used for parts and labor costs incurred during routine maintenance.

Texas Emissions Reduction Plan: The Texas Emissions Reduction Plan (TERP) is the other large state grant program focused on reducing emissions below current diesel levels. Since 2001, TERP has awarded more than $120 million in grants for diesel retrofits, re-powering, and equipment replacement. Through its Emissions Reduction Incentives Grant Program, TERP funds the purchase, lease, retrofit, replacement, or re-powering of equipment and vehicles (which must emit 25 percent less NO_X than the ones they replace) and the installation of refueling and electrification infrastructure. TERP funds cover 50 percent of infrastructure capital costs and up to 80 percent of incremental capital costs of vehicle replacement.

Like the California Carl Moyer program, TERP offers incentives for low-emissions technology and has funded a number of alternative fuel transit projects. It provides funds for refueling infrastructure, which can be costly for some alternative fuels, and for electrification. TERP has no transit or alternative fuels focus, and clean diesel projects are eligible. No operating expenses are eligible for TERP funding.[22]

Tax Incentives

Purchases of fuel, including alternative fuels, are subject to State and Federal excise taxes. While transit agencies are not required to pay excise taxes or income taxes, they can indirectly benefit when reduced capital and operating costs are passed along by suppliers eligible to use the tax credits.

Motor Vehicle and Infrastructure Tax Credits: The Energy Policy Act of 2005 initiated the New Qualified Fuel Cell Motor Vehicle Credit and the New Qualified Alternative Fuel Motor Vehicle Credit. The latter applies to vehicles operating on CNG, LNG, propane, hydrogen and blends of at least 85 percent methanol. For typical transit vehicles, the fuel cell credit is equal to $40,000. The alternative fuel credit is equal to 50 or 80 percent of the vehicle's incremental cost (up to $40,000), depending on its emissions certification. The alternative fuels credit is available until December 31, 2014, while the fuel cell credit expires December 31, 2010. There is a similar credit for hybrid vehicles, the New Qualified Hybrid Motor Vehicle Credit, which offers a substantial fuel economy and conservation tax credit for hybrid electric vehicles effective through 2010. An important provision allows organizations that do not pay taxes to pass the credit on to the vehicle seller, thereby reducing the purchase price. Typical transit vehicles qualify for a tax credit for incremental vehicle costs of up to $30,000, far less than the

[22] www.tceq.state.tx.us/implementation/air/terp/index.html

typical price premium for a hybrid electric transit bus. The credit will phase out after a manufacturer has sold 60,000 qualified vehicles.

Another credit, the Alternative Fuels Infrastructure Tax Credit, applies to the fueling equipment for alternative fuels, including natural gas, propane, hydrogen, blends of at least 85 percent ethanol, and petroleum diesel blends containing at least 20 percent biodiesel. The credit is equal to 30 percent of the cost of alternative refueling property, up to $30,000 for business property. It expires December 31, 2009 or December 31, 2014, if the property relates to hydrogen.

These credits offer subsidies for the purchase of alternative fuel technology, and each includes a clause allowing a non-tax-paying entity (such as a transit agency) to benefit from the credit by passing it on to vehicle seller to negotiate a reduced purchase price. However, the incentive these credits provide to transit agencies is limited because they cover only a portion of the cost premium for alternative fuel vehicles or the cost of alternative fuel infrastructure.

Fuel Producer Tax Credits: These tax credits are available to the producers of alternative fuels. They are designed to lower the costs of some alternative fuels relative to diesel.

SAFETEA-LU established the Volumetric Excise Tax Credit for Alternative Fuels. It applies to propane, P-series fuels, CNG, LNG, liquefied hydrogen, coal-derived Fischer-Tropsch fuels, and biomass fuels. The seller of these fuels is eligible for a tax credit equal to 50 cents for each gasoline gallon equivalent of alternative fuel sold (a quantity that contains the same energy as a gallon of gasoline). For mixtures of alternative fuels with petroleum fuels, only the portion of the mixture that is alternative fuel is counted when calculating the credit.

The 2005 EPAct extended tax credits for biodiesel fuels through 2008. Sellers of biodiesel are eligible for a credit of $.51 per gallon of ethanol at 190 proof or greater, $1.00 per gallon of agri-biodiesel, and $.50 per gallon of waste-grease biodiesel. If the fuel is used in a mixture, the credit amounts to $.01 per percentage point of ethanol, agri-biodiesel or waste-grease biodiesel used. Special tax credits are available to small producers.

The 2005 EPAct also established the Volumetric Ethanol Excise Tax Credit, which provides ethanol blenders and retailers with $.51 per pure gallon of ethanol blended or $.51 per percentage of ethanol blended (e.g., E10 is eligible for $.051/gal; E85 is eligible for $.4335/gal). Special tax credits are available to small producers (less than 60,000 gallons annually) of agri-biodiesel and ethanol. This incentive is available until 2010.

The ethanol and biodiesel tax credits reduce the prices of these fuels for all consumers, including transit agencies. However, the prices have remained higher than those for diesel, except during diesel price spikes such as those that occurred following Hurricane Katrina in September, 2005. Because the new alternative fuel tax credit is not yet available to producers, its effect on fuel prices relative to diesel is not yet known.

Non-Financial Incentives

Incentives that do not provide funding to transit agencies can still promote using alternative fuels through a variety of mechanisms. Some Federal and state initiatives aim to increase the use of alternative fuels through emissions reduction credits, technical assistance, fuel supply requirements, information sharing, and engine testing. These help mitigate barriers categorized in this report as technical challenges and institutional barriers.

Clean Air Act Amendments of 1990: The Clean Air Act Amendments of 1990 established standards and procedures for reducing human and environmental exposure to a range of pollutants generated by industry and transportation. If a state contains one or more Nonattainment Areas (defined by the Clean Air Act), the state must develop a State Implementation Plan (SIP) that outlines how air quality standards will be achieved within a given time frame. Programs that reduce emissions from diesel transit vehicles can provide states with credits toward required SIP emissions reductions. This requirement encourages alternative fuel transit projects and other initiatives that offer predictable and quantifiable emissions results.

Renewable Fuel Standard: The 2005 EPAct established a Renewable Fuel Standard (RFS) that requires a small percentage of the U.S. fuel supply to be renewable domestic fuels, including ethanol and biodiesel. The standard helps support the increase in biodiesel production described in **Section 2**. The RFS production target starts at 4 billion gallons in 2006 and increases to 7.5 billion gallons in 2012. This helps ensure a reliable supply of fuel, which is a mission-critical concern for transit operators.

Clean Cities Initiative: The mission of the U.S. Department of Energy's Clean Cities Initiative is to advance the Nation's economic, environmental, and energy security by supporting local decisions to adopt practices that contribute to the reduction of petroleum consumption. Clean Cities provides assistance through its participation in State Energy Program grants, as described above; coordination of technical assistance projects; maintenance of databases; web sites; and publication of fact sheets, newsletters, and related technical materials. The program helps supply transit officials with the information they need to invest in alternative fuels with confidence.

Emission Reduction Credit Trading Programs: Under an emission reduction credit trading program, fleet operators can earn mobile source emission reduction credits (MERC) for reducing emissions beyond what is required by pre-existing regulations. These are not the same as SIP credits discussed above. At least 14 states have adopted programs that allow fleet owners to sell their MERCs to stationary sources (such as power plants) who must meet NO_X emission offset requirements. The revenue generated from the sale of these valuable credits can be an incentive for use of clean-burning alternative fuels.

CARB On-Road Fleet Rules: The California Air Resources Board (CARB) regulates two types of transit vehicles: transit fleet vehicles and urban transit buses. Transit fleet vehicles are on-road, heavy-duty vehicles such as commuter coaches that are not urban transit buses. Both types of vehicles are subject to NO_X and PM emissions standards.

Urban transit buses statewide must conform to one of two sets of requirements: the alternative fuel path or the diesel fuel path. Transit agencies that choose the alternative fuel path must specify alternative fuel buses with certified PM emissions for 85 percent of their bus purchases and/or leases. They must also maintain a fleet with low average NO_X and PM emissions. Transit agencies that choose the diesel fuel path must purchase buses that meet stringent NO_X and PM emission standards. They must maintain a fleet with low average NO_X and PM emissions, but they must meet the PM standards two years earlier than agencies on the alternative fuel path. This provides an incentive for agencies to choose the alternative fuels path.

Biodiesel Engine Testing Program: Section 757 of the EPAct of 2005 authorizes a Biodiesel Engine Testing Program. It directs DOE to work with engine manufacturers and fuel injection manufacturers to test biodiesel in advanced diesel fuel engines, determine impacts of different biodiesel blendstocks, and study the emissions and warranty impacts of different blendstocks. The 2005 EPAct authorizes $5 million each year for this activity from 2006-2010. However, Congress has appropriated no money to carry out this program. If funded, it could collect needed biodiesel engine durability data and lead to better fuel stability specifications and other standards for biodiesel and biodiesel blends, reducing the size of current barriers to greater use of a potentially attractive fuel. The Biobased Transportation Research program authorized by Section 5201(m) of SAFETEA-LU is expected to address some of these issues.

Summary

In addition to State and local initiatives adopting alternative fuel vehicles, there are a variety of Federal and State programs that provide funds or other incentives for doing so.

Barriers Facing Alternative Fuels

Every alternative fuel reviewed in this study imposes some increased capital costs, operating costs, technical challenges, or institutional issues as compared to diesel fuel. Barriers inhibiting greater use of alternative fuels in public transportation vehicles include:

- Higher capital costs of alternative fuel vehicles and supporting facilities, especially natural gas facilities and electrification of routes for trolley buses or commuter rail lines;
- Higher costs of the fuels themselves;
- Higher operating costs for maintaining vehicles and equipment;
- Unproven reliability and durability of early production models of new alternative fuel vehicles that could affect transit service dependability;
- Limited availability of new alternative fuels;
- Risk of interruptions in fuel delivery;
- The need to develop and adopt product standards for alternative fuel performance and stability comparable to those used in specifying diesel fuel quality;
- Higher logistics costs of adding a duplicative inventory of components and spare parts peculiar to the alternative fuel vehicles;
- Costs of developing new operating and maintenance procedures for safe handling alternative fuels; and,
- Costs of conducting special training for mechanics and drivers.

Capital costs that can be higher for fleets of vehicles using alternative fuels than for diesel fleets include costs of the vehicles themselves, fueling facilities, storage tanks, and maintenance facilities.

Higher operating costs than for diesel vehicles can be those for fuel purchase and fleet maintenance. There may also be additional costs of special training for employees to work with alternative fuels and maintain alternative fuel vehicles and supporting systems.

Risks include reliability concerns, performance issues, safety codes, standards, and institutional issues affecting the design or equipment changes necessary to acquire and operate an alternative fleet.

One way to determine the barriers to using alternative fuels in transit is to analyze the experience of transit operators who have overcome barriers in adopting alternative fuels. Three U.S. Government surveys and one focus group have examined this topic in the recent past. They are the main source of the information presented in this section. Although all four studies were focused on buses, many of the conclusions are applicable to other types of transit vehicles.

Sources for This Section
In 1996, the National Renewable Energy Laboratory (NREL) published results from a program studying the performance, reliability, costs, and emissions of alternative fuel buses versus conventional diesel buses. The program involved collected data from eight transit agencies operating a total of more than 100 buses running on CNG, LNG, ethanol, methanol, and biodiesel. In 1999, the General Accounting Office (GAO) interviewed twelve transit operators with experience using alternatively fueled transit buses. In 2002 and 2003, NREL published comments of transit agency representatives and others on their experiences with alternative fuels. The comments were collected from an eight-member focus group and 53 questionnaire respondents. Finally, in 2005 the Northeast Advanced Vehicle Consortium (NAVC) interviewed 28 transit bus industry representatives including 11 transit operators.

Capital Costs

For alternative fuels, unique capital costs include alternative-fuel vehicles, maintenance facility modifications, and fueling infrastructure. The NREL survey found that capital costs are driven by bus, fueling, and maintenance facility costs. Vehicles, infrastructure, facilities, and other capital costs vary greatly from fuel to fuel. Diesel and certain alternative diesel fuels and blends are the only fuels that require no capital investment to modify vehicles or facilities.

Vehicle costs: For full-size, 40-foot transit buses, vehicle costs range from about $300,000 for a diesel bus to more than $1 million for a hydrogen fuel cell bus or a trolley bus. Buses powered by liquid fuels, such as ethanol, methanol, propane, and even LNG, have more modest price premiums over diesel buses than do electric vehicles or those using gaseous fuels like CNG and hydrogen. Generally, alternative fuel buses produced as demonstration prototypes or in limited production quantities are much more costly than diesel buses.

FTA requires that transit operators operate large transit buses purchased with Federal funds for at least 12 years or 500,000 miles. As transit agencies rely upon demographic and service-based formula grant assistance for fleet replacement, the capital funding yielded by the formula often limits the frequency of vehicle replacement, even for large agencies. The gradual accumulation of fleet replacement funds and FTA financial penalties for early retirement make it difficult to move quickly in replacing diesel buses with alternative fuel buses. Limited funds can also preclude transit agencies from paying more for cleaner technologies.

Fueling facility costs: The costs of fueling and maintenance facilities vary widely from fuel to fuel. Alternative diesel fuels require no upgrades to existing diesel fueling facilities. Costs to upgrade fueling facilities are lowest for liquid fuels like ethanol and methanol and highest for gaseous fuels like CNG and hydrogen.

Electrically-Powered Buses and Trolley Buses: Battery-electric vehicles require expensive charging units, and trolley buses, like electric rail vehicles, require expensive overhead electrical wires and a power distribution system.

The trolley bus is an anomaly in the transit program because the overhead catenary power line for the rubber-tired electric trolley buses is defined in law as a “fixed guideway.” A transit agency may use its formula funds to replace trolley buses or extend trolley bus service to a new area. For any medium or small urbanized area considering trolley buses for the first time, however, apportioned formula funds are likely to be insufficient for design and construction of the electric power distribution system. A project requesting discretionary funding for new or extended trolley bus electrification is defined in law as a new Capital Investment, which subjects it to a highly competitive process that militates against most urban areas even proposing new trolley bus service.

Maintenance facility costs: Maintenance facility requirements are dictated by maintenance requirements and safety considerations. Most alternative fuels, except for alternative diesels and electricity, require safety upgrades because their vapors form a combustible mixture with air, and steps must be taken to avoid a fire or explosion. This includes upgrading electrical wiring and installing ventilation equipment and automatic leak detection devices. The cost varies widely with the type of fuel and the location of the facilities, but can range up to $1 million or more per facility.

Operating Costs

Operating costs unique to alternative fuels include the fuel itself, replacement parts, personnel training, insurance, and maintenance of the vehicles and fueling infrastructure.

Fuel costs: NREL found that increased operating costs for alternative fuels were largely due to fuel price premiums as compared to diesel. Table 7 below shows that fuel costs range from $0.17 to $0.51 per mile for electricity to $0.96 per mile for ethanol. Only electricity and natural gas vehicles are less expensive to fuel than diesel buses, which cost $0.64 per mile. Hydrogen is the most expensive of all the fuels considered.

The main reasons for the higher costs of alternative fuels are the higher cost of the fuel itself and lower fuel economy. Lower fuel economy is caused by lower energy density of the fuel, lower engine efficiency, and higher weight of most alternative fuel vehicles as compared to diesel buses. Most liquid alternative fuels have energy density that is 5 to 50 percent lower than diesel's. Ethanol and methanol have the lowest energy densities of these fuels, while alternative diesels have the highest.

Most of today's alternative fuel engines (except for alternative diesel, electric, and fuel cells) use spark ignition, which results in about 25 percent fuel economy penalty compared to pure compression ignition (diesels).

Vehicles operating on gaseous fuel must carry heavy, reinforced fuel tanks. For this reason, CNG buses weigh 3,000 to 3,900 pounds more than a diesel bus. Large battery electric buses are seldom used because their range is limited by the charge stored in the battery, and increasing the size of the battery imposes an adverse tradeoff between vehicle weight and range.

NREL found that weight was also a concern to transit agencies to because of Federal axle-weight limits on Interstate highways, although there is a temporary waiver for transit buses. This means that a heavier alternative fuel bus may be able to carry fewer passengers legally than a diesel.

Table 7. Estimated average transit fuel prices, fuel economy and cost per mile, February 2006[23]

Fuel	Fuel cost per unit[24]	Fuel Economy[25]	Fuel Cost per mile
Petroleum Diesel	$2.32 per gallon	3.64 mpg	$0.64
B20	$2.40 per gallon	3.55 mpg	$0.68
B100	$2.99 per gallon	3.26 mpg	$0.92
Fischer-Tropsch Diesel	$2.55 per gallon[26]	3.50 mpg	$0.73
Ethanol	$1.89 per gallon	1.96 mpg	$0.96
Methanol	$1.00 per gallon[27]	1.39 mpg[28]	$0.93
Propane	$1.84 per gallon	1.89 mpg	$0.99
CNG	$1.42 per therm	2.02 miles per therm	$0.71
LNG	$1.16 per gallon	1.64 mpg	$0.71
Electricity (battery electric buses)	$0.086 per kilowatt-hour[29]	0.51 miles per kilowatt-hour[30]	$0.17[31]
Catenary Electricity (trolley buses)	$0.086 per kilowatt-hour[23]	0.17 miles per kilowatt-hour[24]	$0.51
Hydrogen (November 2005)	$10.39 per kilogram[32]	3.05 miles per kilogram	$3.41

Vehicle maintenance costs: For all alternative fuels, maintenance costs are higher on a per-mile basis than fuel costs. Maintenance costs for alternative fuel transit buses are higher than for diesel buses because of the higher skill levels required to maintain them. Maintenance workers require additional training in technically complex equipment and in the extra safety precautions required. For example, working with CNG buses requires knowing which components are on the low-pressure side and which are on the high-pressure side, understanding the differences in tolerances and types of fittings required, and taking the proper precautions. Compressed gas cylinder inspections are required for buses using gaseous fuels like CNG, and working with cryogenic fuels like LNG and liquid hydrogen requires caution to avoid frostbite.

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[23] Fuel costs were adjusted to exclude Federal motor fuels excise taxes (which transit agencies do not pay), but they were not adjusted for state taxes. Fischer-Tropsch was calculated as 10 percent higher than petroleum diesel according to EPA guidance. Methanol cost is an early 2006 figure. A new alternative fuel producer tax credit contained in the 2005 energy legislation is expected to reduce the price of most alternative fuels besides ethanol, biodiesel, and electricity. The price of ultra-low sulfur diesel is expected to be 5 to 12 cents higher than petroleum diesel.
[24] Except as noted, U.S. Department of Energy, *Alternative Fuels Price Report, February 2006*, Table 1.
[25]Except as noted, TIAX 2003. (n.d.) Retrieved May 17, 2006 from http://www.eere.energy.gov/afdc/apps/toolkit/docs/mod09b_transitcost.xls.
[26] U.S. Environmental Protection Agency, "Clean Alternative Fuels: Fischer-Tropsch", factsheet EPA-420-F-00-036, March 2002.
[27] Dewitt & Co., Methanol and Derivatives, Issue 403, April 21, 2006.
[28] Transportation Research Board. *TCRP Report 38: Guidebook for Evaluating, Selecting, and Implementing Fuel Choices for Transit Bus Operators*. National Academy Press: Washington, DC, 1998.
[29] U.S. Energy Information Administration, Monthly Energy Review, March 2006, Table 9.9.
[30] American Public Transportation Association, 2006 Public Transportation Factbook, Table 30.
[31] Battery electric buses tend to be smaller than the 40-foot size assumed for other buses and thus less costly to fuel.
[32] November 2005 hydrogen costs from NREL report on preliminary evaluation of fuel cell testing at Santa Clara Valley Transportation Authority and San Mateo County Transit District.

Diesel has the lowest maintenance costs, along with alternative diesel and electricity. The variation in maintenance costs, on both a percentage and absolute basis, is smaller than that for fuel costs. The highest maintenance costs, those for methanol and ethanol vehicles, are estimated to be about $0.30 per mile higher than for diesels.

No fuel considered in this study has lower maintenance costs than diesel. As noted earlier, alternative fuels are generally cleaner burning than diesel, a characteristic that usually means fewer engine deposits and less engine wear. However, alternative fuel engines use unique, relatively expensive (because of low production volume) parts that tend to drive up maintenance costs. Electric-drive buses have fewer drive train and transmission maintenance requirements but may require costly battery replacements. Maintenance costs vary widely for electric drive buses, but this report assumes that they are equivalent to diesel costs on average. Hydrogen buses have not been produced in sufficient numbers to determine maintenance costs, but requirements are similar to CNG for hydrogen internal combustion engines.

In 2007 and beyond, diesel engine maintenance requirements are expected to increase because of increasingly complex emissions control technologies. Maintenance costs of some alternative fuel engines, on the other hand, may be expected to decline as the engines become more proven and parts become more common.

Non-vehicle maintenance costs: The major non-vehicle maintenance expense associated with alternative fuels is that for the fueling infrastructure. A typical diesel fueling facility requires $5,800 to $8,200 in maintenance per year. Alternative fuels like ethanol, methanol, and propane are similar or slightly higher. CNG, LNG, and hydrogen fueling facility maintenance costs are much higher than diesel’s, at about $8,000 to almost $60,000 per year.

Other operating costs: Dispensing gaseous fuels like CNG and hydrogen requires a compressor that can be expensive to maintain. Using alternative fuels safely requires additional training for operators, maintenance personnel, and emergency responders, and this can be a significant expense as well.

Technical Challenges

Technical challenges are defined as problems that affect the functionality of the vehicle, such as durability, reliability, and performance issues.

Early adopter issues: For transit agencies, the challenges associated with being an early adopter of a new technology are significant. Early adopters of alternative fuel buses have reported durability and reliability problems, difficulty finding parts and qualified technicians, and performance problems. As some alternative fuel technologies move toward full commercialization, manufacturers are able to resolve these issues.

Reduced durability or reliability: When transit agencies reported to NREL in 1996 that their alternative fueled buses were less reliable than conventional diesel buses, in many cases NREL found the issues to be relatively minor or easily correctable with better training and maintenance practices. Operators surveyed by GAO for its 1999 report found more reliability issues, including engine and fuel system failures, in alternative fuel buses than in diesel buses, but some recent evidence suggests that reliability of late-model CNG buses and B20 buses is comparable to that of diesel buses.

Insufficient data has been gathered to assess the durability of alternative fuel buses compared to conventional diesel buses over the 12-year, 500,000-mile lifespan expected for heavy-duty transit buses.

Reduced performance: If the alternative fuel buses cannot meet the performance requirements of the transit agency, they will not be used. For example, in the 1999 GAO survey, transit operators indicated that battery-electric buses suffered from reduced performance and range compared with those of conventional diesel buses. On the other hand, superior hill-climbing performance was a major factor in San Francisco's 2006 decision to purchase diesel-electric hybrid buses instead of those powered by CNG.[33]

Institutional Issues

Institutional issues are problems created by or relevant to the concerns of internal or external organizations, agencies, or individuals.

Technical capability of transit workforce: As indicated above under the discussion of relative maintenance costs, operating, servicing and maintaining alternative fuel vehicles generally require higher skill levels than for traditional diesel buses. Recruiting and training the transit workforce to cope with high-tech requirements of modern diesel buses is a major concern of transit agencies that becomes even more challenging for alternative fuel buses.

Reduced environmental advantage as diesel emissions improve: GAO's results showed that because diesel bus emissions have become significantly cleaner, some transit agencies no longer find alternative fuels to be cost-effective in reducing emissions. In fact, agencies can retrofit existing diesel buses with exhaust treatment devices to achieve low emissions levels for only a few thousand dollars per vehicle. While retrofit kits cost much less than new vehicles, durability in transit operations is unknown. EPA offers a list of verified retrofit technologies on its website http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm.

Information: There is a general lack of easily compared, up-to-date data on alternative fuel vehicles' durability, costs, and emissions performance. Some small transit agencies do not have access to complete information about alternative fuel bus technologies, their benefits and drawbacks, and their maintenance and training requirements.

Safety concerns: Alternative fuels safety is a concern for anyone who operates, maintains, or rides the vehicles or who lives or works in communities where they operate. The 1999 GAO survey revealed safety concerns about all the alternative fuels, but those concerning ethanol and battery-electric were relatively minor. The major safety concern is fire; the vapors of most

[33] Bowman, Becky, "Muni cleans up its act: adding 56 hybrid buses: New diesel-electric coaches cut exhaust, boost fuel economy," San Francisco Chronicle, June 2, 2006.

alternative fuels, except alternative diesels, form a combustible mixture in air that can ignite or explode. Addressing safety concerns requires training, equipment, and building modifications compared to those required for conventional diesel. Table 8 below summarizes major safety concerns associated with specific fuels.

If a diesel bus is involved in an accident, it is generally not towed back to its base if it can still run and there is no sign of diesel fuel leaking. On the other hand, if a transit bus powered by natural gas is involved in an accident, the standard policy is to tow the involved vehicle back to its base so that it can be inspected for damage to the fuel supply system before being released for revenue service. This applies even if it can still run and there is no sign of a fuel leak because the damage may be hidden and the risks of fire or explosion are greater than for diesel.

Table 8. Safety concerns associated with alternative fuels[34]

Fuel	Type of storage	Safety concerns
Diesel	Liquid	• Vapors do not form a combustible or explosive mixture • Diesel fumes are considered unhealthful
Petroleum diesel blends		• Generally the same as diesel, above • Diesel blends containing ethanol pose some handling concerns due to flammability
B100	Liquid	• Possibility of spontaneous combustion in highly saturated Materials
Fischer-Tropsch diesel	Liquid	• No reported safety issues
Ethanol	Liquid	• No major concerns
Methanol	Liquid	• High toxicity (hazard from inhalation, ingestion, or skin contact) • Burns with an invisible flame
Propane	Compressed gas	• Fittings and plugs can become projectiles if opened inadvertently • Leaking propane may be a fire/explosion hazard
CNG	Compressed gas	• Fittings and plugs can be projectiles if opened inadvertently • Leaking gas may be a fire/explosion hazard
LNG	Cryogenic liquid	• Skin contact with leaking fuel can cause frostbite • Tank pressure can increase from ambient heat • Leaking gas may be a fire/explosion hazard
Hydrogen	Compressed gas	• Tendency to leak; leaks difficult to detect • Fittings and plugs can be projectiles if opened inadvertently • Leaking gas may be a fire/explosion hazard • Ignites easily and burns with a clear flame
Hydrogen	Cryogenic liquid	• Skin contact with leaking fuel can cause frostbite • Tank pressure can increase from ambient heat • Leaking gas may be a fire/explosion hazard • Burns with a clear flame
Electricity	Battery	• High-voltage electrocution hazards

[34] General Accounting Office. Mass Transit: Use of Alternative Fuels in Transit Buses. GAO/RCED-00-18. Washington, D.C. December 1999.

Codes and standards: Transit agencies rely on codes and standards to assure the public that their technology and practices are safe. While codes and standards are available for most alternative fuels, an incomplete set for hydrogen and alternative diesel fuels currently presents a barrier to their greater use in transit vehicles (see box).

Other Alternative Diesel Barriers

Alternative diesel fuel, including Fischer-Tropsch and certain diesel blends, such as B20, appears to be a promising choice for transit agencies because it does not require them to upgrade their vehicles, fueling facilities, or infrastructure. It could offer low fuel and maintenance costs (though supply is currently limited). A closer look at these fuels reveals some risks involved with using them.

Fischer-Tropsch diesel, ethanol/diesel blends, and B20 all lack industry-wide fuel specifications. A fuel specification must be written for each blend, which requires time and resources. Both Fischer-Tropsch and biodiesel are susceptible to oxidation. The B20 standard currently under development, ASTM D6761, lacks an oxidation stability specification. According to NREL, a lack of data on fuel stability, fuel stability test results, and engine deposit formation has been hindering the effort to develop this specification. The Engine Manufacturers Association recently released a test specification for B20.[35] The B100 standard, ASTM D 6751, "Standard Specification for Biodiesel Flue Blen Stock (B100) for Middle Distillate Fuels," was first published in 2003. There are insufficient data to determine whether various concentrations of biodiesel have higher or lower NO_X emissions compared to petroleum diesel.

The need for fuel standards for alternative diesels fuels is related to concerns over engine deposit formation seen in diesel engines running on biodiesel at higher concentrations.

The National Biodiesel Board website[36] contains detailed rebuttals to purported barriers to biodiesel.

Fuel availability: Service disruptions are major incidents for transit operators, so fuel availability is a mission-critical concern. Diesel, electricity, and natural gas are the most widely available transit fuels. Some alternative fuels, such as propane, are available from a sizeable network of distributors. Others, like LNG and hydrogen, are available from only a few suppliers. Availability of alternative diesels like biodiesel and Fischer-Tropsch is currently low, but fuel companies are investing heavily in new production facilities. For more information, please see box below, "Alternative Diesel Production and Availability." Until alternative fuels are available in reasonable proximity to the agency that will use them, they must be transported over longer distances, adding to the cost of delivery and raising the cost of operating the buses.

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[35] Engine Manufacturers Association, "Test Specifications for Biodiesel Fuel," May 31, 2006, http://www.enginemanufacturers.org/admin/library/upload/924.pdf
[36] http://www.biodiesel.org

Alternative Diesel Production and Availability

Biodiesel and Fischer-Tropsch diesel use are limited by low production volumes. However, production continues to ramp up. In 2005, on average 4,900 barrels of biodiesel were produced every day, up from about 1,600 per day 2004 and just 130 per day in 2000. Fifty-three plants in 26 states produce biodiesel, and 44 more in 24 states are under construction. Domestic biodiesel production capacity is currently 23,100 barrels per day and is expected to grow to 44,600 per day by the end of 2007.[37] This represents less than one percent of expected 2007 petroleum consumption by all transportation modes in the U.S.

Fischer-Tropsch is currently produced in limited quantity at a demonstration plant in Tulsa, OK, although an Alaskan facility has been proposed. Production facilities are currently located in countries with low-cost natural gas supplies, like Indonesia, Malaysia, and South Africa. Global production capacity is expected to increase to about 274,000 barrels per day in 2010 and about 838,000 barrels per day in 2015. This is equal to about one percent of world petroleum demand in 2005. This capacity increase is due to investments in new production facilities located in countries like Qatar and Nigeria.

Local fuel availability also limits the daily range or routes on which alternative fuel transit vehicles can be used. Alternative fuel transit buses cannot be used on extremely long transit routes that might require refueling if refueling cannot be done by a service truck as it is done for diesel fuel. In such circumstances, alternative fuel transit buses that run out of fuel must be towed back to their base for refueling. Buses using non-diesel alternative fuels cannot be used for emergency evacuations, such as moving hurricane victims to another state, unless appropriate alternative fueling stations are available en-route.

Engine availability: Engines that run on alternative fuels (other than electricity) must be EPA certified or qualify for precertification. No ethanol or methanol transit bus engines are EPA certified for the 2006 model year (primarily for lack of market demand). Only one propane engine, suitable for buses and shuttles smaller than the standard 40-foot city bus, is certified on the diesel engine cycle. Only three natural gas engines are available. This limited choice is a reflection of the current limited market for alternative fuel vehicles.

Price volatility: The price of motor fuels continues to fluctuate greatly. This makes evaluating the life cycle costs of alternative and diesel fuels difficult. Fuels that are domestically produced, such as biodiesel, or fuels that can be made from a variety of feedstocks, like Fischer-Tropsch diesel, biodiesel, and hydrogen, are somewhat insulated from these price fluctuations. Biofuels are also subject to the unrelated volatility of farm commodity prices, which are affected by weather and worldwide crop production. Price escalation can affect specific alternative fuels if unanticipated increases in demand, from sectors other than public transportation, result in price increases that make them very expensive compared to diesel. Transit agencies can insulate themselves from near-term price fluctuations and ensure availability by locking in fixed-price fuel contracts.

[37]The National Biodiesel Board, "Biodiesel Fact Sheets," http://www.biodiesel.org/resources/fuelfactsheets/

Summary

Capital costs, operating costs, technical challenges, and institutional issues vary widely from fuel to fuel. However, no fuel offers low barriers in each of the four categories, and none is a clearly dominant choice for transit agencies. Each fuel involves a trade-off among a number of variables and concerns.

Policy Options

SAFETEA-LU directs that the study consider the necessary levels and type of support necessary to encourage additional use of alternative fuels for transit vehicle operation and recommend regulatory and legislative alternatives that will result in the increased use of alternative fuels in transit vehicles.

This policy analysis focuses on three options as a basis for recommending regulatory and legislative alternatives: (1) Defer Action, (2) Mandate the Use of Alternative Fuels, and (3) Create Enhanced Incentive Programs.

In the U.S. market there remains a clear demarcation between buses carrying their own fuel and externally powered electric modes of public transportation. While there are several hundred electric trolley buses in use (Seattle, Boston, San Francisco), their numbers are not growing. And, while electric buses (carrying their own batteries) have been tested and used in specific areas, their numbers are not growing either. Further, while many commuter rail lines are electrified, many others are not, and the capital investment required for electrification of those lines, many of which are not owned by the transit agencies that operate commuter rail service on them, vastly exceeds FTA funds available for fixed guideway modernization. Thus, the discussion of alternative fuels for buses devolves to one surrounding on-board power generation.

The three policy options should be understood from the context that diesel fuel is viewed by some as inherently unhealthful, with both the fuel and its emissions being identified by EPA as carcinogenic. Thus, even significant advances in particulate matter or other emissions, such as will result from the 2007 emission standards for diesel transit buses, may not be sufficient to address local environmental and socio-political concerns. Also, there is the underlying fact that roughly half of the diesel used in heavy engines nationwide comes from imported oil, thus maintaining our dependency on other countries for our energy security. These circumstances are not easily quantified, but they maintain a steady pressure for public transportation and other municipal fleets to consider and adopt a range of alternative fuels.

Defer Action

The first policy option is to take no additional action now and allow existing incentive programs and the transit vehicle market to work together to create the appropriate mix of alternative fuel and diesel transit vehicles in the U.S. Diesel prices have more than doubled in the last two years, which would imply that this is the single most effective way of motivating increased alternative fuel use. However, increases in alternative fuel use occurred before the steep rise in diesel prices. And, given the proportional linkage between alternative fuel prices and the cost of their production inputs (i.e., petroleum fuel), the market may be too volatile to allow any original equipment manufacturer to make firm choices between alternative fuels and technologies.

This study found that electricity is already widely used in transportation (subways, commuter rail, light rail and trolley buses), and alternative fuels currently represent 18 percent of the fuels used in non-electric transit vehicles. The alternative fuels share is growing, and it is not unreasonable to assume that it will continue to grow in response to market forces such as recent oil price increases, current incentive programs, and local initiatives. We have been unable to determine the relative effects of existing incentives to engine manufacturers, incentives to fuel producers, and local social and political pressures on the growth in use of alternative fuels. It is apparent that many transit agencies are benefiting indirectly from manufacturers' cost savings[38], realized due to Federal and state incentives. However, it is equally apparent that decisions to shift from diesel to an alternative fuel are being made for more than economic reasons.

Thus, a "defer action" option could eventually lead to decreased use of alternative fuels as current incentives expire. This is primarily because we cannot predict at what point it becomes uneconomic for either a manufacturer or a fuel supplier to provide a product to the market. At some point, even the firmest State or local policy will be unable to motivate the market to produce alternative fuel technology if there seems to be no future for the market (as with methanol engines). The current incentives seem to work because there is an expectation of a "shaking out" of the technology, with certain technologies and fuels ultimately becoming "winners." It is at this point that manufacturers and suppliers expect to begin making life-cycle profits on their years of fuel and engine research and development. The Federal incentives provide the foundation for testing fuels and technologies, but without these incentives are State and local pressures and incentives enough?

First, a number of tax credits discussed in Section 3, including the New Qualified Fuel Cell Motor Vehicle Credit, the New Qualified Alternative Fuel Motor Vehicle Credit, and the Alternative Fuels Infrastructure Tax Credit, and fuel producer tax credits for biodiesel and ethanol, are set to expire in the 2008-2014 timeframe. These incentives have the effect of lowering the "entry price" of alternative fuel and technology for the producer or the user, or both. If the market for specific alternative fuels has not grown to the point of equalizing the price of the fuels with clean diesel by 2008 to 2014,[39] then capital and operating costs for alternative fuels will increase once more as incentives are discontinued, probably resulting in decreased use.

Another incentive for alternative fuels use is their emissions benefits compared to current 2006 diesel engines. As new emissions standards for buses take effect, the PM, NO_x, NMHC, and CO emission rates of diesel will approach or equal those of some alternative fuel engines like CNG, LNG, propane, methanol, and ethanol. These engines could offer emissions benefits comparable to clean diesel if equipped with the same emission controls, but it is not clear whether engine manufacturers will produce such engines – particularly since methanol and propane engines have been tried and discontinued in heavy bus use.

[38]As tax-exempt municipal entities (also exempt from motor fuel taxes), public transit agencies do not benefit directly from any of the tax incentives for alternative fuels. However, they may benefit indirectly as manufacturers and suppliers are able to provide less-than-market-efficient quantities of engines and fuels for start-up alternative fuel programs in specific cities.

[39]Because the "price" of the alternative fuel results from both the cost of the fuel and the capital cost required to use it, it may be that ultra-low sulfur diesel would retain a price advantage even when the cost of the fuel itself is greater than the cost of the alternative fuel. This has happened with natural gas, for example.

For these reasons, a “defer action” policy has the highest likelihood of achieving no results. The remaining uncertainty, however, is the level of demand for the alternative fuel use induced by State and local laws and regulations. For example, California has stringent air quality standards that affect what types of fuels and technologies may be purchased for public transportation in that State. Individual cities, such as Albuquerque, Phoenix, and Port Huron, Michigan, have opted to convert their entire fleets to a particular fuel and technology to achieve certain air quality and other operational benefits. They have undertaken these initiatives at a time (1995 through 2003) when the incremental cost of the fuel was 20% or more above diesel and the cost of the infrastructure and vehicles was at least 50% greater than for diesel buses. As the differences in costs between alternative fuel and diesel fleets diminish, State and local initiatives favoring alternative fuels could increase, but this is not likely to happen on any consistent or predictable basis. It would take multiple states, agreeing to a uniform policy, to have the market effect of a Federal incentive on alternative fuel use.

Mandate the Use of Alternative Fuels

A second policy option is to mandate the use of alternative fuels in all U.S. public transportation vehicles. This policy could be implemented in different ways: (1) require that all transit operators fuel their existing vehicles with compatible alternative fuels or alternative fuel blends, or (2) require that all new transit vehicle purchases be dedicated alternative fuel vehicles, or (3) both. The first choice would result in a more immediate increase in alternative fuel use (subject to fuel availability), than the second choice, which would depend upon the rate of vehicle replacement in the fleet and could take ten years or more to implement.

The National Biodiesel Board estimates current production capacity at about 350 million gallons per year. To convert the entire existing transit fleet to B-20 would require approximately 95 million gallons per year. Without considering transportation distance and geographic distribution of the biofuel, it would appear that such a mandate could be undertaken. However, the Energy Information Administration indicates that demand for biofuel nationwide, just as a 1% additive to diesel to enhance the lubricity of ultra-low sulfur diesel, would raise demand for biofuel to more than 470 million gallons per year.

This policy option offers more predictable and immediate effects than deferring action. Transit operators would likely respond to this requirement by fueling their diesel vehicles with alternative diesel, such as blends of petroleum diesel with biodiesel or ethanol, and Fischer-Tropsch diesel if it becomes available. For new vehicle purchases, they might choose any of the fuels reviewed in this study, recalling that methanol, LNG, and ethanol have already been tested and found to have significant drawbacks in use.[40]

This type of mandate has been applied to fleets operated by Federal government agencies. The Energy Policy Act of 1992 requires fleet operators to purchase alternative fuel or dual-fueled vehicles, and the Energy Policy Act of 2005 requires Federal fleets to use alternative fuels in dual-fuel vehicles. Another rule, contained in the Energy Policy Act of 2005, Section 111(c),

[40] New Flyer is currently marketing a gasoline-hybrid-electric bus, because the gasoline engine produces virtually no particulate matter emissions and the electric motor provides the torque necessary for urban bus applications, making this configuration fully competitive with a diesel bus.

requires use of energy efficient motor vehicles in the management of the National Parks and other public lands.

However, an alternative fuels mandate leaves many of the barriers discussed in Section 2 unaddressed. Associated with each alternative fuel reviewed in this study is a set of barriers to greater use including increased capital costs, operating costs, technical challenges, and institutional issues as compared with existing fuels. For instance, Fischer-Tropsch diesel is not widely available today. These barriers would undoubtedly lead to higher costs for transit agencies that could not be recovered through operational savings or other direct benefits to the transit operation.

The result could be an unintended decrease in the level of service for many transit agencies across the country if these issues are not addressed. This is especially true for small agencies that have limited access to technical expertise for complying successfully with such a requirement, and limited resources to afford the higher capital costs generally.

The public transportation sector has already faced significant mandates, including the Americans with Disabilities Act, the Clean Air Act and amendments, and a wide variety of safety and security requirements. Either a fuels or technology mandate may be difficult to implement without significant economic and political disruption, thus defeating the purpose of a mandate.

For these reasons, this policy has a higher risk of unintended consequences and is likely to incite political opposition.

Create New or Enhance Existing Incentive Programs

This policy involves neither maintaining the status quo nor mandating a change. This report presents barriers to increased use of alternative fuels and analyzed current incentive programs. There are significant hurdles in four categories – capital costs, operating costs, technical challenges, and institutional issues – and current programs offer only limited incentives for transit operators to use alternative fuels. In fact, recent hikes in petroleum-based fuel prices have had more effect on the affordability of alternative fuels than incentives.[41] Enhanced incentive programs would address these barriers by creating stronger incentives that would interact with market forces to increase the use of alternative fuels.

Stakeholders who participated in surveys and focus groups found in the literature - as well as interviews conducted for this study - stated that incentives were the preferred approach. No stakeholders advocated for the status quo or for new mandates. The time of these surveys and focus groups was from two to five years ago, prior to the recent spikes in motor fuels, and may not reflect the most current opinion.

[41]Natural gas was cheaper than diesel in transit use for the six months ending in March 2006, particularly in California. The capital cost of CNG buses has not declined much, however, and they remain at least $30,000 more expensive than a similar diesel bus.

A carefully designed policy along the lines of incentives and market mechanisms would have a higher likelihood of success than the first policy (Defer Action) and a lower likelihood of unintended consequences than the second (Mandate the Use of Alternative Fuels).

Stakeholders' Recommendations

As described above, the identified stakeholders preferred the third option: Create New or Enhanced Incentive Programs. Their comments address the ways in which such a policy could be crafted to achieve results while minimizing unintended consequences. Their recommendations address each of the barriers: capital costs, operating costs, technical challenges, and institutional issues. They can be summarized as: "Allow a higher Federal share for capital cost, provide flexibility to allow new technology to be incorporated, and allow greater flexibility in use of funds for operations as well as capital (similar to the CMAQ program[42])."

Sources

In 2002, the Transportation Research Board (TRB) of the National Research Council formed a committee of 16 experts representing various institutional perspectives in the transportation field. The committee formulated recommendations for increased effectiveness of the Congestion Mitigation and Air Quality Program (CMAQ), described in Section 3. Their recommendations are specific to CMAQ but can be easily applied to other initiatives.[43] In 2005, the Northeast Advanced Vehicle Consortium (NAVC) interviewed 28 transit industry representatives, including 11 transit operators, and held a widely attended meeting of transit industry stakeholders. It asked how policy could address the remaining barriers to greater hybrid electric transit vehicle deployment. Many of the responses are applicable to alternative fuels in transit.[44]

Capital Costs

As described earlier in this report, current grant programs and tax incentives address capital costs but provide only weak incentives for use of alternative fuels. Stakeholders suggested several changes to create stronger incentives for increased use of alternative fuels in public transportation vehicles. These included increasing the Federal share of new alternatively fueled buses to 90 or 95 percent (as compared with the current 83 percent for buses equipped to comply with the Clean Air Act or 80 percent for standard diesel buses), facilitating pooled procurements of new technology buses, and allowing full reimbursement of research and development costs to

[42]Under the Congestion Mitigation and Air Quality Program (CMAQ) a State may undertake an experimental project to achieve certain air quality attainment goals. The costs of such a project, including operating as well as capital costs, can be federally reimbursed for up to three years.
[43]National Research Council. *The Congestion Mitigation and Air Quality Improvement Program: Assessing 10 Years of Experience -- Special Report 264 Committee for the Evaluation of the Congestion Mitigation and Air Quality Improvement Program.* ISBN: 0-309-55021-1. 2002.
[44]Callaghan, Lisa and Sheila Lynch. *Analysis of Electric Drive Technologies for Transit Applications: Battery-Electric, Hybrid-Electric, and Fuel Cells.* Federal Transit Administration. Washington, D.C. Final Report. FTA- MA-26-7100-05.1. August 2005.

lower the subsequent production cost of the alternative fuel bus. This type of incentive has already been proposed for hybrids.

The total cost of manufacturing an alternatively fueled bus, which may exceed that of a standard diesel bus by 50% to 100%, would not be reduced by offering a larger Federal share. It would be reasonable to expect, however, that the effects of policies that increase demand for alternatively fueled vehicles will be partially offset by increases in the prices of these vehicles. Manufacturers might actually achieve economies of scale in production, but they would have no incentive to reduce prices of the new buses until a substantial proportion of demand had been met. This effect would be most pronounced in the short run.

The barrier associated with defining the catenary electrical power distribution for trolley buses as "fixed guideway" could be eliminated by a technical correction of 49 U.S.C. Section 5302(a)(4). Electric power for trolley buses could be defined as belonging instead to the category of "bus-related facilities" that does not require competition within the New Starts program for discretionary funding.

Operating Costs

Stakeholders have made a number of recommendations for incentive programs targeting the operating cost barriers associated with alternative fuels. These range from renewal of current producer and user tax credit programs that are due to expire in the next couple of years, to direct subsidies for alternative fuels in transit use, and Federal support for training programs in support of greater alternative fuels use.

Subsidies could treat fuels equally

As described above, some alternative fuels – Fischer-Tropsch diesel and some alternative diesel blends such as B20 – require zero or very little capital investment to vehicles but have somewhat higher operating costs than petroleum diesel. Other fuels offer low operating costs but high capital investment requirements.

Current incentive programs that cover only capital expenses, including FTA grants, favor fuels that require capital investments. To increase the use of alternative fuels that have low capital costs but possibly higher operating costs, Congress could make these programs more flexible – either capital or operating assistance. This would make the subsidies fuel-neutral rather than favoring some fuels over others.

Tax incentives favor both specific alternative fuels and vehicles and facilities using those fuels. Coordinating the expiration dates for tax incentives applying to specific alternative fuels, with consideration for current market conditions, could make them fuel-neutral as well.

Technical Challenges

The major recommendations for easing technical challenges pertain to early adopter issues. They include an accelerated depreciation "credit" that would allow a new technology vehicle to be replaced with Federal funds earlier than the normal 12-year cycle, or fund early upgrade or replacement of the power plant to incorporate new technologies. It was also suggested that a peer network would help smaller transit agencies and those less experienced with alternative fuels to enter the market and implement alternative fuel programs at lower risk and expense than pioneering "first adopters."

Institutional Issues

Stakeholders recommended programs to address institutional issues through a greater focus on education, training, and testing activities. Given that FTA already sponsors courses through the National Transit Institute, they suggested that a fuel-neutral course be developed to allow transit agencies to more confidently adopt new fuels and technologies. The peer exchange network was proposed in a different context, to provide an impartial source for operating and cost characteristics, possibly organized by FTA.

Stakeholders also suggested that alternatively fueled buses be tested particularly for durability and emissions, with OEMs sharing in the cost of such testing. This implies a prior testing phase to the currently required "new model" bus testing at Altoona. FTA is currently implementing a new requirement in SAFETEA-LU for brake testing and emission testing protocols. Another suggestion was a centralized database to allow comparisons of tested vehicles by fuel and technology.

Conclusion

A wide variety of incentives are proposed by diverse stakeholders, but with the exception of certain cost-sharing proposals there is no strong push for new financial incentives. Rather, the central theme of the proposals appears to be one of data gathering, providing impartial information, and reducing implementation risks through peer exchange networks. The market appears adequate – with the present level of Federal incentives for fuels and technologies – to the task of introducing and marketing alternative fuel buses for transit service, since there are over 10,000 non-diesel alternative fuel buses in service today. However, this does not answer the question of whether the cost of alternative fuel use in transit – taking into account vehicles, facilities, and the fuel itself – will decline to a point that is comparable to diesel, even at today's high prices. This could require implementation of alternative fuels beyond the urban bus market.

This report does not address a far larger market, upon which public transportation vehicles are almost entirely dependent: the heavy-duty truck market. Public transit buses represent less than 5 percent of the heavy duty engine market. Thus, while public transit agencies test new vehicles and fuels in transit service, unless those new fuel and engine technologies are adopted in the larger trucking market, manufacturers are unlikely to achieve significant economies of scale in the production of alternative fuel transit propulsion technologies.

Appendix: Alternative Fuels Study, Public Law 109-59, August 10, 2005

Section 3016 NATIONAL RESEARCH AND TECHNOLOGY PROGRAM
(c) ALTERNATIVE FUELS STUDY.—

(1) STUDY.—The Secretary shall conduct a study of the actions necessary to facilitate the purchase of increased volumes of alternative fuels (as defined in section 301 of the Energy Policy Act of 1992 (42 U.S.C 13211[45])) for use in public transit vehicles.

(2) SCOPE OF STUDY.—The study conducted under this subsection shall focus on the incentives necessary to increase the use of alternative fuels in public transit vehicles, including buses, fixed guideway vehicles, and ferries.

(3) CONTENTS.—The study shall consider—
   - (A) the environmental benefits of increased use of alternative fuels in transit vehicles;
   - (B) existing opportunities available to transit system operators that encourage the purchase of alternative fuels for transit vehicle operation;
   - (C) existing barriers to transit system operators that discourage the purchase of alternative fuels for transit vehicle operation, including situations where alternative fuels that do not require capital improvements to transit vehicles are disadvantaged over fuels that do require such improvements; and
   - (D) the necessary levels and type of support necessary to encourage additional use of alternative fuels for transit vehicle operation.

(4) RECOMMENDATIONS.—The study shall recommend regulatory and legislative alternatives that will result in the increased use of alternative fuels in transit vehicles.

(5) REPORT.—Not later than 1 year after the date of enactment of this Act, the Secretary shall submit to the Committee on Banking, Housing, and Urban Affairs of the Senate and the Committee on Transportation and Infrastructure of the House of Representatives a report containing the results of the study completed under this subsection.

[45] § 13211. Definitions
. . .(2) the term “alternative fuel” means methanol, denatured ethanol, and other alcohols; mixtures containing 85 percent or more (or such other percentage, but not less than 70 percent, as determined by the Secretary, by rule, to provide for requirements relating to cold start, safety, or vehicle functions) by volume of methanol, denatured ethanol, and other alcohols with gasoline or other fuels; natural gas, including liquid fuels domestically produced from natural gas; liquefied petroleum gas; hydrogen; coal-derived liquid fuels; fuels (other than alcohol) derived from biological materials; electricity (including electricity from solar energy); and any other fuel the Secretary determines, by rule, is substantially not petroleum and would yield substantial energy security benefits and substantial environmental benefits. . . .

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