Alternative Fuel Guidelines for Alternative Transportation Systems

January 2011

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The Department of Interior

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Acronyms and Definitions

AFDC	Alternative Fuels & Advanced Vehicles Data Center
AFV	Alternative fuel vehicles
ATS	Alternative transportation system
ATSM	American Society for Testing and Materials
BEV	Battery electric vehicle
BLM	Bureau of Land Management
B20	Blend of 20 percent biodiesel and 80 percent petroleum diesel
B100	Pure or neat diesel
CMSA	Consolidated metropolitan statistical area
CNG	Compressed natural gas
CO	Carbon monoxide, an odorless, colorless and toxic gas. CO contributes to the formation of ground-level ozone (smog), and can cause harmful effects on the cardiovascular and central nervous system.
CO_2	Carbon dioxide, a greenhouse gas that traps heat in the atmosphere and contributes to global climate change.
DOE	Department of Energy
DOI	Department of Interior
ECRA	Energy Conservation Reauthorization Act
EPA	Environmental Protection Agency
EPAct	Energy Policy Act
FAST	Federal Automotive Statistical Tool
FFV	Flexible fuel vehicle
FHWA	Federal Highway Administration
FLMA	Federal land management agency
FY	Fiscal year
FTA	Federal Transit Administration
GGE	Gasoline gallon equivalent
GHG	Greenhouse gases, i.e. gases that trap heat in the atmosphere. The primary greenhouse gases produced by the transportation sector are carbon dioxide, methane, nitrous oxide and hydrofluorocarbons.

GVWR	Gross vehicle weight rating
HC	Hydrocarbons, chemical compounds that contain hydrogen and carbon. Hydrocarbons include many toxic compounds that cause cancer and other adverse health effects.
HEV	Hybrid electric vehicle
kWh	Kilowatt-hour
ILUC	Indirect land use changes
LNG	Liquefied natural gas
LPG	Liquid petroleum gas
MSA	Metropolitan statistical area
NEPA	National Environmental Protection Act
NFPA	National Fire Protection Association
NGV	Natural gas vehicle
NO_x	Nitrogen Oxides, a group of highly reactive gasses that includes nitrogen dioxide, nitrous acid, and nitric acid. NO_x contribute to the formation of ground-level ozone, and can cause or worsen respiratory disease and aggravate existing heart disease.
NPS	National Park Service
NREL	National Renewable Energy Laboratory
OEM	Original equipment manufacturer
PM	Particulate matter, a complex mixture of extremely small particles and liquid droplets, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles. PM pollution can cause reduced visibility, acidify lakes and streams, as well as serious health problems, including adverse respiratory and cardiovascular effects.
PHEV	Plug-in hybrid electric vehicle
psi	Pound per square inch
RFS	Renewable fuel standard
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service

Introduction

Federal Land Management Agencies (FLMAs), including the U.S. Forest Service in the Department of Agriculture (USDA), and the Bureau of Land Management (BLM), Fish and Wildlife Service (FWS), and National Park Service (NPS), all in the Department of the Interior (DOI), are committed to the conservation and stewardship of the nation's public lands, and the cultural and natural resources within those lands. As part of this commitment, FLMAs continually strive to improve their environmental and energy performance. A key component of this goal is to reduce the petroleum consumption of FLMA transportation operations.

Using alternative transportation fuels to replace or reduce petroleum use is one method that FLMAs have instituted to help achieve their environmental stewardship and greenhouse gas (GHG) reduction goals. Alternative fuels are non-petroleum-based fuels derived from either renewable or fossil sources. Renewable alternative fuels include those derived from biomass, such as ethanol and biodiesel, while fossil-based alternative fuels include natural gas and propane. Alternative fuels can be used as a pure fuel or can be used in blends with conventional fuels (i.e. gasoline and diesel).

FLMAs have several reasons to consider using alternative fuels. Increased reliance on alternative fuels can help reduce U.S. dependence on foreign petroleum, and improve the health of the environment and the population by reducing emissions of harmful pollutants and GHGs. In addition, several pieces of federal legislation have encouraged or required agencies to increase use of alternative fuels.

FLMAs have been using alternative fuels for transportation for a number of years. However, the overall percentage of alternative fuel use as compared to petroleum remains low (see Figure 1 and 2).

Figure 1 : DOI and USDA fuel consumption, alternative fuel versus petroleum, 2000 to 2009.
Source: AFDC, Alternative Fuel Consumption by Agency, January 20, 2010

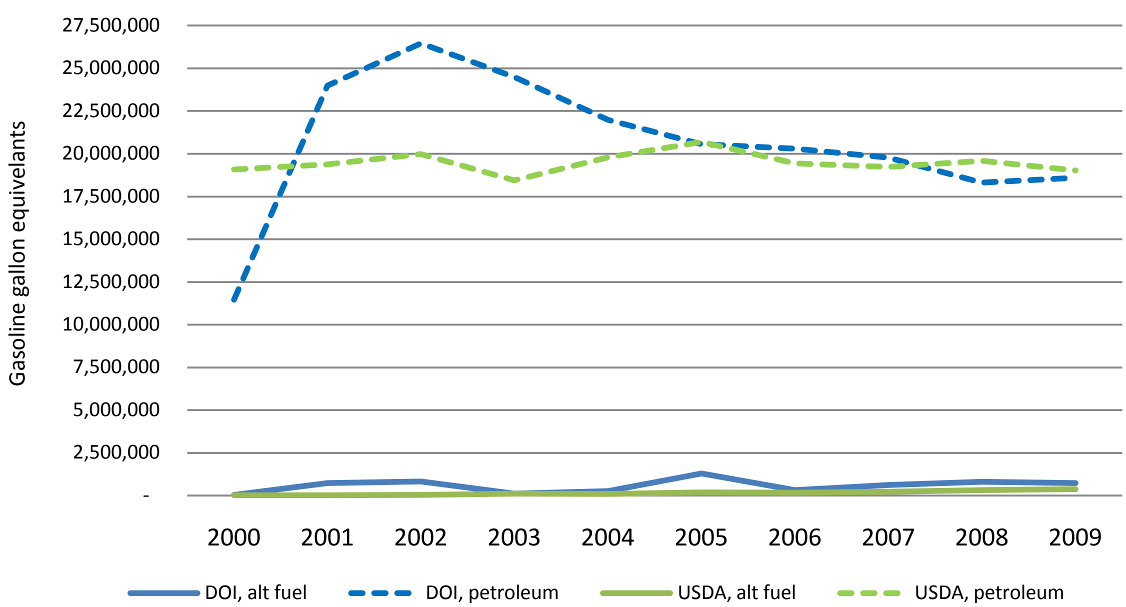
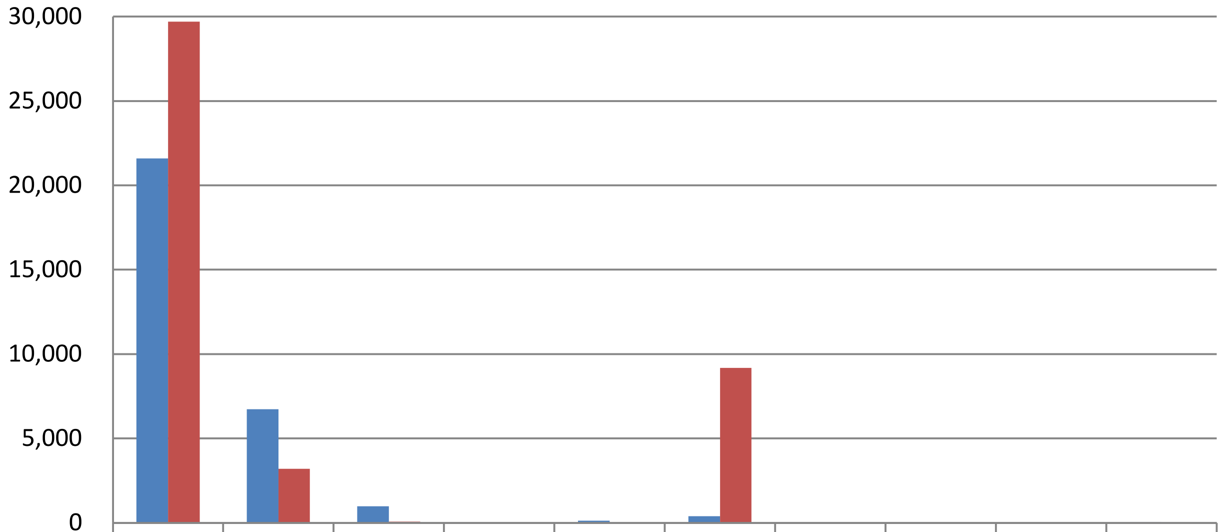


Figure 2: DOI and USDA vehicle inventory by fuel type, FY2009
Source: GAO, Federal Fleet Report, Fiscal Year 2009



	Gasoline	Diesel	Gasoline-Hybrid	Diesel-Hybrid	CNG	E85	Electric	Hydrogen	LNG	LPG
DOI	21594	6737	982	18	134	396	10	0	7	50
USDA	29711	3196	74	0	30	9188	0	0	0	17

While alternative fuels can create a number of benefits, they may not be feasible for all visitor transportation applications. A number of factors need to be evaluated as part of service and vehicle procurement planning to determine whether alternative fuel is a viable option. For example, although alternative fuels are available in a variety of large passenger vehicles, the range of vehicle types offered is still much more limited than conventionally-fueled vehicles. As a result, not all transportation services will be able to identify an available alternatively-fueled vehicle that meets its particular environmental and operating conditions. Another large factor in the ability to rely on alternative fuel is the availability and proximity of the fuel source. For those that do not have a usable fuel source nearby must carefully consider what it will take to install the proper fueling infrastructure to meet their needs. There are many elements to consider when building alternative fueling infrastructure, such as codes and standards, the right fueling appliances, safety standards, and employee training. Those that do go forward with constructing on-site facilities will need to conduct an environmental review as required by the National Environmental Policy Act (NEPA).

Purpose

This alternative fuels guide is intended to assist FLMAs with understanding when and how alternative fuels can be an effective part of visitor transportation plans and systems. The document provides information that will be useful to a variety of staff, including officials and superintendents who need to be informed on the basics of alternative fuels, staff and planners who develop alternative transportation systems and apply for project funding, and the maintenance staff who work directly with the fueling systems and vehicles.

The guide includes four primary sections:

- **Federal policy:** provides a summary of the key pieces of legislation designed to reduce U.S. dependence on imported petroleum by accelerating the use of alternative fuel by federal agencies.

- **Alternative fuels overview:** provides an overview of the following commercially available alternative fuels: biodiesel, ethanol, natural gas, propane, electricity, and hydrogen. The overview for each fuel includes information on fuel characteristics, available vehicle types, operational and maintenance issues, fuel costs, and environmental, health and safety considerations. This section also provides examples of alternative transportation systems on federal lands that use alternative fuels.
- **Decision process framework:** outlines the issues to considered when determining whether alternative fuels make sense in the context of a given transportation project.
- **Annotated bibliography:** an inventory of existing literature, including policy documents, operational assessments, and case studies on the use of alternative fuels.

Federal Policy

The following section highlights those key pieces of federal legislation and policies designed to reduce U.S. dependence on imported petroleum by accelerating the introduction of alternative fuel vehicles (AFVs) in federal government fleets.

- ***Energy Policy Act (EPAct) of 1992*** – requires that 75 percent of new light-duty vehicles acquired by certain federal fleets[1] must be AFVs. Compliance with the EPAct of 1992 is met by AFV acquisition credits, which are earned through the purchase of light-, medium- and heavy-duty AFVs, as well as operating these vehicles exclusively on alternative fuels. The following fuels are defined or designated as alternative fuels under the EPAct of 1992:
    - Methanol, denatured ethanol, and other alcohols;
    - Blends of 85 percent or more of methanol, denatured ethanol, and other alcohols with gasoline or other fuels;
    - Natural gas and liquid fuels domestically produced from natural gas;
    - Liquefied petroleum gas (propane);
    - Coal-derived liquid fuels;
    - Hydrogen;
    - Electricity;
    - Biodiesel (B100);
    - Fuels (other than alcohol) derived from biological materials;
    - P-Series fuels.

- ***Energy Conservation Reauthorization Act (ECRA)*** – amended the EPAct of 1992 to allow fleets to generate AFV acquisition credits for the use of fuel blends containing at least 20 percent biodiesel (B20) in medium- and heavy-duty vehicles.

- ***Energy Policy Act (EPAct) of 2005*** – requires federal fleets to use alternative fuels in dual-fuel vehicles unless the Secretary of Energy determines an agency qualifies for a waiver. Grounds for a waiver are 1) alternative fuel is not reasonably available to the fleet, and 2) the cost of alternative fuel is unreasonably more expensive than convention fuel.

- ***Executive Order 13423, Strengthening Federal Environmental, Energy, and Transportation Management (2007)*** – requires federal agencies with 20 vehicles or more in their U.S. fleet to decrease petroleum consumption by 2 percent per year, relative to their Fiscal Year (FY) 2005 baseline, through FY 2015, while increasing alternative fuel consumption by at least 10 percent annually (compared to an FY05 baseline). Also requires federal agencies to use plug-in hybrid electric vehicles (PHEVs) when commercially available at a cost reasonably comparable, on the basis of life-cycle cost, to non-PHEVs.

- ***Energy Independence and Security Act of 2007*** – requires federal agencies to develop executable plans to meet mandatory fuel consumption requirements and to report annually to the Department of Energy (DOE) on their progress towards meeting the goals laid out in this plan. DOE is currently completing rulemaking and developing guidance to assist agencies in complying with this requirement. This act also directs federal agencies to install

[1] EPAct requirements apply to fleets of 20 or more light duty vehicles that are centrally fueled or capable of being centrally fueled and are primarily operated in a metropolitan statistical area (MSA)/consolidated metropolitan statistical area (CMSA). Vehicles heavier than 8,500 pounds of gross vehicle weight rating (GVWR) or not located or operated primarily in a covered MSA or CMSA are exempt from these requirements.

at least one renewable fuel pump at fueling centers under their jurisdiction by January 1, 2010, and to provide annual reports on their progress in meeting this requirement.

- *Energy Improvement and Extension Act of 2008* – amended the EPAct of 1992 to classify four new vehicles as AFVs. These four new categories of vehicles are:
    - A new qualified fuel cell motor vehicle
    - A new advanced lean-burn engine technology motor vehicle
    - A new qualified hybrid motor vehicle
    - Any other type of vehicle that the Administrator of the Environmental Protection Agency (EPA) demonstrates to the Secretary of Energy would achieve a significant reduction in petroleum consumption.

Alternative Fuels Overview

The following section provides an overview of alternative fuels that FLMAs can utilize as part of their transportation systems. The overview includes information on the fuel characteristics, operational and maintenance issues, costs, and environmental, health and safety considerations. Examples of FLMAs currently deploying each alternative fuel are also highlighted.

The fuels addressed in this section are:

- Biodiesel
- Ethanol
- Natural gas
- Propane
- Electricity
- Hydrogen

Biodiesel

Biodiesel is a liquid fuel produced from renewable sources such as plant oils, animal fats, and recycled cooking oils. Biodiesel can be blended with petroleum diesel in any percentage to create a biodiesel blend. Blended biodiesel is denoted by the percentage of biodiesel it contains. For example, B20 contains 20 percent biodiesel and 80 percent petroleum diesel, while pure or neat diesel is known as B100.

Biodiesel blends of up to 20 percent volume can be used in any application that uses petroleum diesel. Blends over 20 percent require special handling and may require equipment modifications. Because the level of special care needed is high, the DOE's National Renewable Energy Laboratory (NREL) does not recommend the use of high-level biodiesel blends, except where human exposure to diesel particulate matter (PM) is elevated and health concerns merit the additional attention to equipment and fuel handling.[2]

The ECRA amended the EPAct of 1992 to allow fleets to generate one AFV acquisition credit for every 450 gallons of pure biodiesel (equivalent to 2,250 gallons of B20) purchased for use in medium- and heavy-duty diesel vehicles. To achieve AFV acquisition credit through biodiesel consumption, the biodiesel must be in blends of B20 or higher.

Biodiesel

- Nontoxic, biodegradable; may reduce serious air pollutants.
- B20 can generally be used in unmodified diesel engines.
- Can be used in pure form (B100), but may require engine modifications.
- Has a higher cetane number, a measurement of the combustion quality of the fuel, and provides more lubricity.
- B20 contains eight percent less energy content per gallon than does #2 diesel.

[2]National Renewable Energy Laboratory (NREL) (2009), *Biodiesel Handling and Use Guide.* Online at http://www.nrel.gov/vehiclesandfuels/pdfs/43672.pdf

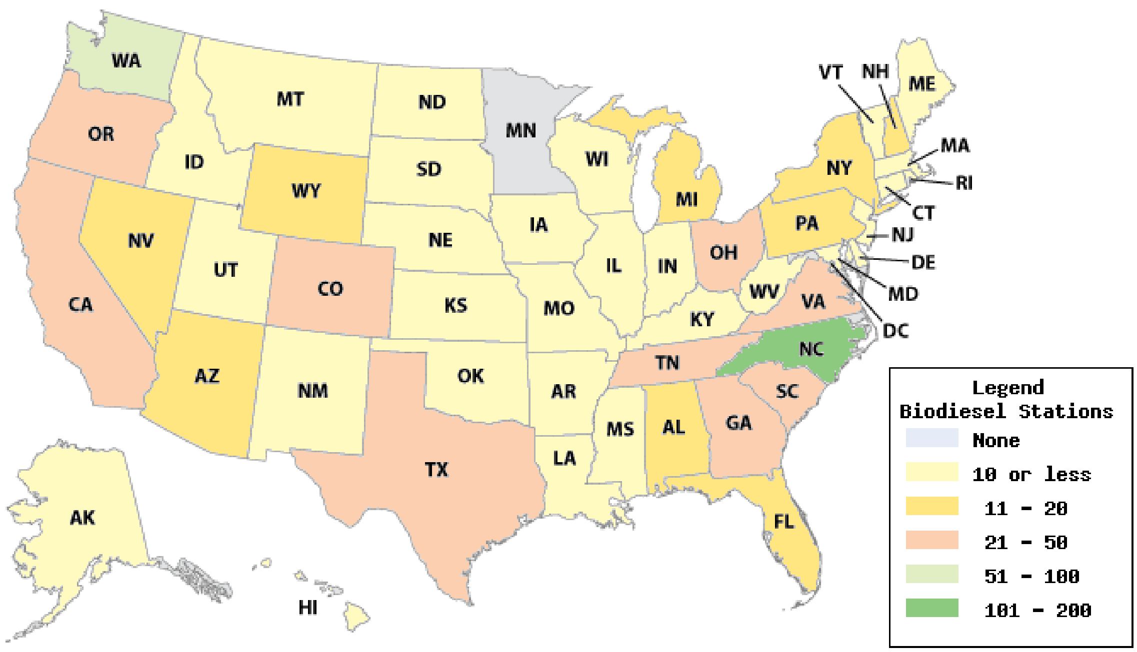
Vehicle Availability

Biodiesel blends of up to 20 percent can be used in any light-, medium-, and heavy-duty vehicle that uses petroleum diesel with no engine modification. Vehicles operating on pure biodiesel or higher blends may require equipment modifications, specifically in terms of engine seal and gasket materials.

Fueling Facilities

Biodiesel blends up to B20 can use the same dispensing system as used for petroleum diesel. As of February 2010, there were 683 biodiesel fueling stations located in 49 states (see Figure 3). Specific station locations are listed at NREL's Alternative Fuels & Advanced Vehicle's Data Center at http://www.afdc.energy.gov/afdc/locator/stations/.

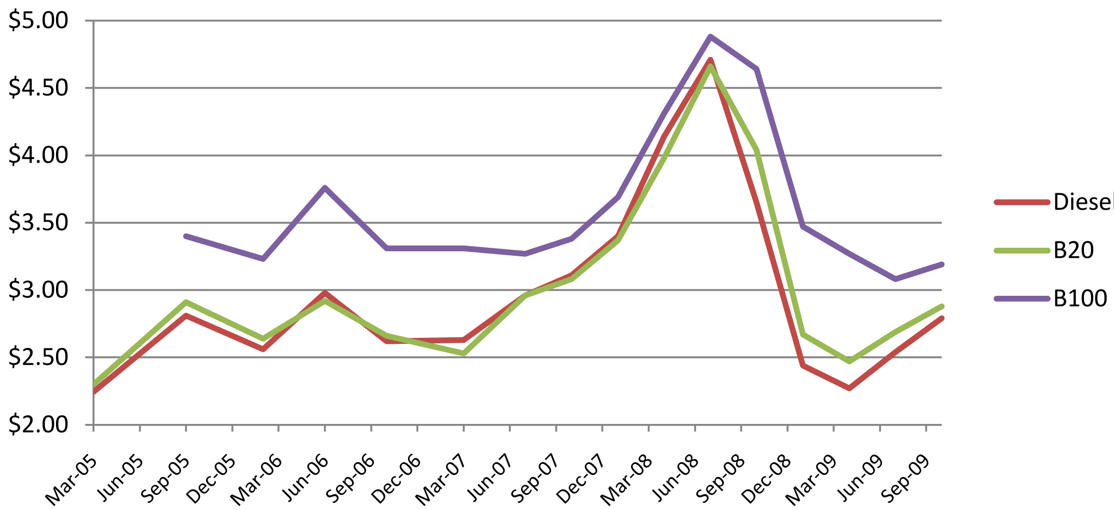
Figure 3: Biodiesel fueling station locations
Source: Alternative Fuels & Advanced Vehicles Data Center, February 2010



Fuel Prices

The price of B20 is comparable to conventional diesel (see Figure 4). The price of B100 is greater than both B20 and conventional diesel. As of October 2009, on average, B20 cost about nine cents per gallon more than conventional diesel fuel.[3] However, in some regions, including New England, the Midwest, and the West Coast, the average price of B20 was lower than that of petroleum diesel.

Figure 4: Nationwide average fuel price of B20 and B100 compared to diesel, per gallon
Source: DOE's Clean Cities Alternative Fuel Price Report, March 2005 to October 2009



Operational and maintenance issues

The American Society for Testing and Materials (ASTM) defines the fuel standard for biodiesel. The ASTM biodiesel standard represents the minimum accepted values for properties of the fuel needed to provide adequate customer satisfaction and/or protection. The ASTM standard for biodiesel in blends of B6 to B20 is ASTM D7467-09A.

Low Temperature Issues

Biodiesel requires special attention when storing and using in cold weather environments because biodiesel can freeze or gel as the temperature drops. A fuel's cloud point is the minimal low temperature at which the fuel can operate, defined as the temperature at which solid crystals begin to form within the liquid fuel. Below the cloud point, the solid crystals that form may plug filters or cause water infiltration in a storage tank. With B20, the cold flow properties of the blend can be 3-10° F higher than average No. 2 petroleum diesel. The biodiesel standard, ASTM D7467, does not have a specific cloud point requirement; instead, users should ensure that the biofuel's cloud point is adequate for the region and time of year the fuel will be used. In some very cold climates, low cloud point petroleum diesel or low-temperature flow additives may need to be blended with the biodiesel to compensate for the low temperature issues. In addition, it is important for biodiesel to be stored at temperatures of at least 5° to 10° F higher than the fuel's cloud point.

Engine Warranty

An engine warranty covers the "materials and workmanship" of the engine, and does not cover damage caused by external conditions, including failures caused by fuel. It is important for users to

[3] Based on the October 2009 *Clean Cities Alternative Fuel Price Report* (DOE), online at http://www.afdc.energy.gov/afdc/pdfs/afpr_oct_09.pdf

determine whether an engine manufacturer will void its parts and workmanship warranty when biodiesel is used. Most major engine companies have stated formally that the use of blends up to B20 and/or biodiesel that meets ASTM D-6751 specifications will not void their parts and workmanship warranties.[4] While damage to an engine caused by the use of biodiesel will not be covered by the manufacturer's warranty, it may be covered by the fuel supplier's general liability insurance.

Cleaning Effect

Due to the high cleaning effect of pure biodiesel, B100 will dissolve accumulated sediments in diesel storage and engine fuel tanks, which can result in the plugging of filters. This cleaning effect is minimized at blends of B20 or lower. However, minor filter plugging may still be an issue during the initial weeks of B20 use. This may result in the need to change filters more frequently when first using biodiesel until the whole system has been cleaned of the deposits left by the diesel.

Performance

Biodiesel contains approximately eight percent less energy per gallon than petroleum diesel. For B20, this decrease in energy content equates to a one to two percent loss in fuel economy. However, using biodiesel may improve engine operations; its lubricity properties can lengthen the life of a vehicle's moving parts, such as fuel pumps, and its high cetane number, which is a measurement of the combustion quality of the fuel, improves fuel efficiency. Vehicles operating on B20 have similar horsepower and torque as those running on conventional diesel.[5]

Storage and Handling Issues

Biodiesel can be stored in the same storage tanks as those used to store petroleum diesel (except for concrete-lined tanks). Acceptable storage tank materials include aluminum, steel, fluorinated polyethylene, fluorinated polypropylene and teflon.

When transitioning petroleum diesel storage tanks to B20, it is recommended that storage tanks be cleaned and free of sediment and water. Low level blends (B5) made from biodiesel that meet ASTM D-6751 specifications can be stored for up to one year, while blends of up to B20 can be stored for at least eight months. However, if stored for longer than a few months experts recommend adding a synthetic antioxidant to reduce the formation of corrosive materials.[6]

Environmental, health and safety considerations

Scholarly debate on how to accurately model the indirect lifecycle GHG emissions of biofuels has raged intensely over the past few years, particularly with regard to assessing the impact of converting forested lands to agricultural land for growing biofuel feedstock (known as indirect land use changes or ILUC). However, EPA lifecycle analysis has confirmed that soy-based biodiesel meets the 20 percent GHG emission reduction threshold set by the Renewable Fuel Standard (RFS2)[7] even when ILUC factors are taken into account. Non food-based biodiesel sources, such as waste grease and switchgrass, were found to have even greater GHG emission reduction results (80 percent and 128 percent, respectively).

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[4] National Biodiesel Board. *OEM Information/Standards and Warranties.* Online at http://www.biodiesel.org/resources/oems/default.shtm

[5] NREL (2009), *Biodiesel Handling and Use Guide. Online at http://www.nrel.gov/vehiclesandfuels/pdfs/43672.pdf*

[6] *Ibid.*

[7] The RFS2 program, established in the Energy and Independence Security Act (EISA) of 2007, requires that the lifecycle GHG emissions of a qualifying renewable fuel must be at least 20 percent less than the lifecycle GHG emissions of the 2005 baseline average gasoline or diesel fuel that it replaces, to qualify as a renewable fuel, 50 percent less to be classified as biomass-based diesel or advanced biofuel, and 60 percent less to be classified as cellulosic biofuel. See http://www.epa.gov/otaq/renewablefuels/420f09024.pdf

In addition to the GHG benefits, biodiesel also reduces tailpipe emissions. Biodiesel is the first and only alternative fuel to have had a complete evaluation of emission results and potential health effects submitted to the EPA under the Clean Air Act Section 211(b).[8] The EPA's emission testing results show that soybean-based B20 reduces carbon monoxide (11 percent), particulate matter (10 percent), hydrocarbons (21 percent), and air toxins, as compared to conventional diesel. The emission testing also found that the use of soybean-based biodiesel may increase nitrogen oxide (NO_x) emissions (2 percent for B20 and 10 percent for B100). However, later studies reported mixed results, with some showing small increases and others showing small decreases of NO_x emissions.

Biodiesel is nontoxic and biodegradable, and is suitable for sensitive environments. Biodiesel has a flash point (i.e. the lowest temperature at which the vapor above which a combustible liquid can be made to ignite in air) that is higher than diesel, so it is considered less dangerous.

Example of uses on federal lands

- Channel Islands National Park, California – The park began its biodiesel program in August 2000. In 2001, the park launched use of the Sea Ranger II, which was powered by B100. *Kent Bullard, Maintenance Supervisor, kent_bullard@nps.gov*.
- Rocky Mountain National Park, Colorado – operates bio-diesel powered 28-passenger buses and 44-passenger school buses. The buses are operated by a concessionaire from June to September.
- Yellowstone National Park, Wyoming, Montana, Idaho – biodiesel program started in 1995 with use of an unaltered diesel pickup truck fueled by neat biodiesel (100 percent rapeseed ethyl ester). An onsite biodiesel processor has been purchased by the concessioner to manufacture biodiesel from oils collected in the valley, and B20 refueling is available onsite at the El Portal maintenance complex. *Jim Evanoff, Environmental Protection Specialist, jim_evanoff@nps.gov*.
- Assateague Island National Seashore, Maryland – all park operations are using B20. *Ish Ennis, Maintenance Mechanic Supervisor, ish_ennis@nps.gov*.
- Glacier National Park, Montana – the park converted operations to B20 in the fall of 2002. The park uses B20 to fuel both equipment and vehicles, and operates two biodiesel fueling stations within the park. *Jack Polzin, Maintenance Mechanic Supervisor, jack_polzin@nps.gov*.
- Harpers Ferry National Historic Park, West Virginia – uses B20 to fuel its Park Explorer shuttle buses. The shuttle transports visitors from the Lower Town district to the park's visitor center.
- Scotts Bluff National Monument, Nebraska – the park's Summit Shuttle, a 15-passenger Ford E250 van, operates on B20. The shuttle transports visitors to and from the top of Scotts Bluff.

[8] EPA (2002), *A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions*, Available at http://www.epa.gov/otaq/models/analysis/biodsl/p02001.pdf

Ethanol

Ethanol is a liquid alcohol renewable fuel that can be mass-produced through fermentation from any plant (feedstock) that contains a large amount of sugar or components that can be converted into sugar, such as starch or cellulose. In the United States, ethanol is produced primarily from corn starch grown on agricultural land. Technologies to utilize second-generation sources (i.e. fuel derived from cellulosic biomass, such as perennial grasses, and agricultural, forestry, and municipal waste) are currently under development.

Ethanol can be blended with conventional gasoline to produce transportation fuel. Blended ethanol is denoted by the percentage of ethanol it contains. Almost all regular gasoline now contains up to 10 percent ethanol (E10), which can be used in conventional gasoline-powered vehicles without any modification.[9] E85 (85 percent ethanol, 15 percent gasoline) is used in light-duty vehicles, and E95 (95 percent ethanol, 5 percent gasoline) is used for heavy-duty vehicles.

Vehicle Availability

E85 cannot be used in conventional gasoline powered engines, but only in flexible fuel vehicles (FFVs), which are specifically designed to run on either gasoline, E85, or any combination of the two. FFVs have specialized components to handle the specific properties of ethanol, which includes increased conductivity, corrosiveness, and cleansing effect as compared to gasoline. Available FFVs include sedans, pickup trucks, sport utility vehicles, and vans. Currently, there are no medium- or heavy-duty vehicles that can operate on ethanol.

Conventional gasoline vehicles may be converted to run on E85; however, such conversions are required to be certified by the EPA.[10]

Ethanol

- Alcohol-based fuel produced from starch crops or cellulosic biomass (trees and grasses). Currently, corn is primary feedstock.
- High octane (100+) enhances octane properties of gasoline and used as oxygenate to reduce CO emissions.
- Original equipment manufacturers estimate 15 percent - 30 percent decrease in mileage.
- E85 vehicles demonstrate a 25 percent reduction in ozone-forming emissions compared with those using gasoline.
- As an alternative fuel, most commonly used in a blend of 85 percent ethanol and 15 percent gasoline (E85).

Fueling Facilities

E85 fueling infrastructure is comparable to that of gasoline; however, special E85 compatible equipment and materials are required. E85 refueling stations require a storage tank (either aboveground or underground), vapor recovery equipment, a pump, and dispensers.

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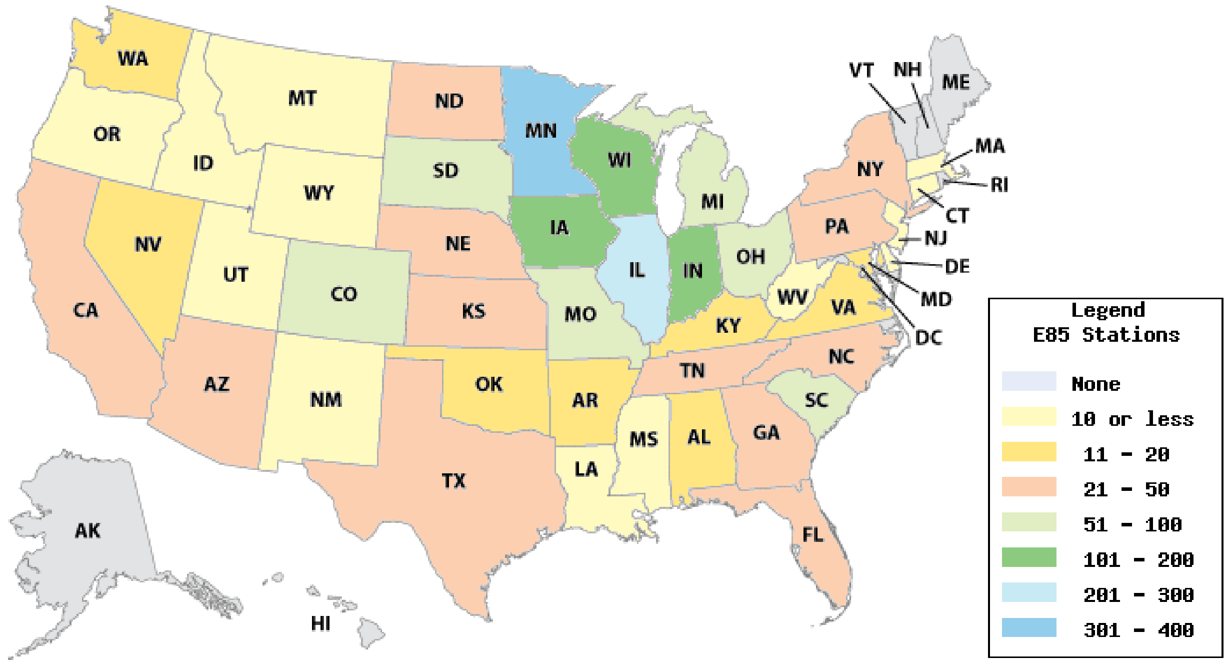
[9] EPA is now considering whether to allow the use of E15 (an intermediate ethanol blend) in conventional gasoline-powered vehicles.

[10] All vehicle conversions must be certified to meet applicable federal requirements. The EPA issues Certificates of Conformity that cover a test group, i.e. specific vehicles or engine models that are modified to operate on an alternative fuel. An aftermarket conversion may only be performed on a vehicles if a Certificate of Conformity has been issued for that vehicle's test group. In addition, the vehicle conversion can only be performed by those associated with a certificate holder.

In 2008, U.S production of corn ethanol reached approximately 9 billion gallons. As of February 2010, E85 was sold in more than 2,000 fueling stations in 44 states (see Figure 5).[11] The majority of domestic ethanol is produced in the Midwest, and, as a result, a large percentage of E85 fueling stations are located in that region. Specific station locations are listed at NREL's Alternative Fuels & Advanced Vehicle's Data Center at http://www.afdc.energy.gov/afdc/locator/stations/.

Figure 5: E85 fueling station locations
Source: Alternative Fuels & Advanced Vehicles Data Center, February 2010



Cost of Infrastructure
A NREL survey found that the average cost of adding E85 equipment to an existing gasoline fueling station was $71,735 if the station needed to install a new underground tank, and $21,031 if the station converted existing equipment and only needed to retrofit or replace dispensers.[12]

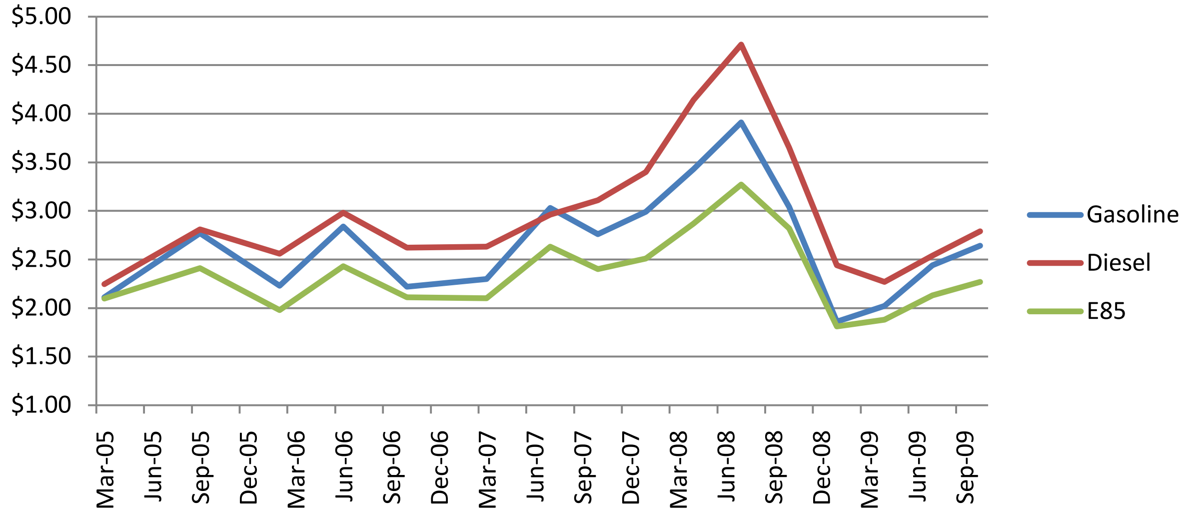
Fuel Prices

The price of E85 is generally less than that of conventional gasoline (see Figure 6). As of October 2009, on average, E85 cost about 37 cents less than regular gasoline; however, the price difference varied by region. For example, the price of E85 in New England was greater than the price of regular gasoline.

[11] AFDC, "E85: An Alternative Fuel". Accessed on January 5, 2010 from http://www.afdc.energy.gov/afdc/ethanol/e85.html

[12] NREL (2008), *Cost of Adding E85 Fueling Capability to Existing Gasoline Stations: NREL Survey and Literature Search.* http://www.afdc.energy.gov/afdc/pdfs/42390.pdf

Figure 6: Nationwide average price of E85 compared to gasoline and diesel, per gallon
Source: DOE's Clean Cities Alternative Fuel Price Reports, March 2005 to October 2009



Operational and maintenance issues

The ASTM standard for E85 is ASTM D5798. To ensure optimal performance it is recommended that only E85 that meets the ASTM standard is used.

E85 can only be used in FFVs that have specialized components to handle the specific properties of ethanol, which includes increased conductivity, corrosiveness, and cleansing effect as compared to gasoline.

Low Temperature Issues
In order to avoid vehicle starting issues associated with cold weather, ethanol blends are seasonally adjusted. In cold temperatures, a minimum blend of 70 percent ethanol and 30 percent gasoline is recommended (the ASTM fuel standard permits a minimum of 70 percent of ethanol in the winter blend).

Performance
E85 fuel contains 27 percent less energy than gasoline, which equates to a range of 5 to 25 percent decrease in a vehicle's fuel economy.[13] Ethanol is a high octane fuel, which helps prevent engine knocking and increase engine performance.

Storage and Handling issues

To produce E85, pure ethanol is blended with gasoline at bulk storage facilities. The blended product is then delivered to fueling stations via ground transportation. Only E85-compatible materials should be used in the storage and dispensing systems. E85 is not compatible with certain metallic materials, including aluminum, zinc, brass, and lead. Contact with such materials can contaminate the fuel, resulting in poor vehicle performance or engine damage.

Environmental, health and safety considerations

Similar to biodiesel, the climate impact of ethanol is largely dependent upon the fuel source, and how the source is managed and produced. Currently, ethanol is produced primarily from grain and sugar crops grown on agricultural land. These first-generation biomass sources can have higher GHG

[13] NREL (2008), *Handbook for Handling, Storing, and Dispensing E85.*

emissions than conventional fuels due to the substantial biomass and soil carbon release that occurs when carbon-rich land, such as a forest, is cleared to grow the crops.[14] In addition, the production practices associated with the growing of the biomass input for corn ethanol has negative impacts on water and soil quality. The increased land area needed, and the fertilizers and pesticides used to produce corn can result in surface and groundwater pollution, soil degradation and loss of biodiversity.

EPA analysis suggests that biofuel-induced land use changes can produce significant near-term GHG emission, but over the long term the emissions savings from petroleum displacement will exceed the earlier land conversion impacts.[15] Second-generation ethanol sources, such as perennial grasses, crop residues, and municipal and solid waste, tend to not have the same land use implications as first-generation ethanol sources, and therefore have less negative environmental impacts. EPA's GHG lifecycle analysis determined that ethanol produced from corn starch at a new natural gas-fired facility using advanced efficient technologies typical of new production facilities complies with the 20 percent GHG emission reduction threshold established by the RFS2 program; however corn ethanol produced at a coal-fired facility did not. Ethanol produced from sugarcane complies with the applicable 50 percent GHG reduction threshold.[16]

In addition to the GHG reduction benefits of ethanol, the use of E85 also has localized air emission benefits. On average, the use of E85 reduces tailpipe emissions of CO (20 percent), PM (34 percent), hydrocarbons (8 percent), and NO_x (18 percent) as compared to gasoline.[17] Emissions that increase with the use of E85 fuel include formaldehyde, acetaldehyde and methane.

E85 fuel is flammable, poisonous, and may contain additives that can be harmful even with casual contact. In general, the safety standards for handling E85 are the same for those for gasoline. However, because ethanol is water miscible, specific equipment and materials are needed to respond to spills and fires. For example, a specialized foam known as AR-AFFF is required to put out an ethanol fire. The Ethanol Emergency Response Coalition provides numerous educational materials, training programs and products to inform emergency responders on how to effectively respond to fires, spills, and other emergencies involving ethanol.[18]

Example of uses on federal lands

- Mammoth Cave National Park, Kentucky - operates 35 E85 flexible fuel vehicles. The park and its principal concessioner, Forever Resorts, jointly operate an alternative fueling station that is used for government and concessions vehicles and equipment. *Steve Kovar, Chief of Maintenance, steve_kovar@nps.gov*.

[14] Inderwildi, O. et al. *Future of Mobility Roadmap: Ways to Reduce Emissions While Keeping Mobile.* University of Oxford, Smith School of Enterprise and the Environment.
[15] EPA (200). *EPA Lifecycle Analysis of Greenhouse Gas Emissions from Renewable Fuels. http://www.epa.gov/otaq/renewablefuels/420f09024.pdf*
[16] EPA (2010), *EPA Finalizes Regulations for the National Renewable Fuel Standard Program for 2010 and Beyond.* http://www.epa.gov/otaq/renewablefuels/420f10007.pdf
[17] Based on a review of published emission testing studies and certification emission tests of FFV reported to the EPA. Yanowitz, J, and R. McCormick (2009). "Effect of E85 on Tailpipe Emissions from Light-Duty Vehicles". *Journal of the Air & Waste Management Association*, http://www.afdc.energy.gov/afdc/pdfs/technical_paper_feb09.pdf .
[18] EERC training materials are available at http://www.ethanolresponse.com/about.html.

Natural Gas

Natural gas is a clean burning fossil fuel composed primarily of methane, with smaller quantities of ethane, propane, butane and pentane. It is drawn from gas wells or extracted in conjunction with crude oil production. Natural gas can be used in vehicles as one of two forms:

- Compressed natural gas (CNG) – CNG is stored on board a vehicle in high-pressure tanks at 3,000 to 3,600 pounds per square inch (psi).
- Liquefied natural gas (LNG) – LNG allows more energy to be stored on board a vehicle in smaller volumes. In order to produce LNG, natural gas is purified and cooled to -260°F. In order to maintain the low temperature, LNG must be stored in double-walled, vacuum-insulated pressure vessels. Since LNG occupies only a fraction (1/600) of the volume of natural gas, and takes up less space, it is more economical to transport across large distances and can be stored in larger quantities. LNG can be heated to return it to its gaseous state.

Natural Gas

- A clear, odorless, gaseous mixture of hydrocarbons primarily composed of methane.
- Used in two forms, CNG and LNG.
- Provides slightly reduced vehicle driving range, due to fuel storage constraints and tank size.
- Yields drastically reduced ozone-forming emissions and slightly lowered GHG emissions.
- Safer than other fuels in the event of a spill; natural gas is lighter than air, and disperses quickly when released.

Vehicle Availability

Natural gas can be used in spark-ignited internal combustion engines. Natural gas vehicles (NGVs) are available as either dedicated natural gas vehicles (run only on natural gas) or bi-fuel natural gas vehicles (operates on either natural gas or a conventional fuel).

Light Duty

At this time, the only light-duty natural gas vehicle offered by an original equipment manufacturer (OEM) is the Honda Civic GX sedan. Conventional vehicles may be converted to run on natural gas; however, such conversions are required to be certified by the EPA. [19,20] Light-duty natural gas vehicles can cost $5,000 to $7,000 more than conventional vehicles.

Medium and Heavy Duty

A wide variety of medium- and heavy-duty natural gas vehicles (both CNG and LNG) and engines are currently on the market.[21] Available vehicles include transit buses, school buses, trolleys, shuttles, and refuse trucks. Natural gas-fueled heavy-duty vehicles can carry an incremental cost of $30,000 to $50,000 more than their conventionally-fueled counterparts.

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[19] All vehicle conversions must be certified to meet applicable federal requirements. The EPA issues Certificates of Conformity that cover a test group, i.e. specific vehicles or engine models that are modified to operate on an alternative fuel. An aftermarket conversion may only be performed on a vehicles if a Certificate of Conformity has been issued for that vehicle's test group. In addition, the vehicle conversion can only be performed by those associated with a certificate holder.

[20] See the Natural Gas Vehicles for America's *Guide to Available Natural Gas Vehicles and Engines* for a list of vehicles and engines that have been certified by the EPA. http://www.ngvamerica.org/pdfs/marketplace/MP.Analyses.NGVs-a.pdf

[21] The DOE's Alternative Fuels & Advanced Vehicles Data Center maintains an up-to-date database of medium/heavy duty alternative fuel vehicles and engines that can be easily searched. See http://www.afdc.energy.gov/afdc/vehicles/heavy.

Fueling Facilities

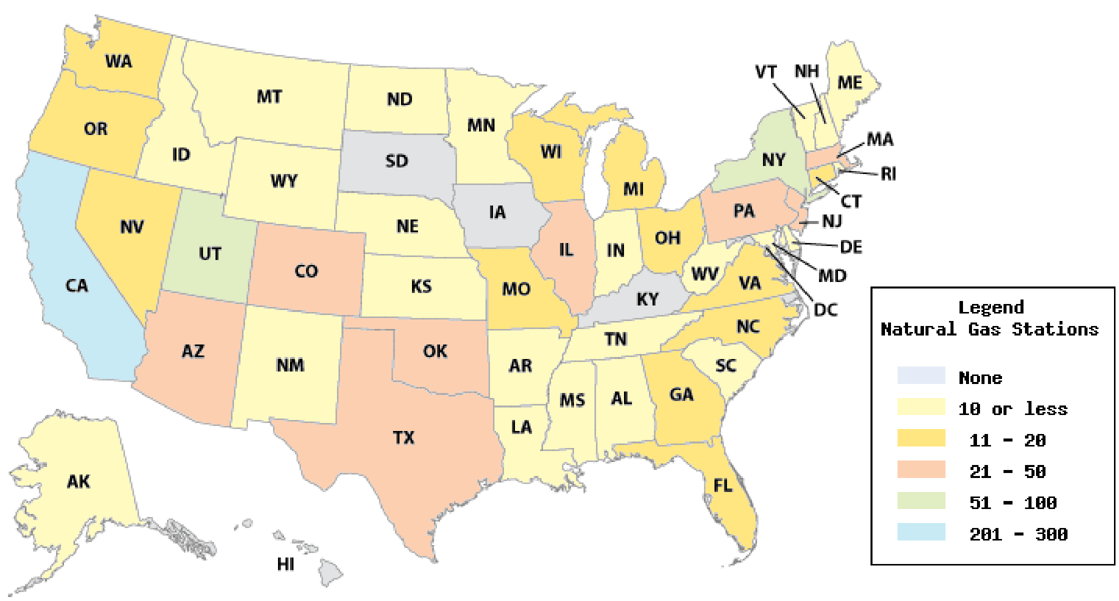
Compressed natural gas
CNG refueling takes place through either a fast-fill or time-fill dispenser. With either system the natural gas can be compressed onsite or compressed off site and transported to the location in tanks.

At a fast-fill station, the natural gas is compressed under high pressure (up to 5000 psi), and dispensed into static storage cylinder tanks, called a cascade, that hold the gas at high pressures. The gas is transferred to a vehicle's on-board storage tank directly from the cascade at a flow rate that is sufficient to fill a vehicle tank in less than 10 minutes. A fast-fill system requires CNG storage volumes 3 to 4 times the fleet's fill requirement. Due to the storage space requirements, these stations are best suited for fueling light-duty vehicles and low-volume stations.[22]

In contrast, time-fill dispensers utilize a smaller dispenser and do not require a storage system. With a time-fill dispensers a vehicle is filled directly from the compressor over a longer period of time, typically at a rate of one gallon per hour. Due to the slower fueling rates, these stations are best used for vehicles that regularly return to a central station and can be fueled while parked for an extended period of time (typically six to eight hours).

As of February 2010, there were 825 CNG fueling stations located in 46 states (see Figure 7). While public CNG refueling stations do exist, most fleets build their own infrastructure to meet their refueling needs. Specific station locations are listed at NREL's Alternative Fuels & Advanced Vehicle's Data Center at http://www.afdc.energy.gov/afdc/locator/stations/.

Figure 7: CNG fueling station locations
Source: Alternative Fuels & Advanced Vehicles Data Center, February 2010



Liquefied natural gas
LNG fueling facilities consist of two primary parts: the LNG storage tank and the LNG dispensing unit. The LNG storage tanks are double-walled and insulated. The LNG dispensing unit consists of a

[22] DOE. *Alternative Fuel News*. 7(1). Available online at http://www.afdc.energy.gov/cleancities/ccn/pdfs/afn7_1.pdf

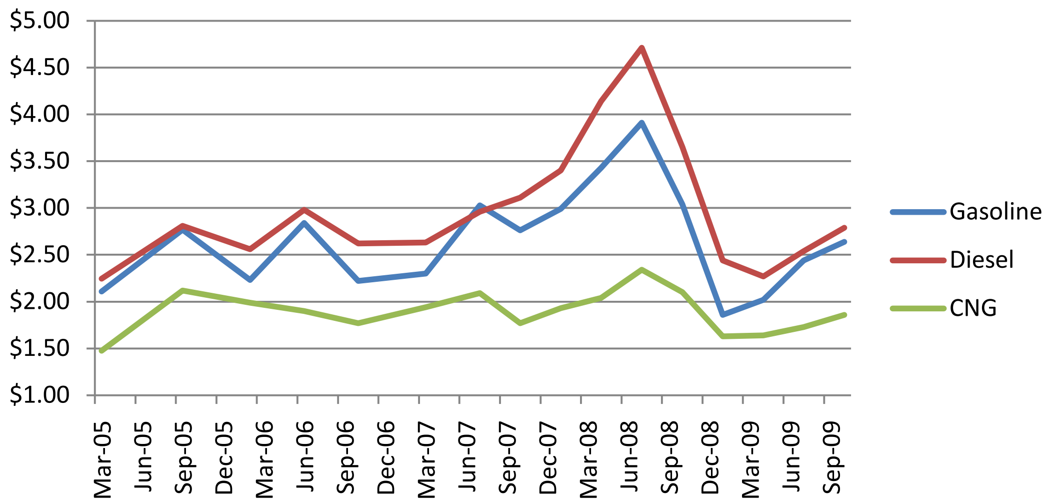
fuel transfer pump, a heat exchanger/conditioning system to ensure the fuel is at the proper pressure for vehicle use, and a fuel dispenser (pump and hose).[23] The filling time for a LNG vehicle is relatively short, approximately five minutes.

LNG is typically purchased directly from the producer. Due to transportation costs, it is generally not economical to transport LNG farther than 500 miles in any direction.[24] The availability of LNG fueling facilities is far less than those for CNG. As of February 2010, there were 38 LNG fueling facilities in four states. Because public LNG fueling facilities are scarce, most fleets build their own infrastructure to meet their refueling needs.

Fuel Prices

On average, CNG costs less than gasoline and diesel (see Figure 8). As of October 2009, the price of CNG was about $0.78 less than gasoline on a per gallon equivalent basis. When compared to diesel, CNG costs about $0.71 less on a per diesel equivalent basis.

Figure 8: Nationwide average fuel price of CNG compared to gasoline and diesel, per gallon
Source: DOE's Clean Cities Alternative Fuel Price Reports, March 2005 to October 2009



Operational and Maintenance Issues

Natural gas has a lower energy content compared to gasoline or diesel. As a result, the driving range of natural gas vehicles is less (16 to 27 percent less)[25] than comparable gasoline- and diesel-powered vehicles. In addition, compared to diesel or gasoline, natural gas requires much more onboard fuel storage volume for an equivalent range. As a result, some natural gas vehicles have a more limited range or have reduced passenger or storage capacity due to fuel storage space requirements. However, vehicles powered by natural gas have similar horsepower, acceleration, and cruising speed.

[23] Battelle (2002). *Resource Guide for Heavy-Duty LNG Vehicles, Infrastructure, and Support Operations.* http://www.afdc.energy.gov/afdc/pdfs/lng_resource_guide.pdf
[24] *Ibid.*
[25] Hesterberg, T. et al (2009), "An evaluation of criteria for selecting vehicles fueled with diesel or compressed natural gas", *Sustainability: Science, Practice, & Policy*, 5(1):20-30.

Storage and Handling issues

Typically, CNG is sourced from the local gas utility line at low pressure, and then compressed and stored in storage tanks at high pressure. The size of the storage tanks needed depends upon the size of the fleet, and the time frame in which the vehicles need to be filled. But because of the lower energy content of natural gas, the volume of the tank needed to store natural gas is at a minimum five times the size for an equivalent quantity of diesel storage.

Since LNG is more compact than CNG, liquefying natural gas makes it is easier to transport it over long distances, particularly where pipeline transport is not feasible. LNG can be stored above or below ground in highly insulated tanks. The stored LNG must be kept cold (between -260° and -117° F). Stored LNG fuel is susceptible to weathering (when the lighter gases in the fuel, such as methane, vent off, leaving the heavier components); therefore, it cannot be stored for a prolonged period of time.

Fuel storage cylinders used in NGVs are built much stronger than regular gasoline and diesel fuel tanks, and are subjected to a number of federally required "severe abuse" tests.[26] Still, maintenance staff must be properly trained as the inadvertent opening of valves or loosening of fittings containing high pressure natural gas will not only lead to creation of a fire hazard, but can also result in the high velocity ejection of metal parts or fragments that could be lethal to nearby personnel.[27]

Vehicle Storage and Maintenance Facilities

Certain design considerations for vehicle storage and maintenance facilities are required when using CNG or LNG. Such design requirements are necessary in order to address safety concerns associated with a natural gas release from vehicles. Design measures include providing adequate ventilation and air flow, as well as removing potential ignition sources, such as electrical and heating elements. In addition, facilities should have a combustible gas detection system, including gas sensors and alarms. Relevant codes, such as the National Fire Protection Association's (NFPA) Vehicle Gaseous Fuel Systems Code (NFPA 52-10), should be reviewed and followed.

Environmental, health and safety considerations

Natural gas is nontoxic, noncorrosive, and non-carcinogenic, and is suitable for use in sensitive environments. It is not a threat to soil, surface water, or groundwater. Compared to conventional gasoline vehicles, light-duty natural gas vehicles produce less smog-forming emissions: 10 percent less VOC, 20-40 percent less CO, and 80 percent less PM.[28] Emissions benefits of using CNG in heavy-duty vehicles varies depending upon the type of vehicle and drive cycle. An evaluation of transit buses equipped with model year 2004 CNG engines found a reduction in NO_x (49 percent) and PM (84 percent) compared to buses equipped with model year 2004 diesel engines.[29] In terms of lifecycle GHG emissions, various studies have found that natural gas vehicles emit 20-25 percent less GHG emissions than conventional petroleum vehicles.[30]

The ignition temperature for natural gas is approximately 1,200°F (compared to 600°F for gasoline). Natural gas has a narrow flammability range; it is only flammable when the fuel concentration in air is between 5 and 15 percent.

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[26] Natural gas vehicle fuel systems must meet Federal Motor Vehicle Safety Standards 303 and 304.

[27] Battelle (1995). *Summary Assessment of the Safety, Health, Environmental and System Risks of Alternative Fuel.*

[28] Argonne National Laboratory (ANL), *A Full Fuel-Cycle Analysis of Energy and Emissions Impacts of Transportation Fuels Produced from Natural Gas*. Online at http://www.ipd.anl.gov/anlpubs/2000/01/34988.pdf

[29] NREL (2005). *Emission Testing of Washington Metropolitan Area Transit Authority (WMATA) Natural Gas and Diesel Transit Buses.* http://www.afdc.energy.gov/afdc/pdfs/36355.pdf

[30] ANL's GREET 1.5 Transportation Fuel-Cycle Model, Volume 2: Appendices of Data and Results. Online at http://www.transportation.anl.gov/modeling_simulation/GREET/pdfs/esd_1v2.pdf

Example of uses on federal lands

- Grand Canyon National Park, Arizona – the park began using CNG powered buses in 1998. The park recently replaced its diesel and LNG buses with 29 new low-floor CNG powered transit buses.
- Cabrillo National Monument, California – 25 percent of the park's fleet is CNG vehicles.
- Lake Roosevelt National Recreation Area, Washington – has an on-site CNG fueling station.
- Lake Mead National Recreation Area, Nevada and Arizona – the park operates 11 CNG pickup trucks and a six-unit CNG fueling station.

Propane

Propane, also called liquefied petroleum gas (LPG), is a clean-burning fossil fuel that can be used to power internal combustion engines. LPG is produced as a byproduct of natural gas processing and crude oil refining. Liquid propane is stored onboard vehicles in a tank pressurized to 300 psi. LPG is the third most commonly used engine fuel after gasoline and diesel.

Propane

- A byproduct of natural gas processing and petroleum refining.
- Provides the longest driving range of any alternative fuel, although contains less energy than gasoline (25 to 30 percent less).
- Emits fewer GHG and air pollutants (NOx, CO, hydrocarbons and toxins) than gasoline and diesel.
- Higher octane rating than gasoline, allowing for a higher compression ratio in the engine and greater engine efficiency.

Vehicle Availability

Light-Duty

Currently, there are no light-duty propane vehicles available for sale by automotive OEMs. However, many light-duty vehicles can be retrofitted for propane operation. Propane conversions require EPA approval and must be performed by a licensed propane conversion technician. The average cost of conversion of a light-duty vehicle from gasoline to dedicated propane fuel ranges from $4,000 to $12,000.

Medium- and Heavy-Duty

Propane engines and fueling systems are available for school and transit buses, shuttles, trolleys, and street sweepers. The DOE's Alternative Fuels & Advanced Vehicles Data Center maintains an up-to-date database of medium/heavy duty alternative fuel vehicles and engines at (http://www.afdc.energy.gov/afdc/vehicles/heavy).

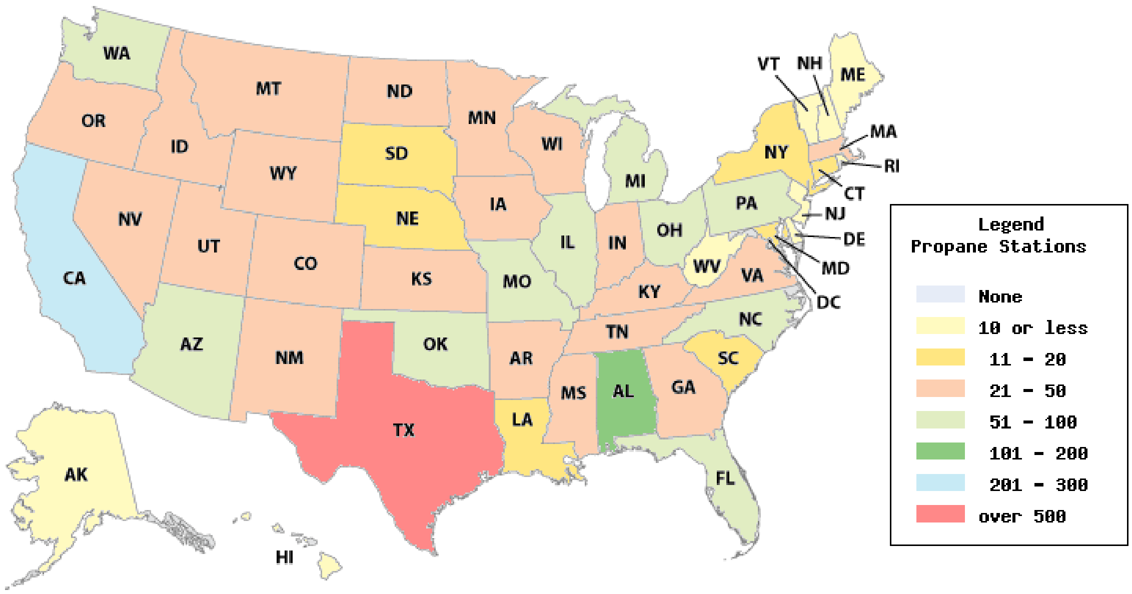
Fueling Facilities

Propane is normally supplied through distributors and is delivered to sites via ground transport. A propane fueling facility requires several systems including a cargo transfer/unloading system, storage tanks, piping, pumps, fuel transfer and dispensing systems, and safety systems. Propane fueling facilities are required to be outdoor facilities.

Filling a propane vehicle is similar to filling a conventional gasoline vehicle. Liquid propane is stored in a storage tank, which is connected to the dispenser that fills the vehicle's on-board storage tank. The key difference between propane and gasoline refueling is that, with propane, a tighter connection is made between the hose and the vehicle tank to prevent the pressurized fuel from escaping. Existing conventional fueling stations can be converted or modified to dispense propane.

As of February 2010, there were over 2,400 LPG refueling stations located in each of the 50 states (see Figure 9). Specific station locations are listed at NREL's Alternative Fuels & Advanced Vehicle's Data Center at http://www.afdc.energy.gov/afdc/locator/stations/.

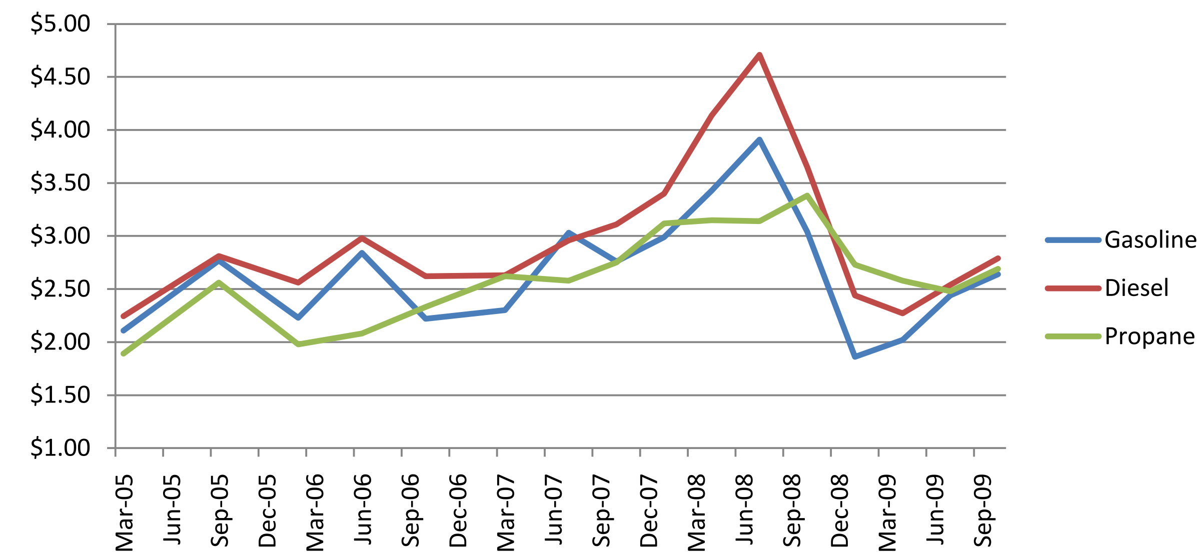
Figure 9: LPG fueling station locations
Source: Alternative Fuels & Advanced Vehicles Data Center, February 2010



Fuel Prices

The price of propane fluctuates above and below the cost of gasoline, though typically propane costs less than diesel (see Figure 10). As of October 2009, the average price of propane was about five cents per gallon more than gasoline.

Figure 10: Nationwide average fuel price of propane compared to gasoline and diesel, per gallon
Source: DOE's Clean Cities Alternative Fuel Price Reports, March 2005 to October 2009



Operational and maintenance issues

Propane has a high octane value and is well suited for spark-ignited internal combustion engines. The high octane rating (104-112 compared with 87-92 for gasoline) is associated with improved engine performance. The use of propane can extend the life of a vehicle's spark plugs; spark plugs in unleaded gasoline engines typically need replacement after 30,000 miles, while those in propane vehicles can last 80,000-100,000 miles.[31]

Performance and Fuel Economy

New liquid injection systems have improved the efficiency of propane (until recently, propane vehicles commonly used a vapor pressure system, which reduced the fuel efficiency).[32] Although propane provides the longest driving range of any alternative fuel, the energy content of propane is still less than gasoline or diesel (73 percent of gasoline). In addition, propane tanks add weight to a vehicle, which can lead to a slight increase in the consumption of fuel.[33] Acceleration, cruise speed, payload, and power of propane powered vehicles are comparable to conventionally fueled vehicles.

Storage and handling issues

Propane is stored and handled as a liquid. Propane storage tanks are constructed of steel, and are required to be set at specific distances from other tanks, buildings, and property lines (distance depends on the size of the storage tank). Storage tanks must be installed outdoors above ground, and on a firm foundation.

Vehicle Storage and Maintenance Facilities

Certain design considerations for storage and maintenance facilities are required when using propane in order to minimize the potential for ignition of LPG vapors, which may be accidentally released from the vehicle's fuel system. Such design measures call for providing adequate ventilation and air flow, as well as removing potential ignition sources, such as electrical and heating elements. Relevant codes, such as the NFPA 58: Liquefied Petroleum Gas Code, and 29 CFR 1910.110, Occupational Safety and Health Standards, Storage and handling of liquefied petroleum gases, must be followed when designing and constructing propane facilities.

Environmental, health and safety considerations

Propane is a nontoxic, nonpoisonous fuel that does not contaminate aquifers or soil. Compared to gasoline, propane combustion emits fewer GHGs (12 percent), NO_x (20 percent), hydrocarbons (60 percent), CO (60 percent), toxins and carcinogens (96 percent), PM (80 percent), and less noise as compared to diesel.

Propane has the lowest flammability range of any fossil fuel; it is only flammable when the fuel concentration in air is between 2.2 and 9.6 percent. However, because propane becomes a gas when leaked it is more likely to ignite than gasoline.

Example of uses on federal lands

- Mammoth Cave National Park, Kentucky – operates 7 propane buses. The park and its principal concessioner , Forever Resorts, jointly operate a alternative fueling station that is used for government and concessions vehicles and equipment. *Steve Kovar, Chief of Maintenance, steve_kovar@nps.gov.*

[31] Propane Education & Research Council, http://www.propanecouncil.org/Fleettemplate.aspx?id=3320

[32] Argonne National Laboratory. (2009). *White Paper on Propane Vehicles: Status, Challenges, and Opportunities.* Available online at http://www1.eere.energy.gov/cleancities/pdfs/propanepaper09_final.pdf.

[33] *Ibid.*

- Acadia National Park, Maine – operates a fleet of 29 propane-powered 28-passenger buses, called the Island Explorer. The buses are operated by a concessioner during mid-June to mid-October.
- Zion National Park, Utah – in 2000, the park began fueling its shuttle bus operations with propane. The park's 30 shuttle buses and 21 trailers have been powered by propane ever since. The park constructed a maintenance and refueling facility on-site.

Electricity

Electricity can be used to power battery electric vehicles, hybrid-electric vehicles, and plug-in hybrid electric vehicles. In each case, the vehicle stores electricity in the on-board battery system.

Vehicle Availability

All Electric

Battery electric vehicles (EVs) store electricity in an energy storage device, such as a battery, The electricity powers the vehicle's wheels via an electric motor. At this time, light-duty battery electric vehicles (BEVs) are not commercially available from the major auto manufacturers; however, at least one manufacturer has announced plans to introduce an all-electric vehicle to the market within a few years.[34]

There are a number of low-speed electric vehicles, those limited to operating on roads with speed limits of 35 miles per hour or less, currently available. These low-speed vehicles, which include neighborhood electric vehicles and electric trams, can be used for transporting passengers within designated areas. However, due to speed limitations, such vehicles are not permitted to drive on public roadways. A limited number of heavy-duty vehicle manufacturers currently produce electric buses.[35]

Electricity

- Batteries in electric vehicles are recharged via electrical outlet, gasoline engine on-board vehicle, or regenerative braking.
- Electricity sources for power outlets are diverse (coat, natural gas, nuclear, wind, solar and other renewables).
- All-electric and PHEVs can have significant benefits on localized air quality.

Hybrid Electric Vehicles

Hybrid electric vehicles (HEVs) combine the internal combustion engine of a conventional vehicle with the battery and electric motor of an electric vehicle. An HEV internal combustion engine can be fueled with gasoline, diesel or an alternative fuel source, such as biodiesel, ethanol or natural gas. The HEV battery is recharged through both regenerative braking, which captures the energy lost during braking and returns it to the battery, as well as through the on-board gasoline/diesel motor.

A variety of HEVs are available in light-[36], medium-, and heavy-duty applications, including shuttles, trolleys, and transit and school buses. The DOE's Alternative Fuels & Advanced Vehicles Data Center maintains an up-to-date database of medium/heavy duty alternative fuel vehicles and engines at (http://www.afdc.energy.gov/afdc/vehicles/heavy).

Plug-in Hybrid Electric Vehicles

Plug-in hybrid electric vehicles (PHEVs) combine components of an all electric vehicle and hybrid electric vehicle. PHEVs are similar to HEVs in that they are powered by two energy sources: an energy conversion unit (e.g. an internal combustion engine or fuel cell) and a battery and electric motor. The energy conversion unit can be powered by gasoline, diesel, or alternative fuel. Unlike HEVs, the battery in a PHEV is primarily recharged by plugging it into an electric outlet. PHEVs have a larger battery pack than HEVs, and operate primarily on all electric power. The vehicle's internal

[34] Nissan plans to begin delivering its all-electric Leaf vehicle in North America by 2012.

[35] The DOE's Alternative Fuels & Advanced Vehicles Data Center maintains an up-to-date database of medium/heavy duty alternative fuel vehicles, engines, and hybrid propulsion systems that can be easily searched. See http://www.afdc.energy.gov/afdc/vehicles/heavy.

[36] Such as the Toyota Prius and Honda Insight

combustion engine is only used when the battery pack is depleted, and serves as a generator to run the electric drive motors and charge the batteries.

PHEVs are not currently available to the public; however, several auto manufacturers have announced plans to introduce PHEVs to the market in the next couple of years.[37]

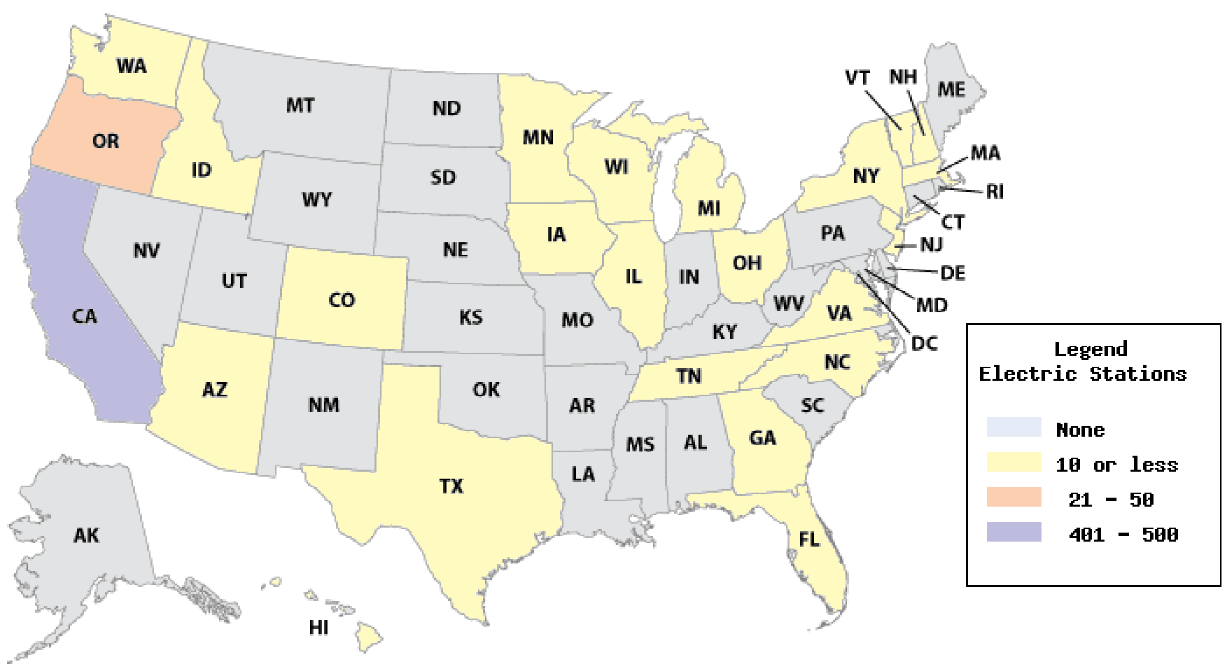
Fueling Facilities

All electric vehicles and PHEVs have limited energy storage capacity. The battery is replenished by plugging in into an electric source. Battery chargers come in three levels, which vary by the level of power provided to the battery pack:

- Level 1: Common household circuit, rated to 120 volts AC and 15 amperes. These chargers use the standard three-prong household connection, and they are usually considered portable equipment.
- Level 2: Permanently wired electric vehicle supply equipment used especially for electric vehicle charging; rated up to 240 volts AC, up to 60 amps, and up to 14.4 kilowatts.
- Level 3: Permanently wired electric vehicle supply equipment used especially for electric vehicle charging; rated up to 480 volts AC, up to 400 amps, and greater than 14.4 kilowatts.

Electric vehicle battery chargers may be located onboard the electric vehicle or at a fixed location. As of February 2010, there were 521 public electric recharging stations located in 24 states (see Figure 11). Specific station locations are listed at NREL's Alternative Fuels & Advanced Vehicle's Data Center at http://www.afdc.energy.gov/afdc/locator/stations/.

Figure 11: Electric charging station locations (all-electric and plug-in hybrid electric vehicles)
Source: Alternative Fuels & Advanced Vehicles Data Center, February 2010



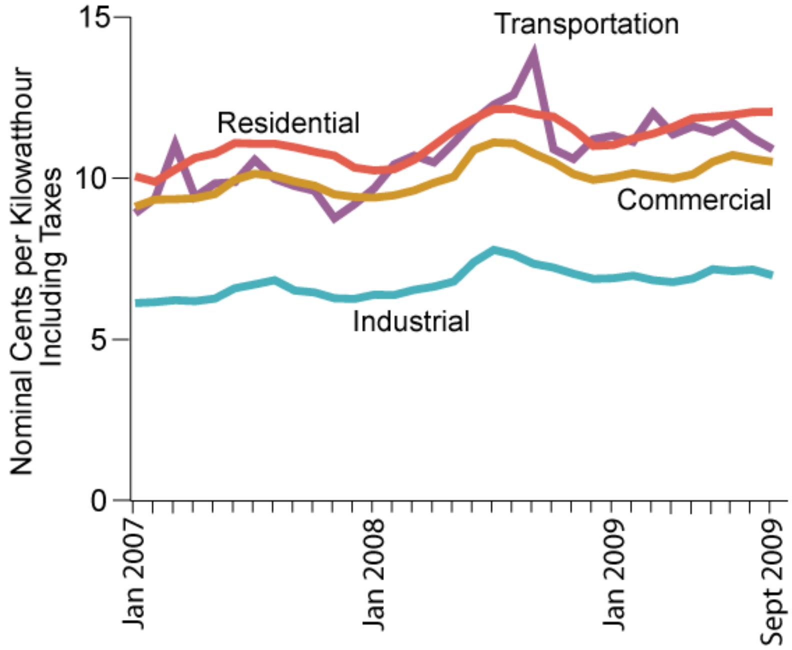
[37] The Chevrolet Volt, a plug-in hybrid electric, is scheduled to be released late 2010.

Fuel Prices

Electric charging varies in cost depending upon the type of charging conducted, the number of vehicles and batteries charged, and the cost of electricity. The cost of electricity varies depending upon region, fuel source, customer type, time of day and season. See Figure 12 for the monthly average retail prices of electricity by sector.

Vehicles with direct current (DC) electric systems get approximately 0.4 killowatt-hours (kWh) per mile, while those with alternative current (AC) systems get about 0.174 to 0.288 kWh per mile.[38] Using 9.74 cents kWh, the average retail price of electricity in the United States for 2008,[39] it would cost $0.04 per mile for DC operation and $0.03 per mile for AC operation. In comparison, when gasoline sells at $3.00 per gallon, it costs $0.12 per mile to fuel a vehicle that gets 25 mpg.

Figure 12: Monthly average retail prices of electricity by sector
Source: U.S. Energy Information Administration, *Monthly Energy Review, September 24, 2009*



Operational and Maintenance Issues

Electric vehicles have fewer moving parts than internal combustion engines. These vehicles do not have timing belts, water pumps, radiators, fuel injectors or tailpipes, nor do they require tune-ups or oil changes, which limit maintenance costs. However, because the drive and electrical system of electric and hybrid vehicles differ from conventional vehicles, operators and maintenance staff must be trained on the new vehicle technology.

Currently, the primary operating challenge associated with electric vehicles is current battery technology. Vehicles utilizing current battery technology have limited range and reduced

[38] DOE, Clean Cities (2009) *Alternative Fuels Overview.* http://www1.eere.energy.gov/cleancities/toolbox/docs/fuel_overview.ppt

[39] EIA, *Electricity Explained: Factors Affecting Electricity Prices.* Available online at http://tonto.eia.doe.gov/energyexplained/index.cfm?page=electricity_factors_affecting_prices

acceleration, and require longer refueling time. Increasing a vehicle's range and/or acceleration performance demands larger, heavier batteries, which in turn impacts the vehicle's performance and functionality.

All-electric and hybrid electric vehicles can use a variety of battery technologies. Current battery types include:

- Lead-acid – widely used in industrial vehicles, however low performance and limited life cycle are impediments to use. Recycling infrastructure is in place.
- Nickel-metal hydride – widely used in commercial hybrids, including the Prius. These batteries are safe, durable, and have a longer life cycle than lead-acid batteries. Components are recyclable, but a recycling infrastructure is not yet in place.
- Lithium-ion – high energy density, power, and efficiency. In order to be commercially viable the technology requires improvement in performance, safety, and production cost.

Each battery technology has its own advantages and disadvantages in terms of range and acceleration. As a result, vehicle use patterns and intended application play a significant role in choice of battery technology. In addition, the environmental conditions in which the vehicle will be operating will also impact the choice of battery type.

Storage and Handling issues

Battery recharging requires particular precautions in terms of siting, storage and handling. Building storage locations for batteries must be ventilated to ensure that the gases emanated when batteries are charged dissipate sufficiently. In addition, because of the prevalence of high voltage electric cables, wires, outlets and high power battery chargers in the garages, vehicle storage and maintenance facilities should follow NFPA 70, *National Electric Code.*

Environmental, health and safety considerations

Because all-electric vehicles have no tailpipe emissions, and PHEVs will have very few, both can have significant benefits on localized air quality. However, the complete emission implications of electric vehicles are relative to the fuel mix used in the electricity generation that charges the vehicles batteries. For instance, PHEVs operated on electricity generated by coal plants would only modestly decrease net CO_2 emissions versus a conventional gasoline engine, as shown in Table 1. Those using electricity produced from natural gas-fueled power plants, nuclear plants, or other renewable sources would translate into greater GHG reductions. While the emissions benefits for HEVs are not as great as BEVs and PHEVs, such vehicles do emit less CO_2 and air pollutants than conventional gasoline and diesel powered vehicles.

Table 1: Carbon Emission Reductions for driving a PHEV on Electrical Power Rather than Gasoline
Source: NREL

Technology	Carbon*	
	Per Gallon	Per Mile
Gasoline Engine	6.6 lb	.22 lb
PHEV/Modern Coal-Fired Power Plant	5.6 lb	.19 lb
PHEV/Gas Combined-Cycle Power Plant	2.5 lb	.08 lb

**Assumes 10 kWh of electricity is required to drive the same distance (30 miles) as on one gallon of gasoline; includes 10% transmission loss.*

An additional environmental consideration associated with electric vehicles is the lifecycle impacts of the battery. Batteries contain toxic elements, and depending upon the type of battery used, recycling and disposal may be an issue.

The primary safety issue with electric and hybrid-electric vehicles is the risk of electric shock. These vehicles contain high voltage (300V to 600V) circuits that may be active even when the vehicle is not operating. Risk of electric shock can be mitigated through appropriate engineering, labeling, and maintenance practices.[40] An additional safety concern with electric vehicles is the potential for hydrogen gassing during the recharging of batteries. As such, battery charging must be done in well ventilated areas to ensure that hydrogen concentrations remain below the lower explosion limit.[41] In addition, fire characteristics and the techniques of fighting electrical fires are different from those from a combustible fire. Therefore, emergency response personnel should be trained in the appropriate response procedures.

Example of uses on federal lands

- Patuxent National Wildlife Research Refuge, Maryland – operates a 40 passenger, all-electric tram. The tram is used to provide the public with an interpretive tour around a 2-mile unimproved route from mid-March through mid-November. *Nell Baldacchino, Education/Outreach Team Leader, Nell_Baldacchino@fws.gov*
- Golden Gate National Recreation Area, California – operates the Sustainable Easy Access Transport (SEAT), an electric shuttle for individuals with mobility and physical needs.
- Yosemite National Park, California – in 2005, the park began operating 18 40-foot, low-floor, diesel-electric hybrid buses. Vehicle maintenance is performed on-site by trained park staff.
- Carl Sandburg Home National Historic Site, North Carolina – in 2009, the site acquired an electric visitor service shuttle. The shuttle, which can carry 10 passengers, is equipped with solar panels and electric batteries.

[40] Federal Transit Administration (2003). *Design Guidelines for Bus Transit Systems Using Electric and Hybrid Electric Propulsion as an Alternative Fuel.*
[41] *Ibid.*

Hydrogen

While not currently a commercially available fuel choice, hydrogen may be a promising clean transportation fuel for the future. Hydrogen, and the associated hydrogen fuel cell, offers the potential for near-zero tailpipe emissions and high efficiency.

While hydrogen is an abundant element, very little of it is present in the Earth's atmosphere in the pure gaseous form. Instead most hydrogen occurs in compounds, such as water and methane. Currently, extracting hydrogen from these compounds in an energy and carbon efficient manner is one of the major barriers to being able to utilize hydrogen as a major fuel source. In addition, current vehicle storage technologies are insufficient to meet the needs of hydrogen. Because hydrogen has a low volumetric energy density (a low amount of energy by volume) storing enough hydrogen to achieve a driving range of 300 miles would require a tank size that is larger than the trunk of a typical car.[42]

Hydrogen

- Can be produced from both renewable and non-renewable sources.
- Can be stored as a gas or cryogenic liquid.
- Not yet a commercially available fuel choice due to barriers to hydrogen extraction and storage.

The DOE, the California Fuel Cell Partnership, major auto manufacturers and numerous other partners have a number of hydrogen research and development projects underway. These projects are focused on overcoming the challenges inherent in the use of hydrogen as a transportation fuel source, in particular those related to production, delivery, storage, and vehicle technologies.

Example of uses on federal lands

- Hawaii Volcanoes National Park, Hawii – received a $989,000 research and development grant from the FTA to test the feasibility and performance of a hybrid battery/hydrogen fueled shuttle system. *Mardie Lane, Park Ranger, Mardie_Lane@nps.gov*

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[42] AFDC. *Hydrogen as an Alternative Fuel.* Available online at http://www.afdc.energy.gov/afdc/fuels/hydrogen_alternative.html

Decision Process Framework

The following section is intended to lead FLMA staff through the process of deciding whether alternative fuel is a viable option for alternative transportation systems. It does so by posing questions that should be considered in order to elicit more thoughtful decision making.

The decision process involves four primary tasks:

- Determine transportation needs and operating conditions.
- Identify preferred vehicle type.
- Identify alternative fuel options.
- Analyze cost and operational implications for each fuel option.

Task 1: Determine transportation needs

The first step in the decision making process is to identify the transportation needs of the site and to determine the best alternative solution to meet those needs. The type of visitor transportation service provided will have a direct effect on the feasibility of using alternative fuel. The following issues should be considered as part of the transportation and feasibility planning and analysis.

- *Type of operation:* What is the primary purpose of the visitor transportation system: to transport visitors to/from or within the public land, or to provide interpretive tours?
- *Level of demand:* What is the expected level of demand for alternative transportation? How many vehicles will be needed to serve the demand?
- *Anticipated duty cycle:* What locations will be served? What is the length of the service route(s)? How long will each trip take? How many routes will the vehicles operate per day/week?

Task 2: Identify preferred vehicle type

Once a site has determined the appropriate service to provide to meet its transportation needs, the next step in the decision making process is to identify appropriate vehicle options to complement the service. When considering vehicle types it is important to determine which vehicle characteristics are required for the transportation operation (primary characteristics), and which would be nice to have but are not essential (secondary characteristics).

The environment in which the vehicle will operate in will greatly impact vehicle characteristics such as the vehicles overall size, suspension, and power and engine capabilities. The environmental and operating conditions that must be considered include:

- Grade – what are the maximum grades and associated lengths?
- Road surfaces – will the vehicle operate on smooth, paved services, or off-road environments?
- Weather and altitude – what are the minimum and maximum temperatures?
- Route limitations – what size vehicles can the route accommodate? Does the route have a load-bearing limit?

There may be additional environmental conditions unique to the area that must be taken into consideration. For example, the presence of fire danger along the route or the proximity of marine environments or use of road salt will impact the type of vehicle components that should be considered.

In addition to the operating conditions, requirements for visitor perspective and experience also impact vehicle type. The passenger conditions that must be considered include:

- Passenger capacity.
- Interior seating configuration.
- Floor height.
- Number and placement of windows.
- Need for air conditioning and heating.

Task 3: Identify alternative fuel options

Once a site determines the type of vehicle(s) that will meet the transportation service and design requirements, it can then determine whether alternative fuel is a viable option. The vehicle that meets the FLMA site's service and design requirements may only be available with certain fuel types. Questions to consider include:

- Is the preferred vehicle type identified in task 2 available as an alternative fueled vehicle from an original equipment manufacturer?
- If not, can a vehicle be converted to run on alternative fuel? It is important to keep in mind that all vehicle conversions must be certified to meet applicable federal requirements. The EPA issues Certificates of Conformity that cover a test group, i.e. specific vehicles or engine models that are modified to operate on an alternative fuel. An aftermarket conversion may only be performed on a vehicle if a Certificate of Conformity has been issued for that vehicle's test group. In addition, the vehicle conversion can only be performed by those associated with a certificate holder.[43]

Task 4: Analyze cost and operational implications for each fuel option

If the preferred vehicle is available with multiple fuel types the FLMA site will need to evaluate which alternative fuel option, if any, is best suited for its particular transportation application. To do so, a detailed feasibility analysis of the following factors is needed:

- *Fuel source availability and proximity*
    - What is the proximity of the closest alternative fueling station?
    - For those with on-site fueling facilities:
        - Can existing facilities be converted to utilize alternative fuel?
        - Does an alternative fuel distributor provide service to the area?
    - If new fueling infrastructure is needed, are there local partners that the FLMA can coordinate with on the construction of a new fueling station?
- *Site specific infrastructure needs*
    - Can maintenance on an AFV be performed within existing facilities, or will existing facilities need to be modified or new facilities constructed?
    - Does the site have the necessary space available to meet the siting and design requirements for AFV maintenance and storage facilities?

[43] AFDC, *Conversions.* http://www.afdc.energy.gov/afdc/vehicles/conversions.html

- *Availability of qualified staff*
    - Does staff possess the appropriate qualifications and skills needed to operate and maintain an alternative fueled vehicle?
    - What is the availability of warranty service and support for alternative fuel vehicles and technologies in the area?

- *Evaluate performance*
    - Do other public lands with similar operating environments and conditions have experience using the particular alternative fuel? It is highly recommended that staff speak with other FLMA's that have experience with the fuel to discuss lessons learned.

- *Determine costs*
    - What are the projected capital and operating costs, and how will those costs be covered? Total costs include:
        - Vehicle and/or power system
        - Infrastructure development and/or modification
        - Fuel
        - Training for maintenance and operators

The careful consideration of each and all of these factors will be critical to the success of the alternative fuels program.

Appendix A: Annotated Bibliography

Reports

ARCADIS Geraghty & Miller, Inc (1998). ***TCRP Report 38: Guidebook for Evaluating, Selecting and Implementing Fuel Choices for Transit Bus Operations. Available online at http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_38-a.pdf***

- The guidebook provides details on the assessment, selection, and implementation of alternative fuel options (CNG, LNG, methanol, ethanol, and LPG) for transit buses. It includes a spreadsheet-based computer tool to assist in the quantification of costs associated with the potential conversion to alternative fuels.

Battelle (1995). ***Summary Assessment of the Safety, Health, Environmental and System Risks of Alternative Fuel.*** **Available online at http://transit-safety.fta.dot.gov/publications/CleanAir/Alt_Fuel/alt_fuel.htm**

- Handbook of safety, health, and the environmental issues of the production, bulk transport, and bulk storage of alternative fuels with emphasis on transport and storage. Fuels included are: compressed natural gas, liquefied natural gas, propane, methanol and methanol blends, ethanol and ethanol blends, biodiesel, hydrogen, and electricity. Safety topics include fire hazards, toxicity, and environmental effects of spills.

Battelle (2002). ***Resource Guide for Heavy-Duty LNG Vehicles, Infrastructure, and Support Operations.*** **Available online at http://www.afdc.energy.gov/afdc/pdfs/lng_resource_guide.pdf**

- This Guide is designed to assist decision makers and fleet managers, in considering the use of LNG in heavy-duty vehicles. The Guide provides answers to questions regarding implementation of LNG fuel in the fleet, e.g., getting started, likely costs, benefits, and lessons others have learned.

Clark, N., Zen, F and Wayne, W. S. (2009). TCRP Report 132: ***Assessment of Hybrid-Electric Transit Bus Technology.*** **Available online at http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_132.pdf.**

- Provides decisionmaking guidelines coupled with a comprehensive life cycle cost model (LCCM) to assist transit managers in evaluating, selecting, and implementing hybrid-electric technology options for transit buses.

Connecticut Academy of Science and Engineering. (2005). ***Demonstration 9and Evaluation of Hybrid Diesel-Electric Transit Buses.*** **Available online at http://www.ct.gov/dot/LIB/dot/documents/dresearch/CT-170-1884-F-05-10.pdf**

- This evaluation program compared two 2003-model-year, 40-foot, low floor New Flyer Allison hybrid diesel-electric buses, and two virtually identical 2002-model-year, 40-foot, low floor New Flyer standard clean-diesel buses. The hybrids and base buses were operated in virtually identical conditions on equivalent routes each day, duplicating revenue service in all cases. The evaluation results found that the hybrid buses achieved a 10 percent better fuel economy as compared to the diesel-buses. In addition, the gaseous emissions (carbon dioxide, carbon monoxide, oxides of nitrogen, and unburned hydrocarbons) and particulate matter emissions were virtually identical for the hybrid buses and the base clean-diesel buses.

EA Engineering, Science, and Technology, Inc. (2004). *Alternative Fuels Study Glacier National Park.* Available online at http://workflow.den.nps.gov/staging/8_Transportation/Documents_and_Studies/Glacier%20National%20Park%20Alternative%20Fuels%20Study%20Report.pdf

- The report outlines a strategy to support alternative transportation systems, including alternative fuel vehicles and fueling infrastructure, in Glacier National Park and its surrounding region. The report highlights other NPS units' experiences with alternative fuel vehicles, including Yellowstone National Park. Based on an analysis of the Glacier National Park's transit system needs and alternatives, the report recommends that new vehicle new vehicle purchases or vehicle conversions be based on the use of alternative fuels that are already available and already proven in applications in the park or the surrounding region. These include LPG, ethanol/gasoline blends, and biodiesel.

Propane Education & Research Council. *Propane fleet case study: Propane powers Zion National Park's shuttle bus service.* Available online at http://www.propanecouncil.org/uploadedFiles/Zion%20National%20Park%20case%20study_FINAL.pdf.

- Offers a brief case study on Zion National Park's propane-powered shuttle fleet. The case study provides information on the fleet composition and performance, refueling and infrastructure, training and maintenance, and emission and noise reduction benefits.

Renewable Fuels Association (2009). *E85 Fuel Ethanol: Industry Guidelines, Specifications and Procedures.* Available online at http://www.ethanolrfa.org/resource/e85/documents/RFAE85FUELETHANOL090301.pdf

- This guidance document, developed by the national trade association for the U.S. fuel ethanol industry, provides information on the specifications, properties and their importance as well as other important topics related to E85. The purpose of this document is to serve as a condensed technical reference for manufacturers and retailers of E85 and other interested parties who need such information.

TranSystems Corporation (2008). *Alternative Fuel (E85) Performance/Economics/Quality/Usage.* Available online at http://library.modot.mo.gov/RDT/reports/Ri07043/or09006.pdf

- This study provides an overview of E85, including performance experiences of flexible fuel vehicles (FFV) powered by E85 and the potential environmental benefits. The costs and benefits associated with E85 are applied to the Missouri DOT's FFV fleet to help guide the agency's future fleet operating decision.

U.S. Department of Energy, Federal Energy Management Program (2003). *Federal Technology Alert: Alternative Fuel Vehicles.* Available online at http://www.nrel.gov/docs/fy03osti/26066.pdf.

- This technology alert describes the federal government's plans and progress in meeting the goals for AFVs stated in EPAct and Executive Order 13149. It provides information about alternative fuels, including data on associated costs, fuel availability, performance attributes, and emission, and lists actual and potential uses in federal fleets.

U.S. Department of Energy, National Renewable Energy Laboratory (1998). *Using CNG Truck in National Parks.* Available online at http://www.afdc.energy.gov/afdc/pdfs/CNGTrk.pdf.

- This report outlines the steps required to put CNG trucks in operation in the NPS fleet. The report offers lessons learned based on the experiences of the National Capital Parks Central area's utilization of a CNG powered refuse hauler.

U.S. Department of Energy, National Renewable Energy Laboratory (2006). ***Case Study: Ebus Hybrid Electric Buses and Trolleys.*** **Available online at http://www.afdc.energy.gov/afdc/pdfs/38749.pdf**

- This evaluation focuses on the demonstration of 22-foot hybrid electric buses and trolleys produced by Ebus, Inc. used by the Indianapolis Transportation Corporation (IndyGo) and Knoxville Area Transit (KAT). The agencies collected performance and operating data during the 6-month deployment of diesel- and LPG-fueled Ebus hybrids. Lessons learned included matching vehicles to an appropriate duty cycle and training drivers and maintenance personnel adequately.

U.S. Department of Energy, National Renewable Energy Laboratory (2006). ***Effects of Biodiesel Blends on Vehicle Emissions.*** **Available online at http://www.nrel.gov/docs/fy07osti/40554.pdf**

- The evaluation tested eight heavy-duty diesel vehicles (three transit buses, two school buses, two class 8 trucks, and one motor coach). Each vehicle was tested on a petroleum-derived diesel fuel and on a soy-derived B20. The testing results showed that on average B20 caused PM and CO emissions to be reduced by 16% to 17% and HC emissions to be reduced by 12% relative to petroleum diesel. Emissions of these three pollutants nearly always went down, the exception being a vehicle equipped with a diesel particle filter that showed very low emissions of PM, CO, and HC; and there was no significant change in emissions for blending of B20. The NO_x impact of B20 varied with engine/vehicle technology and test cycle ranging from -5.8% to +6.2%. A preliminary examination of real-time NO_x emission data did not reveal any consistent reason for the wide range. On average NO_x emissions did not change (0.6%±1.8%).

U.S. Department of Energy, National Renewable Energy Laboratory (2006). ***New York City Transit (NYCT) Hybrid (125 Order) and CNG Transit Buses.*** **Available online at http://www1.eere.energy.gov/vehiclesandfuels/avta/pdfs/heavy/nyct_report_final.pdf**

- This report describes the evaluation results for new Orion VII low floor buses at NYCT with CNG propulsion (equipped with Detroit Diesel Corporation Series 50G CNG) and new hybrid propulsion (equipped with BAE Systems' HybriDrive propulsion system). This evaluation focuses on bus operations spanning the first two years of the minimum 12-year life of a transit bus. The CNG buses' average total maintenance cost was $1.29/mile which was 5% higher than the hybrid buses ($1.23/mile) during the evaluation period. The CNG buses' average propulsion-related maintenance costs per mile were 5% lower than the hybrid buses.

U.S. Department of Energy, National Renewable Energy Laboratory (2006). ***Washington Metropolitan Area Transit Authority: Compressed Natural Gas Transit Bus Evaluation.*** **Available online at www.nrel.gov/docs/fy06osti/37626.pdf**

- The objective of this report is to provide a reasonable comparison between currently available CNG and standard diesel transit buses. Two CNG bus propulsion systems were evaluated: the Cummins Westport, Inc C Gas Plus and the John Deere 6081H. Evaluation results found that the CNG buses had fuel economies 16%–18% lower than the diesel buses. The CWI CNG buses had engine- and fuel-related costs 11% higher than the diesel buses, and the Deere CNG buses had costs 3% higher than the diesel buses. The higher maintenance cost for the CNG buses versus the diesel buses for these systems was expected because of higher-cost engine oil, fuel filters, and the addition of the spark plugs and ignition systems for the CNG buses. However, during this period the CNG buses had 12% lower total maintenance costs than the diesel buses, and the Deere CNG buses had 2% lower total maintenance costs than the diesel buses. Finally, both CNG bus groups had better miles between road call (an unscheduled maintenance requiring either the emergency repair or service of a vehicle in the field) rates than the diesel buses.

U.S. Department of Energy, National Renewable Energy Laboratory (2006). ***100,000-Mile Evaluation of Transit Buses Operated on Biodiesel Blends (B20).*** **Available online at http://www.nrel.gov/docs/fy07osti/40128.pdf**

- This evaluation compared nine 40-foot transit buses (model year 2000 Orion V equipped with Cummins ISM engines), five of which were operated on B20 and four operated on petroleum diesel. The two groups were compared in terms of fuel economy, vehicle maintenance cost, road calls, and emissions. The evaluation results found no difference between the on-road average fuel economy of the two groups (4.41 mpg) based on the in-use data, however laboratory testing revealed a nearly 2% reduction in fuel economy for the B20 vehicles. Engine and fuel system related maintenance costs were nearly identical for the two groups until the final month of the study. Component replacements near the end of the study on one B20 bus caused average maintenance costs to be higher for the B20 group ($0.07 vs. $0.05 per mile). However, engine and fuel system maintenance costs varied widely from bus to bus so the $0.02 per mile average difference between the two groups is not statistically significant. There was no significant difference in miles between road calls (an unscheduled maintenance requiring either the emergency repair or service of a vehicle in the field)

U.S. Department of Energy, National Renewable Energy Laboratory (2008). ***Handbook for Handling, Storing, and Dispensing E85.*** **Available online at http://www.nrel.gov/docs/fy02osti/30849.pdf.**

- This guidebook contains information about EPAct alternative fuels regulations for fleets, FFVs, E85 properties and specifications, and E85 handling and storage guidelines. It describes how to successfully and safely use fuel ethanol, including E85, in vehicles.

U.S. Department of Energy, National Renewable Energy Laboratory (2008). ***St. Louis Metro Biodiesel (B20) Transit Bus Evaluation: 12-Month Final Report*****. Available online at http://www.nrel.gov/vehiclesandfuels/fleettest/pdfs/43486.pdf**

- The report highlights the results of an evaluation comparing B20 and ultra-low sulfur diesel (ULSD) buses in terms of fuel economy, vehicle maintenance, engine performance, component wear, and lube oil performance. The buses evaluated were 40-foot model year 2002 transit buses manufactured by Gillig, equipped with model year 2002 Cummins ISM engines. Results found that B20 buses had a 1.7 percent lower fuel economy and experienced higher engine and fuel system maintenance costs as compared to the ULSD buses. Reliability and total maintenance costs between the two groups were comparable.

U.S. Department of Energy, National Renewable Energy Laboratory (2009). ***Biodiesel Handling and Use Guide.*** **Available online at http://www.nrel.gov/vehiclesandfuels/pdfs/43672.pdf**

- This document is a guide for those who blend, store, distribute, and use biodiesel and biodiesel blends. It provides basic information on the proper and safe use of biodiesel and biodiesel blends in compression-ignition engines and boilers, and it is intended to help fleets, individual users, blenders, distributors, and those involved in related activities understand procedures for handling and using biodiesel fuels.

U.S. Department of Energy, National Renewable Energy Laboratory (2009). ***Twelve-Month Evaluation of UPS Diesel Hybrid Electric Delivery Vans.*** **Available online at http://www.nrel.gov/docs/fy10osti/44134.pdf**

- Evaluation results comparing a parallel hybrid-electric diesel delivery van propulsion system with standard diesel systems operated by the United Parcel Service (UPS). The evaluation results found hybrid vehicles':
  - Average monthly mileage rate was 20 percent less than the diesel vans.
  - Fuel economy was 28.9 percent greater than the diesel vans.
  - Total maintenance costs per mile were 8 percent less than the diesel vans.

- Had a slightly lower reliability rating compared to the diesel vans (95.5% uptime versus 99.3%).
- Showed improvement in some emissions, but the results varied significantly depending on the cycle being run. The hybrid vans showed an increase in NOx for all cycles.

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (1999). ***Alternative Fuel Fleet Start-Up Experience: Denver SuperShuttle CNG Fleet Evaluation.*** **Available online at http://www.nrel.gov/docs/fy99osti/26439.pdf**

- Provides an overview of how Denver's SuperShuttle CNG evaluation project was formed. The project, which was jointly funded by the Gas Research Institute and the DOE, began in 1998. The document highlights lessons learned in developing the evaluation program.

U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy (2010). ***Clean Cities 2010 Vehicle Buyer's Guide.*** **Available online at http://www.afdc.energy.gov/afdc/pdfs/46432.pdf.**

- The 2010 Buyer's Guide includes vehicle-specific information on fuel economy, emissions, vehicle specifications, estimated cost, and warranty. This booklet helps you compare similar alternative fuel vehicles to make an informed buying decision.

U.S. Department of Energy, Regional Biomass Energy Program (2004). ***Another RBEP Success: Bringing "green machines" to national parks, part 2: cleaner, quieter park fleets.*** **Available online at http://devafdc.nrel.gov/pdfs/trucks_parks.pdf**

- Case study on the use of a biodiesel-powered pickup truck at Yellowstone National Park. The truck operated without modification on 100 percent biodiesel under normal operating conditions as a maintenance inspection vehicle. Periodic emission testing of the vehicle determined that biodiesel reduced undesirable emissions and did not result in the generation of new harmful compounds. Vehicle performance monitoring found that normal cold-weather diesel modifications are sufficient to permit using biodiesel in cold conditions.

U.S. Department of Transportation, Federal Transit Administration (1996). ***Design Guidelines for Bus Transit Systems Using Compressed Natural Gas as an Alternative Fuel.*** **Available online at http://transit-safety.fta.dot.gov/publications/cleanair/dg_bus_cng/pdf/dg_bus_cng.pdf**

- This guidelines document presents various facility and bus design issues that need to be considered to ensure safe operations when using CNG as the alternative fuel. Fueling facility, garaging facility, maintenance facility requirements and safety practices are indicated. Among the issues discussed are fuel properties, potential hazards, fuel requirements for specified level of service, applicable codes and standards, ventilation, and electrical classification. Critical fuel related safety issues in the design of the related systems on the bus are also discussed.

U.S. Department of Transportation, Federal Highway Administration and Federal Transit ***Administration (2001). Federal Lands Alternative Transportation Systems Study: Candidate Vehicle Technologies.***

- This report documents alternative transportation needs in lands managed by the National Park Service, the U.S. Fish and Wildlife Service, and the Bureau of Land Management. It identifies and describes over 30 mass transit vehicle technologies in five categories -- (1)Bus, (2)Rail/Guided, (3)High Gradient, (4)Water, and (5)Snow -- with potential applicability for federal lands. The descriptions include data on physical, operating, and economic characteristics, an assessment of the principal advantages and disadvantages, and information on typical applications of each technology. An attached appendix provides information on alternative fuels/propulsion systems.

U.S. Department of Transportation, Federal Transit Administration (2003). ***Design Guidelines for Bus Transit Systems Using Electric and Hybrid Electric Propulsion as an Alternative Fuel.*** **Available online at http://transit-safety.volpe.dot.gov/publications/cleanair/DesignGuidelines/PDF/DesignGuidelines.pdf**

- This guidelines document presents various facility and bus design issues that need to be considered to ensure safe operations when using electric or hybrid electric propulsion. Fueling facility, garaging facility, maintenance facility requirements and safety practices are indicated. Among the issues discussed are electric storage device properties, potential hazards, requirements for specified level of service, and applicable codes and standards. Critical fuel related safety issues in the design of the related systems on the bus are also discussed.

U.S. Department of Transportation, John A. Volpe National Transportation Systems Center. (2005). ***Electric Trams: Lessons Learned at Cape Cod National Seashore.*** **Available online at http://www.nps.gov/transportation/tmp/documents/Shuttles/CACO%20Tram%20Lessons%20Learned%20-%20Final%20Report.pdf**

- In seeking to obtain environmentally friendly replacement vehicles for its parking shuttle service, Cape Cod National Seashore set out to procure two hybrid-electric trams in 1998. Ultimately, battery-powered trams were delivered with multiple safety and performance problems that were never successfully remedied. This report examines the causes of these deficiencies and identifies several critical "lessons learned" that will assist other parks to avoid similar problems when undertaking future procurements of similar vehicles.

U.S. Department of Transportation, John A. Volpe National Transportation Systems Center. (2004). ***Alternative Transportation Systems – Vehicles and Supporting Infrastructure Guide. Plan Implementation Considerations for National Park Managers.***

- This document serves a guide to the basic concepts involved and issues to be addressed by NPS staff in the of acquisition of vehicles, supporting infrastructure, as well as information on the need for maintenance facilities and specialized staff to operate and maintain transportation system to serve visitors to national parks, recreation areas, historic sites, and monuments. It provides an overview of alternative fuel options, as well as vehicle types that are particularly suitable for visitor transportation.

U.S. Government Accountability Office (2009). ***Federal Energy and Fleet Management: Plug-in Vehicles Offer Potential Benefits, but High Costs and Limited Information Could Hinder Integration into the Federal Fleet.*** **Available online at http://www.gao.gov/new.items/d09493.pdf**

- Executive Order 134231 calls for federal agencies to begin using plug-in hybrid electric vehicles when they become commercially available and can be procured at a reasonably comparable life-cycle cost to conventional gasoline-powered vehicles. The GAO report examines the (1) potential benefits of plug-ins, (2) factors affecting the availability of plug-ins, and (3) challenges to incorporating plug-ins into the federal fleet.

Western Transportation Institute (1999). National Parks: Transportation Alternatives and Advanced Technology for 21st Century, Conference Proceedings. Available online at http://ntl.bts.gov/lib/jpodocs/proceedn/11803.pdf

- The conference included a panel focused on how alternative fuel vehicles can be better integrated into the national parks. The panelists reviewed various vehicle, engine and fuel technology options and identified the challenges and barriers to their application.

Policy and Legislation

Energy Policy Act (EPAct) of 1992. Full text available at http://thomas.loc.gov/cgi-bin/query/z?c102:H.R.776.ENR

- Set statutory requirements for the acquisition of AFVs by federal agencies. Starting in fiscal year 2000, 75% of light-duty vehicle (LDV)(vehicles that weigh less than 8,500 pounds).
- Requirements apply to fleets of 20 or more LDVs that are centrally fueled or capable of being centrally fueled and are primarily operated in a metropolitan statistical area (MSA)/consolidated metropolitan area (CMSA). Vehicles heavier than 8,500 pounds GVWR or not located or operated primarily in a covered MSA or CMSA are exempt from these requirements.
- Compliance is met by AFV acquisition credits, which are granted based on the number of AFVs acquired and the quantity of biodiesel fuel used.

Energy Policy Act of 2005. Full text available at http://www.interior.gov/iepa/EnergyPolicyActof2005.pdf

- Section 701 requires the use of alternative fuels in federal dual-fueled AFVs unless the Secretary of Energy determines that an agency qualifies for a waiver.

***Documentation Requirements for Waiver Requests under EPAct 2005 Section 701. Available online at* http://www1.eere.energy.gov/femp/pdfs/701_guidance.pdf.**

- The waiver covers vehicles operated by an agency in a particular geographic area in which:
  - The alternative fuel required for use in the vehicle is not reasonably available (within a 5 mile or 15 minute drive of the vehicles' garaged location) as certified to the Secretary by the head of the agency.
  - The cost of the alternative fuel required for use in the vehicle is unreasonably more expensive compared to a gallon of gasoline as certified to the Secretary by the head of the agency.

Energy Conservation Reauthorization Act

- Amended the EPAct of 1992 to allow fleets to generate one alternative-fuel vehicle (AFV) acquisition credit for every 450 gallons of pure biodiesel (B100, equivalent to 2,250 gallons of B20) purchased for use in medium- and heavy-duty diesel vehicles (vehicles weighing more than 8,500 pounds gross vehicle weight rating). To achieve AFV acquisition credit through biodiesel consumption, the biodiesel must be in blends of B20 or higher. Federal fleets are allowed to use these credits to fulfill no more than 50% of their EPAct 1992 AFV acquisition requirements. These credits can be claimed only in the year in which the fuel is purchased for use and cannot be traded among fleets.

Energy Independence and Security Act (EISA) of 2007

- Section 141 prohibits federal agencies from acquiring light-duty vehicles and medium-duty passenger vehicles that are not low greenhouse gas (GHG)-emitting vehicles.
- Section 246 directs federal agencies to install at least one renewable fuel pump at fueling centers under their jurisdiction by January 1, 2010, and to provide annual reports on their progress in meeting this requirement. Department of Defense fueling centers that consume less than 100,000 gasoline gallon equivalent (GGE) of fuel per year are exempt from this requirement.

National Defense Authorization Act of 2008

- Amended the EPAct of 1992 and classified four new vehicles as "alternative fueled vehicles" (AFV) as defined in Section 30B of the Internal Revenue Service (IRS) Code:
    - A new qualified fuel cell motor vehicle
    - A new advanced lean-burn engine technology motor vehicle
    - A new qualified hybrid motor vehicle
    - Any other type of vehicle that the Administrator of the EPA demonstrates to the Secretary of Energy would achieve a significant reduction in petroleum consumption.
- Guidance document, *New Alternative Fuel Vehicle Definitions under Section 2862 of the National Defense Authorization Act of 2008* available at http://www1.eere.energy.gov/femp/pdfs/ndaa_guidance.pdf

Executive Order 13514; *Federal Leadership in Environmental, Energy, and Economic Performance.* Full text available online at http://edocket.access.gpo.gov/2007/pdf/07-374.pdf

- When establishing annual GHG emission reduction targets, federal agencies must consider reducing petroleum consumption in agency fleets of 20 or more 2 percent annually through fiscal year 2020 relative to a fiscal year 2005 baseline.
- Instructions for implementing E.O. 13423 available at http://www1.eere.energy.gov/femp/pdfs/instructions_eo13423.pdf