ENCYCLOPEDIA ARTICLE

Alternative fuels for vehicles

Conventional fuels such as gasoline and diesel are gradually being replaced by alternative fuels such as gaseous fuels (natural gas and propane), alcohol (methanol and ethanol), and hydrogen. Conventional fuels can also be modified to a reformulated gasoline to help reduce toxic emissions. Technological advances in the automotive industry (such as in fuel cells and hybrid-powered vehicles) are helping to increase the demand for alternative fuels.

Two key issues associated with the use of conventional fuels for vehicles prompt interest in alternative fuels: (1) gasoline- and diesel-powered vehicles are considered to be a significant source of air pollution; and (2) conventional fuels are produced from crude oil, a nonrenewable energy resource. The success of alternative fuels in the marketplace will depend on numerous factors, including public understanding and consumer awareness; economics; automobile performance; availability of fuels, vehicles, and distribution and marketing systems; and changes in technology. See also: Air pollution

Gaseous fuels

Vehicle emissions from natural gas and propane are expected to be lower and less harmful to the environment than those of conventional gasoline. Because natural gas and propane are less complex hydrocarbons, the levels of volatile organic compounds and ozone emissions should be reduced. Both of these fuels are introduced to the engine as a gas under most operating conditions and require minimal fuel enrichment during warm-up. Leaner burning fuels, they also achieve lower carbon dioxide and carbon monoxide levels than gasoline. However, because they burn at higher temperatures, emissions of nitrogen oxide are higher. An important property of gaseous fuels is their degree of resistance to engine knock. Because of their higher-octane value relative to gasoline, there is less of a tendency for these fuels to knock in spark-ignition engines. To achieve the optimal performance and maximum environmental benefits of natural gas and propane, technological advancements must continue to reduce the costs of dedicated vehicles to be competitive with conventional vehicles, and the necessary fueling infrastructure must be ensured.

Natural gas

Natural gas is a colorless, odorless hydrocarbon that is neither carcinogenic nor corrosive. Once processed at a gas plant, natural gas is composed of about 97% methane (CH_4). Being lighter than air, it does not pool on the ground when leaked but dissipates into the atmosphere, reducing the hazard of fire. One drawback as a transportation fuel is its very low energy density relative to gasoline or diesel fuel. To eliminate bulkiness, the gas is compressed and stored in cylindrical tanks. At a pressure of 3000 pounds per square inch (20 megapascals), the volumetric energy density of a typical natural gas cylinder is only 20% that of a similar volume of gasoline. Thus, the driving range of a natural gas vehicle carrying the same volume of fuel as a gasoline-fueled vehicle will be less. Larger vehicles, carrying two or three natural gas tanks, can achieve an adequate driving range for most personal or fleet purposes, but at the cost of space and the additional weight of the cylinders. See also: Methane

Natural gas engine technology is fairly well developed, including heavy-duty applications. Vehicle refueling appliances have reduced the constraints associated with the lack of distribution and refueling infrastructure; however, the associated costs in addition to those related to conversion tend to limit natural gas usage to high-mileage vehicles. Significant advances have been made with regard to lighter and stronger fuel cylinders, and there is more variety of natural gas vehicles produced by original equipment manufacturers than for any other alternative fuel. Still required for market competitiveness of natural gas is a refueling infrastructure with widespread access and low-cost fast-fill capabilities. See also: Liquefied natural gas (LNG); Natural gas

Propane

Propane (C_3H_8), a hydrocarbon produced from crude oil and natural gas, has been one of the more successful alternative transportation fuels. A cleaner-burning fuel than gasoline or diesel fuel, it can result in lower maintenance costs, requiring fewer spark plug and oil changes, and less wear on such components as piston rings and bearings. Since propane has a higher octane rating than gasoline, propane-fueled vehicles can use higher engine compression ratios, resulting in more power and better fuel efficiency.

Propane has a lower energy density than gasoline by volume but a higher energy density by weight; therefore, the weight of a tank full of propane is similar to that of one filled with gasoline. Compared to ethanol, methanol, or natural gas, propane has a higher energy content by weight and volume, so it can take a vehicle farther on an average-capacity tank than a similar tank of any of the other alternative fuels. Refueling time for propane is similar to conventional fuels.

Several factors related to customer convenience and conversion costs have been restrictive to automotive propane market development. The physical characteristics of propane require modifications to conventional vehicles by either the automotive manufacturer at the factory or after-market conversions; either way, the cost of the modifications adds to the price paid by the consumer for a gasoline or diesel vehicle. In order to maintain a liquid state, propane must be stored under pressures of up to 200 psi (1.3 MPa). Because of this fact and the lower energy density of propane relative to gasoline, propane-powered vehicles must be fitted with storage tanks that impose weight and space penalties in order for the vehicles to travel the same distance as gasoline counterparts. Also, the vapor pressure of propane varies in relation to the atmospheric temperature. At temperatures of −43°C (−45°F) and colder, the pressure in a fuel tank is essentially zero, the product becomes liquid, and propane fuel systems simply do not operate. Another inconvenience arises due to the potential hazard of vapor accumulation at ground level; for this reason, some city and municipality bylaws forbid propane vehicles from parking in underground facilities.

On the basis of a grams per unit of distance traveled, propane full fuel cycle emissions compare favorably with gasoline, except for nitrogen oxides. With further development of propane vehicles by original equipment manufacturers, the establishment of certification standards for propane conversions, and continued technological improvements in emission control systems, the environmental impact of propane could prove even greater. The potential economic benefits from conversion to propane are greatest in high-fuel-consumption fleets such as taxis, where payback occurs in 1–2 years.

Alcohol fuels

The most significant advantage of alcohol fuels over gasoline is their potential to reduce ozone concentrations and to lower levels of carbon monoxide. Another important advantage is their very low emissions of particulates in diesel engine applications. In comparison with hydrocarbon-based fuels, the exhaust emissions from vehicles burning low-level alcohol blends (such as gasohol containing 10% alcohol by volume) contain negligible amounts of aromatics and reduced levels of hydrocarbons and carbon monoxide but higher nitrogen oxide content.

Exposure to aldehydes, in particular formaldehyde which is considered carcinogenic, is an important air-pollution concern. The aldehyde fraction of unburned fuel, particularly for methanol, is appreciably greater than for hydrocarbon-based fuels; therefore, catalytic converters are required on methanol vehicles to reduce the level of formaldehyde to those associated with gasoline. See also: Alcohol fuel

Methanol

Methanol (CH_3OH) is a clear, colorless, high-performance liquid fuel that can be used in both spark-ignition and diesel engines. It can be burned as a neat (100% methanol) or near-neat fuel in internal combustion engines. A blend of 85% methanol and 15% gasoline, M85, is the most common form of methanol fuel used in light-duty vehicles. M100, or neat methanol, is used in some heavy-duty trucks and buses.

The appeal of methanol as an alternative to gasoline stems from its being a relatively inexpensive clean-burning liquid fuel. A constraint is the fact that it has only half the energy density of gasoline, compensated to some degree by its better thermal efficiency. Safety concerns relate to the fact that methanol is toxic and can be absorbed through the skin. Also, neat methanol burns with an invisible flame, making methanol fires without a colorant difficult to detect.

Besides being used as a neat or near-neat transportation fuel, methanol has been used to produce methyl tertiary butyl ether (MTBE), an oxygenate which, if blended with gasoline up to 10%, adds one octane number to the fuel. Concerns related to MTBE leaking and contaminating ground water in some areas in the United States resulted in a reexamination of the use of this oxygenate, and the phase-out of its use in California by December 31, 2002. Methanol is also being tested in the transportation industry as a source of the hydrogen in hybrid fuel cell vehicles. See also: Ether; Methanol

Ethanol

Ethanol (C_2H_5OH) produced from biomass is a renewable fuel source currently being marketed in neat, near-neat, and low-level premium fuel blends. In addition to providing environmental benefits, use of ethanol fuel produced from fermentable starch or sugar crops provides economic advantages to the agriculture sector. However, ethanol production costs are very high relative to gasoline and must be reduced substantially if ethanol is to compete on an economic basis.

To date, in the fuel industry ethanol has been used mainly as an additive in low-level gasohol blends. These blends have been successfully used in unmodified gasoline vehicles with warranty coverage provided for automobiles sold in North America. Neat ethanol, generally used in heavy-duty applications, is less common and requires costly engine modifications. Flexible fuel vehicles can operate on a mixture of gasoline and up to 85% ethanol (E85). Ethanol has also been used in the production of ethyl tertiary butyl ether (ETBE), but to date it has not been economically competitive with MTBE.

The oxygen content of ethanol fuels used in properly modified vehicles results in increased energy efficiency and engine performance. Extended spark-plug life and lower carbon deposits are also expected because ethanol burns cleaner than gasoline.

A significant drawback of ethanol is its much lower energy density than gasoline (approximately 34% less). To travel distances similar to a gasoline-powered vehicle without refueling would require a much bigger fuel tank; this requirement is slightly offset by the greater energy efficiency of ethanol. See also: Ethyl alcohol

Hydrogen

Hydrogen is the lightest and most abundant element in the universe. It can be produced from a number of feedstocks in a variety of ways. The production method thought to be most environmentally benign is the electrolysis of water, but probably the most common source of hydrogen is the steam reforming of natural gas. Once produced, hydrogen can be stored as a gas, liquid, or solid and distributed as required. Liquid storage is currently the preferred method, but it is very costly. Metal hydride and compressed storage are also being investigated. See also: Metal hydrides

Hydrogen-powered vehicles can use internal combustion engines or fuel cells. They can also be hybrid vehicles of various combinations. When hydrogen is used as a gaseous fuel in an internal combustion engine, its very low energy density compared to liquid fuels is a major drawback requiring greater storage space for the vehicle to travel a similar distance to gasoline. Although hybrid vehicles can be more efficient than conventional vehicles and result in lower emissions, the greatest potential to alleviate air-pollution problems is thought to be in the use of hydrogen-powered fuel cell vehicles. Though currently very expensive, fuel cells are more efficient than conventional internal combustion engines. They can operate with a variety of fuels, but the fuel of choice is gaseous hydrogen since it optimizes fuel cell performance and does not require on-board modification.

Numerous hydrogen fuel cell vehicle models are being developed and tested with the objective of having such vehicles available for sale to the public in the early years of the twenty-first century. However, for gaseous hydrogen to become a fuel of choice in the transportation industry, numerous technical and economic constraints related to hydrogen production, on-board and site storage, and marketing and distribution systems must be overcome. Safety issues and perception must also be addressed. See also: Fuel cell; Hydrogen

Reformulated fuels

Conventional gasoline and diesel fuels are complex mixtures of many different chemical compounds. Over time these fuels have undergone reformulation to improve their value to the transportation industry; this reformulation ranged from mild, like the backing-out of butane to reduce the volatility, to severe adjustments that substantially change the composition.

The U.S. Clean Air Act Amendments (CAAA) have served to increase interest in using regulated changes to motor fuel characteristics as a means of achieving environmental goals. The reformulated gasoline (RFG) program was designed to resolve ground-level ozone problems in urban areas. Under this program, compared to conventional gasoline, the amount of heavy hydrocarbons is limited in reformulated gasoline, and the fuel must include oxygenates and contain fewer olefins, aromatics, and volatile organic compounds.

Diesel-powered heavy-duty trucks and buses are said to account for about a quarter of the nitrogen oxides (NO_x) that result in smog formation and well over half of the particulates produced by mobile sources. Particulates, unburned fuel particles, can stick to the lungs if inhaled, causing increased susceptibility to respiratory illness. Research is under way to develop diesel fuel that will reduce both the particulate and NO_x levels. These fuels will have higher cetane ratings than conventional diesel fuel and lower sulfur and aromatics.

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Bibliography

- R. L. Bechtold, *Alternative Fuels Guidebook: Properties, Storage, Dispensing, and Vehicle Facility Modifications*, 1997
- R. L. Busby, *Hydrogen and Fuel Cells: A Comprehensive Guide*, 2005
- Society of Automotive Engineers, *State of Alternative Fuel Technologies 2000*, 2000

Additional Readings

- L. Gill, *The Environmental Benefits and Economics of Hydrogen as a Vehicle Fuel in Canada*, Can. Energy Res. Inst. Study no. 82, January 1998
- M. Heath et al., *Alternative Transportation Fuels in Canada: Prospects and Policies*, Can. Energy Res. Inst. Study no. 70, November 1996

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