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Reducing Petroleum Dependence: Alternative Fuels and Alternative Fuel Vehicles

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It's not exactly breaking news that gas prices are high and getting higher! United States oil refineries operated at 95 percent capacity in August (Schoen). Then hurricanes Katrina and Rita roared through the Gulf, reducing the operating capacity to 84 percent in September with a weekly low of less than 70 percent (Dept. of Energy (e)).

This current supply squeeze may be short term. But we have a long-term supply problem too: Oil is a non-renewable resource and estimating world reserves is very difficult. Classic supply and demand theory predicts that oil prices will increase to ration an ever-more limited supply over an ever-more increasing demand.

U. S. demand for motor fuel increased 26 percent from 1990 to 2004. Consumption in the first half of 2005 is little changed from that of 2004. In Virginia alone, highway miles traveled have increased 83 percent from 1983 to 2003 (Va. DMV). As consumption has increased, so have prices. The U. S. cities average price for gasoline increased 81 percent from 1990 through August 2005 (Figure 1). The average price for gasoline in September 2005 was \$2.90 per gallon, over 31 percent more than in August 2005 (Krueger).

In economic terms, U. S. demand for gasoline is price-inelastic: Consumers do not respond very much to fuel price increases. The design of our communities requires that we drive to work, the grocery, the library, the mall, and other places. We like the freedom of being able to travel at our convenience. We do not like being tied to the schedules of public transportation or carpools. Many people prefer sport utility vehicles (SUVs) and light trucks, which use more gas than smaller vehicles.

Higher gas prices are slow to drive the search for alternatives to petroleum (petro fuels) and more efficient vehicles while

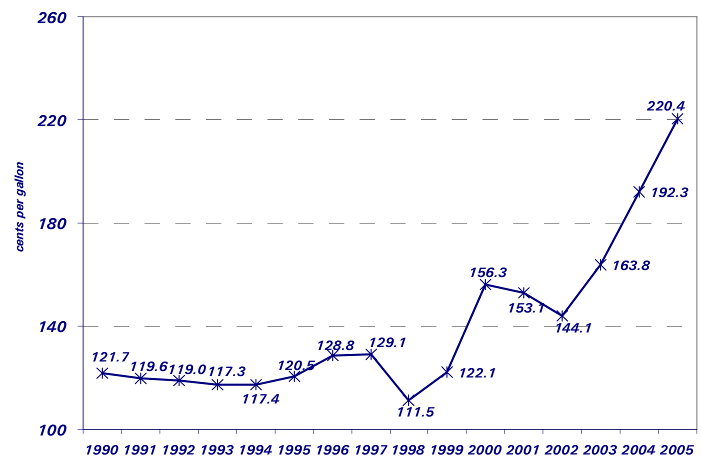

Figure 1. U. S. cities average retail price of gasoline including taxes, 1990 – August 2005

Source: Dept. of Energy (d)

policies related to environmental issues seem to play a large role. The processing and use of petro fuels produces ozone (O_3), carbon dioxide (CO_2), particulate matter (PM), carbon monoxide (CO), sulfur oxides (SO_X), and nitrous oxides (NO_X). O_3 at ground level is a major contributor to smog (EPA). PM represents small particles of carbon that help create smog. All these petroleum byproducts cause air pollution in the form of smog, ozone, and greenhouse gases (GHG).

GHG occur naturally. They " . . . allow sunlight to enter the atmosphere freely. When sunlight strikes the Earth's surface, some of it is reflected back towards space as infrared radiation (heat). [GHG] absorb this infrared radiation and trap the heat in the atmosphere." (Jack Faucett Assoc. et al). The heat trapped in the atmosphere is similar to the heating that

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results from light and moisture trapped in a greenhouse. This phenomenon is called the "greenhouse effect." The greenhouse effect is often cited as a cause of global warming.

Defining Alternative Fuels

Does the U.S. have alternatives to the ever-increasing use of non-renewable oil? Would any of the alternatives be less polluting? Finally, would any of the alternatives be no more costly than petro fuels?

Alternative fuels are defined in the Energy Policy Act of 1992 (EPAct). They include ethanol, methanol, and other alcohols; blends of 85 percent or more of alcohol with gasoline; natural gas; liquefied petroleum gas; coal-derived liquid fuels; hydrogen; electricity; P-series; and biodiesel 100 (Dept. of Energy (a)). P-series fuels contain at least 60 percent non-petroleum energy. The energy content is derived from methyltetrahydorfuran (MTHF) and ethanol manufactured solely from biological materials and electricity, including solar energy (Federal Register). While not defined as an alternative fuel, biodiesel processors receive a tax credit of one penny for each percent of biodiesel produced from agricultural products and 0.5¢ for each percent of biodiesel produced from recycled oils (National Biodiesel Board (c)).

Ethanol and Biodiesel

Recently, blends of ethanol and biodiesel have received a great deal of attention. Both types of fuels can be made from renewable agricultural resources. The percentage of ethanol added to gasoline or of biodiesel added to petrodiesel is the number that follows the type. For example, Ethanol 85 (E85) is 85 percent ethanol and 15 percent gasoline; biodiesel 20 (B20) is 20 percent biodiesel and 80 percent petrodiesel. B100 is 100 percent biodiesel or "neat" biodiesel. These fuels are not yet widely available across Virginia or the U.S., primarily because of insufficient infrastructure for processing and delivery.

Ethanol

In the early 1900s, Henry Ford designed his Model-T to run on ethanol. With the advent of inexpensive gasoline, ethanol was not cost effective, and the growing automobile industry dropped it as an alternative fuel. Today, gasoline prices and pollution concerns are causing people to reconsider ethanol as a vehicle fuel. Ethanol is typically produced from corn, but other feedstocks can also be used: barley; wheat; sugar cane; cellulosic materials, which can come from forest and field residues, fast growing woody plants, paper mill waste, and some municipal solid waste (Hund). The technology for cellulosic ethanol production is relatively new and still being developed. The technology for corn ethanol production, however, is well known.

Ethanol has higher octane and provides more complete combustion than regular gasoline. One drawback, though, is that it reduces gas mileage slightly. Ethanol reduces emissions compared to those from Methyl Tertiary Butyl Ether (MTBE). MTBE, which replaced lead additives used to boost octane in gasoline and provide more complete combustion. E10 can be used in any gas powered automobile without modification to the vehicle engine while E85 requires modifications to the engine.

> *Energy life cycle* is the amount of energy required to deliver the whole system from product production to fuel production to consumption.

Some researchers assert that more energy is needed to produce a gallon of ethanol than is provided by that gallon. The result is would be a net loss of energy as measured in British thermal units (Btu). In an attempt to resolve the controversy, USDA researchers (2002) compared studies on the energy life cycle of ethanol. The various studies showed net energy ranges from -33,462 Btu to 30,589 Btu, depending on the assumptions made about corn yields, fertilizer application rates, and the efficiency of the ethanol processing plant. USDA researchers concluded that a gallon of ethanol produces a net energy increase of 34 percent beyond what is required to produce the ethanol (Table 1).

Table 1. Energy Balance/Energy Life Cycle Inventory

Fuel	Energy yield*	Net Energy loss or gain percent
Gasoline	0.805	-19.5
Diesel	0.843	-15.7
Ethanol	1.34	34.0
Biodiesel	3.20	220.0

* Life cycle yield in liquid fuel Btus for each Btu of fossil fuel energy consumed.
Source: Compiled from USDA data by Minnesota Dept. of Ag.

Corn-based ethanol, depending on the blend, reduces GHG emissions by 18 percent to 29 percent per gallon compared to gasoline. Cellulosic ethanol can reduce GHG emissions by 85 percent (Dept. of Energy (c)).

Blends up to E10 have been available throughout the Midwest for a number of years. In many regions, E10 has replaced the mid-grade gasoline and is often the same price or less than regular gasoline.

Federal regulations instituted in 2000 require that 75 percent of new ". . .public and private [fleets] of 20 or more vehicles operating in metropolitan areas with population of 250,000 or more. . ." must be alternative fuel vehicles (AFVs) (Hund, p. 12). However, the regulations do not require the use of alternative fuels in these vehicles. Flexible fuel vehicles run on either gasoline or E85. Because of the limited availability of E85, most of these vehicles use gasoline. In 2002, Maryland audited their state's compliance with the EPA regulations. They found that agencies did not keep accurate records of vehicles purchased and that use of alternative fuels was minimal (Md. Legislative Affairs).

E85 is currently available in only two stations in Virginia: one in Newport News and another located between Arlington and Alexandria.

Biodiesel

Biodiesel can be made from plant oil, animal fats, recycled cooking greases, or a combination of these oils. Soybeans are the most commonly used feedstock in the U.S., but they do not have the highest oil concentration (Table 2). Estimates indicate that only about 10 percent of all petrodiesel could be replaced by biodiesel if the oil from all oil crops in the U.S. were used to make biodiesel (van Vuueren).

Table 2. Oil content from plant sources

Source	Oil content Gallons/acre
Soybeans	40 – 50
Rapeseed	110 – 145
Industrial mustard	140
Palm	650
Algae*	10,000 – 20,000

* not produced on commercial scale

B20 can be used in diesel vehicles without modification to the vehicle. Experience shows that B100 can be used in most late-model diesels without engine modification. However, biodiesel production results in a fatty acid. When used in older vehicles, the fatty acid causes rubber hoses and fittings to deteriorate.

Vehicle manufacturers state in their engine warranties that B5 and lower should pose no operating problems. The American Society of Testing and Materials (ASTM) develops standards for fuels. They have written standards for B100 but not for the blends. Engine manufacturers are concerned that fuel standards do not exist for biodiesel blends. Without standards, engine manufacturers' are reluctant to encourage the use of higher concentration blends.

Biodiesel mileage is lower than that of petrodiesel. Like petrodiesel, biodiesel has cold flow problems which make it gel in temperatures below 32^o F for soy biodiesel (National Biodiesel Board (a)). Gelling is overcome in the same ways for both biodiesel and petrodiesel: by mixing with #1 petrodiesel fuel; by using an additive to enhance the cold flow properties; by using fuel line, tank, and filter heaters; or by storing vehicles in or near a building when not in use.

Use of B100 eliminates sulfur emission, unless sulfur is added in the manufacturing process. Unburned hydrocarbons are reduced by 68 percent; CO_2 by 44 percent, and PM by 40 percent (Higgins). Biodiesel degrades faster than petrodiesel and presents a less serious environmental problem in the case of spills. "Within 28 days [B100] degrades 85 to 88 percent in water . . ."(Higgins, p 5). B20 improves biodegradability of petrodiesel by about 30 percent (Higgins). GHG emissions are reduced by 12 to 16 percent with B20. However, without an additive, biodiesel produces more NO_x emissions than petrodiesel.

Minnesota and California have mandated the use of B2 or higher in state and local government fleets and for sale at stations selling diesel fuel throughout their states. Biodiesel is currently not available in most of Virginia or across most of the U.S. Currently, nine biodiesel stations are found in northern Virginia, the Northern Neck (where the a processor is located), Richmond, and the Shenandoah Valley. James Madison University and the University of Virginia have both made the decision to use biodiesel in their diesel buses.

Currently, biodiesel costs 20 to 50¢ per gallon more than petrodiesel. A new biodiesel plant in Iowa is expected to produce B100 at a cost of about $1.50 per gallon (Gustafson). While fuel is typically higher in Hawaii than in the continental U.S., petrodiesel was recently $3.28 per gallon, while B100 is $2.64 per gallon (Mundy).

Other alternatives

Other alternative fuels are much further from commercial introduction. Natural gas, liquefied petroleum gas, coal-derived liquid fuels, hydrogen, electricity, and P-series fuels are either available on a limited basis or are still in the testing stage. Production technologies and the lack of processing and delivery infrastructure currently limit their usefulness.

Mobile energy alternatives include more fuel efficient vehicles, hybrid, and AFVs. Hybrid vehicles can typically run on battery-stored electricity using no petroleum fuel at speeds of 25 miles per hour or less. At higher speeds, petroleum fuel is used. Hybrid vehicles do not have to be plugged in to the electrical grid for the batteries to be recharged. Some models recharge batteries while braking while other models use the energy from the petro fuel to recharge the batteries. However, if hybrid vehicles run only on the battery, the distance they travel could be limited. Miles per gallon of gasoline consumed ranges from 22 to 60 in the city and 25 to 66 on the highway, depending on the vehicle and the operator's driving habits. (Dept. of Energy (b)). Hybrid diesels and hybrid E85 AFVs are only in the experimental stage.

In 2002, more than 4,000 electric vehicles were in use in the U.S. (Environmental Protection Agency), with California having the greatest concentration. A major cost drawback of electric vehicles is that the lead-acid batteries must be replaced every three years at a cost of nearly $8,000. A further drawback is the limited driving range of 40 to 120 mile per charge. Charging the battery can take from 4 to 14 hours. In addition to using no petro fuels, electric vehicles require no timing belts, water pumps, radiators, tune-ups, or oil changes.

Hydrogen-powered fuel cell vehicles use chemical energy rather than combustion energy to generate power. Hydrogen fuel is essentially pollution–free, depending on the original fuel feedstock. In its normal state, hydrogen is a gas, which makes turning it into a usable form for vehicles challenging. The technology is still in the development stage. Currently, hydrogen fuel is expensive to produce, and the infrastructure to support production and distribution is limited.

Honda and Ford have each produced a fuel cell vehicle with a range of 190 and 200 miles, respectively. These vehicles are available for lease but only in the few locations that provide access to fuel (Dept of Energy (c)).

Conclusion

Even with increasing gasoline prices, development and introduction of practical and cost-competitive alternative fuels has been slow in the U.S. Lack of supply and distribution infrastructure, even for the most commercially available E85 and B20 (or lower) fuel blends, is the major impediment to widespread use. With our increasing demand for energy, we may never become energy independent. We can, however, decrease our dependence on imported petroleum through further development of ethanol and biodiesel fuels, improved fuel-efficiency in vehicles, use of public transportation and carpools, reduced speeds, and altered driving patterns.

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