

**Battery Electric Vehicles (BEV)** use electric motors instead of internal combustion engines to provide motive power. In BEVs, the power is stored on board in rechargeable battery packs.

*Advantages:* BEVs are efficient, quiet, have excellent acceleration, and are inexpensive to operate and maintain on a daily basis. They have no pollution from the tailpipe, reduce emissions even when electricity is generated by today's power plants and can easily use renewably produced electricity. Electricity is domestically produced and the infrastructure (electric grid) is already in place.

*Disadvantages:* Current battery capacity and/or cost limit driving distances to 100 miles or less. Proper manufacture and disposal of certain batteries must be developed to avoid pollution. Replacement batteries could be expensive. If electricity is generated from coal, full-cycle emissions would be high. Emergency response people need to receive training.

**Biodiesel** is a liquid fuel produced from new or used vegetable oils. It can be used in traditional diesel engines or in diesel hybrid vehicles alone or mixed with diesel. Note: Biodiesel is not to be confused with salad or fryer oil, which can be used as a feedstock for biodiesel. Fryer oil may also be used directly in diesel engines but has a high flash point so that it cannot be used to start the engine. It also congeals at a high temperature so that it cannot be left in the engine when the vehicle is not in use.

*Advantages:* Biodiesel is a domestically produced renewable fuel with an energy content similar to conventional diesel. It can be used in traditional diesel engines and refueling is the same as with diesel fuel. Compared to traditional diesel vehicles, it reduces carbon dioxide emissions by 78%, reduces sulfur oxide by 100%, reduces particulate emissions by 30-50%, reduces carbon monoxide by 50%, reduces ozone-forming and toxic hydrocarbons by 50-75% respectively, and is less dangerous because its flashpoint is over 300 degrees F compared to 150 degrees F. Its characteristics suggest it would be a good fuel choice for heavy-duty vehicles.

*Disadvantages:* Compared to regular diesel, it causes a 13% increase in nitrogen oxide emissions and it is harder to ignite at low temperatures. It is expensive to produce. It takes a lot of land to produce the plant source for biodiesel so that the U.S. DOE expects that the total amount of available biodiesel will be limited.

**Ethanol** is a renewable liquid fuel made by fermenting any plant matter high in carbohydrates. It can be used alone or mixed with gasoline in conventional engines.

*Advantages:* Ethanol is a domestically produced renewable fuel. It can be used in traditional internal combustion engines with few modifications. Refueling is the same as with gasoline. If produced from corn, although it reduces fossil energy use by 50-60% and carbon dioxide emissions by 20-30%, one study shows that it takes more energy to produce it than it produces. Ethanol produced from biomass would reduce greenhouse gas emissions even more, require less energy produce, and be manufactured from material that is now burned or buried such as corn husks, saw grass, and wood chips. Ethanol itself contains no sulfur, which would help emissions control devices work better, thereby reducing emissions from other pollutants. However, sulfur is emitted in the production of corn based ethanol so that overall it increases sulfur emissions by 77%. Many feel that ethanol made from cellulose could be cost competitive in the future.

*Disadvantages:* Compared to gasoline, it contains only 80% of the energy per gallon, resulting in slightly lower driving range. It is more flammable than gasoline, is corrosive, and degrades some elastomers and metals. It is hard to start vehicles in cold temperatures and formaldehyde is emitted at the tail pipe. If used in large volume, it would require large volumes of land to produce crops for energy production. Current production methods are energy intensive and expensive.

**Hybrid Electric Vehicles** use both electrical and mechanical energy. They combine the efficiency of electric drive systems with the longer driving range provided by liquid or gaseous fuel. Today all hybrids on the market use gasoline as their liquid fuel, but they could use some other fuel to gain additional advantages.

*Advantages:* In comparison to a traditional gasoline vehicle, a hybrid electric drive system can increase fuel efficiency by 20-50%, provide comparable or better performance, and increase driving range. It can use readily available gasoline or be designed to use any targeted fuel, and all its emissions are lower. Exact emissions depend on fuel type and on-board emission controls. Several automakers are marketing hybrid vehicles to the general public.

*Disadvantages:* Maintenance is more complicated. They are more expensive to build than conventional cars.

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**Hydrogen (H<sub>2</sub>)** is a gas. It can be produced by extracting hydrogen atoms from a hydrocarbon fuel, such as natural gas, or from water. It can be used in internal combustion engines or in fuel cells.

*Advantages:* Hydrogen is a domestically produced gas that can be produced from many fuels. It can be burned in an internal combustion engine or used in a fuel cell. Hydrogen refueling systems could be similar to natural gas or propane. If used in a fuel cell, its emissions on a per-mile basis can be reduced because of the high energy efficiency of fuel cells and electric vehicles. Emissions from its full life cycle can be zero if produced from renewably produced electricity and water.

*Disadvantages:* Hydrogen's energy density is low unless compressed or liquefied (which takes energy), which could adversely affect vehicle range. Hydrogen storage systems are not well developed. Hydrogen distribution and dispensing are not widely established. Safety codes and standards must be developed. Hydrogen causes metal embrittlement. Hydrogen, if produced from coal or nuclear power plants, could increase the number of these plants which have their own unique disadvantages.

**Methanol (CH<sub>3</sub>OH)** is a colorless, odorless liquid fuel produced from any carbon-based material, such as natural gas, coal, or biomass.

*Advantages:* It can be domestically produced from just about anything containing carbon, including landfill gas, which is renewable and would have the added benefit of reducing methane, a greenhouse gas 20 times as potent as carbon dioxide. Methanol's octane rating is high. It can be used in internal combustion engines with few modifications or in fuel cells. Emissions can be somewhat lower, depending on the feedstock.

*Disadvantages:* It is highly toxic and it is water soluble, so there is a great potential for water contamination. It is very corrosive to metal, rubber, and plastic. Formaldehyde is a by-product, which is a suspected carcinogen. Methanol conducts electricity. Its energy density is half that of gasoline, which reduces driving range. Vehicles have a hard time starting at low temperatures and the capital cost to produce methanol is high.

**Natural Gas (CH<sub>4</sub>)** is a naturally occurring fossil fuel found by itself or near crude oil deposits. It is usually used in either compressed (CNG) or liquid (LNG) form.

*Advantages:* It is non-toxic, non-corrosive, non-carcinogenic, has high thermal efficiency, and is already in extensive use for heating and cooking. Compared to a

gasoline vehicle, it has low engine maintenance, reduces most emissions, including carbon dioxide by about one third. Global and US natural gas supplies are more plentiful than those of oil and it has the lowest projected full-cycle cost of all the alternative fuels. It is well suited to heavy-duty vehicles. Several car, bus, and truck manufacturers offer CNG vehicles for sale.

*Disadvantages:* It is not renewable. Low energy density makes it necessary to compress or liquefy which takes energy, and usually reduces driving range by 50%. It has a cumbersome fuel tank. It is lighter than air so that it could cause explosions in enclosed areas. Fueling stations would need to be modified. New supply strategies would be necessary, as present distribution system is separate from gasoline distribution.

**Propane (LPG)** is a by-product of natural gas processing and oil refining. Although it is a non-renewable fossil fuel, it is already used as cooking gas.

*Advantages:* LPG is currently the third most commonly used transportation fuel. It's used primarily by fleet vehicles such as fork lifts and school buses. It can be used in internal combustion engines with minor modifications and it is well suited to heavy-duty vehicles. It delivers comparable performance to gasoline vehicles, tends to be safer in a car crash, reduces engine maintenance, reduces criteria emissions from 20-70%, reduces carbon dioxide emissions by 15%, and is not a threat to groundwater. Over 90% of the LNG used in the US is domestically produced. Fueling stations are common and it is currently available at low prices.

*Disadvantages:* LPG is a non-renewable fossil fuel, so supplies are limited and subject to price shocks. It is heavier than air and has a low flashpoint, so it poses safety hazards if it leaks. It has a high coefficient of expansion so that temperature changes could cause tank rupture. In comparison to gasoline vehicles, it has a low energy density which reduces driving range. It has a cumbersome fuel tank and it can be hard to start at cold temperatures.

***For more information:***

Electric Drive Transportation Association [www.electricdrive.org](http://www.electricdrive.org)  
Green Car Club [www.GreenCarClub.org](http://www.GreenCarClub.org)  
Methanol Institute [www.methanol.org](http://www.methanol.org)  
Northeast Sustainable Energy Association [www.nesea.org](http://www.nesea.org)  
National Biodiesel Board [www.biodiesel.org](http://www.biodiesel.org)  
National Ethanol Vehicle Coalition [www.e85fuel.com](http://www.e85fuel.com)  
Natural Gas Vehicle Coalition [www.ngvc.org](http://www.ngvc.org)  
Propane Vehicle Council [www.propanevehicle.org](http://www.propanevehicle.org)  
Renewable Fuels Association [www.ethanolrfa.org](http://www.ethanolrfa.org)  
U.S. Fuel Cell Council [www.usfcc.com](http://www.usfcc.com)