

CHEMISTRY

Ethanol – Valuable Fuel

PART A – RESEARCH

Ethanol is considered to be an alternative for car fuel. Summarise the use of ethanol as a valid alternative for fuel for a car and evaluate the success of the current usage.

¹Ethyl alcohol, or ethanol, (known as C₂H₅OH, CH₃CH₂OH and C₂H₆O) is a monohydric alcohol and has been used since ancient times.¹ Its popularity as an alternative for car fuel has prospered into the 21st century, changing not only our lives but also the economy in constructive ways.

Ethanol is commonly used as a biofuel additive for petrol (saving conventional fuels in times of environmental or economic hardships), but also as a valid alternative for car fuel. It is commonly a clear and colourless, flammable and volatile liquid. The properties of ethanol are listed in the table below.

Properties	
Molecular formula	C ₂ H ₆ O
Molar mass	46.07 g mol ⁻¹
Appearance	colourless clear liquid
Density	0.789 g cm ⁻³
Melting point	-114.3 °C, 159 K, -174 °F
Boiling point	78.4 °C, 352 K, 173 °F
Solubility in water	miscible in all proportions
Acidity (pKa)	15.9

(Source: Ethanol <http://en.wikipedia.org/wiki/Ethanol>)

It is also widely renowned as a valid alternative for car fuel because when it combusts in the air, it releases carbon dioxide, water and heat. ²Because the ethanol molecule contains an oxygen atom, the combustion is virtually always complete. Barely any polluting CO or C is formed, which regularly forms from the incomplete combustion of many other hydrocarbons.²

Ethanol fuel is derived from both crops and traditional fossil fuels. It is a renewable energy source because the energy is generated by using a naturally replenishing resource; sunlight. Ethanol can be made from plant material and the products of its combustion, carbon dioxide and water, are used by these plants for photosynthesis and growth. ³Creation of ethanol starts with photosynthesis causing feedstock, such as sugar cane, corn, potato, manioc and corn to grow.³ These feedstock's are then processed into ethanol. ⁴It also burns cleaner than petroleum based fuels due to its chemical composition, alleviating some of the strain placed on the environment by exhaust emissions.⁴

¹ **Alcohol** <http://www.history.com/encyclopedia.do?vendorId=FWNE.fw..al058100.a#FWNE.fw..al058100.a>

² **Alcohol Fuel** http://en.wikipedia.org/wiki/Alcohol_fuel#Methanol_and_ethanol

³ **Ethanol Fuel** http://en.wikipedia.org/wiki/Ethanol_fuel#Production_process

⁴ **Ethanol As An Alternative** http://news.carjunky.com/ethanol_as_an_alternative_abc240.shtml

When measuring the success of ethanol as an alternative and additive for and in car fuel, it is crucial to examine the level of achievement of ethanol in major aspects of society including the economy and environment. As well as the benefits, the economic and social costs must also be studied. Hence, the success of ethanol fuel use will be determined if the benefits outweigh the costs.

Due to the rising awareness of the environmental advantages and cost efficiency, the current use of ethanol or ethanol-blend fuels is increasing. ⁵E10, a blend of 10% ethanol and 90% petroleum, has become more common than pure ethanol or E85 fuels in Australia. All new cars are able to use E10,⁵ highlighting the success of the product. It can be labelled reasonably successful because it increases the fuel's octane rating (which is already higher than European fuel's octane rating) and acts as an oxygenate (a chemical compound containing oxygen as a part of its chemical structure). This encourages complete combustion and hence liberates more heat. Furthermore, adding ethanol to petrol reduces costs for fuel suppliers.

In Australia, pure ethanol or E85 (an 85% ethanol, 15% petrol combination) is rarely used as an alternative car fuel. Running a normal engine on pure ethanol would require extensive, expensive modifications and few engines which are designed to run on ethanol without the product causing damage to their fuel systems are sold. ⁶In other nations around the world, such as Brazil and the USA, "Flexible Fuel Vehicles" are becoming increasingly popular. These vehicles run on E85 and are produced by Ford, General Motors, Daimler-Chrysler, and Mazda.⁶

Other than Australia, many other nations are encouraging the use of pure ethanol or ethanol blend fuels. One example of the success of ethanol is The Pro-Alcohol Program (1970) in Brazil. This attempted to reduce the country's dependence on oil imports and thus its vulnerability to soaring prices. Presently, ⁷10% of total national energy output in Brazil is from ethanol combustion, while nearly half the cars operate on pure ethanol.⁷

Ethanol also has considerable potential as an alternative car fuel, but comes with disadvantages as well as advantages. The advantages of ethanol begin as it has been proposed as an alternative liquid fuel for vehicles because of its liquidity which readily burns and is easily transportable. In recent times ethanol has been used as a petrol extender with modern engines being able to burn 10-20 % ethanol fuel mixed with normal petrol without any modifications.

In environmental terms, ethanol use is an advantage as it is a dramatic improvement on petroleum. Not only is ethanol a renewable resource that would reduce the use of fossil fuels, but it could also reduce greenhouse gas emissions. Ethanol is a renewable resource because it can be produced from biomass whereas fuels (such as oil, coal and gas) are non-renewable because the regularity of their use exceeds the time it takes for the resource to be replenished. When ethanol undergoes complete combustion water and carbon dioxide are released these are required in photosynthesis which ⁸creates monomers to make cellulose the component in biomass, biomass is renewable so therefore ethanol is renewable as well.⁸ Because ethanol as fuel is more likely to undergo complete combustion than petrol (as it contains an oxygen atom) it is more environmentally friendly as it doesn't release any harmful products. Additionally, spark plugs do not need to be replaced as often as less carbon is deposited.

The almost complete combustion of ethanol: $\text{C}_2\text{H}_5\text{OH (l)} + 3\text{O}_2 \text{(g)} \rightarrow 2\text{CO}_2 \text{(g)} + 3\text{H}_2\text{O (g)} + \text{heat}$

⁵ Ethanol Fuel http://en.wikipedia.org/wiki/Ethanol_fuel#Production_process

⁶ Flexible- fuel vehicle http://en.wikipedia.org/wiki/Flexible-fuel_vehicle

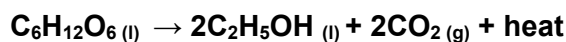
⁷ The Ethanol Program in Brazil http://www.iop.org/EJ/article/1748-9326/1/1/014008/erl6_1_014008.html

⁸ SpringerLink <http://www.springerlink.com/content/m23p388573h17717/>

⁹Glucose (a simple sugar) is created in the plant by photosynthesis.



During ethanol fermentation, glucose is decomposed into ethanol and carbon dioxide.



During combustion ethanol reacts with oxygen to produce carbon dioxide, water, and heat:



After doubling the combustion reaction because two molecules of ethanol are produced for each glucose molecule, and adding all three reactions together, there are equal numbers of each type of molecule on each side of the equation, and the net reaction for the overall production and consumption of ethanol is just:

light \rightarrow heat

The heat of the combustion of ethanol is used to drive the piston in the engine by expanding heated gases. It can be said that sunlight is used to run the engine.

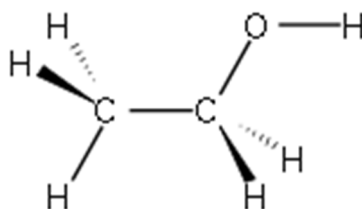
Ethanol may also be produced industrially from ethene (ethylene). Addition of water to the double bond converts ethene to ethanol:



This is done in the presence of an acid which catalyzes the reaction, but is not consumed. The ethene is produced from petroleum by steam cracking.

(Source: Ethanol Fuel - Chemistry

<http://en.wikipedia.org/wiki/File:Ethanol-3d-stick-structure.svg>)

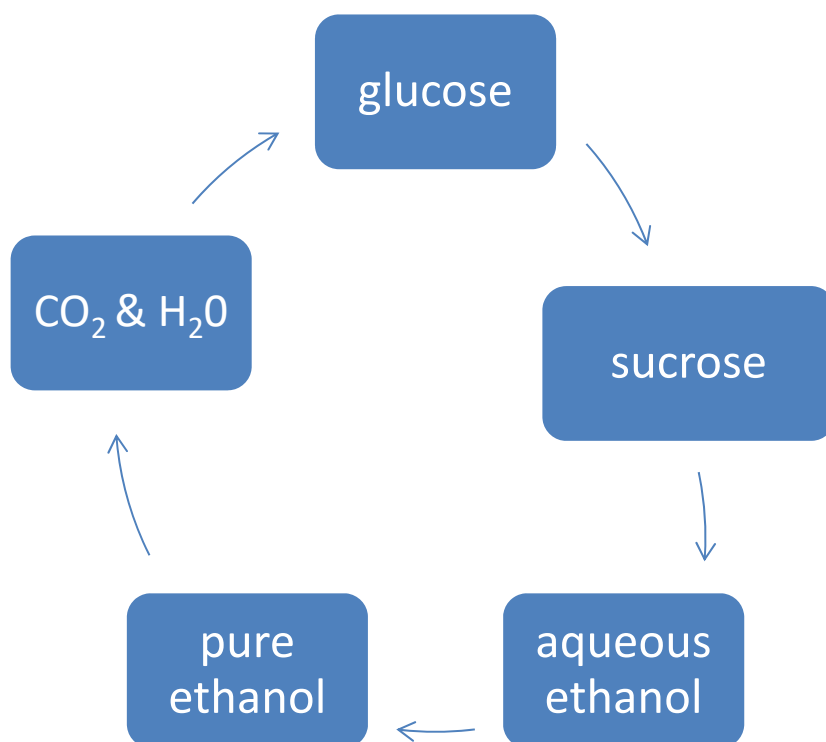
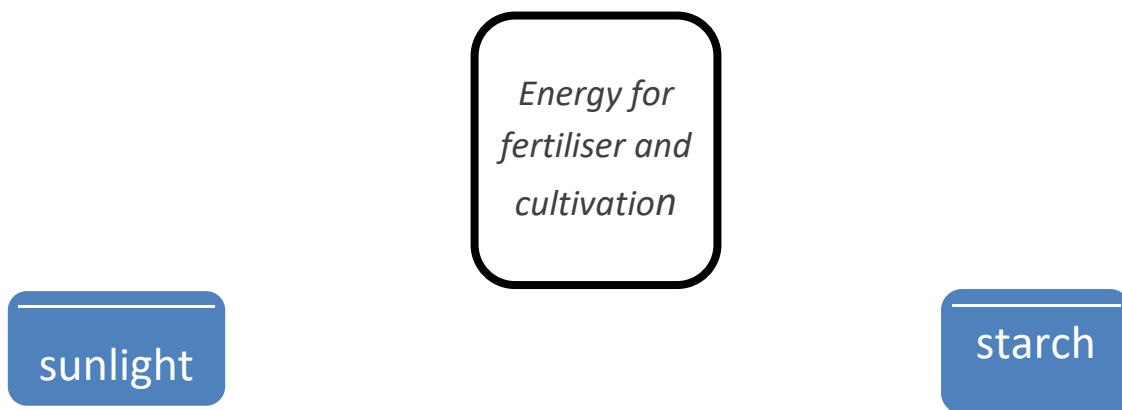


Structure of ethanol molecule, where all bonds are single bonds.⁹

Ethanol is also 'greenhouse neutral'.¹⁰ It has been advocated as a fuel on the grounds that it is neutral with respect to the greenhouse effect (the carbon dioxide it liberates when it burns is just that which was used in the synthesis). However, this ignores the other energy inputs in the ethanol cycle. The blue cycle below is 'greenhouse neutral'. However, the energy inputs, shown in black in that diagram, are quite significant – the manufacture of most fertilisers has a large fossil fuel input, and the distillation process requires much energy.¹⁰

⁹ Ethanol Fuel Production Process http://en.wikipedia.org/wiki/Ethanol_fuel#Production_process

¹⁰ *Conquering Chemistry* (3rd edition), pg 31



→ The ethanol cycle: the blue cycle is 'greenhouse neutral'; the black inputs mean that using ethanol as a fuel still contributes significantly to greenhouse gas emissions. (Source: Conquering Chemistry, 2000, pg. 31)



Furthermore, ethanol does not pollute groundwater, so it is an ideal additive to increase the octane rating. Because ethanol almost always undergoes complete combustion the output of the poisonous pollutant carbon monoxide is reduced. ¹¹Ethanol fuel use reduces the emission of other toxins. For example, carbon monoxide that is released into the air is reduced by 32% and the emissions of non-regulated toxins (such as butadiene and benzene) are reduced by 19-27% respectively.¹¹ This is beneficial to both the environment and our health.

Apart from environmental advantages, ethanol use has economic benefits as ethanol production stimulates the economy. An example is Australia (where 90% of ethanol is produced through fermentation), where ¹²encouraging ethanol production boosts the agricultural industry by opening new markets, increasing employment and encouraging scientific research. Furthermore, more than 7 million vehicles today can run on E85, and new biorefineries are increasing capacity.¹² This has the added benefits of reducing dependence on foreign oil. Thus, decreasing the funds needed for importing fuel, creates employment opportunities and adds to the economic benefits of ethanol.

The fact that there is an infrastructure for ethanol already established increases the validity of ethanol as an alternative car fuel. Even though it is not as widespread as the infrastructure for the distribution of petroleum, a considerable production and distribution infrastructure is present for ethanol in Australia. This could be expanded to adapt to a growing demand for ethanol as a fuel.

In addition, the production of cars that are able to run ethanol further establishes the validity of ethanol. One example is the ¹³Lotus Exige 265E, this vehicle is designed to get 45 more horse power on E85 than it gets on petrol. Within the next two years, Suzuki, Ford, GM and numerous other car makers will introduce engines which exploit the advantages of ethanol for its: higher octane, faster flame speed, lower burn temperature, less heat loss, and most importantly for its compatibility with water. ¹³

However, the disadvantages outweigh the advantages both environmentally and economically. Firstly, it would be a complicated and expensive process to change to ethanol-powered cars; petrol is so far a cheaper and more efficient fuel than ethanol. Previously, it was noted that petroleum has a more widespread infrastructure than ethanol. So from an industrial perspective, petrol is easier to distribute because of the established infrastructure. Australian production is also able to supply a guaranteed supply of petrol whereas Australia's ethanol industry would need to be greatly expanded to supply car fuel.

Aside from this, ethanol is not yet an economically viable alternative.¹⁴It has a comparatively low heat of combustion per gram. It produces only 30kJ/g compared to octane at 42.0kJ/g. Therefore, more fuel must combust to produce the same amount of energy.¹⁴ Fuel economy is reduced and larger quantities of fuel must be transported and distributed. As a result, consumer, transporter and distributor costs increase which result in ethanol becoming an uneconomical alternative.

Also, economically, engines not designed to run on ethanol are damaged by ethanol blends.¹⁵Fuels with a higher proportion of ethanol than E10 can cause corrosion of metal parts, damage to rubber parts and increased knocking (due to the different octane rating and the need for higher engine compression ratios).¹⁵ These engines must either be adjusted to run on ethanol or constantly repaired or use E10 fuels which requires time and money and decreases the appeal of ethanol economically.

¹¹ Regulation of Fuels and Fuel Additives <http://www.epa.gov/EPA-AIR/2009/May/Day-26/a10978d.htm>

¹² Ethanol As An Alternative Fuel Source <http://www.content4reprint.com/environment/ethanol-as-an-alternative-fuel-source.htm>

¹³ Ethanol As An Alternative Fuel Source <http://www.content4reprint.com/environment/ethanol-as-an-alternative-fuel-source.htm>

¹⁴ Regulation of Fuels and Fuel Additives <http://www.epa.gov/EPA-AIR/2009/May/Day-26/a10978d.htm>

¹⁵ E10 Tech Paper www.seearoostook.com/welcome/e10-TechPaper.pdf

The production of ethanol is a major issue both economically and environmentally. ¹⁶The planting, fertilizing, irrigating and harvesting of crops is costly, and there is always the risk of poor harvests ¹⁶ and hence, lowered production of ethanol. Expensive distillation processes are also required as the ¹⁷fermentation process yields only a 15% alcohol concentration before the yeast dies.¹⁷ Negative environmental implications are also noted as large quantities of arable and agricultural land would be needed for the mass production of ethanol which includes growing suitable crops, since technology is not at a capable stage of distilling ethanol from waste products. As a result, rainforests, bushland, farming land, etc. would be destroyed in order to satisfy ethanol production, causing severe environmental damage and would be ecologically unacceptable.

There are, however, recent developments with cellulosic ethanol production and commercialisation that may ease some of these concerns. ¹⁸Engineers are developing ways to make ethanol out of material other than food stocks, such as wood chips and old tires. This cellulosic ethanol will be needed to meet upcoming mandates for ethanol production, and will work in cars the same way corn ethanol¹³ but as this version of ethanol is not yet confirmed or available, the environmental disadvantages are still relevant.

Finally, the distillation process of ethanol produces large quantities of reeking wastes that are difficult to dispose of and ¹⁹toxins that increase the output of acetaldehyde, formaldehyde, nitrogen oxides and various other potentially toxic, non-regulated emissions.¹⁹ As a result of this the environmental benefits of ethanol are counteracted.

Therefore, although ethanol has a great deal of potential as a car fuel – in the long-term - it is not yet an economically or environmentally viable alternative. The disadvantages of ethanol production greatly outweigh the advantages of ethanol use. The transition stage from petrol to ethanol would be both difficult and costly for consumers, suppliers and the Australian government. Ethanol has little potential as a fuel for the immediate future, but with further research, it is possible that ethanol will become the fuel of the future.

¹⁶ **Ethanol Fuel** <http://www.alternative-energy-news.info/technology/biofuels/ethanol-fuel/>

¹⁷ **Regulation of Fuels and Fuel Additives** <http://www.epa.gov/EPA-AIR/2009/May/Day-26/a10978d.htm>

¹⁸ **Ethanol As An Alternative Fuel Source** <http://www.content4reprint.com/environment/ethanol-as-an-alternative-fuel-source.htm>

¹⁹ **As An Alternative Fuel Source** <http://www.content4reprint.com/environment/ethanol-as-an-alternative-fuel-source.htm>