

# Ethanol: Literature Review

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## 1 What is Ethanol?

The word alcohol derives from Arabic al-kuhul, which denotes a fine powder of antimony produced by distilling antimony and used as an eye makeup. Alcohol originally referred to any fine powder, but medieval alchemists later applied the term to the refined products of distillation, and this led to the current usage.

(<http://www.ethanol.org/>)

Ethanol is a clear liquid alcohol that is made by the fermentation of different biological materials. This alcohol is known to have many uses, but one in particular is becoming more popular. Ethanol, the most widely used biofuel, is made in a process similar to brewing beer. The ethanol in the end is blended with gasoline to improve vehicle performance and reduce air pollution.

([http://www.nrel.gov/lab/pao/biomass\\_energy.html](http://www.nrel.gov/lab/pao/biomass_energy.html))

## 2 What Ethanol is Made Of

Ethanol is a liquid alcohol that is manufactured by the fermentation of a wide variety of biological materials. These materials include grains such as wheat, barley, corn, wood, and sugar cane. [http://www.nrel.gov/lab/pao/biomass\\_energy.html](http://www.nrel.gov/lab/pao/biomass_energy.html)

In Canada, agricultural crops - particularly grains - are likely to be used because they have both high productivity and high levels of carbohydrates needed for ethanol manufacture.

Ethanol is best produced from lower value grains such as barley, corn and feed wheat. Higher value "bread" wheats would remain in ample supply for export sales, when Canada begins major ethanol manufacturing. Also, poor quality (weather damaged, immature) grains which are less suitable for either human or livestock use are excellent for ethanol production.

Corn and starch based crops are the most common medium used in ethanol production. This indicates that once ethanol is in high demand, the prices of these crops will increase. For this reason other alternatives are being studied. Among these is the use of domestic cellulosic biomass feedstocks such as herbaceous and woody plants, agricultural and forestry residues, and a large portion of municipal solid waste and industrial waste streams. <http://www.ott.doe.gov/pdfs/ethanol.pdf>  
[http://www.ott.doe.gov/pdfs/cell\\_ppr.pdf](http://www.ott.doe.gov/pdfs/cell_ppr.pdf)

Temeco Enterprises, a pulp and paper producer in Quebec started in 1991 to produce ethanol from forest waste. As the technology and economics improve for ethanol production from these materials, they would be expected to become an increasingly important base for ethanol production in Canada. However, excessive amounts of crop residue should not be removed from farmland so that they can continue to build soil organic-matter levels. (<http://www.greenfuels.org/ethafood.html>)

## 3 What Ethanol is used for

Ethanol is miscible (mixable) in all proportions with water and with most organic solvents. It is useful as a solvent for many substances and in making perfumes, paints, lacquer, and explosives. Alcoholic solutions of nonvolatile substances are called tinctures; if the solute is volatile, the solution is called a spirit. [http://www.comalc.com/fuel\\_ethanol.htm](http://www.comalc.com/fuel_ethanol.htm)

Commercial Alcohols have grown to be the largest manufacturer and supplier of industrial grade alcohol (ethyl alcohol or ethanol) in Canada. Its 1700 customers use the product in industrial applications (such as solvents, detergents, paints, printing inks, photo-chemical applications, latex processing, dyes, etc.), the beverage market, medicinal, pharmaceutical and food products and is the sole Canadian manufacturer and supplier to the fuel market in central and eastern Canada. (<http://www.comalc.com/information.htm>)

**Table 1: Summary of products that can be made from ethyl alcohol (ethanol).**

<b>Pure Ethyl Alcohol</b>	<b>The Quality Choice For Use In:</b>
Ethyl Alcohol Anhydrous Ethyl Alcohol 95% Neutral Grain Spirits	Institutions Food Industry Health and Beauty Industry
<b>Specially Denatured Ethyl Alcohol</b>	<b>Authorized for the Manufacture of:</b>
#1 Grade Anhydrous or 95%	Cosmetics & Perfumes Tobacco Flavoring Tincture of iodine And more...
<b>Denatured Ethyl Alcohol #2 Grades</b>	
Anhydrous or 95%	

<http://www.comalc.com/information.htm>)

### 3.1 Fuel Ethanol

Although ethanol has been traditionally thought of as a beverage product for use in spirits, beer and wine, ethanol is an important, viable alternative to unleaded gasoline fuel ([http://www.comalc.com/fuel\\_ethanol.htm](http://www.comalc.com/fuel_ethanol.htm)). Ethanol is used as an automotive fuel; it can be used alone in specially designed engines, or blended with gasoline and used without any engine modifications.

[http://www.comalc.com/fuel\\_ethanol.htm](http://www.comalc.com/fuel_ethanol.htm). Motorboats, motorcycles, lawnmowers, chain saws etc. can all utilize the cleaner gasoline/ethanol fuel. Most importantly, the millions of automobiles on the road today can use this improved fuel.

([http://www.comalc.com/fuel\\_ethanol.htm](http://www.comalc.com/fuel_ethanol.htm)) Farmers, cities, counties, and rural electric co-op fleets, plus snowmobile racers and fishing guides in the U.S. use ethanol blends exclusively with no performance problems. Adjustments may be required for air intake. It is important to consult your owner's manual.

(<http://www.greenfuels.org/ethaques.html>)

Fuel ethanol what has been called "gasohol" - the most common blends contain 10% ethanol mixed with 90% gasoline (E10). <http://www.ethanol.org/>. Because the ethanol is a high-octane fuel (2.5 - 3 points above the octane of the blending gasoline) with high oxygen content (35% oxygen by weight), it allows the engine to more completely combust the fuel, resulting in fewer emissions. Since ethanol is produced from plants that harness the power of the sun, ethanol is also considered a renewable fuel. Therefore, ethanol has many advantages as an automotive fuel. [http://www.comalc.com/fuel\\_ethanol.htm](http://www.comalc.com/fuel_ethanol.htm)

E85 is a federally designated fuel that is composed of 85% ethanol and 15% gasoline. Currently there are thousands of E85 vehicles on the roads in America, driving millions of miles every year. E85 vehicles are flexible fuel vehicles, meaning they will run on whatever is in the tank, from 100% gasoline to 85% ethanol, but run best on E85. (<http://www.ethanol.org/>)

Ethanol is a water-free alcohol and therefore can withstand cooler temperatures. Its low freezing point has made it useful as the fluid in thermometers for temperatures below -40°C, the freezing point of mercury, and for other low-

temperature purposes, such as for antifreeze in automobile radiators.  
(<http://www.ethanol.org/>)

### **3.2 Using Ethanol in Engines**

When the use of ethanol began in 1979 most automobile manufacturers did not even address alcohol fuels. As soon as each manufacturer tested their vehicles, they approved the use of a 10% ethanol blend. Today, all manufacturers approve the use of ethanol and some even recommend ethanol use for environmental reasons.

A number of tests have been done with ethanol in small engines as well. One of them was done at the Lake Area Vo-Tech at Watertown, South Dakota, where they put a lifetime of use on seven different models of small utility equipment. They acquired matched sets of each of the seven models, and ran one on an ethanol blend and the other on an unleaded gasoline. After each test, each motor was torn down for laboratory analysis. The most significant difference was that the ethanol blend engines had slightly fewer carbon deposits.

The Detroit Lakes Technical College at Detroit Lakes, Minnesota studied the "Hydroscopic effects of a marine environment on ethanol blended gasoline", and concluded that the amount of water an ethanol blend will absorb from the atmosphere is minimal, and should not be a concern. (<http://www.sdcorn.org/etheng.html>)  
([http://www.ott.doe.gov/biofuels/what\\_are.html](http://www.ott.doe.gov/biofuels/what_are.html))

### **3.3 Ethanol as a Renewable Fuel Source for Fuel Cells**

For years, fuel cell technology has offered significant promise as an alternative power source to increase energy efficiency, reduce pollution, and minimize our dependence on imported oil. Fuel cell systems have the potential to power automobiles, buses, homes, small generators, and perhaps someday, even computers. Fuel cell vehicles have twice the energy efficiency of internal combustion engines and are capable of achieving up to 80 mpg, with near zero emissions. However, one challenge has historically stood between fuel cell vehicle technology and its successful commercialization - the storage and supply of hydrogen.

The widespread introduction and use of fuel cell vehicles could have a major impact on improving air quality in urban areas and reducing petroleum consumption. Fuel cell vehicles are driven in large part by environmental regulations requiring "zero" or near-zero emission vehicles in a growing number of regions across the country. Rising concerns with the contribution of fossil fuels to global warming provide added impetus to the search for alternatives to petroleum and the internal combustion engine.

These public policy issues are addressed with renewable fuels such as ethanol. In spark ignition engines, ethanol emits significantly less carbon monoxide and air toxic pollution than gasoline, and therefore reduces the amount of harmful emissions released into the atmosphere. When coupled with the efficiency of a fuel cell, the air quality benefits will be substantially greater.

How a Fuel Cell Works: Fuel cells work by combining hydrogen and oxygen in a chemical reaction to create electricity, without the noise and pollution of conventional engines. In principle, a fuel cell operates like a battery. Unlike a battery,

however, a fuel cell does not run down or require recharging. It will produce energy in the form of electricity and heat as long as fuel is supplied. Since the fuel cell relies on chemistry and not combustion, emissions are much lower than from the most efficient internal combustion engines, and consist primarily of water and steam.

(<http://www.ethanolrfa.org/fuelcells.htm>)

#### 4 Co-products

The co-products that results when making ethanol are dependent on the medium used to produce the ethanol. Table 2 shows a summary of the co-products and what they are used for.

In practice, about two-thirds of each tonne of grain (i.e., the starch) is converted to ethanol. The remaining by-product is a high protein livestock feed which is particularly well suited for ruminant animals such as cattle and sheep. This by-product is also known as Distillers' Dried Grains, DDGS. The protein in this material is utilized more efficiently in ruminant nutrition than are other high-protein feed ingredients such as soybean meal. This by-product of ethanol production is particularly good for Canadian dairy, beef and sheep production. It improves the competitive position globally of producers of these farm commodities. The manure from livestock can be used as a major source of fertilizer in grain crop production.

(<http://www.greenfuels.org/ethafood.html>)

Carbon dioxide is another of the by-products produced when making ethanol. Carbon dioxide, given off in great quantities during fermentation will be collected and cleaned of any residual alcohol, compressed and sold as an industrial commodity.

(<http://www.comalc.com/chatham.htm>)

Table 2: Summary of by-products/co-products made through ethanol production.

by-products/co-products	Used for
Flour, Corn Oil, Corn Meal, Corn Grits	Used in producing food for human consumption
Fibrotein <sup>TM</sup>	Used as a high fibre and protein food additive
Corn Gluten Meal and Corn Gluten Feed	Used as high protein animal feed additives
Amino Acids	Used as animal feed additives
Dry Distiller's Grains	Used as high protein and energy animal feed
Carbon Dioxide	Used as a refrigerant, in carbonated beverages, to help vegetable crops grow more rapidly in greenhouses, and to flush oil wells

(<http://www.greenfuels.org/ethaques.html>)

#### 5 The Economics of Ethanol

There are many benefits to the economy when building, producing and selling ethanol. These are discussed in the following sections.

## 5.1 Economics in the United States

The ethanol industry stimulates the economy by providing over 55,000 jobs and increasing corn prices and rural income. Ethanol production offers enormous potential for income, growth and employment in smaller, rural communities where plants are often located.

From 1996 to 2002, the ethanol industry will add \$51 billion to the entire U.S. economy. Farm income for crop producers will be \$2.2 billion or nearly 3% higher each year because of ethanol production. For example, the price of corn increases 8-10 cents per bushel for every hundred million bushels of corn used to produce ethanol. The ripple effects on the price of other commodities adds two cents per bushel to the price of wheat and 10-13 cents per bushel to the price of soybeans. Many states have economic incentives as well to encourage the development of the ethanol industry. Some offer state tax incentives for ethanol blends or financial incentives or a combination of both. South Dakota offers a 2 cent per gallon exemption from state gasoline taxes for ethanol blends, and a payment of 20 cents per gallon to those who produce ethanol from South Dakota agricultural products.

The federal ethanol program saves the government more than \$555 million a year by generating household and farm income, which increases federal income tax revenue. Each dollar's worth of up-stream and on-farm economic activity attributable to ethanol production generates \$3.20 in downstream economic stimulus. Technology has reduced the cost of ethanol production by over 50% in the last ten years.

(<http://www.sdcorn.org/ethecon.html>)

(<http://www.ethanol.org/>)

## 5.2 Ethanol and the Canadian Economy

Fuel Ethanol can benefit the economy as well as the environment. Production of ethanol fuel in Canada (and around the world) will provide a new market for agricultural products-improving financial stability and security for farmers- in addition to direct and indirect employment opportunities for all aspects of ethanol production: from farming to transportation and manufacturing; Commercial Alcohol's Chatham Plant will realize the potential of these opportunities. All totaled, the Chatham plant will create 400 directly related jobs. ([http://www.comalc.com/fuel\\_ethanol.htm](http://www.comalc.com/fuel_ethanol.htm))

There are many benefits to the economy when ethanol is involved. The following is a list of some of these benefits. To get more information on these topics visit the Canadian Greenfuels web page at <http://www.greenfuels.org/ethaecon.html>.

1. Ethanol can substitute for aromatic hydrocarbons, which include the carcinogen benzene. Ethanol can also replace MMT.
2. Canada's growing dependence on imported light crude oil needed for gasoline and diesel fuel manufacture.
3. The cost (financial and environmental) of mega-projects for enhancing Canadian domestic supplies of light crude oil.
4. The net economic benefit of a domestic ethanol industry.
5. The abundant, and renewable, supply of Canadian grain available for fuel ethanol production.

6. The by-product of ethanol production from grain, which is a high-protein livestock feed ingredient.
7. The effect of adding ethanol to gasoline on environmental quality.
8. Many societal costs associated with petroleum energy, such as respiratory and other health problems, crop yield losses and damage to vegetation, environmental disasters (e.g., tanker mishaps), etc.

#### *5.2.1 How will fuel ethanol impact Canadian agriculture?*

Fuel ethanol makes sense for many reasons. Particularly its benefits for Canadian agriculture. These benefits, in turn, could serve to stabilize and improve farm income, which would increase the economic well being of rural and other agriculture-dependent sectors of Canada. (<http://www.greenfuels.org/ethafood.html>)

Ethanol production will not likely affect Canadian grain exports. If all gasoline sold in Canada contained 10% ethanol made from Canadian grains, 8 million tonnes of grain would be used, compared to current exports of 24 million tonnes, and current production of 50 million tonnes. There will still be a surplus for export. (<http://www.greenfuels.org/ethafood.html>)

The Canadian greenfuel web page provides more information on the impact on the Canadian economy. To get this information visit <http://www.greenfuels.org/ethaques.html>. The topics discussed on this page are; Impact on grain prices, Co-products, Can ethanol be produced from off-grade or damaged corn? What are alternative feedstocks for ethanol production? How much ethanol is produced from a bushel of corn or wheat?

#### *5.2.2 Fuel Ethanol: Is it Cost Effective?*

Critics of ethanol- as a transportation fuel- have cited its higher production costs ( 35-45 cents/litre) relative to gasoline (19-24cents/litre). Although this may have been true in the past, the large size and new technology of Commercial Alcohols' Chatham Plant will make ethanol price-competitive, especially considering the environmental costs of burning gasoline. ([http://www.comalc.com/fuel\\_ethanol.htm](http://www.comalc.com/fuel_ethanol.htm))

### **5.3 The Economic Impact of the Demand for Ethanol**

For information on this topic read a report written by Michael K. Evans, Professor of Economics from Northwestern University, this can be found at <http://www.ethanolrfa.org/docs/evans.html>. Information can also be found at the American Coalition for Ethanol web site at <http://www.ethanol.org/>.

## **6 Ethanol and the Environment**

Increasing industrial activity and population growth has resulted in a rising concentration of 'greenhouse gases' in the atmosphere that contribute to the 'Greenhouse Effect'. These gases include carbon dioxide, methane, and nitrous oxide. The term 'Greenhouse Effect' refers to the Earth's trapping of the sun's incoming solar radiation, causing warming of the Earth's atmosphere. This offsets the Earth's natural climatic equilibrium, and results in a net increase in global

temperatures. 'Global Warming' is a term used to describe the increasing average global temperature.

The term 'Climate Change' refers to a wide range of changes in weather patterns that result from global warming. A substantial increase in the Earth's average temperature could result in a change in agricultural patterns and melting of polar ice caps, raising sea levels and causing flooding of low-lying coastal areas. The Earth's climate is already adjusting to past greenhouse gas emissions, and the average global temperature is expected to rise by 1°C to 3.5°C by the year 2100 (This increase in average temperature is larger than that which has been experienced over the last 10,000 years!). By 2100, the Earth's average sea level is predicted to rise by approximately 50 cm. These phenomena could have serious repercussions on the natural and physical environment, as well as on human health. <http://www.greenfuels.org/globalwarm.html>

With the threat of global warming & energy crises in today's environment the need for clean, "green" fuels is quickly becoming a necessity. ([http://www.comalc.com/fuel\\_ethanol.htm](http://www.comalc.com/fuel_ethanol.htm))

The U.S. Environmental Protection Agency considers ozone to be the most widespread air pollution problem. To combat this problem, ethanol is widely used in reformulated gasolines to help urban cities meet public health standards for ozone.

Because it's produced from renewable resources, ethanol is the only transportation fuel that reduces greenhouse gas emissions from cars. Fossil fuels release carbon trapped in the soil into the air, where it reacts with oxygen to form carbon dioxide, a greenhouse gas that traps the earth's heat, contributing to global warming.

Ethanol is made from agricultural crops, which "breathe" carbon dioxide and give off oxygen. This maintains the balance of carbon dioxide in the atmosphere. Increased use of renewable fuels like ethanol, will help counter the pollution and global warming effects of burning gasoline. (<http://www.sdcorn.org/ethenv.html>)

Under current conditions, use of ethanol blended fuels as E85 can reduce the net emissions of greenhouse gases by as much as 30-36% and can further contribute by decreasing fossil energy use by 42-48%. Ethanol blended fuel as E10 reduces greenhouse gases by 2.4-2.9% and fossil energy use by 3.3-3.9%. The E10 blend reductions are lower because a smaller fraction of the blend is ethanol. With improved technologies and use of ethanol made from cellulose, these reductions in emissions will increase. <http://www.greenfuels.org/globalwarm.html>

## **6.1 Environmental Benefits of Fuel Ethanol**

### *6.1.1 Carbon Dioxide*

Carbon dioxide from the burning of fossil fuels is the largest single source of greenhouse gases from human activities, representing about half of all greenhouse gas emissions. Use of 10% ethanol-blended fuels results in a 6-10% CO<sub>2</sub> reduction and higher levels of ethanol can further reduce the net quantity of CO<sub>2</sub> emitted into the atmosphere. <http://www.greenfuels.org/globalwarm.html> More CO<sub>2</sub> is absorbed by crop growth than is released by manufacturing and using ethanol. (<http://www.greenfuels.org/ethaques.html>)

The carbon dioxide produced during ethanol production and gasoline combustion is extracted from the atmosphere by plants for starch and sugar formation during photosynthesis. It is assimilated by the crop in its roots, stalks and leaves, which usually return to the soil to maintain organic matter, or to the grain, the portion currently used to produce ethanol. Only about 40 percent or less of the organic matter is actually removed from farm fields for ethanol production. The rest is returned to the soil as organic matter, increasing fertility and reducing soil erosion. With modern conservation farming practices, this soil organic-matter will build up, representing a net removal of carbon dioxide from the atmosphere. An increase of only 1% in the soil organic matter level means an atmospheric reduction of over 40 tonnes of CO<sub>2</sub> per hectare of farmland. [http://www.comalc.com/fuel\\_ethanol.htm](http://www.comalc.com/fuel_ethanol.htm)

Canada has vast areas of agricultural cropland. Most of these soils could benefit from increasing soil organic matter by several percentage points. Ethanol use in gasoline has tremendous potential for a net reduction in atmospheric carbon dioxide levels.

#### *6.1.2 Carbon Monoxide*

Carbon monoxide, formed by the incomplete combustion of fuels, is produced most readily from petroleum fuels, which contain no oxygen in their molecular structure. Because ethanol and other “oxygenated” compounds contain oxygen, their combustion in automobile engines is more complete. The result is a substantial reduction in carbon monoxide emissions. Research shows that reductions range up to 30%, depending on type and age of automobile, the automobile emission system used, and the atmospheric conditions in which the automobile operates.

<http://www.greenfuels.org/ethaques.html>

Because of health concerns over carbon monoxide, the 1990 amendments to the U.S. Clean Air Act mandate the use of oxygenated gasolines in many major urban centres during the winter (when atmospheric carbon monoxide levels are highest) to reduce this pollution.

#### *6.1.3 Nitrous Oxide (N<sub>2</sub>O)*

Agricultural grain production for ethanol may generate a slight increase in nitrous oxide (N<sub>2</sub>O) emissions resulting from heavy fertilizer use. However, research and advances in agricultural technology in grain production are resulting in a reduction of these emissions, often to levels below other common crops.

(<http://www.greenfuels.org/globalwarm.html>)

#### *6.1.4 Other Octane Additives*

Because of its high octane rating, adding ethanol to gasoline can permit the reduction or removal of aromatic hydrocarbons (such as benzene), and other hazardous high-octane additives commonly used to replace tetra-ethyl lead in Canadian gasoline.

### 6.1.5 Ozone

Because of its effect in reducing hydrocarbons and carbon monoxide in exhaust (that causes respiratory problems), adding ethanol to gasoline results in an overall reduction in exhaust ozone-forming potential.

([http://www.comalc.com/fuel\\_ethanol.htm](http://www.comalc.com/fuel_ethanol.htm))

Adding ethanol to gasoline can potentially increase the volatility of gasoline. This potential is controlled if all ethanol-blended gasoline sold in Canada meets the volatility standards required for other types of gasoline. In contrast, the U.S. Clean Air Act allows gasohol (gasoline plus 10% ethanol) to have a higher volatility than that of gasoline. This results in greater “volatile organic compounds” emissions. Therefore, the Canadian ethanol blend has less potential to form ozone than the American counterpart.

Adding of ethanol to gasoline does create slightly greater amounts of aldehydes during fuel combustion. Yet the resulting concentrations are extremely small and are effectively reduced by the three-way catalytic converters in the exhaust systems of all recent-model cars. The Royal Society of Canada termed the possibility of negative health effects caused by aldehyde emissions with the use of ethanol-blended gasoline as being “remote.” (<http://www.greenfuels.org/ethair.html>)

## 6.2 Environmental behavior

Recent reviews of the environmental behavior of gasoline oxygenates generally note that ethanol is not likely to accumulate or persist for long in the environment. For example, the Interagency Assessment of Oxygenated Fuels observes that ethanol is expected to be rapidly degraded in groundwater and is not expected to persist beyond source areas. Ethanol in surface water is also expected to undergo rapid biodegradation, as long as it is not present in concentrations directly toxic to microorganisms. The half-life of ethanol in surface water is reported to range from 6.5 to 26 hours. Atmospheric degradation is also predicted to be rapid. [http://www.ethanolrfa.org/544\\_er\\_1999.html](http://www.ethanolrfa.org/544_er_1999.html)

## 6.3 Health Effects

Ethanol, the active ingredient of alcoholic beverages, has been part of the human diet — and the human environment — for thousands of years. It is produced by fermentation by fungi and other microorganisms, and is found at low levels in the blood and breath of persons who do not drink alcohol. Ethanol is widely ingested in alcoholic beverages, usually with only mild effects. However, at sufficiently high doses, ethanol can cause toxic effects in humans, both short-term (such as inebriation) and long-term (such as cirrhosis of the liver). If ethanol becomes a common fuel additive, there may be opportunities for exposure by inhalation: ethanol vapors might be inhaled at gasoline stations or in automobiles, for example. Thus, concern has been raised about the possible health consequences of using ethanol for this purpose.

The scientific literature contains virtually no reports of injury to humans from inhaled ethanol. The apparent lack of harm may be attributable to rapid metabolism of ethanol and the difficulty in significantly raising blood ethanol concentrations by

inhalation exposure, which keep internal doses extremely low except in unusual situations, such as heavy exercise in the presence of concentrated vapors.

A report written by Sarah R. Armstrong concludes the following: It is highly unlikely that exposure to airborne ethanol associated with gasoline use could produce toxic effects. The reasons for this are (a) the tiny doses that might be received, which might not be observable in light of endogenous levels of ethanol in blood, (b) the body's rapid elimination of ethanol, and (c) the relatively large doses of ethanol and high blood levels of ethanol associated with toxic effects in people. No data in the scientific literature support the hypothesis that chronic exposure to non-irritating levels of ethanol in air could cause significant elevation of blood ethanol concentrations (unless exposed individuals are exercising at the time), or that a risk of cancer or birth defects would be created. A recent survey of the literature regarding the inhalation toxicity of ethanol by the Swedish Institute for Environmental Medicine reached similar conclusions, namely that "a high blood concentration of ethanol is needed for the development of adverse effects" and "ethanol at low air concentrations should not constitute a risk for the general population". ([http://www.ethanolrfa.org/544\\_er\\_1999.html](http://www.ethanolrfa.org/544_er_1999.html))

For further information on this topic visit Environmental Benefits of Ethanol at <http://www.greenfuels.org/envirobenefits.html>, Emission Impact of Ethanol at <http://www.greenfuels.org/emissionsimpact.html>, and Positive Findings Regarding Ethanol's Environmental Benefits <http://www.ethanolrfa.org/er052099.html>.

## 7 Energy Value

Many have wondered whether ethanol makes sense, from an energy use perspective. In fact, each litre of ethanol contains at least 2-4 times as much energy as is required for inputs for crop production (fuel, machinery, fertilizers, etc.), and ethanol manufacture. Although petroleum-derived energy is used in the manufacture and transportation of inputs, this is more than offset by the solar energy captured through photosynthesis. This positive energy balance is predicted to improve, by up to 25%, as more energy efficient crop and ethanol production becomes common over the next decade. (<http://www.greenfuels.org/ethafood.html>)

When evaluating the energy value many areas need to be researched including Carbon Monoxide, Ozone, Octane Enhancement, Carbon Dioxide, and Aldehydes. These and other benefits can be found on the Canadian Greenfuels web page at <http://www.greenfuels.org/ethaenv2.html>.

An example of the reductions that can be observed when using ethanol blends in your engine is the following (per vehicle mile)

Current Corn and Ethanol Production Case for Corn-Based Ethanol

Use of E10 (10% ethanol and 90% gasoline by volume) achieves:

- 6% reduction in petroleum use,
- 1% reduction in GHG emissions, and
- 3% reduction in fossil energy use.

Use of E85 (85% ethanol and 15% gasoline by volume) achieves:

- 73–75% reduction in petroleum use,
  - 14–19% reduction in GHG emissions, and
  - 34–35% reduction in fossil energy use.
- Use of E95 (95% ethanol and 5% gasoline by volume) achieves:
- 85–88% reduction in petroleum use,
  - 19–25% reduction in GHG emissions, and
  - 42–44% reduction in fossil energy use.
- (<http://www.ethanol.org/>)

## 7.1 Energy Balance of Ethanol

Many questions have been raised as to the net energy efficiency of ethanol production from corn. Over the last decade, much progress has been made in terms of energy-efficient ethanol production methods. Ethanol contains about 32,000 (high heating value) BTUs per litre. It takes about one quarter of that amount to grow the corn and about one third of that amount to process the corn in a modern ethanol production facility. Based on the ethanol "life-cycle", the net energy balance is positive. More information is provided at the Canadian greenfuels page at <http://www.greenfuels.org/energybal.html>.

Table 3. Summary of Energy Inputs and Outputs  
According to the 1995 study produced by the Institute for Local Self-Reliance, using state-of-the-art farming and ethanol production techniques would result in the following energy balance (in Canadian funds):

INPUTS	BTU's/Litre of Ethanol
INPUTS - FEEDSTOCK	
Fertilizer	1,022
Pesticides	107
Fuel	349
Irrigation	1,597
Other	825
<b>Total</b>	<b>3,901</b>
INPUTS – PROCESSING	
Process Steam	6,917
Electricity	1,360
Bulk Transport	211
Other	277
<b>Total</b>	<b>8,766</b>
<b>Total Energy Input</b>	<b>12,667</b>
OUTPUTS	
Energy in Ethanol	22,217
Co-product Credits	9,579
<b>Total Energy Output</b>	<b>31,796</b>
<b>Net Energy Gain</b>	<b>19,130 = 151%</b>

(<http://www.greenfuels.org/energybal.html>)

Do you want to know how much energy it takes to make a gallon of ethanol? or the effects of fuel ethanol use on fuel-cycle energy and greenhouse gas emissions. This information can be found through the American Coalition for Ethanol web site. Go to the Ethanol Studies link at <http://www.ethanol.org/>.

For further information on ethanol and energy visit: Is ethanol production energy efficient? At <http://www.greenfuels.org/ethaques.html>, and Estimating the Net Energy Balance of Corn-Ethanol at <http://www.ethanolrfa.org/aer721.pdf>.

## **8 Ethanol Around the World**

Today, many countries around the world are testing both oxygenated and neat (near 100%) alcohol fuels. Information about ethanol in Brazil, the United States and Canada will be discussed in the next few sections.

### **8.1 Brazil**

Brazil is the world leader in the use of ethanol as an automobile fuel. More than 11 billion litres of ethanol for fuel are produced each year. About 15% of the vehicles with spark ignition engines (the type normally fueled by gasoline) run on neat ethanol, and the rest use a blend of 20% ethanol in gasoline. Ethanol was introduced to reduce Brazil's dependence on expensive foreign oil, and provides an additional market for domestic sugar producers. Beneficial effects on air quality have been an added bonus.

[http://www.comalc.com/fuel\\_ethanol.htm](http://www.comalc.com/fuel_ethanol.htm)

### **8.2 United States**

In the U.S., ethanol blends make up about 12% of the total gasoline market. In some parts of America, projects are underway to test the viability of replacing diesel fuel with ethanol; a project by Greater Peoria Transit is documenting ethanol's usefulness in fighting urban air pollution with its fleet of 14 ethanol-powered buses.

[http://www.comalc.com/fuel\\_ethanol.htm](http://www.comalc.com/fuel_ethanol.htm)

Support for fuel ethanol is a key component in the current U.S. "Clean Air Act" because of its beneficial effect on air quality. "Oxygenated fuels," such as ethanol blends, are mandated in certain regions to reduce carbon monoxide emissions and/or ozone.

Today there are more than 55 domestic fuel ethanol production facilities located in 22 states across the country with annual capacity of approximately 1.8 billion gallons. Ethanol production facilities are largely modular, should certain demand for ethanol arise, expansions could be done quickly by simply adding new equipment to existing production facilities. Expansions to existing facilities could easily add 600 million gallons of production capacity within the next 12-18 months. In sum, a total of 2.8 billion gallons of production could be available in the near term. Furthermore, the U.S. Department of Agriculture has suggested that grain-based ethanol production could grow to as high as 3.3 billion gallons a year by 2004.

In addition, the next generation of ethanol production facilities will include production from cellulose and biomass feedstocks. Earlier this year, there was a

groundbreaking for a new ethanol production plant in Jennings, Louisiana which, when completed, will produce ethanol from rice hulls and bagasse. Three other plants are currently planned in California that will produce ethanol from rice straw. Already, ethanol is being produced from wood waste by Georgia Pacific in Washington State, and production from forest residue is not far behind.

(<http://www.ethanolrfa.org/fuelcells.htm>)

### **8.3 Canada**

In Canada, the ethanol industry is developing momentum, now that ethanol's environmental, economic, energy, rural development, and renewable attributes are being more widely recognized. Although the industry is still in its infancy, with only a few small-scale plants producing ethanol, consumer demand has prompted several gasoline retailing chains to feature ethanol blends, with demand for ethanol exceeding our domestic production. Ethanol-blended gasoline is now available at over 700 gas bars across Canada from Quebec to the Pacific, including the Yukon Territory. In many regions, ethanol blends are available for bulk delivery for farm and fleet use. The federal government and several provinces offer tax incentives, based on environmental, economic development and/or energy diversity benefits, for the production and/or marketing of ethanol-blended gasoline to encourage development of an alternative fuel industry. Also, Environment Canada has designated ethanol-blended gasoline, which meets their specifications, as an Environmental Choice<sup>®</sup> product on the basis of reduced toxic emissions, reduced use of non-renewable resources, and reduced carbon dioxide emissions. However, a firm and broad-based (i.e., multiple departments/ministries) commitment to procurement and incentives for ethanol in the near-term is essential to ensure the successful establishment of this fledgling renewable energy industry.

(<http://www.greenfuels.org/ethatech.html>)

Canada typically produces fewer than 50 million tonnes of grain (wheat, barley, corn, oats, and rye) annually, and exports about half of this. If all Canadian gasoline consumption (presently about 33-35 billion litres annually) contained 10% ethanol, the maximum grain requirement would be 8-9 million tonnes. Canada would remain a major grain exporter.

<http://www.greenfuels.org/ethafood.html>

Canada is a major importer of high-protein animal feed ingredients. The value of imports is typically about \$200 million annually. The by-product resulting from ethanol production from Canadian grain would serve to reduce this importation.

<http://www.greenfuels.org/ethafood.html>

How much fuel ethanol is being produced? Canada's current annual ethanol production, for all markets (1998) is approximately 234 million litres a year. With additional proposed development of ethanol production plants, Canadian potential production in the next few years is at 664 million litres per year.

How much fuel ethanol is being used? It is difficult to ascertain current levels of fuel ethanol use in Canada. In the U.S., it now represents about 9% of total gasoline sales, or the equivalent of the total Canadian gasoline consumption. Over two trillion kilometres have been traveled using fuel ethanol blends.

(<http://www.greenfuels.org/ethaques.html>)

### 8.3.1 Plant locations in Canada

Table 4: The following table is a list of ethanol production plants currently in operation in Canada.

Producer	Location	Capacity	Other Information
Mohawk Oil, Canada, Ltd.	Minnedosa, Man.	10 M. Litres	Wheat-based
Pound-Maker Agventures, Ltd.	Lanigan, Sask.	12 M. Litres	Wheat-based Partnered with a cattle feedlot
Commercial Alcohols, Inc.	Tiverton, Ont.	23 M. Litres	Corn-based
Commercial Alcohols, Inc.	Chatham, Ont.	150 M. Litres	Corn-based
Agri-Partners International	Red Deer, Alta.	22 M. Litres	Wheat-based
Tembec	Temiscaming, Qué.	17 M. Litres	Forestry product-based

(<http://www.greenfuels.org/ethaprod.html>)

### 8.3.2 Mohawk Oil, Canada, Ltd., Minnedosa, Man.

Mohawk Ethanol, in Minnedosa Manitoba sells distillers dried grains or wet mash to the surrounding livestock producers. Mohawk Oil is the retailer for the ethanol from the Minnedosa plant.

Because the Minnedosa plant sells the ethanol co-product and is wholly owned by Mohawk, the economics can be more clearly identified. Capital costs range between \$Canadian 0.6 to 1.0 per litre. In the early eighties the production costs were about 70 cents per litre and have fallen to under 30 in the nineties. The Minnedosa plant is an old distillery, which commenced operation for fuel ethanol production in the early eighties and produced about 7 million litres/year in the late eighties. By 1994 the production at this facility had exceeded 10 million litres per year through advances in yeast strains used and better production procedures.

<http://www.cadvision.com/violetbook/etoh.htm>

### 8.3.3 Pound Maker Agventures, Lanigan, Sask

Pound-Maker Agventures Ltd. along with Mohawk Oil Co. Ltd. and Saskatchewan Wheat Pool are minority shareholders, owning 22%. Pound Maker Agventures Ltd. is in charge of the day to day operations of the feedyard, ethanol plant and the feedmill. The plant has a 10 million litre per year ethanol production plant that employs around 15 people.

In addition to ethanol, the plant produces two by-products, thin stillage and wet distillers grain (WDG), which are utilized fully in their feedlot. The thin stillage is piped to the feedlot as the cattles' only drinking source. The WDG is mixed with other components, such as grain and roughage, as protein in the feed rations. The percentage of WDG in rations fluctuates with the volume produced and is totally fed on a daily basis.

<http://www.greenfuels.org/poundmak.html>

### 8.3.4 Commercial Alcohols, Inc., Tiverton, Ont.

This plant is the second largest distillery in Canada producing 22 million litres of alcohol per year. Commercial Alcohols has grown to be the largest manufacturer and supplier of industrial grade alcohol (ethyl alcohol or ethanol) in Canada. Its 1700

customers use the product in (a) industrial applications (such as solvents, detergents, paints, printing inks, photo-chemical applications, latex processing, dyes, etc.); (b) the beverage market (C.A. supplies alcohol for Russian Prince, Iceberg Vodka, other brands and for the fortification of wines); (c) medicinal, pharmaceutical and food products (cough syrup, mouthwash, medicines, disinfectants for hospitals, doctors and dentists offices, clinics and laboratories, food preparations); and (d) is the sole Canadian manufacturer and supplier to the fuel market in central and eastern Canada.

<http://www.cadvision.com/violetbook/etoh.htm>

#### 8.3.5 *Commercial Alcohols, Inc., Chatham, Ont.*

The new Chatham facility, once operational, will produce 300 million litres of alcohol (ethanol) per year. The first phase is currently complete and is producing 150 million litres per year; the second phase, which will also produce 150 million litres per year, is scheduled to begin operation in 1999 or 2000.

(<http://www.comalc.com/chatham.htm>)

#### 8.3.6 *Agri-Partners International, Red Deer, Alta.*

API Grain Processors is a unique grain fractionation and processing facility. This venture was developed by Agri Partners International Inc. with a view to capitalize on the expanding opportunities in agriculture and food processing in Western Canada. The primary products resulting from grain fractionation of wheat are standard patent flour, gluten, fuel grade ethanol and livestock feed. The facility design attains zero liquid effluent discharge other than that of domestic sewer and waste.

<http://www.cadvision.com/violetbook/etoh.htm>

#### 8.3.7 *Tembec, Temiscaming, Qué.*

For information on this plant go to <http://www.tembec.ca/indexe.htm>.

#### 8.3.8 *Varenes, Quebec*

The Varenes plant is expected to be under construction this summer and on steam in the fall of 1999, commented Jean Roberge, Commercial Alcohol's project development manager in Québec. The plant is expected to produce 115 million litres of fuel ethanol a year and 35 million litres of industrial alcohol.

<http://www.comalc.com/quebec.htm>