Ethanol and sustainable development

by Roger Samson

One alternative to imported oil that is getting increasing attention is ethanol produced from corn. Ethanol is used as a 10 % blend with petroleum gasolines in unaltered gasoline engines. Currently ethanol blended gasolines take up 8 % of the U.S. gas market but Canada has made no real commitment to ethanol to date.

As a potential new industry for Canada, corn ethanol must pass certain environmental criteria, after all this is the new era of "sustainable development". In the words of the Bruntland report this means "development that meets the needs of the present without compromising the ability of future generations to meet their needs". From a practical standpoint there are two major hurdles for corn ethanol to pass over in meeting minimum criteria for sustainable development:

1) Energy positive: is the energy used in the production of corn and processing of corn into ethanol less than the energy provided by the ethanol;

2) Does it liberate less carbon dioxide than gasoline: that is, is the $C0_2$ given off from corn production and the processing and burning of ethanol less than the $C0_2$ released by the processing and burning of gasoline.

A good starting point before evaluating the potential for a Canadian industry is to see how "sustainable" the American industry is. Fortunately, there is a 1989 study by the U.S. Congressional Research Service/ Department of Environment on this very subject that provides both the energy balance and $C0_2$ balance. It provides a useful framework for taking a second look at the energy and C02 balance of the U.S. com ethanol industry.

Corn energy efficiency balance

Comprehensive energy studies on com production were performed by the U.S Department of Agriculture in 1974, 1978, and in 1988. The amount of energy used for the production of the U.S. corn crop ranged from a high of 7,630,000 BTU/acre in the 1974 study to a low of 7,490,000 BTU/ acre in the 1988 study. Since corn yields were reduced dramatically in 1988 because of the drought, a more appropriate comparison would be the high yielding corn crop of 1987 (119 bu/ acre). As well, the amount of ethanol (2.5 gallon/bushel) and corn distillers (.32 bushel) produced from a bushel of corn and the amount of energy it takes to produce these products needs to be known. This latter figure is hard to estimate as both wet and dry milling processes are used for the conversion with dry milling generally being the more energy consuming of the two. The National

Advisory Panel on Cost Effectiveness of Fuel Ethanol Production (1987) states that between 40,000-60,000 BTU is used per gallon of ethanol. A fair estimate of the energy consumed in the processing is therefore approximately 50,000 BTU/ gallon ethanol. As well, the energy contained in the corn distillers must be credited. The main outlet for corn distillers is as a dairy feed. Nutritionally H has the same net energy value for lactation as does regular corn. Therefore we can credit the corn distillers on the basis of the same amount of energy required to produce an equivalent amount of corn.

The energy value of a gallon of ethanol varies from 75,700 BTU 84,000 BTU depending on burning temperature. We will use a figure of 80,000 BTU as this is the energy value of ethanol burning at 25 degrees C.

Based on the high yielding 1988 corn crop of 119 bushels/ acre the energy generated by the ethanol exceeded energy inputs by 16%. However H appears we still have a long way to go to enable this technology to supply our North American oil addiction. In 1989, 400 million bushels of corn in the U.S were used for ethanol production which produced the equivalent energy of 21 million barrels of oil. The U.S uses about 16.5 million barrels of oil per day.

Therefore, the 3.5 million acres of corn would provide America with approximately 30 hours of oil. After the energy required to grow the corn and convert H to ethanol is subtracted from this figure, the 3.5 mil

Reducing Corn Energy Requirements

Farmers could improve the relative energy efficiency of corn production with economical alternative production practices. The pie chart shows on a percentage basis where farmers can save the most energy in their corn production systems. While many corn farmers have developed reduced tillage systems this has very little impact on reducing energy consumption (i.e. going from mouldboard plowing to conventional tillage only saves 6% on energy inputs). Fertilizer (primarily nitrogen) is the biggest energy gobbler followed by propane for crop drying and pesticides.

Technologies are available in each area to enable both livestock and cash crop corn farmers to dramatically reduce energy use. An example could be a cash crop farmer who grew corn on ridges, used a rotary hoe and cultivation for weed control, grew the corn in a crop rotation, followed a hairy vetch cover crop as a nitrogen source, and then stored the corn in a crib for drying. Total energy savings could approach 75 %. This could change the corn production energy input from 25176 BTU/ gallon of ethanol to 6294 BTU/gallon. Accounting for a corresponding drop in the credit for corn distillers this could drop the amount of energy invested per unit of energy returned from .84 to .68.

$C0_2$ Emissions

Although the energy efficiency of corn is barely positive at present, one of the main reasons it is being promoted is its positive effect on carbon dioxide emissions to reduce global warming. Fossil fuel consumption is a major source of carbon loading to the atmosphere and the development of any fuel source which would reduce this loading would be highly desirable.

The Congressional Research Service (CRS)/ Department of Energy (DOE) Report for Congress examined the carbon dioxide loading potential of corn ethanol versus gasoline and found that corn ethanol yields 37% as much CO2 as gasoline on an energy content basis. At first this number looks very encouraging but a closer examination of the report reveals key problems with this analysis. The main problems with the CRS/DOE report are:

1) - the most optimistic value for energy used in the conversion of corn to ethanol is used, 40,000 BTU/gallon (14,110,000 J/kg), 50,000 BTU/ gallon reflects a mean value for the industry.

2) - two different energy values are used for ethanol, 84,500 BTU/gallon ethanol (29,800,000 J/ kg ethanol) and 75,700 BTU/gallon ethanol in the calculations. A commonly used value is 80,000 BTU (28,200,000 J/ kg ethanol), the burning temperature at 25 C.

3) - the carbon credit to byproducts is based on an economic basis after processing at 48.9%. The byproducts should be credited based on the energy required to grow the equivalent quantity of corn (.32 bushel of com distillers is produced from each bushel of corn processed), as corn has the same net energy value for livestock as corn distillers.

4) -The CRS/DOE report states that long term com production does result in a net continuing oxidation of soil carbon, but the flux is generally small and will not be considered further. A soil carbon loss needs to be associated with the growing of corn as it reduces soil carbon levels.

As can be seen from the tables, there is a great deal of discrepancy between the two calculations. At press time, one of the authors in the March, 1989 CRS/DOE report was contacted to see if they have reevaluated their numbers. Our value of 18.10 for kg carbon released per billion J of ethanol was within 10% of their most recent calculation but no additional soil $C0_2$ loss was calculated on their part beyond this point. However, if you do consider a soil carbon loss of .035 % organic matter per year from the growing of corn, corn ethanol produces as much CO_2 as gasoline.

This is bad news because gasoline gives off 21.5 Ibs of CO_2 / per U.S. gallon. Essentially you may as well burn gasoline and use the land base

For reforestation (to store carbon in soil organic matter and standing biomass) than to grow com and produce ethanol.

As the calculations show, one of the key factors affecting the outcome of the carbon balance is the loss of carbon in the form of soil organic matter from annual grain crops. If corn restored soil organic matter like perennials do, the 38.0 Ibs of CO_2 could be a credit which would then cause the corn to release 62% of the CO_2 released by the gasoline.

Developing A Sustainable Ethanol Industry

If we identify other major problems with com ethanol perhaps it may give us some clues to what we really need in developing an ethanol industry that has potential to significantly reduce gasoline requirements. First of all, the energy yield of corn is too low if H is to put a dent in the sea of oil coming into North America. A crop with much higher biomass yield and wider adaptability is required. It must be more energy efficient to grow than corn as well. The annual tillage, planting, spraying, fertilizing and drying of corn gives H a poor energy balance. Corn is also environmentally leaky, nitrogen fertilizer and pesticides get into ground water and soil erodes.

Something that protects the environment and requires lower inputs is required. As well, the corn byproduct market would be swamped if corn ethanol was produced in North America in a major way to compete with gasoline. A ready market is required for additional byproducts generated during the production of ethanol.

One of the biggest problems with the $C0_2$ balance of corn ethanol in the U.S. is the great quantity of CO_2 liberated by using coal as an energy source in the milling and conversion of corn into ethanol. The energy required in the milling process needs to be reduced, but perhaps more importantly a cleaner electricity source than coal needs to be developed to reduce CO_2 emissions.

The final problem with corn ethanol, as previously mentioned, is that annual grain crops are hard on the soil and release $C0_2$ from the loss of soil organic matter. It would be highly desirable if the crop could increase soil organic matter.

Hybrid Willow

In the Northeast the crop with the most potential for developing a sustainable ethanol industry is hybrid willow. The table below identifies the key benefits that willow offers over corn. While it is most likely that the initial entry of willows onto farms will be solely for electricity generation, co-generation of electricity and ethanol will follow. Willow ethanol will be as near a CO_2 neutral liquid fuel as you can get because of two key features:

1) it will store large amounts of carbon in its large root system and restore soil organic matter because of its perennial nature; and

2) it will eliminate the need for the use of coal, for electricity generation in the ethanol processing, which was the major CO_2 loading factor.

It may also enable an efficient and safe use of municipal sewage waste as willows are not a food crop and have a large root mass to prevent nutrient loss from sludge applications.

One of the key problems with the development of willow ethanol is the relative complexity of the technology of extracting ethanol from willow versus corn. However, the technology has improved considerably in recent years and significant opportunities for further improvement exist from the fields of plant breeding and biotechnology.

What about the cost of willow ethanol and its ability to displace gasoline? According to a Montreal company, Techtrol, the current status of ethanol economics is as follows:

1) Pilot plant proven technology: 51 cents/litre

2) Leading lab reports: 24 cents/litre

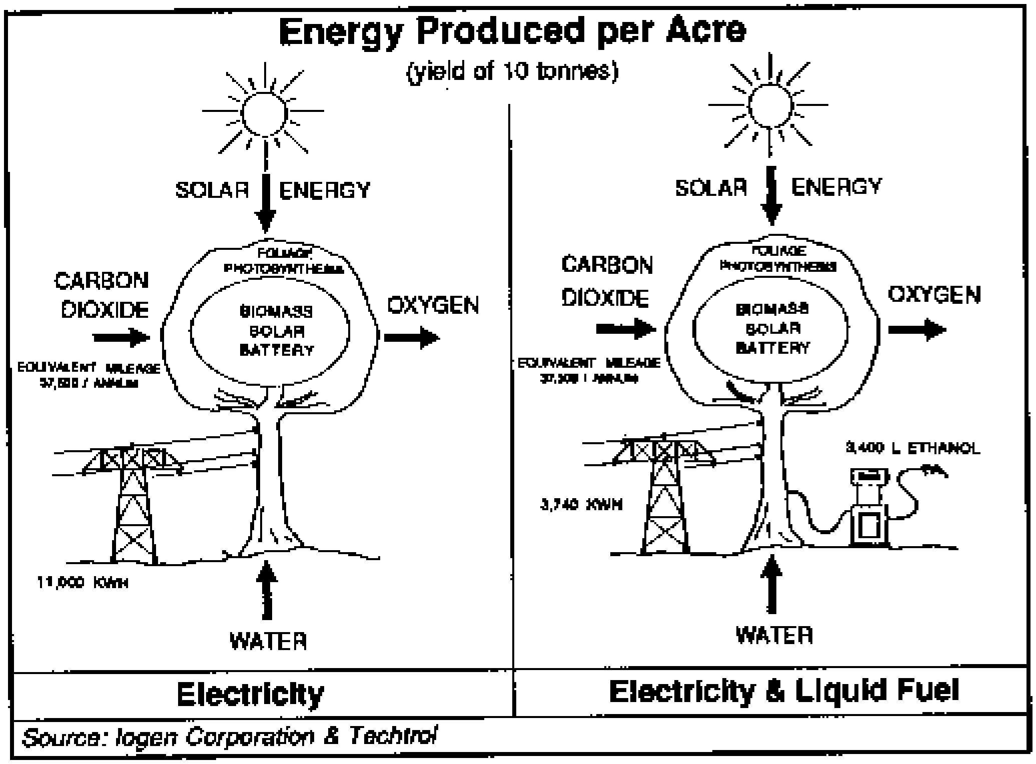
3) Upper bound on technology: 1 7 cents/litre

Based on a 25 tonne/ha yield of hybrid willow, Techtrol claims that 125 miles square of hybrid willow could replace 10 Candu reactors and all of Canada's gasoline requirements. That is a lot of energy from what would amount to 10% of Canada's farmland. It may provide us with a choice - subsidize unwanted export grains or hone in on home grown energy.

Energy Consumption and CO_2 Emissions in Corn Ethanol
(millions of Joules/kg)

	CRS / DOE March 1989	Sustainable Farming
Energy Consumption		
Agricultural	8.85	8.85
(1) Milling and Conversion	14.11	21.16
Total Energy Consumption (millions J/kg ethanol)	22.96	30.01
Carbon Emissions		
Agricultural	0.152	0.152
Milling and Conversion	0.321	0.407
(2) Total Carbon Emitted (kg C/kg ethanol)	0.473	0.559
Carbon Emissions from Ethanol		
Total Carbon Emitted (kg C/billion J ethanol)	0.473 / 29,800,000 = 15.93	0.559 / 28,200,000 = 19.82
(3) Byproduct C Credit	48.9% x 15.93 = 7.79	(0.152 x 0.32) ÷ 0.559 x19.82 = 1.72
Ethanol Carbon (kg C/ billion J ethanol)	8.14	18.10
lbs CO2 / million BTU Ethanol (Ethanol Carbon x 2.2046 lbs/kg x 44 ÷12 (weight CO2/weight C) x1 million J/ 947,800 BTU)	69.4	154.4
(4) lbs CO2 from soil million btu	-	38.0
Ethanol lbs CO2 emitted million BTU	69.4	192.4
Gasoline lbs CO2 emitted million BTU (Production 20 + Combustion 166.6)	186.6	186.6
CO_2 release relative to gasoline	0.37	1.03

@ For ethanol the CO2 released by burning is assumed to be equal to the CO2 uptake by corn.



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