ISSUES IN BIOENERGY DEVELOPMENT IN WESTERN CANADA

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Executive Summary

This paper examines some of the recent criticisms directed at biofuels development in North America, particularly ethanol produced by fermentation of grains, and looks at possible solutions in Western Canada for some of the problems that have been raised.

This paper focuses on ethanol production from grains, since most liquid biofuels plants being built in Western Canada are designed to produce ethanol from grain, such as CPS wheat. An important issue is whether such plants will produce more renewable energy than the fossil fuel inputs required for grain production and subsequent conversion into ethanol, feed co-products called dried distillers grains and solubles (DDGS) and carbon dioxide.

Related to this issue is the question of how much does ethanol reduce fossil fuel inputs into liquid fuel production compared to gasoline. Reducing fossil fuel inputs may also reduce greenhouse gas emissions over the whole fuel life cycle. Gasoline production requires significant fossil fuel inputs to take the crude oil, heavy oil or oil sand crude out of the ground, and convert these raw materials into gasoline and other refined petroleum products. As more and more of Western Canadian gasoline is made from heavy oil or oil sand crude, it would be expected that the fossil fuel-based energy costs and greenhouse gas emissions from making refined petroleum products would increase, as these feedstocks require more energy to convert them into refined products than does conventional crude oil. The goal for Canadian biofuels production, such as production of ethanol, is to significantly reduce greenhouse gas emissions compared to gasoline or diesel fuel.

In the longer term, large scale future production of biofuels will utilize lignocellulosic feedstocks from forest residues, such as sawdust or bark, and agricultural lignocellulosic feedstocks such as crop residues or high-yielding grasses. Routes to ethanol and other liquid biofuels could involve fermentation methods, such as the process being developed by Iogen. Another process route would involve gasification of raw materials to synthesis gas, a mixture of carbon monoxide and hydrogen, followed by catalytic conversion to ethanol or other liquid fuels. Such fuels are expected to reduce greenhouse gas emissions, compared to gasoline, by 60% or more. However, there are no commercial plants operating at the present time, although the first plants are expected to be built in the next few years.

For the near future, the main methods to reduce greenhouse gas emissions in transportation appear to consist of ethanol produced from grains, biodiesel produced from

plant or animal fats and oils, and improvements in the energy efficiency of vehicles. The cost of reducing greenhouse gas emissions from vehicles by improvements in their efficiency could be as low as US$7-33/tonne of carbon dioxide equivalents, according to a recent study in the USA by the Union of Concerned Scientists. The International Energy Agency estimated that the cost of reducing greenhouse gas emissions by use of biofuels such as ethanol would be in the range of US$100-300/tonne of carbon dioxide greenhouse gas equivalents. However, this study was done before the recent rise in the price of crude oil which may have changed the cost of reducing greenhouse gases by use of biofuels. In addition, so far it has proven difficult to enact legislation in Canada or the USA to encourage production of more fuel efficient vehicles.

There may also be a role for biological materials such as flax or hemp fibre, combined with plastics, potentially derived from agricultural raw materials, to produce plastic composite automobile body parts. These could significantly reduce the weight of vehicles, improving their fuel efficiency. This is already starting to be applied in vehicle manufacture in Europe.

It is important to emphasize that improving the fuel efficiency of vehicles is synergistic with introduction of biofuels as part of the transportation fuel system. The more fuel efficient vehicles become, the less fuel is needed to drive the same distance. Thus less fuel is required per unit distance traveled, the less pressure there is on land resources to grow the raw material to produce the renewable fuel needed.

Other reports to the federal government have calculated how much ethanol and biodiesel would reduce greenhouse emissions. This present study focused on ethanol produced from grain and calculated how much fossil fuel energy consumption would be reduced, compared to gasoline. Different methods to produce the grain and different methods to reduce fossil fuel inputs into the processing plant were tested. Some of these methods to reduce fossil fuel inputs into ethanol production are being incorporated into new plants being built or planned in Western Canada.

The calculations used in this study included some energy inputs into crop production and conversion into ethanol and co-products not included in most previous studies. Omission of these inputs was a criticism of previous studies cited by Pimentel and Patzek in a recent article.

Results.

The energy costs of grain production varied considerably depending on crop rotations and the use of manure to provide some of the nitrogen fertilizer costs. Results of a long-term study at Indian Head, Saskatchewan involving different crops, crop rotations and tillage methods were used in a model of the energy costs of CPS wheat as a raw material for conversion into ethanol and DDGS. The study at Indian Head used hard red spring wheat in the experiments. The present study assumed that CPS wheat, more likely to be used for ethanol production, had a 20% or 30% higher yield, based on crop production models used in Saskatchewan. CPS wheat has a higher starch content than hard red spring wheat and would be more suitable for ethanol production.

Some results on the benefits of including the forage legume alfalfa in the rotation were obtained from a study at Winnipeg, Manitoba. Legumes, which fix some of their nitrogen fertilizer needs from the nitrogen in the air, tend to leave some nitrogen fertilizer materials in the soil after their harvest. These nitrogen materials can be used by a following crop to meet some of their nitrogen fertilizer needs, reducing the amount of energy-expensive synthetic fertilizer needed to grow the crop. Alfalfa leaves considerably more nitrogen fertilizer in the soil than does a pulse crop such as peas.

The energy costs of producing ethanol from grain consist of:
1. energy costs to produce the grain (expressed as MJ/L of ethanol produced) +
2. energy costs for grain hauling to the ethanol plant +
3. energy costs to convert the grain into ethanol and DDGS +
4. energy costs to transport and store the ethanol and dispense it into the vehicle, <u>minus</u>
5. energy <u>credit</u> given for the distillers dried grain and solubles (DDGS) animal feed also produced, <u>minus</u>
6. energy credit for carbon dioxide captured during the grain fermentation process and used to replace carbon dioxide produced for commercial uses from fossil-fuel based systems.

It is necessary to give an energy credit for the DDGS feed, since if one didn't use this as an animal feed, one would have to use some other feed ingredients, such as soybean meal and corn grain, in the diet of animals. These other feeds also take fossil fuel energy to grow and process. Thus this energy consumption needs to be deducted from the total energy costs of the ethanol production system. In this study a credit of 4.40 MJ/L of ethanol for the DDGS feed and carbon dioxide capture was deducted from the total energy costs of the ethanol production system to allow for these feed energy and carbon dioxide substitution effects. If no carbon dioxide was captured, the credit for the DDGS alone was estimated to be 2.58 MJ/L of ethanol produced.

All the energy input costs used in this study, such a synthetic nitrogen fertilizer, natural gas use as a heat energy source in the ethanol plant, and diesel fuel used on the farm include factors to account for the energy used to make them and transport them to their point of use.

The energy costs of the grain component of the total energy cost of producing ethanol from CPS wheat varied from 9.278 MJ/L of ethanol produced from CPS wheat grown after another cereal in the rotation down to 3.604 MJ/L of ethanol for CPS wheat grown after alfalfa in the rotation. CPS wheat yield increases of 20% or 30% over hard red spring wheat were tested in this study for their effects on the energy costs of ethanol production. This higher yield of CPS wheat compared to hard red spring wheat can also reduce the energy costs of the grain component of the ethanol production system compared to the use of lower-yielding hard red spring wheat.

The energy efficiency of ethanol plants has been improving at a rate of about 2% per year according to one recent study. In this present study it was assumed that an up-to-date ethanol plant would consume 16.882 MJ of fossil fuel energy per litre of ethanol produced. This includes the energy costs to transport the grain and transport the ethanol to point of use plus the production of ethanol and drying the distillers grains and solubles.

This study tested the effects of different ways to produce the CPS wheat raw material on the final energy cost to make the ethanol. The results are shown in Table 1. The energy effects of ethanol are shown in two ways: the ratio of the renewable energy produced (ethanol) compared to the fossil fuel energy used to produce it (the output to input ratio), or the percent reduction in fossil fuel use if we used ethanol to replace gasoline.

On average, it takes 0.28 MJ of fossil fuel energy to take the present Canadian mix of conventional crude oil, heavy oil and oil sand crude out of the ground, refine into 1.00 MJ of gasoline, and transport to the filling station. This has to be taken into account when comparing the fossil fuel energy required to produce ethanol with the total fossil fuel energy in gasoline plus the fossil fuel energy required to produce it.

Table 1. Energy efficient production of ethanol from CPS wheat. Effects of different methods to grow CPS wheat and different yield benefits of CPS wheat over HRSW wheat on the output:input ratio (renewable energy out/fossil fuel energy in) of ethanol and the percent reduction in total fossil fuel energy consumption by replacing gasoline with ethanol. In parentheses = no carbon dioxide capture.

CPS wheat following another crop in the rotation	Yield CPS/HRSW (%)	Energy output/input	Percent reduction in total fossil fuel energy consumption by replacing 1 MJ of gasoline with 1 MJ of ethanol
W-CPSW	120	1.08:1 (1.01:1)	27.7 (22.3)
W-CPSW	130	1.19:1 (1.03:1)	34.4 (24.1)
P-CPSW	120	1.16:1 (1.07:1)	32.7 (26.9)
P-CPSW	130	1.20:1 (1.10:1)	34.9 (28.8)
A-CPSW	120	1.43:1 (1.29:1)	45.4 (39.5)
A-CPSW	130	1.46:1 (1.31:1)	46.5 (40.5)

Symbols: HRSW = hard red spring wheat; W = cereal crop preceding CPS wheat in a rotation; CPSW = CPS wheat following another crop in the rotation; P = field peas preceding CPS wheat in the rotation; A = alfalfa preceding CPS wheat in the rotation.

The Husky Energy ethanol plant at Lloydminster is reported to be able to take excess steam and process heat from the cogeneration plant and the heavy oil upgrader operations and use them to replace some of the thermal energy requirements of the ethanol plant. For the present study, it was assumed that one-third of the thermal energy requirements would be met by using these sources. The savings in energy costs to produce ethanol were considerable and are shown in Table 2 (compare with Table 1).

Saving energy in the ethanol plant by taking advantage of waste heat from other operations (the heavy oil upgrader) is an example of industrial ecology. It significantly improves the fossil fuel energy savings benefits of ethanol produced from grain.

The data in Table 1 and Table 2 also indicate that the crop rotation used by the farmer and the amount of yield benefits of CPS wheat compared to HRSW both have effects on the energy savings achieved by using ethanol fuel made from CPS wheat.

The Husky Energy ethanol plant will produce 130 million litres of ethanol per year. This represents about 7.9% (on a volume basis) of the total gasoline used in the province. When a requirement for a blend of 10% ethanol in gasoline comes into force, this plant at Lloydminster will provide the majority of the ethanol needed.

Table 2. Energy efficient, energy integrated ethanol production plant. Effects on energy output:input ratio and on the total reduction in fossil fuel consumption when ethanol replaces gasoline. Effects of different methods to produce the wheat raw material. In parentheses = no carbon dioxide capture.

CPS wheat after another crop in the rotation	Yield of CPS wheat compared to HRSW (%)	Output:input ratio	Reduction in total fossil fuel consumption when 1 MJ ethanol replaces 1 MJ gasoline (%)
W-CPSW	120	1.36:1 (1.23:1)	42.6 (36.4)
W-CPSW	130	1.40:1 (1.26:1)	44.2 (38.2)
P-CPSW	120	1.47:1 (1.32:1)	46.9 (40.9)
P-CPSW	130	1.53:1 (1.37:1)	48.9 (42.9)
A-CPSW	120	1.93:1 (1.68:1)	59.5 (53.5)
A-CPSW	130	1.98:1 (1.72:1)	60.5 (54.7)

The CPS wheat coming into the Husky Energy plant at Lloydminster would be some combination of wheat produced in various rotations, of which the ones shown in Table 1 and 2 are examples. Rotations which reduce the energy cost of the wheat raw material (and hence the energy cost of the ethanol produced) would tend to be encouraged, wherever possible. It should be noted that CPS wheat grown after alfalfa in the rotation has considerably lower production economic costs, due to the savings in nitrogen fertilizer and pesticides. The net income from growing CPS wheat in this manner was estimated to be over $30/acre more than CPS wheat grown after another cereal in the rotation.

Some grain-to-ethanol plants might not capture carbon dioxide for sale. This was found to reduce the fossil fuel energy savings of replacing gasoline by ethanol by 10-14%. Substantial reductions in total fossil fuel energy consumption were still found.

Future directions.

Grain to ethanol future directions.

Energy analysis of integration of a grain-to-ethanol production facility with a feedlot and a new biogas/biofertilizer plant process indicated large reductions in the fossil fuel energy required to produce ethanol. A new process for production of biogas (a mixture of methane and carbon dioxide) from feedlot manure has been developed by the Alberta Research Council. The process also produces a solid biofertilizer and water which can be recycled. The process is being demonstrated at a feedlot in Alberta. A grain-to-ethanol plant would be able to feed the distillers grains and solubles in a wet state to the cattle in the feedlot. This would save the considerable energy costs of drying the DDGS for sale off site. The manure would be digested to produce biogas and biofertilizer. The biogas would be used to provide the thermal energy requirements of the ethanol plant. The results of the energy analyses are shown in Table 3.

Table 3. Energy output:input ratio of ethanol produced in an integrated ethanol plant/biogas/feedlot system. Effects of crop rotations, different yield benefits of CPS wheat compared to hard red spring wheat, and use of manure as a partial fertilizer replacement. Reduction in total fossil fuel consumption when ethanol replaces gasoline. Situation with no carbon dioxide capture.

Crop rotation or manure use	Yield of CPS wheat cf. HRSW (%)	Energy output: input ratio	Reduction in total fossil fuel consumption when 1 MJ of ethanol replaced 1 MJ of gasoline (%)
W-CPSW	120	1.59:1	51.0
W-CPSW	130	1.65:1	52.7
W-CPSW (20% manure N)	120	1.67:1	53.1
P-CPSW	120	1.75:1	55.5
A-CPSW	120	2.45:1	68.1

The total reduction in total greenhouse gases (GHGs) by such a process is projected to be considerable. Feeding DDGS to cattle has been shown to improve feed efficiency and hence reduce methane eructation ("burping cows"). Capture of manure in the biogas plant would reduce methane losses from decomposing manure. Recycling manure nutrients as the solid bio-fertilizer would reduce nutrient losses. The large reduction in fossil fuel consumption by using ethanol from such production facilities to replace some of the gasoline now used would also reduce greenhouse gases. The process should be of particular interest in Alberta, where there are many feedlots. Alberta is also the site of a growing number of oil sand plants which have high greenhouse gas emissions. They will be in need of greenhouse gas offset projects. Perhaps these integrated ethanol plant/biogas/feedlot systems could be of such interest.

<u>Lignocellulose to ethanol production processes.</u>

A number of studies have shown that conversion of waste wood, bark, crop residues (where it is acceptable to remove a portion beyond soil protection needs) to ethanol or other liquid biofuels has the potential to substantially reduce greenhouse gas emissions. Such raw materials are available in much larger amounts in Canada and world wide than grains. The proposed ethanol plant at Nipawin plans to use a gasification-catalytic conversion system to produce ethanol from sawdust, bark and flax straw.

<u>Food versus fuel issues.</u>

One estimate is that about one million tonnes of wheat might be available annually for conversion into ethanol and DDGS animal feed in all of Canada. This would represent about 4.3% of average annual production of wheat in Canada. Some 38% of the wheat converted into ethanol would be recovered as the DDGS animal feed. Thus the net loss of food and feed nutritional value would be 2.7%. It should be noted that much of the Canadian wheat production is used for animal feed at the present time. If greater world food shortages and higher grain prices occur in the future, many of the grain-to-ethanol plants could add separation steps, prior to the fermentation step, that would produce (for example) wheat gluten, enriched wheat flour and a poor grade wheat flour that could still be converted into ethanol. This is already being done at the grain bio-refinery at Red Deer, Alberta.

A number of the studies reviewed indicated that the first priority to reduce world hunger is to assist poor farmers in Third World countries (who represent about 50% of the poorest people) to substantially (and cheaply) increase their own food production. A number of ways to do this are briefly indicated.

<u>Other renewable energy options.</u>

The study briefly examines other options for renewable energy production on farms. Wind energy looks promising and could generate considerable new net income for farmers whose land is used for wind electricity production.

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