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COMMENTARY

ECONOMIC GROWTH AND INNOVATION

The Ethanol Trap:

Why Policies to Promote Ethanol as Fuel Need Rethinking

Douglas Auld

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In this issue...

Government support for ethanol production is expensive for governments and costly for consumers

The Author of This Issue

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The Study in Brief

With growing public pressure to curb the rise in greenhouse gas emissions, Canadian governments, like those in many other western countries, have chosen to promote and subsidize the development of ethanol as a fuel additive to gasoline.

The purpose of this study is to examine ethanol policy's goals, evaluate the scientific evidence that is used to justify government support for ethanol production, and determine the costs to government and consumers.

The key findings of the paper include:

- The general body of scientific knowledge that weighs whether ethanol fuel significantly reduces energy use or greenhouse gas emissions, once taking into account the entire production cycle, is inconclusive.
- Assuming that the use of ethanol has a positive impact on CO_2 emissions, public funds contribute approximately $368 for each tonne of CO_2 reduced, roughly seven times greater than the cost of alternative policy measures.
- To the extent that ethanol policy is meant to act as a rural development tool, ethanol mandates and production subsidies provide benefits to some farmers while hurting others, with perhaps more being hurt financially than helped.
- Increased domestic production of ethanol contributes to increases in food prices, both directly and indirectly, for Canadian and foreign consumers. Domestically, increased food prices cost consumers an estimated $400 million each year.

Given the findings of the study, federal and provincial governments should reconsider this policy thrust, and redirect government funds for environmental policy to more promising measures.

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Ethanol production is frequently praised for its purported contributions to reducing greenhouse gas (GHG) emissions, and promoted as a strategy to lower dependence on fossil fuels.

Recently, Canada became a major booster of increased ethanol production: in 2007, the federal government committed more than $2 billion in several multi-year programs to encourage, promote and subsidize the production and use of biofuels as an alternative motor vehicle fuel. The government also characterized this significant expenditure as part of a federal effort to raise rural incomes by supporting farmers.[1] In addition to federal efforts, a number of provinces encourage ethanol production through similar capital and production subsidies.

This *Commentary* questions the wisdom of such policies. It argues that there is no conclusive scientific evidence that ethanol reduces GHGs or energy use. Further it argues that associated support programs for farmers are a double-edged sword, penalizing the majority not involved in ethanol production, and that increased ethanol production has a serious impact on food prices. Finally, the study argues that government spending to reduce GHGs through increased ethanol use is far out of line with reasonable alternatives. For every tonne of carbon dioxide (CO_2) offset under the current ethanol regime, the average subsidy is $368. This is more than seven times the cost of using alternative energy policies to achieve the same reduction.

Policymakers should reconsider the headlong thrust into corn ethanol as a GHG reduction policy. It cannot be justified once the significant price effects, economic costs, and consequences for income distribution in Canada and, indeed, globally are considered. Instead, more cost-effective GHG-reduction strategies that utilize scientifically proven sources should be pursued. As our review of GHG emissions and energy demand for biofuels shows, cellulose-based ethanol blends and solid biofuels provide a more promising approach to reducing GHGs.

Ethanol and Public Policy

What is Ethanol?

Ethanol is a common alcohol produced by the fermentation of organic matter, such as corn, wheat or sugar cane and, more recently, by a synthetic, petrochemical process. Ethanol is used in alcoholic beverages and has several industrial applications in, for example, pharmaceuticals, vinegar production, food extracts, cosmetics, and solvents, as well as being a fuel additive. Corn is the primary source of ethanol in the United States, whereas a combination of corn and wheat is used in Canada. Europeans rely on wheat and sugar beets; in Brazil, ethanol is derived largely from sugar cane.

Another biofuel ingredient is cellulosic ethanol, which is made from straw, crop waste, switchgrass, and certain wood products. These different types of ethanol vary in terms of energy and greenhouse gas emissions during production and use. To avoid confusion, the term ethanol used in this paper refers to corn ethanol unless specified otherwise.

Ethanol begins with crop production then proceeds through a number of stages such as fermentation and distillation before it is blended

In the course of this work, I have benefited from conversations with many people but I am especially indebted to Finn Poschmann, Ben Dachis, Colin Busby and Robin Banerjee of the C.D. Howe Institute for their insight and diligent research, including the calculations used in the study. Several external referees provided a range of suggestions to strengthen the final document.

1 Office of the Prime Minister of Canada, 2007. See "Government's New Biofuel Plan a Double Win: Good for the Environment and Farmers," announcement by Prime Minister Stephen Harper, July 5, 2007. Accessed at http://pm.gc.ca/eng/media.asp?id=1736.

Figure 1: Key Steps in the Production of Corn Ethanol Biofuel

Growing and Harvesting Corn

Dry Milling or Wet Milling

Fermentation

Distillation

Dehydrated and Denatured

Blended with Gasoline to Produce Biofuel

Source: Renewable Fuels Association, Ethanol Industry Outlook 2002: Growing Homeland Energy Security, Washington.

with gasoline by distributors for sale to consumers as ethanol-blended gasoline (Figure 1). Ethanol is commonly available with a ratio of up to 10 percent ethanol to 90 percent gasoline, a blend that will fuel most cars manufactured in North America in the last 25 years. Another fuel with a much higher ethanol content is E85, a blend that is 85 percent ethanol and requires automobiles to be specially designed to accommodate such a high proportion of biofuel.

In addition to ethanol, another alternative fuel is biodiesel, which can be burned in any conventional, unmodified diesel engine. Biodiesel, a non-petroleum-based fuel, can be produced from various sources such as canola oil and animal fats, and can be mixed with various percentages of regular petroleum-based diesel.

Ethanol in the United States and Brazil

Government support for ethanol production has existed for almost 40 years. Although the use of ethanol to power motor vehicles can be traced back to the beginning of the automobile age, this energy source remained on the back burner until the foreign oil embargoes of 1973 and 1979. The current push for ethanol stems from the evidence that when ethanol-blended gasoline is combusted in a motor vehicle engine, the exhaust contains less environmentally harmful gases or GHGs than gasoline without ethanol. As well, growing corn for ethanol acts as a carbon offset by capturing CO_2 from the air. Current US legislation provides ethanol blenders with a tax credit of $0.13 per litre (which will be reduced to $0.12 per litre in 2009 and 2010) alongside an import tariff of $0.14 per litre (Food and Agricultural Policy Research Institute 2008).

The *Energy Independence and Security Act* of 2007 specifies that passenger automobile makers are required to increase average fleet-wide gas mileage to 35 miles per gallon (6.8 L/100 km) from the 2007 level of 27.5 miles per gallon (9.3 L/100 km) by 2020.

Furthermore, the *Act* requires that fuel producers use at least 36 billion gallons (136 billion litres) of biofuel by 2022, up from 4.7 billion gallons (18 billion litres) in 2007, stipulating that 21 billion gallons (79 billion litres) of the 36 billion must be from non-corn starch products.[2]

2 US *Energy Independence and Security Act* (2007).

Upon examination, however, the policy has important inconsistencies. Indeed, as Runge and Senauer (2007) point out, the existence of significant US tariff barriers to ethanol imports belies the government's assertion of environmental goals.

The current US policy is also driven by concerns over energy security – and the attraction of a supply of fuel free from the vagaries of world politics. While the United States is now the largest producer of ethanol in the world, Brazil is the highest per capita consumer of biofuels for automotive transportation. The oil crises of the 1970s propelled Brazil into the biofuel era when its government mandated the development of automobiles that could function on sugar-based ethanol. The directive was accompanied by heavy subsidies and low taxes for producers and consumers of ethanol.

Today, many cars in Brazil run on "flex fuel," allowing them to operate on either gasoline or ethanol, or a blend of the two. For Brazil, ethanol made from sugar cane has become a practical alternative, since the country's climate is conducive to growing sugar cane. As a result, Brazil is a major ethanol exporter.

Ethanol Policy in Canada

Large government subsidies to the private sector, such as those required to produce ethanol, are possibly justified on two theoretical grounds (Rubin et al. 2008). The first rationale concerns a clearly identifiable failure of the market system so that the price and output for a particular good do not reflect the true costs or benefits associated with that product. In the case of ethanol, the market failure is that gasoline users do not take into account the cost, or environmental damage caused by their use of gasoline, and fail to consider the benefits of ethanol.

A second possible rationale is the encouragement of rural development through a redistribution of public funds – in this case, largely paid for by consumers and urban residents. Unlike in the United States, domestic energy security in Canada is not a major rationale for ethanol production.

As we shall see, in Canada's case, even if these theoretical imperatives are met, the resultant policies carry with them high costs for Canadian consumers and for the federal and provincial governments.

Numerous Canadian policies have been implemented to promote ethanol, with an assortment of benefits and costs. Government supports for ethanol in Canada have changed substantially over the last few years. In addition to varying provincial and federal ethanol fuel-content mandates, there exists a wide range of production and capital subsidies. Subsidies can take many forms, apply at all stages of production, and include a fuel-tax exemption on the final product. Another possible subsidy is for consumers who purchase ethanol-fuelled cars (see Banerjee 2007 for a discussion of "feebates"). However, the 2008 federal budget removed the financial incentives to purchase low-emission or ethanol-fuelled vehicles. The policies outlined below represent the majority of current direct federal and provincial programs for ethanol production.

Currently, Canada produces about two-thirds of its ethanol from corn and the rest from wheat. Total ethanol production utilizes 500,000 tonnes of wheat and slightly more than 1 million tonnes of corn (Agriculture and Agri-Food Canada 2006). In contrast, cellulosic ethanol represents only about 0.2 percent of total ethanol production.

Corn production in Canada is concentrated in three provinces. In 2006, Ontario accounted for 57.3 percent of Canada's corn crop, Quebec for 36.4 percent and Manitoba for most of the rest.[3] Most ethanol production in Quebec and Ontario is corn-based, while the majority of the production in the Prairies is wheat-based.

3 Statistics Canada (2007).

Also, similar to the US, Canada maintains a tariff of 4.92 cents per litre on imported ethanol, with the exception of ethanol from NAFTA countries. This subtly raises the price of cheap ethanol imports, such as those from Brazil. In 2007, Canadian ethanol imports were approximately 500 million litres, or about two-thirds of total domestic production.[4]

FEDERAL SUPPORT: Until April 1, 2008, the ethanol component of gasoline sold in Canada was given a special exemption from the 10-cent-per-litre excise tax on fuel.[5] However, this exemption has been replaced by a producer credit program that provides up to 10 cents for every litre of ethanol supplied. The exact amount is based on a measure of industry profitability, with the credit declining as ethanol production becomes more profitable.[6] Also, biodiesel production is given a credit of up to 20 cents per litre. This program, titled "ecoENERGY for Biofuels," is slated to provide $1.5 billion worth of production subsidies to producers of ethanol and biodiesel.

The federal government is also providing capital support for ethanol production facilities and research. For capital assistance, individual loans of up to $25 million are offered. Ottawa is also providing $145 million worth of research grants over several years, partly for biofuel research through the Agricultural Bioproducts Innovation Program.[7] A further $500 million is available for research into non-food-based cellulosic ethanol production, such as from straw, switchgrass and wood (Samson et al. 2008).

The federal government's ethanol content requirement is that, on average, ethanol or other renewable products must be blended to constitute 5 percent of all gasoline sold in Canada by 2010.[8] This does not mean that all gasoline must have 5 percent ethanol, but that the national pooled average must be 5 percent.

Similarly, federal mandates for biodiesel require that diesel and heating oil have 2 percent renewable content by 2012. Assuming that the total amount of energy demanded by Canadian drivers grows at 1 percent per year (the average growth rate since 2001), this will require that 2.2 billion litres of ethanol be produced for Canadian consumption in 2012. This may fall if high fuel prices reduce demand in the future.

PROVINCIAL POLICIES: For both the federal and provincial levels, the array of fuel-tax exemptions, content mandates and producer credits are summarized in Table 1. Over the past year, provincial laws on ethanol have changed substantially (the reported policies are accurate as of June 2008). Four provinces – Ontario, Manitoba, Saskatchewan and British Columbia – have established ethanol content standards in gasoline. Most provinces that had a fuel-tax exemption for ethanol content have moved to a direct producer credit, ranging from a low of 9 cents per litre in Alberta to 20 cents per litre in Manitoba.[9]

4 Import data from World Trade Atlas 2007, production data from Canadian Renewable Fuels Association, http://greenfuels.org/lists.php#ethProd.

5 The exemption depends on the proportion of ethanol in the fuel. For example, if 10 percent of the fuel is ethanol, then 10 percent of the fuel is tax-free, making the federal excise tax nine cents per litre.

6 Specifically, the producer credit is calculated as a function of the necessary price of ethanol to ensure profitability on sales up to a certain limit. The maximum credit will be 10 cents per litre from 2008 to 2010, eight cents per litre in 2011 and decline by one cent per litre each year to four cents per litre when the program is scheduled to end in 2017. See http://oee.rncan.gc.ca/transportation/ecoenergy-biofuels/incentive.cfm?attr=12 for more details.

7 See http://www.agr.gc.ca/index_e.php?s1=prog&s2=ecoabc-iieb&page=faq for details of these programs.

8 Bill C-33 authorizing a nationwide mandate of ethanol content in fuels passed third reading in the House of Commons on May 29, but had yet to receive Senate approval and royal assent as of June 24, 2008.

9 Manitoba's support involves a 20-cents-per-litre subsidy to blenders starting in 2007/08. The subsidy is reduced by five cents per litre every two years. There is no subsidy after 2016. www.gov.mb.ca/stem/energy/ethanol/index.html.

Table 1. Federal and Provincial Legislation on Ethanol and Biodiesel (as of June 2008)

Province	Producer Credit	Fuel-Content Mandate	Fuel-Tax Exemption	Capital Subsidies
British Columbia	N/A	5% for both ethanol and biodiesel in 2010	Ethanol and biodiesel exempt	N/A
Alberta	Between $0.09 and $0.14/L based on producer size	N/A	Phased out in 2007	For commercialization & infrastructure $30 million
Saskatchewan	$0.15/L based on producer size	7.5% for ethanol	Phased out in 2007	$80 million capital program
Manitoba	Currently $0.20/L, declining to $0.10/L by 2013	8.5% for ethanol by the end of 2008	N/A	N/A
Ontario	Variable based on profitability, up to $0.11/L	5% for ethanol as of 2007	Phased out in 2005	Capital assistance of up to $0.10/L
Quebec	Up to $0.18.5/L if crude oil under $65/barrel, otherwise zero	N/A	Biodiesel exempt	N/A
Nova Scotia	N/A	N/A	Biodiesel exempt	N/A
Federal	Up to $0.10/L	5% for ethanol by 2010, 2% biodiesel by 2012	Phased out April 1, 2008	Up to $350 million for first-generation biofuel facility capital and research

Sources: Various Provincial biofuel program documents; Mussel et al. (2007); Agriculture and Agri-Food Canada.

Some provinces, such as Ontario and Quebec, vary the amount of subsidy based on the expected profitability of the ethanol industry. Production capacity is largely concentrated in Ontario, Manitoba and Saskatchewan, with 1 billion, 140 million and 277 million litres of ethanol production capacity expected by 2010 in these provinces, respectively.

Ethanol as Farm Aid and a Rural Development Tool

Federal capital subsidies to ethanol production facilities increase as the percentage of facility owners who are farmers increases, clearly indicating that the program is intended to assist farmers. However, there will be winners and losers from ethanol subsidies among different types of farmers and rural residents.

Slightly more than half of all corn grown in Canada is used as animal feed with the remainder allocated to human or industrial consumption.[10] Recent analysis of the livestock industry suggests that farmers have seen increases in the monthly average of feedstock prices for corn and wheat of between 20 percent and 30 percent over the period 2002 to mid-2007 (Mussel et al. 2007). This is at least partly due to growing ethanol demand.

Ethanol policy will thus benefit some farmers at the expense of others. Proportionally, there are 46,000 more livestock production farms than corn

10 CANSIM Tables 001-0042.

and grain farms.[11] Owners of agricultural land, however, will be ethanol policy's main beneficiaries as the higher prices of farm products are capitalized in higher land prices. Owners of marginal land may also benefit as more acreage is put into corn and/or wheat production.

Ethanol versus Gasoline: Energy and Greenhouse Gas Reductions

From an environmental perspective, the bottom line for ethanol policy is determining whether shifting consumption to ethanol from gasoline reduces greenhouse gases without increasing overall energy use. When ethanol is blended with gasoline, the final consumer emits less greenhouse gases than he/she would using undiluted gasoline. However, once the complete production process of ethanol is taken into account, it is unclear whether ethanol production uses less energy and emits less greenhouses gases overall. Yet current policies, both federal and provincial, do not reflect this uncertainty.

Ethanol and Energy Demands

The production of ethanol as a motor fuel additive requires several steps utilizing various forms of energy. The growing of corn, for one, requires fertilizer, machinery for preparing fields, seeding and harvesting, followed by the milling and distilling processes to create the ethanol. The pure ethanol then has to be shipped to wholesalers for blending with gasoline. Table 2 below highlights the steps of ethanol production that release or sequester CO_2 and consume energy or create co-products, such as livestock feed.

The current body of scientific knowledge offers a wide range of estimates of the net energy balance in producing ethanol. Some studies suggest that, relative to gasoline, it takes more energy to produce ethanol than what is delivered (Pimentel and Patzek 2005, 2007; de Oliveira et al. 2005), while others suggest that ethanol can generate two-thirds more energy than gasoline when considering the energy used and produced at all stages in the production and use of both fuels (Shapouri et al. 2004).
The net energy balance depends on variables such as the energy used to produce the crop itself, the grinding, processing, and transportation of the fuel, distillation and fermenting, the energy used to manufacture the farm equipment and a host of other items. A recent paper published in the journal *Science* (Farrel et al. 2006) compared six major recent studies on the energy requirements of biofuels and found that the results are highly sensitive to the assumptions used by researchers. Hence, the research debate regarding the net energy requirements to produce ethanol suggests that there is not yet any definitive answer to whether or not the production of ethanol requires more energy than is embodied in the final product. Once considering all factors involved in the production and use of gasoline, the likely range of ethanol's net energy balance is between producing marginally more net energy than regular gasoline and producing slightly less net energy than gasoline, but with most estimates suggesting the former.

That said, the net energy balance of all stages of production is a limited metric, as some forms of energy are more useful than others. Energy in liquid form has greater flexibility than energy produced from, say, burning coal; consequently, this contributes to a higher market price per unit of energy from ethanol or gasoline than from coal.

Importantly, however, for the end consumer, ethanol delivers less energy per litre than regular gasoline. Gasoline produces 35 megajoules (a unit of energy) per litre, whereas corn-based ethanol produces only 21 to 23 megajoules per litre (Davis and Diegel 2007). Hence, a 5 percent ethanol content mandate by volume rather than by energy content will require that more fuel – either gasoline or ethanol – be consumed to make up for the lost energy from using a less energetic fuel. In other words, users will have to fill up more often to drive the same distances with ethanol fuel. Cars that run on E85 fuel have lower average volu-

11 CANSIM Table 002-0038.

Table 2. Simple Schematic of Life Cycle GHG Emissions on Energy Processes for Ethanol Production

Step in the Production of Corn Ethanol	Energy Demand	Energy Creation	GHG Impact	GHG Sequestering	Other Environmental Impacts
Growing and harvesting corn	Fertilizer and pesticide production, Harvesting equipment fuel		Farm-vehicle exhaust Nitrogen fertilizer	Feedstocks during growing	Pesticide and herbicide residue and run-off soil erosion Water demands
Milling	Vehicle fuels		Fuels used in process	Co-product emssions offset	
Transportation to distilling and fermenting processes	Plant energy, heat, electricity	Cogeneration of heat energy	Vehicle exhaust		
Distillation and fermentation	Plant energy, heat, electricity, production of inputs for these processes	Cogeneration of heat energy	Gas emissions from process		Liquid-waste disposal
Transportation to blending process	Haulage by truck or rail				

Sources: Author's calculations; Pimental and Patzek (2007); Farrell et al. (2006).

metric fuel efficiencies (19.9 L/100km in the city; 14.0 L/100km on highways) than cars that run on regular gasoline (12.9 L/100km in city driving, 8.7 L/100km on highways).[12] The same is true, although to a lesser degree, for vehicles that use a 5 to 10 percent ethanol blend – ethanol blended with gasoline at 10 percent has 97 percent as much energy per litre as regular gasoline (Davis and Diegel 2007).

Ethanol and Greenhouse Gases

In support of government subsidies and reduced excise taxes, federal and provincial governments have argued that corn ethanol is a fuel that produces appreciably lower levels of GHGs than gasoline. While there is strong evidence that the "tailpipe" emissions – exhaust from vehicles – are reduced when ethanol is used in place of gasoline, this ignores the net life-cycle emissions of ethanol production. There now exists a broad range of recent studies on the net GHG emissions of biofuels (Agriculture and Agri-Food Canada 1999, 2000; Crutzen et al. 2007; Samson et al. 2008; Lipman and DeLucchi 2002). Farell et al. (2006), in their analysis of such studies, find an average GHG reduction of about 7 percent from current production of corn ethanol as opposed to unblended gasoline, but caution that results vary from place to place and may increase net GHG emissions if the ethanol is produced in a GHG-intensive manner. They conclude that only cellulose ethanol offers significant reductions in GHG emissions, a nearly 90 percent reduction in GHGs relative to regular gasoline.

A summary of research by Natural Resources Canada reports that Canadian blended ethanol using 10 percent corn ethanol would reduce GHG

12 Natural Resources Canada Fuel Consumption Ratings for 1,056 different versions of 2008 model vehicles.

emissions per litre of fuel by 3 to 4 percent while a 10 percent cellulose biofuel would lower GHG content by 6 to 8 percent (Forge 2007). Net life-cycle emissions from Canadian wheat- and corn-based ethanol are not substantially different.[13]

Cellulosic ethanol derived from the by-products of wheat and corn production – such as corn stover or wheat straw, instead of the original corn or wheat – does reduce net GHG emissions relative to corn or wheat ethanol (Agriculture and Agri-Food Canada 2006). But the potential to expand the production of ethanol from wheat and corn by-products is limited. Thus, as a review of GHG emissions and energy demand for biofuels shows, while there is little agreement on the effect of corn or wheat ethanol on GHG emission levels, cellulose-based ethanol blends provide a more effective approach to reducing GHGs.

Evidence that ethanol-blended gasoline results in fewer GHGs than gasoline itself is extremely important for justifying government support. But it is clear from the evidence to date that there is no consensus regarding the efficacy of corn-based ethanol to either reduce GHGs or reduce overall energy demands. Taking into account these facts, subsidizing ethanol production and consumption lacks dependable logic.

The Impact and Effectiveness of Ethanol Policy

The Impact of Ethanol

We have seen that a 5 percent blended ethanol will have, at best, a marginal impact on GHG reduction. However, even with the most optimistic position on the effectiveness of ethanol policy in reducing GHGs, a critical policy question is: to what extent do federal and provincial subsidies and mandates accomplish their environmental goals? Before answering, several assumptions must be made for this analysis:

- Gasoline energy demand at the national and provincial levels is projected to grow at the same rate to 2012 as their respective averages from 2001 to 2007.[14]
- Ethanol demand is entirely met with domestic production starting in 2010.
- Estimated national ethanol production is the total of each province's production, based on the amount needed to satisfy the higher of currently proposed national or provincial mandates applicable in the given year. For example, estimated ethanol demand in Manitoba will be 8.5 percent of total fuel demand, based on provincial requirements. In contrast, ethanol demand in Alberta in 2010 will be 5 percent to satisfy the federal content mandate.
- Estimated ethanol production and subsidies from 2007 to 2010 are based on the actual and expected production capacities of ethanol plants either operating or under construction, based on information from the Canadian Renewable Fuels Association. (See Table 3.)

Federal and provincial ethanol-content standards are based on the total volume of fuel that contains ethanol, not the amount of energy therein. As noted earlier, corn ethanol contains between 21 and 23 megajoules (MJ) of energy per litre, whereas regular gasoline has approximately 35 MJ per litre. In other words, for the same volume of fuel, ethanol produces approximately two-thirds the amount of energy as gasoline (Davis and Diegel 2007).[15] For a given car, it will take the same amount of energy to move between two points, regardless of the type of fuel used. If a car uses

13 Some differences between corn and wheat ethanol production are worth noting. Wheat ethanol production in Manitoba, for example, has the benefit of using emissions-free hydroelectric power, reducing the pollution in the production stage. Wheat ethanol is also more effective in reducing emissions from co-products used in animal feed. However, this is offset by the fact that Western wheat uses a more GHG-intensive type of fertilizer and delivers less energy than corn ethanol (Natural Resources Canada 2003).

14 If demand for fuel grows at slower rate after 2008 due to rising prices, this will decrease the total subsidy given to meet production demands. However, this will marginally increase the subsidy per litre as the fixed capital subsidy will be spread over a smaller volume of production.

15 Samson et al. (2008) use 0.021 GJ/L, as that is the estimated efficiency of ethanol-blended fuel at a lower temperature used for measurement. However, the Canadian Renewable Fuels Association uses 0.023 GJ/L in their estimations; this higher energy efficiency is used in all calculations.

Table 3. Gasoline and Ethanol Demand, Energy and CO_2 Equivalent Emissions, 2007 — 2012

	2007	2008	2009	2010	2011	2012
Fuel Demand (million litres)						
Total gasoline demand	41,313	41,696	42,084	42,474	42,869	43,267
Ethanol demand with mandates	1,068	1,082	1,096	2,247	2,274	2,302
Actual ethanol produced	762	1,092	1,667	2,247	2,274	2,302
Energy Produced (million gigajoules)						
Energy produced by ethanol and gasoline offset (Million Gigajoules)	18	26	39	53	53	54
Tonnes of CO_2 Equivalent						
Total CO_2 equivalent emitted from ethanol	1,967,560	2,012,671	3,072,456	4,140,916	4,191,405	4,242,667
Tonnes of CO_2 equivalent from gasoline offset	2,497,644	2,554,909	3,900,213	5,256,529	5,320,621	5,385,693
Total CO_2 equivalent offset from ethanol mandates	530,085	542,238	827,757	1,115,613	1,129,216	1,143,026

Source: Author's calculations. Canadian Renewable Fuels Association. "The Supply and Disposition of Refined Petroleum Products in Canada." October 2007. Catalogue no. 45-004-X. CANSIM Table 134-0004.

ethanol-blended gasoline, it will require a greater volume of fuel, relative to regular gasoline, to travel the same distance.

The level of GHG emissions is directly related to the amount of energy produced from the ethanol and gasoline used, but also depends on the energy and emissions required in the production of the fuels. In fact, the total amount of CO_2 equivalent emitted from producing and burning pure Canadian corn ethanol is 62.03 kg/GJ [16] whereas regular gasoline emits 99.56 kg/GJ of CO_2 equivalent (Samson et al. 2008). During the production of corn ethanol, another major greenhouse gas nitrous oxide (N_2O) is produced, accounting for one-fifth of all GHG emissions from ethanol. Total GHG emissions from the production and use of corn ethanol in Canada are 78.43 kg of CO_2 equivalent per GJ of energy.

It should be noted that other types of biofuels will result in different net GHG balances depending on the type of fuel and the specific production process. For example, according to estimates from Natural Resources Canada,[17] Canadian wheat ethanol does have lower net GHG emissions than US production of corn, partly due to the lower emissions from predominantly hydroelectric power sources used in Canada. However, wheat and corn ethanol have similar net GHG emissions when both are made in Canada (Natural Resources Canada 2003).

The different environmental impacts of biodiesel and ethanol are also important. The production and use of biodiesel can result in half the amount of greenhouse gases it takes to produce and use traditional diesel. But the net GHG balance of biodiesel varies widely since it can be produced from varied sources such as animal waste products, fats and canola oil. Expected domestic production of biodiesel is expected to be considerably smaller than gasoline ethanol – approximately one-fifth by 2012 – and is currently less than one-tenth of current ethanol production. Because biodiesel

16 This is the sum of 62.03 kg/GJ in CO_2 emissions and 16.4 kg/GJ in N_2O expressed in the equivalent amount of CO_2 emissions. Canadian corn ethanol has a lower CO_2 content than US corn ethanol that emits approximately 100.3 kg/GJ of CO_2 equivalent emissions. See Samson et al. (2008).

17 Using greenhouse gas life-cycle emissions software GHGenius 3.11.

Table 4. Total Federal and Provincial Subsidies to Ethanol Producers per Litre of Ethanol Produced and Tonne of CO_2 Equivalent Offset, 2007–2012

	2007	2008	2009	2010	2011	2012	Total Subsidies
Producer and capital subsidies ($million)	204	238	297	382	386	383	1,891
Subsidy per litre of ethanol (cents per litre actually produced)	26.8	21.8	17.8	17.0	17.0	16.7	18.3
Subsidy/tonne of CO_2 equivalent offset from gasoline	540	440	359	343	342	335	368

Source: Author's calculations. Note that calculations do not include subsidies for biodiesel or cellulosic ethanol.

makes up a considerably smaller share of biofuels production than ethanol, it is not analyzed in the study.

According to the estimates presented here, somewhat less CO_2 equivalent will be emitted by using energy from ethanol as opposed to producing the same amount of energy from traditional gasoline. Under the currently proposed federal and provincial renewable fuel mandates, the total amount of CO_2 equivalent offset will likely be around 1.1 million tonnes by 2010 and beyond. To put this in perspective, this amounts to approximately 30 kg of CO_2 equivalent per Canadian. Jaccard and Rivers (2007) calculate a similar expected offset in CO_2 equivalent of 1 million tonnes from ethanol mandates.

The Cost of Ethanol Subsidies

It is helpful to compare the effectiveness of replacing gasoline with corn ethanol to the amount of subsidies given to ethanol producers to reduce GHG emissions. The estimated total amount of federal and provincial subsidies up to and including 2009 is based on expected production capacity. After 2010, subsidies are estimated based on the amount of fuel needed to meet federal and provincial renewable fuel content standards. Estimates of the total subsidies include (i) the amount of producer credit, (ii) the capitalized annual costs of research grants and (iii) the opportunity cost of federal loans given on generous terms.

Assuming that domestic ethanol production can meet the 2010 federal and provincial mandates, total annual subsidies to ethanol producers from both the federal and provincial levels will approach $400 million. Between 2007 and 2012, the total federal and provincial subsidies for ethanol capital and production – excluding biodiesel and second-generation ethanol grants and subsidies – will be nearly $1.9 billion (Table 4).

As production increases and federal and some provincial subsidies decline, the subsidy per litre of ethanol will decline from 26.8 cents per litre in 2007 to 16.7 cents per litre in 2012. At the consumer level, the effective subsidy will fall from 1.34 cents per litre of 5 percent blended fuel in 2007 to 0.84 cents per litre by 2010.

How cost effective are ethanol subsidies in reducing greenhouse gases? Using the cumulative amount of GHG offset and the cumulative subsides given through 2012, it will cost the federal and provincial purses roughly $368 per tonne of CO_2 equivalent that is offset by ethanol. The cost per tonne of CO_2 equivalent offset will be reduced to $335 per tonne by 2012. In comparison, the costs of CO_2 offset from US, European and Australian ethanol subsidies range from a low-end estimate of $330 per tonne to more than $700 per tonne (Metcalf 2008, Steenblik 2007). However, if net greenhouse gas emissions increase from ethanol production and use, as some studies suggest, then the government subsidies will actually cause an increase in GHGs.

Current prices in world markets for offsetting CO_2 are in the range of $30 per tonne, with upper-boundary estimates of the future offset cost at $200 per tonne by 2020 (Rivers and Sawyer 2008). Thus, when measuring the cost of subsidies versus the environmental benefits, the federal subsidy is excessive. Also, Samson et al. (2008) show that biodiesel subsidies are only marginally more cost-effective, costing $98 to $114 per tonne of CO_2 offset. But these CO_2 offset subsidies are only part of the total cost of ethanol. A 70-cent-per-litre production cost (the current production cost used in Shapouri and Gallagher 2005) suggests that the value of raw material, capital and labour inputs used to produce all ethanol in Canada would be more than $1.5 billion in 2010 alone, far more than the federal and provincial subsidies given that year.

The opportunity cost of the public subsidies spent on ethanol is considerable. The efficacy of energy replacement programs depends on the sources that are being replaced. Government subsidies for biofuel production can be more cost effective when solid biofuels – pellets from wood and grass – are used to displace coal-generated electrical power rather than trying to replace liquid gasoline. For example, $48 of government subsidies for solid biofuels can reduce one tonne of GHG emissions from a coal electricity generating facility (Samson et al. 2008). Another alternative for liquid fuels is cellulosic ethanol, but the subsidies given to cellulosic ethanol are still likely to be at least $118 per tonne of CO_2 offset (Koplow 2006). Production costs for cellulosic ethanol are still well above those for corn and wheat ethanol, and future reductions in production costs may not be sufficient to make this form of ethanol competitive with them (Steenblik 2007).

Ethanol and Food Prices

Increased demand for corn by the ethanol industry has had a significant impact on nearly all food prices, through the higher cost of inputs for other food production and the higher costs of agricultural land. In May 2008, the one-year futures price of corn at the Chicago Board of Trade was around $6.50 per bushel, compared to just over $2.00 a bushel two years earlier.[18] As a result, the agri-food industry, which uses corn and wheat as an input for a wide range of products, must now pay higher prices. A recent report from the Organisation for Economic Co-operation and Development (OECD) estimated there will be a 20 percent to 50 percent increase in food prices in the next decade (OECD 2007). While not holding biofuel demand solely responsible for the expected increases, the report notes that it is a key factor in the upward price pressure (Doornbosch and Steenblik 2007). In Mexico, a country with a corn-based diet, the price of tortillas has increased 60 percent. And, in response to public pressure, the Mexican president has imposed price controls on certain corn-based products. The United Nations World Food Program notes that it is increasingly difficult to provide food aid to poor nations because land has been diverted from food to much more lucrative ethanol feedstock production (Blas and Wiggins 2007).

As cropland is diverted from corn-for-food to corn-for-domestic-fuel, the quantity available for export will drop and the price will rise. However, there may be a windfall gain from the price rise to subsistence farmers in less-developed countries who will profit from higher corn prices, perhaps providing them with a source of capital for improvements to agricultural productivity. If, however, they also switch to crops for ethanol production, the food shortage will be accentuated. Further, a doubling or tripling of corn or wheat prices can lead to a significant rise in the value of arable land, resulting in a windfall for owners of

18 Chicago Board of Trade website accessed June 18, 2008.

agricultural land, but not necessarily for the farmers or farm workers.

As long as ethanol subsidies are in place, it is likely that corn prices will rise along with a greater annual harvest devoted to ethanol production. But is there sufficient arable land to expand corn production? The OECD estimates that to replace 10 percent of transportation fuel with biofuel, Canada and the EU would have to devote between 30 percent and 70 percent of current crop areas to biofuel feedstock production.

In 2006, 2.77 million acres of land in Canada was devoted to corn production. By 2007, this had risen to 3.5 million acres.[19] It is estimated that to reach Canada's biofuel target of 5 percent of total fuel consumption by 2010, approximately one-half of the current farmland used for corn will be required.[20] And as more corn is devoted to ethanol, prices of corn starch, corn syrup and other corn-based products will rise.

To the extent that Canada dedicates more wheat production to ethanol, there will be a host of similar price increases. In contrast, cellulosic ethanol can be grown on marginal land that would not otherwise be used for production, meaning it would have a negligible impact on food prices. As well, if cellulosic ethanol production becomes more efficient, this will increase the return on switchgrass production relative to corn and wheat farming. However, as with most other agricultural products, switchgrass production is more productive on higher-quality land using fertilizers than on marginal lands. Therefore, without restrictions on the type of land that cellulosic ethanol can be grown on, "second generation" ethanol production will continue to affect food prices.

Income Distribution

The current and proposed subsidies to encourage and support the production of ethanol constitute a major public expenditure. Politicians have stated that these subsidies are good for farmers and generally good for rural areas of the country, but there has been little study on the overall economic impact of such transfers, especially taking higher food prices into account.

Unfortunately, it is difficult to disentangle the effects of ethanol policy and production on food prices from other factors, such as higher food demand from developing countries and higher energy prices. No comprehensive study has been conducted on the impact of Canada's ethanol policy on food prices, although the situation is now being investigated in the United States. Empirical estimates of the increase in food prices that isolate the effect of ethanol mandates, tariffs and credits in the US suggest that biofuel policy has led to an increase in consumer expenditure of $4.7 billion dollars, an approximately 0.5 percent increase in total US food expenditures compared to a baseline where there is no mandate for ethanol content in fuel, tax credits or tariffs (Food and Agricultural Policy Research Institute 2008). Edward Lazear, Chairman of the US Council of Economic Advisers, reported that the increase in US production of ethanol has led to an increase in world food prices of approximately 1.2 percentage points, but that the effect of ethanol-supporting policies is still indeterminate.[21]

Tokgoz et al. (2007) and Tokgoz and Elobeid (2006) model the marginal increase of US ethanol production and higher oil prices on the price of agricultural feedstocks. To the extent that production credits and mandates act in the same ways as higher oil and gasoline prices to improve the profitability of ethanol producers, the estimates in Tokgoz et al. (2007) of higher food prices can also apply to ethanol production credits and mandates that bring ethanol producers to the point of profitability. They predict higher food prices based on higher feedstock prices for wheat and corn.

The crucial assumption is that Canadian producers behave in a similar manner to US

19 OECD (2006) and Teneycke (2007).

20 Forge (2007).

21 Testimony of Edward P. Lazear Chairman, Council of Economic Advisers Before the Senate Foreign Relations Committee Hearing on "Responding to the Global Food Crisis" Wednesday, May 14, 2008 http://www.whitehouse.gov/cea/lazear20080514.html

Table 5. Increase in Canadian Food Prices due to Ethanol Policy using 2004 Food Expenditures

	Change in Prices *(percent)*	Personal Expenditures *($ million, 2004)*	Increase in Cost for Consumers *($ million)*
All Food	1.1	67,387	424
All Food at Home	1.2	35,322	280
Meat	3.7	8,213	159
Dairy Products	2.1	6,809	78
Fruit and Vegetables	0	5,396	0
Other	0.8	14,904	42
Restaurant Meals	0.9	32,065	144

Sources: National Economic Accounts, Statscan; Tokzog et al. (2007).

producers, and that there is an analogous increase in food prices from comparable market conditions. The expected increase in food prices and personal expenditures on food products as a result of ethanol subsidies are shown in Table 5. In 2004, the most recent year with detailed consumption data, Canadian consumers spent approximately $67 billion on food products. On average, domestic food prices are expected to increase by around 1.1 percent using a baseline of ethanol production not artificially supported by subsidies. Certain domestic food products will rise in price by up to 7 percent, whereas fruits and vegetables – which are mainly imported and do not use corn and wheat in their production – are assumed to be immune from ethanol-related price increases, but may increase due to other factors not investigated in Tokgoz et al. (2007).

The estimate of how much consumers are paying for food due to higher ethanol production is presented in Table 5. These estimates are calculated using two steps, first by estimating the increase in the cost of food on total consumption, and second, by estimating the expected fall in consumer demand due to higher prices.[22] In total, Canadian consumers can be expected to pay roughly $400 million more annually for food items due to ethanol supports. As these are 2004 estimates of Canadian food consumption, more recent data would likely yield larger total costs because of higher total expenditures on food. The estimates in Table 5 represent the minimum economic costs, since they do not account for the aggregate economic losses in a constrained market supply for food.

This increase in food costs is effectively a transfer of wealth from consumers to producers of corn and wheat. Since the increased demand for corn and wheat from the ethanol-producing sector raises input costs for other agricultural firms and percolates down the supply chain, taxpayers are making an indirect transfer to ethanol producers. The demand for corn and wheat by ethanol producers is driving up the price of ethanol feedstock. As a result, the profitability of ethanol producers is being eroded, potentially engendering calls for even greater subsidies.

The total estimable wealth transfer to farmers is the sum of direct ethanol subsidies and indirect transfers from consumers caused by higher food prices. Based on the above estimates and the total amount of subsidies offered, these wealth transfers will amount to more than $600 million in 2008 and some $800 million in 2012.

However, there are other forces at play in setting Canadian food prices. Canada's ethanol program is

22 A demand-price elasticity of 0.5 is assumed for most goods. Some goods that are considered more price elastic or inelastic were adjusted based on prevailing empirical estimates. Not including the estimate of lower-consumption increase, the cost to consumers is nearly $850 million in increased consumption costs.

small compared to that of the United States, whose market has a strong influence on the world price for agricultural commodities. Canadian ethanol production is only one factor in setting domestic food prices.

Conclusion and Recommendations

Canada's ethanol policy has several disconcerting features. First, the provision of large subsidies to encourage ethanol production distorts agricultural markets and food prices in Canada and elsewhere. Second, the scientific evidence concerning the reduction in GHGs and energy consumption afforded by switching to blended biofuels is questionable. Finally, a simple analysis of the costs and benefits associated with ethanol policies suggests that the government is paying seven times more than it could be if ethanol policy were explicitly geared to reducing GHG emissions.
In short, Canada's current ethanol policy imposes a significant cost on Canadian and foreign consumers, benefits only a few groups of Canadian farmers at the expense of many others, contributes to rising global food prices and has a large fiscal cost for government. More cost-effective policies are available.

Given the knowledge vacuum in which ethanol promotion policies have been framed, it would be prudent to place a moratorium on any further support for this initiative. The federal government's plan does provide a limited window to redirect some of the committed resources to explore cellulose ethanol technology and production. This involves a significant $500 million seven-year grant to develop large scale cellulosic "second generation" production facilities, such as the Investing in Cleaner Fuels program.[23]

The main drawback to cellulose ethanol at this time is the cost of production. While there are some commercial plants in the world and at least one in early stages of production in Canada, lowering production costs remains a significant research challenge. Given the major advantages of cellulose ethanol over corn ethanol in terms of land use, GHG emissions, energy needs and impact on food prices, it would be prudent to scale back the nearly $2 billion commitment to corn and wheat ethanol production and allocate a portion of that to the commercialization of cellulose ethanol and solid biofuels.

Upon review of the reasons that underpin federal government and provincial ethanol programs, and in light of the questionable evidence regarding corn ethanol's effectiveness in combating GHG emissions, one is prompted to ask why governments are pursuing these policies. The answer seems to be growing public demand for environmentally friendly policies. Regrettably, ethanol programs were launched without adequate research or a detailed examination of their consequences. Given the widespread belief that ethanol-blended fuel has a strong mitigative effect on global warming, it will take political will to admit that current policy is misguided, and offers little if any contribution to reducing greenhouse gases.

23 In 2007, the federal government also announced a $7.7 million repayable loan to Iogen, a Canadian firm specializing in cellulose production.

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