The Conference Board of Canada
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Ethanol's Potential Contribution to Canada's Transportation Sector

ENERGY, ENVIRONMENT AND TRANSPORTATION POLICY

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Ethanol's Potential Contribution to Canada's Transportation Sector
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Preface

Ethanol's contribution to Canada's supply of transportation fuels is important in many respects, and government support has been offered based on GHG reductions, agricultural benefits, and energy diversity.

Ethanol's Potential Contribution to Canada's Transportation Sector explores four basic questions regarding ethanol in Canada:

1. What are the economic aspects of manufacturing and using ethanol in Canada?
2. How green is ethanol?
3. What is the impact of ethanol on Canadian public health?
4. What is the energy balance in producing ethanol?

The report also looks at the policy objectives that underpin government support of the ethanol industry, comparing key elements to other nations.

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Acknowledgements

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EXECUTIVE SUMMARY

Ethanol's Potential Contribution to Canada's Transportation Sector

> **At a Glance**
>
> - Ethanol can contribute to reducing Canada's greenhouse gas (GHG) emissions. Government support has been offered based on GHG reductions, agricultural benefits, and energy diversity.
> - Ethanol reduces GHG emissions relative to gasoline by between 40 and 62 per cent, depending on agricultural practices and production technologies.
> - Historically, ethanol demand for corn and wheat in Canada has caused no increases in cropped areas or land-use changes. The impact of ethanol feedstock demand in North America has put little pressure on crop prices.
> - Next-generation technologies, high-blend infrastructure, flex-fuel vehicles, and supporting policies could extend the role ethanol plays in Canada's transportation markets.

Ethanol's contribution to Canada's supply of transportation fuels is an important topic within the overall context of energy security, environmental pressures, health impacts, climate change mitigation, and the economic contribution of renewable fuels. Worldwide, the production of ethanol has grown to 75 billion litres per year.[1] Ethanol production in Canada has reached almost 2 billion litres per year[2] and will continue to grow because a federal renewable fuel standard has been implemented and transportation fuel markets continue to expand.

The ethanol industry worldwide is at a crossroads. Renewable fuels can help reduce dependency on fossil fuels and improve energy self-sufficiency. Renewable fuels also contribute to reducing greenhouse gas (GHG) emissions when compared with gasoline, and reduce environmental pressures related to producing and transporting fuel to end consumers.

Ethanol technology is evolving, with cellulosic ethanol and thermochemical processes at the pre-commercialization stage. Today's biorefinery has transformed the way ethanol is produced, with additional potential gains on the horizon. The cost of government support programs has largely been offset through value-added agricultural crops and job creation programs.

Energy security is an ever-present global theme, which the unrest in the Middle East in 2010 and 2011 has brought into greater relief. Although Canada is self-sufficient in crude oil and transport fuels, its two largest provinces—Ontario and Quebec—both rely heavily on imported transportation fuels. At the same time, for environmental

1 (Renewable Fuels Association February 2010)

2 (Canadian Renewable Fuels Association November 2010)

reasons, renewable fuel standards in Canada and the United States are imposing minimum ethanol content requirements in gasoline. While both countries are investing in next-generation technologies, questions remain about the net energy production, environmental impacts, emissions, and economic impacts of current ethanol production levels.

Good policy is based on accurate information and careful assessment of the alternatives. The purpose of this report is to assess the evidence and to contribute to policy discussions around ethanol.

DIVERSIFYING THE FUEL MIX

Ethanol is vying for position as more than just a gasoline-blending additive. As an octane enhancer, it outperforms aromatics, methyl tert-butyl ether (MTBE), and lead. However, the opportunity exists to use ethanol as a transportation fuel, as Brazil has demonstrated. For Canada, this would require increased ethanol production, a greater availability of flex-fuel vehicles, and investment in infrastructure needed to deliver high-blend ethanol to the consumer. Canada's past programs to support ethanol have succeeded in creating a market for ethanol as a blending agent. The next step would likely require support for service station investments and ethanol transportation infrastructure to ensure that consumers have ready access to E85 (a blend of 85 per cent ethanol and 15 per cent gasoline that can be used by flex-fuel vehicles). Additional analysis is required to measure the long-term benefits and costs of this as a policy option.

ETHANOL AND GHG EMISSIONS

Numerous studies have been published that examine the GHG emissions impact of ethanol production and consumption. Current studies use life cycle analysis (LCA) and consider the GHG emissions resulting from each step: crop production, crop transportation to the ethanol plant, conversion to ethanol, transportation of ethanol, and consumption. The LCA studies conclude that GHG emissions from producing, transporting, and using ethanol are 40 to 62 per cent lower when compared with gasoline, depending on the agricultural processes and ethanol production technology used. As cropping practices and yields continue to improve, and as ethanol plants rely more on renewable energy (primarily agricultural wastes), GHG emissions per litre of ethanol will continue to decline. The shift to newer technologies as they become commercially viable will also contribute to reducing GHG emissions intensity.

THE COMPETITION FOR FOOD CROPS

Most ethanol production technologies require agricultural crops as a feedstock. In Ontario and Quebec this is primarily corn, and in Western Canada it is wheat. Those who contend that ethanol competes with food put forward two arguments. One is that the demand for crops as an ethanol feedstock puts upward pressure on grain prices. Oft-cited evidence for this is the 2006–08 spike in agricultural prices. The second argument is that higher prices for corn and higher demand for corn world-wide are encouraging deforestation in developing nations (indirect land use).

It is important to distinguish the impact of rising fuel costs on agricultural prices from that of biofuels demand, as rising oil prices have much stronger impacts.

The evidence indicates that although ethanol demand for corn has risen rapidly in both Canada and the U.S. over the past decade, the total area harvested has not increased. The major reason for this is the increase in corn yields, which produces a much larger crop from the same acreage. Although ethanol producers cite higher corn prices as a benefit to local farmers, biofuels demand for corn has not significantly impacted land use in North America. Numerous studies point to rising ethanol production and rising agricultural prices from 2006–08, assuming direct causality. However, that period was also a period of rapidly rising oil prices. Given that the cost of diesel fuel is a key element of farm costs, it is important to distinguish the impacts that rising fuel costs have on agricultural prices from those caused by biofuels demand. A 2006 study by the Organisation for Economic Co-operation and Development (OECD) is one of the few that explicitly measured the impact of crude oil prices against that of biofuels demand, and it found that oil prices have a much stronger effect. The studies of agricultural prices dealing with the 2006–08 period that do not separate the impacts of biofuels demand from oil prices must therefore be viewed with caution.

There is no evidence to date that ethanol has caused changes in land use in North America. The transition to advanced biofuels envisaged by the U.S. anticipates a broader range of feedstocks (including forest waste, special purpose grasses, and clean sorted municipal waste) to help avoid the land-use impacts that might otherwise occur.

ECONOMIC IMPACTS

The cost of government programs to encourage ethanol production is well documented, as are the economic benefits generated by the ethanol industry. Ethanol plants are located in rural areas near corn and wheat farms, providing a new market for farmers. It is estimated that the industry contributes more than $1.2 billion in net economic benefits each year. Ethanol production also generates tax revenues (combining all three levels of government) that, from 2006 to 2012, will likely equal the direct funding provided by governments in support of ethanol (although tax revenues are clearly not the reason governments have supported ethanol production financially).

THE FUTURE OF THE BIOREFINERY

Ethanol provides the foundation for the biorefinery. Many products and chemicals manufactured today from non-renewable resources can be created from renewable feedstocks such as energy crops, biomass, and waste. Ethanol is the base model for a new breed of refinery. The possibilities extend well beyond transportation fuel. Today, ethanol plants are integrating green power generation and producing biochemical building blocks as co-products, replacing those from petroleum. The future will see even greater strides from cellulosic ethanol and a full complement of bioproducts from the next-generation ethanol biorefineries.

POLICY IMPLICATIONS

Canada's ethanol producers have received financial support and have benefited from policies that promote its use and create markets. However, much of the financial support is from programs whose funding levels and duration are fixed, with annual payments declining. Market support through the renewable fuels standard will continue, as will a certain level of funding for research and development (R&D), and commercialization. However, the industry is evolving in directions that will likely require new and innovative policies.

Next-generation technologies are emerging. Demonstration projects are under way to use thermochemical processes to convert inorganic waste diverted from landfills into ethanol. Converting wood waste or special purpose crops to ethanol is also moving closer to demonstration, with an eventual commercial goal. Canada has a leadership position in this technology development process. Close cooperation among government, industry, and academia will be required on an ongoing basis to maintain that leadership.

The Renewable Fuel Standard places a floor under ethanol market demand. Further market opportunities could be created through support of ethanol transportation infrastructure and service station capacity to make ethanol blends up to 85 per cent more broadly available to the public. Brazil has demonstrated success in this area. U.S. studies have shown that E85 infrastructure and blender pumps are low cost, particularly when compared with other measures that reduce GHG emissions from transportation. Canada could contribute to meeting the GHG emissions reductions expected through tailpipe emissions standards by supporting the development and use of E85 and blender pump infrastructure. Coordinating policies regarding next-generation technologies, infrastructure investments, and market development could achieve more collectively than isolated policies in any of the three areas alone.

CHAPTER 1

Introduction

Chapter Summary

- Ethanol production capacity in Canada has risen to almost 1.9 billion litres per year, with 60 per cent of ethanol produced using corn as the feedstock.
- Almost 85 per cent of the capacity has come into service since 2005—Canada's ethanol plants use modern, energy-efficient technologies.
- Next-generation fermentation, biochemical, cellulosic, and thermochemical technologies are at the demonstration stage and are expected to move to commercial scale in coming years.

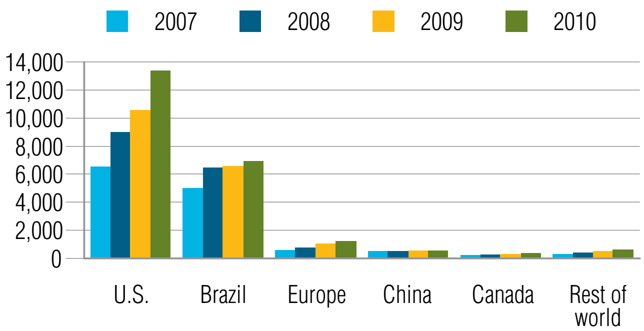
The ethanol industry has been the subject of intense debate in Canada and around the world. Many studies and reports in recent years have examined a wide range of issues and impacts related to the use of ethanol as a transportation fuel. Ethanol has been both praised and criticized for its impact on local communities, regional economics, environmental and health issues, and agriculture. The purpose of this study is to examine the Canadian ethanol industry in the context of transportation fuels, economic impacts, greenhouse gas (GHG) emissions, land use and other environmental pressures, technology developments, and public policy objectives.

The use of ethanol as a transport fuel dates back to 1908, the year Henry Ford began producing his Model T. Ford designed the Model T to run on gasoline, ethanol, or a combination of the two fuels, creating the first flex-fuel vehicle. Although ethanol fuel was eclipsed by the growth of the petroleum industry in the early part of the 20th century, interest in its use as a transport fuel re-emerged during the oil supply disruptions of the 1970s and 1980s. Since then, the United States and Brazil have channelled significant government resources into developing their ethanol industries and have emerged as world leaders in ethanol production.

Government support and private sector investment has increased Canada's ethanol production capacity significantly.

Canada's ethanol industry, on the other hand, has developed at a significantly slower pace. Canada is the world's fifth-largest producer of ethanol, but production in Canada lags far behind the U.S., Brazil, and the European Union. (See Chart 1.) The industry

Chart 1
World Ethanol Production 2007–2010
(million gallons per year)



Source: Renewable Fuels Association.

has achieved market success with the use of ethanol as a gasoline extender in Canada, but so far has not developed a substantial market for its use as an alternative to gasoline.

Ethanol production in Canada began in the 1980s with a refinery located in Minnedosa, Manitoba, followed by a second plant in Lanigan, Saskatchewan, in 1990, and a third plant in Red Deer, Alberta, in 1998. All three of these initial refineries used wheat as a feedstock. Corn ethanol production in Canada began in 1997 at a plant near Tiverton, Ontario.[1]

Today, corn is the most common feedstock for ethanol production in Canada and the United States. In 2009, an estimated 69 per cent of ethanol produced in Canada was made from corn, 30 per cent from wheat, and 1 per cent from wood waste and wheat straw.[2]

Canada's federal and provincial governments have taken steps to support the growth of ethanol production by providing capital cost support for building ethanol plants, offering producer and tax incentives, and implementing a renewable fuel standard that mandates a minimum of 5 per cent ethanol in the gasoline-blending pool. As a result of these support mechanisms, as well as significant private sector investment, Canada's ethanol production capacity has grown to about 1.9 billion litres per year. (See Table 1.) Nearly 80 per cent of capacity comes from plants that were built after 2005. Moreover, Canadian firms are at the forefront of R&D of next-generation technologies. Looking ahead, ethanol industry stakeholders are interested in increasing ethanol's contribution to Canada's transport fuel mix, particularly once the new generation of production technologies reaches commercial status.

Ethanol industry stakeholders want to increase ethanol's contribution to Canada's transport fuel mix, particularly when new technologies reach commercial status.

This report explores ethanol's role in Canada's transportation sector. It presents the findings from a thorough review of an extensive range of reports and scientific studies about ethanol technologies, costs, environmental impacts, infrastructure, and policy support, with a particular focus on research using peer-reviewed, scientific methods. The main objective was to accurately document the characteristics of ethanol production in Canada, and to assess the impact of public policies to support the ethanol industry, to address the following issues:

- economic impacts
- environmental and public health impacts
- ethanol's energy balance (energy used for production versus the energy content of ethanol)
- impacts on land use and food prices
- ethanol's role in energy security and independence[3]

1 (Laan, Litman and Steenblik 2009)

2 (Dessureault 2009)

3 Note that energy security must balance several factors—the need for corn imports as part of ethanol production, the volume of imported gasoline displaced, and any ethanol imports that occur. Canada's Renewable Fuel Standard (RFS) requires a 5 per cent renewable fuel content in gasoline, but exempts Newfoundland and Labrador and the three northern territories. Based on 2010 data, gasoline sales in Canada that would be subject to the RFS totalled 42.75 billion litres, with 2.14 billion litres of ethanol required to meet the RFS. With production capacity in-service of 1.87 billion litres, and a total in-service plus proposed capacity of 2.1 billion litres, ethanol imports or additional production capacity will be required to meet the RFS as gasoline demand in Canada grows.

Table 1
Ethanol Production Facilities in Canada—Capacity
(millions of litres per year)

Ownership	Location	Capacity	Start date
Alberta Ethanol and Biodiesel LP	Innisfail, Alta.	150	Proposed
Amaizeingly Green	Collingwood, Ont.	58	2007
Atlantec Bioenergy	Milford, N.S.	n.a.	Demonstration
Enerkem Alberta Biofuels	Edmonton, Alta.	36	Under construction
Enerkem Inc.	Sherbrooke, Que.	0.475	Demonstration
Enerkem Inc.	Westbury, Que.	5	Demonstration
GreenField	Johnstown, Ont.	230	2008
GreenField	Chatham, Ont.	195	1996
GreenField	Tiverton, Ont.	27	1989
GreenField	Varennes, Que.	155	2007
Growing Power	Hairy Hill, Alta.	40	Proposed
Husky Energy	Lloydminster, Sask.	130	2006
Husky Energy	Minnedosa, Man.	130	2007
IGPC Ethanol	Aylmer, Ont.	162	2008
Iogen Corporation	Ottawa, Ont.	2	Demonstration
Kawartha Ethanol	Havelock, Ont.	80	2010
NorAmera BioEnergy	Weyburn, Sask.	25	2005
North West Terminals Inc.	Unity, Sask.	25	2009
Permolex	Red Deer, Alta.	42	1996
Pound-Maker Agventures	Lanigan, Sask.	12	1991
Suncor Energy*	Sarnia, Ont.	400	2006
Terra Grain Fuels	Belle Plaine, Sask.	150	2008
G2 Biochem	Chatham, Ont.	0.58	Demonstration
Total operating capacity:		1,829.06	

*Includes Phase 2.
Source: Canadian Renewable Fuels Association.

CHAPTER 2

Economic Impacts

Chapter Summary

- Building and operating biofuels plants in Canada has been estimated to generate $2.33 billion in investment, 14,177 person-years of employment during construction, annual economic benefits of $1.47 billion, and 1,038 permanent jobs.
- Over the period from 2006 to 2012, the annual taxes paid by the industry will have been about equal to government support payments to the industry.
- Ethanol provides a high-value market for corn farmers, and can provide a natural hedge against high oil prices.

Government support programs provide substantial funding for Canada's ethanol industry. This support has encouraged ethanol producers to finance and build production facilities and contributes toward operating costs. Ethanol production generates considerable benefits in the local, regional, provincial, and national economies. Ethanol supporters argue that the economic benefits generated outweigh the cost of support programs; critics argue the opposite. Numerous studies have been conducted, both in Canada and the U.S., to measure the economic impacts of ethanol production. The results presented in this chapter indicate that ethanol production in Canada produces positive net economic impacts, and that the taxes paid by ethanol producers to federal, provincial, and municipal governments are approximately equal to the historical average annual government support paid to the industry.

Ethanol production in Canada produces positive economic impacts, and the taxes paid by producers equal the average annual government support paid to the industry.

This report does not include a relative comparison of subsidies paid to ethanol producers against subsidies paid to oil producers. Both industries receive government support in various forms. However, the analysis in this report addresses the balance for ethanol only. This report does not consider in detail the question of whether subsidies should be paid to either industry. The government support is taken as a given, and its impact examined.

ECONOMIC AND EMPLOYMENT IMPACTS

The economic and employment impacts of Canada's ethanol industry can be measured for both the initial investments to build ethanol plants and the longer-term benefits of operating the plants. The measured economic impacts include:

- GDP increases from building and operating ethanol plants
- employment from building and operating ethanol plants

- displacement of imported gasoline
- increases in gasoline and crude oil available for export
- higher corn prices
- potentially higher feed grain prices (partially offset by ethanol by-product sales)
- local, provincial, and federal income tax revenues

Most of the economic impacts can be easily quantified using input-output analysis or econometric models. The impacts on corn and feed grain prices are more complex. Feed grain prices in particular are more controversial since rising feed grain prices are a benefit to feed grain producers, but are also raising costs for cattle producers. A number of analyses have been performed to measure both impacts.

Several factors have been identified that influence the extent to which the overall impacts from ethanol production remain within the local economy:[1]

- labour force requirements versus availability
- the ability to source plant components locally during construction
- the ability to source feedstocks locally
- the ownership structure of the ethanol plant[2]
- the sources of financing available

One of the key elements of economic impact analysis is determining how much of the initial direct investment will remain within the local economy and how much will leak out to other regions. The leakages occur whenever the local economy is unable to supply the goods or services required to construct and operate an ethanol plant. Of course, the more narrowly one defines the local economy, the larger the leakages since smaller regions or communities are less likely to be able to supply everything necessary. Recent analysis indicates that most of the requirements of the ethanol industry can be supplied within Canada, limiting leakages at the national level.[3]

In addition to the direct benefits of investment in ethanol production, ownership of ethanol plants provides a potential market hedge for farmers who own a share of the production facility. Because oil product prices are a key element of farm operating costs, when oil prices rise, farm costs rise. On the one hand, these price increases may only be partially recovered through higher crop prices. On the other hand, high oil prices mean higher margins for ethanol producers so that a farmer who owns a share in an ethanol plant has a potential hedge against oil price changes.[4]

With high oil prices meaning higher margins for ethanol producers, a farmer who owns a share in an ethanol plant has a potential hedge against oil price changes.

Table 2 compares the results of four analyses of the economic impacts of ethanol production in Canada. The study by (S&T)[2] is now somewhat dated in that it was completed in 2005, before most of Canada's ethanol capacity was in service. The Doyletech reports are more recent. The Doyletech (Canada) and (S&T)[2] results can only be broadly compared since they use different methodologies and the Doyletech (Canada) study addresses both ethanol and biodiesel plants whereas (S&T)[2] is limited to ethanol. The other two Doyletech reports address specific ethanol plants.

As is typical of capital-intensive projects, the largest benefits occur during the construction period. However, the Doyletech studies indicate significant operating benefits as well as more than $220 million in annual government revenues, of which approximately $175 million results from ethanol production (allocated based on production capacity for ethanol versus biodiesel).

Numerous U.S. studies[5] indicate that the economic impacts from Canadian ethanol plants are somewhat higher, while the employment impacts are lower. The installed cost of ethanol capacity in Canada appears to

1 (Kulshreshtha and others 2009, 13); (Musaba 1997, Chapter 7)

2 (Urbanchuk 2006)

3 (Doyletech Corporation May 2010, 5)

4 (Morris 2006, 4)

5 (Parcell and Westhoff 2006, 377); (Fortenbery and Deller 2006, 11); (Urbanchuk and Kapell 2002); (Swenson 2005, 5); (Swenson 2006, 16); (Swenson and Eathington 2006, 5)

Table 2
Estimated Economic Impacts of Renewable Fuel Plants in Canada

Item	Units	Doyletech (Canada)	Doyletech (Aylmer)	Doyletech (Johnstown)	(S&T)^2
Ethanol production capacity	million litres	1,777.5	162.0	208.0	1,500.0
Biodiesel production capacity	million litres	471.0	n.a.	n.a.	n.a.
Total production capacity	million litres	2,248.5	n.a.	n.a.	1,500.0
Number of facilities		28	1	1	12
Construction Phase					
Capital cost	$ millions	2,330.0	100.0	198.0	620.0
Municipal government revenues	$ millions	n.a.	7.8	7.8	n.a.
Provincial government revenues	$ millions	492.1	44.2	47.9	n.a.
Federal government revenues	$ millions	679.9	70.1	58.4	n.a.
Total economic activity	$ millions	2,950.0	276.1	302.4	1,240.0
Direct plus indirect employment	Person years	14,177	1,152	1,281	18,600
Operations Phase—Gross					
Annual municipal government revenues	$ millions	n.a.	0.6	0.8	n.a.
Annual provincial government revenues	$ millions	151.5	5.2	8.2	n.a.
Annual federal government revenues	$ millions	145.4	5.2	6.7	n.a.
Annual economic benefit	$ millions	2,139.0	n.a.	n.a.	898.0
Direct plus indirect employment	Permanent jobs	1,038	55	69	5,000
Annual oil export benefit	$ millions	540.0	n.a.	n.a.	n.a.
Operations Phase—Net					
Annual municipal government revenues	$ millions	n.a.	0.6	0.8	n.a.
Annual provincial government revenues	$ millions	108.8	5.2	8.2	n.a.
Annual federal government revenues	$ millions	111.8	5.2	6.7	n.a.
Annual economic benefit	$ millions	1,473.0	53.8	89.8	n.a.
Direct plus indirect employment	Permanent jobs	1,038	55	69	n.a.

Notes: The data in the table were taken from a series of reports: Doyletech Corporation May 2010; Doyletech Corporation January 2010; Doyletech Corporation November 2009; (S&T)^2 Consultants Inc. 2005, Table ES 2.
n.a. = not available
Sources: Doyletech; (S&T)^2, Table ES2; The Conference Board of Canada.

be significantly higher, with U.S. estimates of capital costs in the range of US$330,000 per million litres of capacity around the year 2005 compared with the C$600,000 to C$950,000 shown for Canadian plants. The U.S. studies also determine that direct employment for a 50-million litre per year ethanol plant will be in the range of 35 to 50 permanent jobs, with a total employment impact of 100 to 200 jobs. More recent analysis of actual employment effects rather than input-output results indicate a 155-million litre per year plant actually creates 53 permanent jobs,[6] which is similar to the results reported by Doyletech.

6 (Schlosser, Leatherman and Peterson 2008, Table 3)

GOVERNMENT SUPPORT

The ethanol industry benefits significantly from government support programs. These programs are considered in this chapter from the point of view of their economic costs. Their policy implications are considered in Chapter 7. This section focuses narrowly on government support for ethanol in Canada, recognizing that programs and support levels are very different in other nations. Because the programs have been catalogued and the level of support estimated elsewhere,[7] this report examines estimates of their cost and compares this to the economic benefits of ethanol production. The comparison is somewhat problematic in that the estimates come from different sources and are not strictly comparable.

THE BALANCE BETWEEN ECONOMIC IMPACTS AND SUPPORT PROGRAM COSTS

Ethanol production contributes to the national, provincial, and local economies. The federal and provincial governments contribute to ethanol producers. A thorough analysis of the balance between the two does not appear to have been published. However, some preliminary observations can be made, based on a comparison of available data.

It is important to note that the studies cited are economic impact studies. Such studies are often based on input-output analyses, or use other methodologies that assume the impacts are incremental to the economy being studied. They also consider primarily the direct and indirect impacts that projects have on GDP and employment. A broader cost-benefit analysis of the ethanol industry has not been undertaken for this study.

The economic impact studies that have been done for Canada conclude that construction of Canada's biofuels production facilities have required a total investment of just under $3 billion and have generated more than 14,000 person-years of employment. The operating phase is estimated to create almost 1,040 permanent jobs and $1.47 billion in annual net economic impacts. Although these numbers are not separated between ethanol and biodiesel, approximately 80 per cent of the total installed capacity is for ethanol, suggesting that a very large share of the impacts is from ethanol production.

Ethanol production is contributing almost $1.2 billion in annual economic impacts and generating almost $240 million in federal and provincial tax revenues.

In a 2008 study, the International Institute for Sustainable Development (IISD) estimated the total cost of Canadian federal and provincial government support programs for ethanol from 2006 to 2012.[8] Producer incentives represent the most significant current and future source of government support identified by IISD, and the federal ecoAction producer payment was changed after the IISD report was published.[9] The IISD low case numbers represent a healthy ethanol industry that is generating sufficient income to meet its financial obligations, including repayment of capital grants and R&D funding. This represents the path the ethanol industry is currently pursuing. Based on its low case estimate, adjusted to reflect the current fixed producer incentive payments under the ecoENERGY program, government support can be estimated to average $260 million per year from 2006 to 2012. Note that the capital grants are no longer available and the producer incentives will be phased out by 2017, so that the support level will fall to very low levels unless new programs are created or current programs extended. It is also important to note that the IISD work is limited to a short period of time, and that ethanol plants constructed during the support programs will continue to operate long after the support payments end. A more complete analysis based on the lifetime production from the plants is included in Chapter 7.

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7 See Agriculture and Agri-Food Canada 2002; Auld 2008; Laan, Litman and Steenblik 2009; Kulshreshtha and others 2009; Mabee 2006; Olfert and Weseen 2007; (S&T)² Consultants Inc. 2005.

8 (Laan, Litman and Steenblik 2009, 66, 74)

9 (Natural Resources Canada 2010, 2)

Comparing the results suggests that ethanol production is contributing something approaching $1.2 billion in annual economic impacts (80 per cent of $1.47 billion from Table 2) as well as generating almost $240 million in federal and provincial tax revenues (80 per cent of $296.9 billion). This suggests that incremental tax revenues from ethanol production are very nearly offsetting the total government support over the period examined. The balance will improve in favour of ethanol, as the current support programs wind down and existing ethanol plants continue to operate.

ECONOMIC IMPACTS ON AGRICULTURAL INDUSTRIES

Ethanol production in Canada consumes primarily corn or wheat as feedstock, both of which are agricultural products. In addition to the food versus fuel issue discussed in Chapter 5, the question has been raised whether ethanol production puts pressure on feed grain prices and markets. This would result in upward pressure on livestock feed costs that could exceed the savings from DDGS[10] as a feed.

The question of interactions between ethanol demand for corn or wheat, ethanol plants supplying DDGS, and the cost of livestock feeding in Canada have been investigated and reported on by the George Morris Centre. The authors used a linear programming model to examine the period from 2003 through to May 2007.[11] The results show increases of 23 to 28 per cent in the cost of feeding animals from the historical case (2003–06) to the current price case (early 2007), with the increases only slightly moderated by the introduction of DDGS.[12] The authors assert that the price increases experienced in early 2007 were entirely driven by ethanol production. Some analysis would be required to prove the assumption. A more likely assumption might be that rising fuel costs in early 2007 were the primary driver of increasing feed prices, and that ethanol production was a less important factor.[13] The report clearly demonstrates the link between feed prices and the cost of feeding livestock, falling short of demonstrating that ethanol production was the only factor that led to increased feed grain prices. One of the authors uses these results to conclude that ethanol production influences feed grain prices through its influence on corn basis, and that the entire increase in the cost of feeding livestock is due to ethanol production.[14] Once again, the conclusion rests on the assertion that feed grain prices in the first five months of 2007 rose entirely because of ethanol production.

Canadian ethanol production consumes mostly corn or wheat as feedstock. The question is whether ethanol production puts pressure on feed grain prices and markets.

Further analysis of the potential impact of corn demand from ethanol plants in Ontario focuses on the "crowding out" impact on livestock production. The work examines the impact of growing demand for corn in Ontario as a result of ethanol production. The finding was that by 2009, ". . . the net cost of the corn reallocation from red meat to ethanol to the Ontario economy can thus be expected to be $148 million to $156 million per year."[15] However, the result is misleading in that it reflects both the impact of ethanol demand for corn (estimated at 923,341 tonnes in 2007 rising to 2,747,688 tonnes per

10 Distillers Grains and Solubles (DGS) and Dried Distillers Grains and Solubles (DDGS) are co-products of ethanol plants. Ethanol production removes the starch from the grains and converts it to sugars for fermentation. This leaves a high-protein, high-fibre portion (DGS) that is suitable for mixing into animal feed rations. It can be dried into DDGS to last longer before it must be consumed.

11 (Mussell, Oginskyy and Stiefelmeyer October 2007, 12)

12 (Mussell, Oginskyy and Stiefelmeyer October 2007, Table 3.5)

13 This theme is discussed more fully as part of the food versus fuel debate. The emerging evidence indicates that grain prices fell back with crude oil prices beginning in the second half of 2008, a period when ethanol production was still rising in North America.

14 (Mussell and Martin November 2007, 5)

15 (Mussell and others, September 2008, 31)

year,[16] when all ethanol plants planned are in service), and the complete elimination of corn imports of between 1 and 2 million tonnes per year. Further, the treatment of rising corn yields is not stated. An appropriate conclusion might be that some portion of the identified impact on livestock markets can be attributed to ethanol production, and that the balance can be attributed to the assumption that corn imports are eliminated.

A recent study of Ontario ethanol production concludes that corn prices are $0.50 higher with ethanol demand for corn, and that in recent years, the differential between Ontario and Michigan has narrowed.[17]

The economic impacts of ethanol occur through feedstock and ethanol production, as well as ethanol transportation and high-blend filling station infrastructure.

The economic impacts of ethanol occur through feedstock production, ethanol production, and the necessary infrastructure. There are two infrastructure components that could contribute to the economic impacts of ethanol: ethanol transportation infrastructure and high-blend filling station infrastructure.

Ethanol is transported from the production facility to the blending or retailing facility primarily by truck, with some rail use in the United States. A detailed study of the market opportunity for the U.S. indicated that ethanol pipelines would not be economic, even in the largest market.[18] The study did conclude that the rail, terminal, blending, and retailing infrastructure could be installed at an average cost of US$0.01/gallon for a 10 per cent ethanol blend.[19] For an 85 per cent ethanol blend, the costs are more significant at US$0.06/gallon for retail station infrastructure and US$0.08/gallon for ethanol transportation.[20] The total E-85 cost converts to US$0.036/litre. A more recent survey of E-85 infrastructure in the U.S. does not provide a unit cost, but confirms similar facilities investment costs to those used in the earlier study.[21] The U.S. Department of Energy also prepared a feasibility study for a 2.8-billion gallon per year ethanol pipeline from the Midwest to the East Coast, based on anticipated ethanol demand over the 40-year life of the pipeline. It concluded that such a pipeline would be feasible only with significant capital support from government. To operate without subsidies, the throughput would need to increase to 4.1 billion gallons per year.[22]

Canada does not currently have high-blend ethanol infrastructure, although the costs would be expected to be similar to those identified for the U.S. since the scale of operations for individual blending and retailing operations would be similar.

16 (Mussell and others, September, 2008, 13)

17 (Daynard and Daynard April 2011, ii)

18 Kinder Morgan ships ethanol in batches through its Central Florida Pipeline that carries refined petroleum products, and is not a dedicated ethanol pipeline. For more information, see www.afdc.energy.gov/afdc/pdfs/km_cfpl_ethanol_pipeline_fact_sheet.pdf.

19 (Downstream Alternatives Inc. 2002, ES-7)

20 (Downstream Alternatives Inc. 2002, ES-16)

21 (Moriarty and others December 2009)

22 (U.S. Department of Energy March 2010, iv)

CHAPTER 3

Input Versus Output Energy

Chapter Summary

- Recent studies conclude that U.S. ethanol contains up to 2.23 times the energy required to produce it. Canadian ethanol production has lower energy inputs because it uses less nitrogen fertilizer and does not use irrigated land to grow corn.
- The energy out:energy in ratio will increase further as corn yields and ethanol plant technologies continue to improve.
- As ethanol plants become more complex biorefineries, they are also becoming more reliant on renewable sources of input energy, and less reliant on hydrocarbons and purchased electricity.

There is a long-standing debate over the ratio of output energy to input energy in ethanol production. One of the more recent studies was conducted by the United States Department of Agriculture (USDA), finding both corn farming and ethanol production to have positive energy balances, based on a survey of corn farms and ethanol production plants for the crop year 2008. Numerous other studies have considered this question in some detail, with a very broad range of results.[1] There are several key inputs or assumptions that often account for at least a portion of the differences:

- the energy inputs required to produce the feedstock
- whether indirect energy inputs in agriculture are considered
- whether the analysis is limited to fossil fuels
- the ethanol production technology used
- the credits allocated to the by-products of ethanol production (DDGS and CO_2)
- the source of electric energy used to produce ethanol
- the source of process heat used to produce ethanol
- the feedstock used to produce ethanol

One of the reasons that assumptions differ between studies is simply that farming practices and ethanol production methods have improved over time. As a result, older studies often show higher energy requirements to produce feedstocks and convert them to ethanol. Another reason appears to be that different analyses take very different points of view regarding what energy should be included. Appendix A provides further detail on the energy definitions used by several key studies. The life cycle analysis (LCA) studies relied on in this analysis are based only on fossil fuel inputs, drawing a direct link to greenhouse gas (GHG) emissions.

1 See, for example, United States Department of Agriculture 2010; $(S\&T)^2$ Consultants Inc. 2009; Liska and others 2008; Auld 2008; Greene 2004; Levelton Engineering Ltd. 2000; Patzek June 2003 (submission date); Pimentel 2003; Pimentel and Patzek 2005; Tampier and others 2005; $(S\&T)^2$ Consultants Inc. 2005.

Fortunately, as GHG policies and regulatory measures have evolved, there has been an increased standardization of the approach to measuring the energy used to produce ethanol and feedstocks. This is because ethanol is considered a source of emissions offsets. A common element of GHG reduction programs, whether mandatory or voluntary, is the use of offsets to emissions that would otherwise occur. Offsets arise when one source of GHG emissions is reduced, and the reduction is used as an offset against emissions elsewhere. In Alberta's regulatory framework, emissions reductions are mandatory, and offsets can be purchased within the province to help meet emissions targets. Across Canada, emitters may choose to offset their emissions voluntarily. For ethanol, calculating the quantity of emissions offset requires careful LCA of ethanol production compared with gasoline production. Because energy is a key source of GHG emissions, the LCA must focus on energy consumption, and non-renewable energy in particular.

FEEDSTOCK PRODUCTION AND HARVESTING

The primary feedstock used in ethanol production in North America today is corn. Wheat and other grains are also used, and next-generation technologies are emerging that can convert forest waste, grasses, and even municipal solid waste to ethanol. This report focuses on corn and wheat as the feedstock, since those are the primary crops now in use. Feedstock production requires energy inputs in a range of activities, which includes seed production, farm machinery (both as fuel and to produce the machinery), fertilizer, pesticides, irrigation, electricity, and transporting the harvested crop to the ethanol plant. Fertilizer, fuel, and irrigation are the most important sources of energy consumption in corn production in particular,[2] although the corn used in Canadian ethanol production is not irrigated, and in the U.S. only about 15 per cent of the corn crop is irrigated. Further, Canadian corn producers use less nitrogen fertilizer than do U.S. producers because they use more manure. This results in a smaller energy input.

2 See Pimentel 2003, Table 1, for a detailed listing.

Based on U.S. data, the energy balance for corn production varies significantly between sources, although much of the variation can be explained rather easily. The USDA finds that the total energy required to produce corn is 41,029 BTUs per bushel of corn produced. The inputs include (in order of importance) fertilizers, fuel for machinery, insecticides, fuel for drying, electricity, and seeds. The energy inputs reported by the USDA are further reduced by approximately one-third to reflect the proportion of the corn that is sold as Dried Distillers Grains and Solubles (DDGS) and not converted to ethanol. DDGS is a high protein by-product of ethanol production that is used as a component of animal feed. As a result, the energy inputs and GHG emissions related to corn growing and ethanol production must be apportioned between ethanol, DDGS, and other by-products. Other studies include the energy required to produce farm machinery and feed the farmer, exclude the energy credit for DDGS, and conclude about twice the energy input for corn production.[3] The USDA concludes that the total energy required to produce corn is 9,811 BTUs/gallon of ethanol produced (or 27,079 BTUs/bushel of corn net of the DDGS credit), a ratio of 7.75:1 (based on a lower heating value for ethanol of 76,000 BTUs/gallon).[4] The USDA study is considered more accurate because it is based on a very recent survey of farm practices in the major corn-growing states that supply ethanol producers.

ETHANOL PRODUCTION

The second major use of energy is in the ethanol plant itself. In this case, it is important to ensure that the energy balance is based on the actual technology being used by the ethanol plant, since there is a wide variation. The very first ethanol plants used wet milling processes and coal as the energy source. Most ethanol plants in operation in the U.S. and all but one operating plants in Canada that use corn or wheat as feedstock employ dry milling

3 See, for example, Pimentel 2003 and Patzek June 2003 (submission date).

4 (United States Department of Agriculture 2010, Table 2)

processes with natural gas, biomass, and electricity as the input energy sources. The Illinois Corn Growers Association (ICGA) has released the results from its 2008 survey of dry milling corn ethanol producers, which concludes " . . . that the average liter of anhydrous corn ethanol produced during 2008 requires 28% less thermal energy than 2001 ethanol: 7.18 MJ/l compared to 10 MJ/l. Also, 2008 ethanol requires 32% less electricity: 0.195 kWh/l compared to .287 kWh/l . . . ."[5] When converted to common units, this represents 28,282 BTU/gallon of ethanol produced, and is comparable to the 27,083 BTU/gallon estimated by the USDA (net of by-products credit).

Based on a number of studies, it is reasonable to conclude that ethanol contains more energy than is required to produce it, on a full cycle basis.

The actual energy consumption per gallon of ethanol produced varies from plant to plant depending on the technology used, installation date, fuel source, electricity source used, and other factors. A recent survey found a range for U.S. ethanol plants of between 1.29:1 and 2.23:1 for the net energy ratio, based on combined agricultural activities and ethanol production.[6]

CANADIAN RESULTS

The results presented above are based on U.S. experience. There are some important differences between Canadian and U.S. agriculture and ethanol production processes, with the result that the energy used to grow corn and produce ethanol in Canada is reduced. There are also differences that increase energy use. A net impact has not been calculated. Two factors significantly reduce agricultural energy consumption. First, corn in Canada is grown with about half of the nitrogen fertilizer used per acre compared with the U.S., with manure being used in place of fertilizer. Second, irrigation is not used to grow corn in Canada. On the other side, Canadian corn yields per acre are somewhat lower than U.S. corn yields. It is also true that Canada imports corn from the U.S. for ethanol production. However, over the 2005–09 period, corn imports remained relatively constant while corn use for ethanol production quadrupled.[7] This suggests that imports of corn play a minimal role in Canada's ethanol industry and supports the view that the corn used in Canadian ethanol production is less energy-intensive than the corn used in U.S. ethanol production.

At the ethanol plant, although natural gas is the primary source of process heat, there is also electricity consumed for motors, lighting, etc., and the electricity source has an impact on the primary energy required to produce ethanol, if not the secondary energy. Primary energy refers to the total energy used to produce electricity, whereas secondary energy is the electricity itself. In the U.S., the majority of electricity in corn-growing states is produced from coal, with only 25 to 30 per cent of the energy in the coal being transformed into electric energy. In Canada, electricity used to produce ethanol varies by province, with Quebec using almost entirely hydro power, Alberta and Saskatchewan primarily coal or natural gas, and Ontario a mix of technologies. The expectation is that the primary energy required in Canada to produce the electricity used for ethanol production would be smaller than in the U.S., although this report does not include the necessary calculations. Some work has been done on the GHG emissions resulting from electricity in each province that is used for ethanol production. This work is summarized in Chapter 4.

A somewhat dated analysis of Canadian ethanol production in 2000 concluded that the energy required to produce corn-based ethanol was 54,135 BTUs/U.S.

5 (Mueller 2010, 1261)

6 (Liska and others 2008, Table 1)

7 (Dessureault 2009, Table 7.2)

gallon[8] and that the net energy ratio is 1.5:1.[9] That study was based on the agricultural methods, corn yields, electricity generation, and ethanol production methods in use at the time. Given the more recent U.S. studies that conclude an energy output ratio of 2.23:1, and the lower fertilizer use and lack of irrigation in Canadian corn production, an update of the Canadian results would be expected to produce a figure that is higher than 2.23:1.

8 (Levelton Engineering Ltd. 2000, Table 3-14)

9 Calculated from Levelton Engineering Ltd. 2000, Table 5-1.

Broader international comparisons have been done, concluding that the output:input energy ratio for ethanol in 2005 was 1.42:1.[10] Based on the evidence, it is reasonable to conclude that ethanol contains more energy than is required to produce it, on a full cycle basis.

10 ((S&T)^2 Consultants Inc. 2009, Table 3-3)

CHAPTER 4

Environmental and Health Impacts

Chapter Summary

- The full life cycle GHG emissions from ethanol production and use are between 40 and 62 per cent lower than those from gasoline production and use, depending on the production technologies and energy sources used.
- The non-GHG emissions from ethanol result primarily from the vehicle. Testing to date in the U.S. and Canada has indicated that ethanol vehicles produce different emissions than gasoline vehicles, and that the impact on human health is minimal.
- Ethanol production impacts on water and land are relatively modest and occur primarily because of feedstock production (i.e., growing the crop).

One of the objectives of biofuels production is to reduce the environmental impacts of human activities that produce and use transportation fuels. As a result, there are two control cases against which the impacts can be measured: the direct environmental impacts, and the impacts compared with those of fossil fuels used in transportation. As is true of most environmental interactions, the intensity of land use and processing activities is a key determinant of the resulting impact.

The process of growing, harvesting, and transporting crops used in ethanol production requires energy and water, and uses land. So does ethanol production and transportation to the point of sale. Ethanol consumption also has environmental impacts. The emissions, land impacts, and water impacts of each step can be measured, and are most often compared with gasoline. They include GHG emissions, other tailpipe emissions, water consumption, and water-quality impacts. Land use and land-use changes are key drivers of the intensity of environmental impacts; this is addressed in Chapter 5.

Life cycle analysis studies of current data from operating ethanol plants indicate clearly that ethanol reduces GHG emissions relative to gasoline.

Ethanol is a high octane fuel whose primary use in North America has been as a blending component in gasoline. One of the environmental benefits is the potential for ethanol to reduce GHG emissions from vehicles. This is also an argument in favour of higher-blend levels for ethanol.[1] Ethanol, when used as an octane enhancer, is preferred over lead, benzene, tylene, or zylene from the point of view of health impacts.

1 Most ethanol is currently used in blends of 10 per cent or less in North America. One of the reasons is a reluctance of auto makers to provide warranty coverage for vehicles using higher concentrations. With flex-fuel vehicles becoming more broadly available, blends of 40 to 85 per cent can be used, potentially increasing the environmental benefits.

GREENHOUSE GAS EMISSIONS

Renewable fuel standards in both Canada and the U.S. have set targets for the minimum share of the gasoline pool that will be provided by ethanol, and have cited GHG emissions reductions as a resulting benefit.[2] Recent applications of life cycle analysis (LCA) to this question indicate clearly that ethanol reduces GHG emissions relative to gasoline, despite previous arguments to the contrary. The LCA studies are based on current data from operating ethanol plants, and draw clear boundaries around the energy inputs that are in scope versus those that are not relevant (e.g., sunshine, rainfall, and farmer nutrition).[3] As noted in Chapter 3, LCA is one of the primary tools currently used in measuring the GHG emissions impacts of an industrial activity. The basic objective as applied to ethanol production is to measure the GHG emissions resulting from each element of the supply chain and production process. The first step is to set boundaries to determine the scope of the analysis to be performed. For example, in the agricultural part of the value chain, it is common practice in Canada to include both the emissions from fuels burned in farm machinery and the emissions from producing the farm machinery. Once the boundary is set, the data can be gathered to measure or estimate the emissions. A baseline must also be prepared that represents emissions levels in the absence of the activity being assessed. For ethanol, the baseline is life cycle emissions from gasoline.

The life cycle GHG intensity of ethanol in Canada has been measured and compared with gasoline. In LCA, the location is important because the emissions characteristics are location-specific. For example, electricity is an important input to ethanol production. The GHG emissions related to electricity production vary by province in Canada because of the generation technology and fuel mix used, requiring adjustments between provinces.

2 (United States Environmental Protection Agency 2009, 3); (Environment Canada, Government of Canada, 2010)

3 (Auld 2008); (Earley and McKeown 2009); (Patzek June 2003 (submission date)); (Pimentel 2003)

The LCA also considers as a baseline the emissions from crude oil production and conversion to gasoline based on the crude oil that is being produced (or imported), refined, and consumed as gasoline within the region being analyzed.

Life cycle analysis studies of current data from operating ethanol plants indicate clearly that ethanol reduces GHG emissions relative to gasoline.

Life cycle analysis is central to GHG emissions offset protocols. These protocols are used to measure the GHG emissions reduction benefit that results from a range of activities. In Alberta where GHG emissions intensity levels have been capped, these emissions credits (or offsets) can be certified and used to meet emissions caps or offered for sale. In other provinces where emissions caps have not yet been implemented, protocols may still be used to determine offsets that can be sold in voluntary carbon markets. The emissions protocol for ethanol was first proposed by The Delphi Group in 2006.[4] Alberta Environment issued a quantification protocol under the Specified Gas Emitters Regulation that was based on the Delphi work.[5] The protocol includes discussion of each element of the life cycle emissions that is to be included or excluded from the analysis, together with quantification methodologies. The protocol was applied to GreenField Ethanol's plant at Varennes, Quebec, with a determination that, based on ethanol production of 150 million litres in 2009, the net reduction in GHG emissions was 2,070 grams of CO2e per litre of ethanol produced (88 grams of CO2e per megajoule of ethanol).[6]

Life cycle GHG emissions from 100 per cent pure ethanol (E100) have been calculated to be 1,714 grams of CO2e per litre, compared with 2,967 grams of CO2e per litre

4 (The Delphi Group 2006)

5 (Alberta Environment 2007)

6 (Enviro-Acces inc. 2010, i)

of gasoline.[7] Although E100 is not currently used in Canada, results for E10 have been scaled. A further adjustment must be made to convert both gasoline and ethanol emissions to reflect their relative energy contents. When this adjustment is made, the reduction in GHG emissions from using pure ethanol rather than gasoline would be 62 per cent.[8] Separating the total effect between vehicle operation, fuel production, and feedstock production and transport provides additional information. On a volumetric basis, the feedstock production and transportation emissions as well as fuel production emissions are higher for ethanol than for gasoline even though ethanol has lower energy content. However, the emissions from vehicle operations are lower, resulting in lower life cycle emissions.[9] The vehicle emissions are lower because ethanol is a renewable fuel, and the CO2e emissions from the fuel itself are excluded from the calculation. Those who argue that GHG emissions are higher for ethanol than for gasoline reject the view that the carbon sequestered by corn and then released as ethanol is burned should be excluded from ethanol-related emissions.[10]

A broader study considered the potential for future improvements in GHG emissions from corn-based ethanol. A starting point comparison indicated that in 2005, ethanol reduced GHG emissions relative to gasoline by an average of 39 per cent calculated on an energy basis.[11] The analysis considered each element of the life cycle for both gasoline and ethanol and concluded that GHG emissions from corn-based ethanol could be reduced by as much as 25 per cent between 2005 and 2015, whereas life cycle emissions from gasoline would rise slightly.[12] Most of the improvements for ethanol would occur within the ethanol plant itself, with some additional gains in fertilizer production and feedstock harvesting. These estimates are based on improvements in current technologies and continued increases in corn yields and do not consider next-generation technologies. Life cycle emissions for ethanol in 2015 could be reduced to 45 per cent below 2005 levels by using corn stover as an energy source in ethanol production.[13] The increases in emissions from gasoline production are primarily due to declining resource quality, resulting in higher energy inputs required to recover feedstocks and refine them into petroleum products.

Advanced biofuels must come from a crop of some kind. The nature of the crop and the location in which it is grown are important factors in determining whether GHG emissions rise or fall.

The opposing view is that ethanol results in higher GHG emissions than gasoline. One reason is that because most GHG emissions result from fossil fuel combustion, the energy balance of ethanol described in Chapter 3 plays an important role in GHG calculations. Analyses that find a negative energy balance for ethanol also find that GHG emissions increase.[14] Another reason is the inclusion of indirect land-use impacts attributed to crops produced for ethanol production—a debate that is based on global agricultural models and that has not yet resulted in clear conclusions.

Land use is considered in more detail in Chapter 5, with only the GHG implications discussed in this chapter. Studies that conclude there will be land-use implications are based on the assumption that increasing ethanol production in the U.S. from 15 billion gallons per year to 35 billion gallons per year will require conversion of

7 The life cycle analysis was performed by Cheminfo Services Inc. and based on a survey of ethanol producers undertaken in 2008–09, plus emissions calculations from Natural Resources Canada's GHGenius model. A previous study for corn-based ethanol in southern Ontario produced very similar results for E10 blends (Levelton Engineering Ltd. 2000, ii). The baseline emissions for gasoline reflect data that were used in GHGenius when the analysis was done.

8 (Cheminfo Services Inc. November 2009, Table 2). Note that other analyses provide different results. For example, (S&T)^2 Consultants Inc. 2009, Table 3-5 shows a 39 per cent reduction for ethanol compared with gasoline on an energy content basis, and Levelton Engineering Ltd. 2000, Table 5-8 predicted a 44.5 per cent reduction on a mileage-equivalent basis.

9 (Cheminfo Services Inc. November 2009, Table 4)

10 (Patzek June 2003 (submission date), 9)

11 ((S&T)^2 Consultants Inc. 2009, Table ES-2)

12 ((S&T)^2 Consultants Inc. 2009, Table 4-5)

13 ((S&T)^2 Consultants Inc. 2009, Tables 4-5 and 4-8)

14 See, for example, Earley and McKeown 2009; Auld 2008; Patzek June 2003 (submission date); Pimentel 2003; Pimentel and Patzek 2005.

lands in other countries from other uses to agriculture. Given that current U.S. ethanol production capacity is already very close to the 15 billion gallons that the U.S. renewable fuels standard targets from conventional technologies, and given that corn yields continue to rise, meeting the target should not result in a significant increase in corn acreage. However, advanced biofuels must come from a crop of some kind. The nature of the crop and the location in which it is grown are important factors in determining whether GHG emissions rise or fall.

There are three broad competing uses of land: forests, pastures, and crops. Converting land from one use to another releases carbon into the atmosphere.

There are three broad competing uses of land: forests, pastures, and crops. Converting land from one use to another releases carbon into the atmosphere, whether it is forest carbon released by removing the forest, carbon released from tilling pasture, or carbon released in connection with changes between crops and resulting agricultural practices.

WATER AND LAND

Ethanol production has relatively limited impacts on water, although the impacts vary according to the feedstock and region in which it is grown. In Central and Eastern Canada, corn is grown without irrigation. In the U.S., corn is the primary feedstock and is sometimes grown on irrigated land. Irrigation is both water- and energy-intensive, increasing the impact. Irrigation has negative impacts on soil quality and on water availability in the U.S., and these impacts must be carefully managed. The anticipated transition to switchgrass or other crops adapted to cellulosic processes would contribute to this management.

Nutrient levels may be a more pressing concern for water management. Corn is a very demanding crop that must be grown in rotation with other crops to protect soil. Nitrogen fertilizer is a major input to corn production. Once again, this is more of an issue in the U.S. than in Canada because Canadian corn farmers use more manure and less nitrogen fertilizer, and because wheat production is not nitrogen-intensive. Despite best efforts to manage fertilizer applications (including manure), not all of the nitrogen applied is absorbed into the corn plants. A portion of the nitrogen remains on the land and eventually finds its way into rivers and lakes. Nitrogen is a nutrient in water bodies, just as it is in the fields. An increased level of nitrogen can cause incremental plant growth in the water, reduced oxygen, and negative impacts on the ecosystem (a chain of events referred to as eutrophication).[15] The impact of ethanol feedstock production on ecosystem nutrient levels has not been specifically studied.

Within the ethanol plant, much less water is consumed by the current dry-milling technologies than was true in the early days of ethanol production. However, each gallon of ethanol produced requires an input of three gallons of water, with the losses mostly occurring as steam, which is released to the atmosphere.

VEHICLE EMISSIONS AND RELATED HEALTH IMPACTS

Whether ethanol is blended with gasoline or used directly as a vehicle fuel, combustion results in emissions of toxic substances. The primary questions are whether these emissions increase or decrease as a result of ethanol use, and whether human exposure and health are impacted for the better or the worse.

Toxic emissions from gasoline-powered or ethanol-powered vehicles have been reduced by continuous improvements in engine and exhaust technologies. Today's engines remove the vast majority of harmful emissions, regardless of the fuel used. Because of the improvements through time, more recent analyses are of greater value in capturing the impact of the current vehicle fleet. This is also an area of great complexity because emissions of toxic substances can interact to

15 Eutrophication is a highly complex process. For a complete discussion, including the role that nutrients such as nitrogen can play, see Schindler and Vallentyne 2008.

create new substances once they are in the atmosphere, and because atmospheric concentrations and human exposures vary depending on local emissions levels, climatic conditions, etc.

In the U.S., the Environmental Protection Agency (EPA) has considered the emissions, atmospheric concentrations, and human exposures to pollutants that would result in 2022 from full implementation of the "RFS2" program. The program requires the inclusion of an increasing minimum volume of renewable fuels (primarily ethanol but also including biodiesel). The EPA found significant emissions reductions from the use of ethanol for pre-tier 2 vehicles.[16] However, based on recent testing for tier 2 vehicles, the EPA chose not to attribute the same level of benefits.[17] Similarly, the EPA chose not to include any emissions benefits from E85 vehicles in its analysis.[18] The EPA's quantification showed the monetized health benefits of the RFS2 to be small and negative, in that certain harmful emissions are increased as a result of ethanol use.[19] Studies by Health Canada and Australia's Department of the Environment have found that ethanol provides a small health benefit, although the Health Canada study found the benefit to be within the range of accuracy of the analysis performed.[20]

16 Tier 2 vehicles were introduced in 2004 based on emissions standards announced in 2000. For the 2004 model year, 25 per cent of vehicles were required to comply with tier 2. For the 2009 model year, all vehicles were to meet the standard.

17 (United States Environmental Protection Agency 2010, 507–08)

18 (United States Environmental Protection Agency 2010, 509)

19 (United States Environmental Protection Agency 2010, 955)

20 (Health Canada 2010); (Department of the Environment, Water, Heritage and the Arts June 2008)

CHAPTER 5

Land Use and Food for Fuel

Chapter Summary

- Ethanol production has increased rapidly since 2004 in both Canada and the United States. This increasing demand for feedstock has been met through surplus and higher yields, not new farmland.
- Corn is the primary ethanol feedstock in the U.S., with corn and wheat used in Canada. Crop data do not show evidence of land-use changes in either nation as a result of ethanol production.
- Studies that have examined both the impact of crude oil prices and biofuels demand on agricultural prices conclude that oil prices are the more influential factor.

The increasing demand for corn in the U.S. and Canada as feedstock for ethanol production, coupled with rising crop prices between 2004 and 2008, has raised the question of the extent to which a growing biofuels industry has contributed to agricultural price increases. This chapter considers the more recent experience with agricultural prices and ethanol feedstock demand. Although recent food price increases suggest that history may be repeating itself, the available studies cover the 2004–08 period. A recent study for the Ontario Grain Growers Association examines the impact of ethanol production on corn and food prices, concluding that Ontario corn prices are \$0.29/bushel higher with ethanol production, and that North American food prices in 2008 were 1 per cent higher as a result of ethanol production.[1]

Numerous studies have considered whether biofuels demand for crops might be absorbing an increasing portion of the cropped land or causing land to be converted.

The 2004–08 period in North America witnessed two concurrent trends: biofuels demand for corn was rising rapidly, and crude oil prices were rising rapidly. Numerous analyses consider the period as a whole, and fail to separate the impact of rising crude oil prices on agricultural commodities from the impact of biofuels demand. Those that separate the influences of crude oil prices and biofuels production find that even aggressive biofuels policies would result in single-digit increases in agricultural prices, and that crude oil has a much stronger influence.

Numerous studies have examined whether growing biofuels feedstock demand for corn in particular might be bidding up the price of corn and crowding out corn use for animal or human food. They have also considered whether biofuels demand for crops might be absorbing an increasing portion of the cropped land, or even causing land to be converted from forests or pasture to cropping.

1 (Daynard and Daynard April 2011, ii–iii)

The agricultural impacts depend critically on the rate of expansion of biofuels production and are different in each of the major biofuels-producing countries or regions. This analysis focuses primarily on ethanol in North America, although evidence is cited from global studies. As one might expect, the relative ability to accommodate biofuels demand in Canada and the U.S. is greater than in Europe. This is because of lower population density, larger agricultural land area, and a greater reliance on ethanol versus biodiesel. However, even in North America, biofuels production is subject to a natural rate of expansion that can be supported by existing cropped areas. If biofuels grow beyond that rate, land-use implications would be more visible—a situation that has not yet occurred. The expansion to date has been accommodated without land-use changes because of improvements in seed, better agricultural practices, continued growth in crop yields, technological improvements in ethanol production, and the introduction of new crops for ethanol production.

FOOD FOR FUEL AND LAND USE

The impact of increased biofuels production on land allocation is one of the key elements of the land-use debate. The responses to this question are most often generated by agricultural models, which try to forecast potential changes in cropping patterns, expansion of cropped areas, competition for pasture land or forests, and interactions between biofuel demand for crops and other uses of those crops based on a set of assumptions and behavioural relationships. Some models treat relative crop prices endogenously, others do not. The regional scope and detail of the models also vary considerably. As is often the case with complex models, differing results can be ascribed to different assumptions, further complicating the analysis. Not surprisingly, the largest ethanol-producing countries/regions are the primary focus: the U.S., Brazil, China, India, and the European Union.

The theory is that if ethanol demand for feedstocks causes a shift in the mix of crops that are grown in each country, this can cause prices for feedstock crops to rise and land to be reallocated. If the higher agricultural prices that result from ethanol demand increase the area cultivated, negative environmental impacts could result. For example, the analysis reported in Fabiosa and others (2009) makes use of the partial equilibrium Food and Agricultural Policy Research Institute (FAPRI) model developed at Iowa State University. That analysis indicates that doubling the production of corn-based ethanol in the U.S. would increase the area devoted to corn by 14.3 per cent and the area devoted to barley by 10.3 per cent. Cropped areas for soybeans would be reduced by 9.9 per cent, canola by 1.7 per cent, and sunflowers by 4.5 per cent.[2] It is important to note that these results are based on corn ethanol production (hence do not include cellulosic options) and are based on the period from 2006 to 2015. Smaller impacts are observed for other nations when U.S. ethanol production is increased, as one would expect. The model results are also based on instantaneous adjustment assumptions and do not represent the market dynamics that unfold over a period of years. The basic land reallocation conclusion can also be partially tested against historical data for 2000–09, a period of rapid growth in biofuels demand for corn. Based on acres harvested in the U.S. and Canada through 2009, the results in Fabiosa and others are based on land allocation changes that are not occurring.

There seems to be a relationship between the rate of improvement in corn yields and the rate of increase in corn ethanol production that is largely land-use neutral.

The question of harvested area that is required to produce ethanol feedstocks has also been investigated. An OECD analysis considered the period from 2005 to 2014 using a baseline projection, assumptions of a constant level of biofuels production, a scenario where all countries would have met their biofuels targets (as they existed in 2004 for 2015), and two high oil price cases. The results show that for corn and wheat, meeting ethanol production targets increased world prices by less than 5 per cent.[3]

2 (Fabiosa and others 2009, Table 2)

3 (Organisation for Economic Co-operation and Development 2006, Figure 9)

The interaction between corn yield, the total area devoted to corn grown for ethanol, the impact of ethanol by-products, and ethanol production has also been investigated for the U.S. based on a corn ethanol production target of 15 billion gallons of ethanol production in 2015. That analysis indicates that with a 2 per cent annual improvement in corn yield (consistent with historical performance and ". . . driven by improved agronomics, breeding and biotechnology"[4]), the total area devoted to corn would peak in 2007, then decline through 2015, even though corn production, corn used for ethanol production, and the share of the corn crop used for ethanol would all increase over the period.[5] Similar results were obtained for Canada, where corn area was shown to increase slightly and wheat area would continue to decline based on the U.S. ethanol production target.[6] This suggests that there is a relationship between the rate of improvement in corn yields and the rate of increase in corn ethanol production that is largely land-use neutral. Implicitly, if increases in corn yield for the entire crop produce sufficient incremental corn to meet growing ethanol demand, food use and corn exports can be maintained. Exceeding that natural rate of increase would, of course, lead to entirely different results.

The interaction between climate change impacts, biofuels production, and agricultural prices has also been modelled. Based on biofuels supplying 2 per cent of global transportation fuels in 2020, rising to 3 per cent in 2050, agricultural prices would be impacted by 5 to 7 per cent in 2030. Quadrupling the biofuels contribution would increase cereals prices by 57 per cent and crop prices by 47 per cent in 2030.[7] These results point clearly to the need to ensure that policy targets are properly balanced against agricultural capacity and technology developments. The world ethanol industry, to date, has been on the more conservative supply path. In North America, the focus is entirely on next-generation technologies for the next tranche of ethanol supply.

4 (Darlington 2009, 27)

5 (Darlington 2009, Table 2)

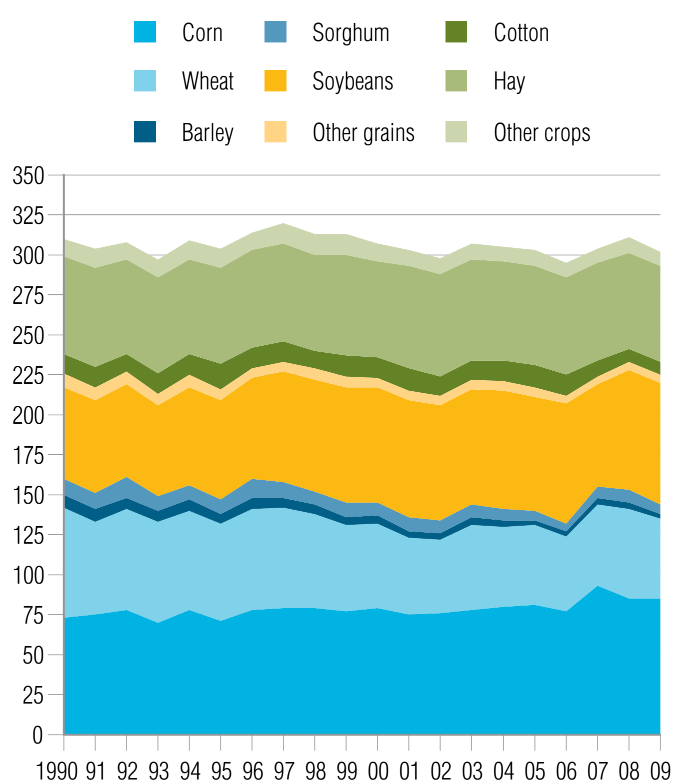
6 (Darlington 2009, Table 6)

7 (Fischer 2009, Tables 6.4 and 7.2)

THE AGRICULTURAL DATA

Much of the discussion on the future environmental and agricultural impact of ethanol production is based on assumptions regarding cropped areas, yield, and the relationship between agricultural prices and ethanol feedstock use. Ethanol production has increased rapidly since 2005 in both Canada and the U.S., so there is only a limited history to report. However, some useful conclusions can be drawn. Chart 2 shows the number of acres harvested by crop in the U.S. since 1990.[8]

Chart 2
U.S. Area Harvested by Crop
(million acres)



Source: U.S. Department of Agriculture.

8 Note that the agricultural data used for both the U.S. and Canada reflect acres harvested. Total land available for agriculture would include acres that are seeded but not harvested, as well as land that is in temporary pasture or summer fallow. This is particularly important in considering the indirect land-use impacts of ethanol. A current treatment of this issue for the U.S. can be found at www.arb.ca.gov/fuels/lcfs/workgroups/ewg/expertworkgroup.htm.

In the U.S., there has been a long-term trend toward increasing acreage devoted to corn and soybeans, with declining harvested areas for wheat, barley, and sorghum. The total harvested area in the 1990s averaged 326.7 million acres compared with an average of 322.7 million acres since 2000. Most of the increase in soybean area occurred before 2000, as did most of the decline in wheat area. Given that ethanol production did not begin to increase rapidly until 2005, these long-term trends are at least partially a result of other factors.

Although the trend in harvested area does not entirely refute the arguments that global ethanol production has influenced land use, it clearly shows that the impacts have not occurred in the United States. Total acreage harvested has trended down slightly during the main period of ethanol expansion.

Chart 3 shows harvested areas for Ontario, where the total acreage has increased by about 500,000 acres (6 per cent) over the 20 years shown. The areas harvested from corn and soybeans have varied from year to year, but the long-term trend has been very flat in both cases. Once again, a link between ethanol production and harvested area is not evident in the data. The more supportable conclusion for Ontario as well as the U.S. is that increases in corn yield per acre have provided most of the additional corn used as ethanol feedstock, with some reallocation of corn supplies from other uses and a limited reallocation of cultivated land. The harvested areas do not show a strong increase in the total cropped area, which suggests that reallocation from forest to crops or from pasture to crops has not occurred in North America.

The Global Agricultural Information Network (GAIN) of the U.S. Department of Agriculture (USDA) estimates the quantity of corn used for ethanol feedstock in Ontario on an annual basis, and calculates the allocation of corn production plus imports between feed and ethanol uses. According to GAIN, Ontario corn production rose from 9.3 million tonnes in 2005 to 10.5 million tonnes in 2009, while the total volume of corn available, including imports, rose from 11.5 to 12.9 million tonnes over the same period. Feed corn use rose from 7.8 to 9.1 million tonnes, and ethanol use from .56 to 2.4 million tonnes.[9] The GAIN data support the view that ethanol production has not impacted the availability of corn for feed, and has not significantly increased total corn imports to Ontario.

Although not shown here, the data for Quebec indicate long-term growth in corn and total area harvested that predates growth in ethanol production in the province. Any land-use analysis for that province would need to investigate the influence of ethanol production in the context of other factors that account for the long-term trend.

Saskatchewan data suggest that ethanol represents an agricultural opportunity with limited land-use impacts since total area harvested and wheat area have been in long-term decline that has not entirely been offset by increases in canola production. The GAIN report indicates that in 2009, just under 5 per cent of Canada's wheat crop went to ethanol production, with only a minor increase expected for 2010.[10] The report also anticipates increasing competition between ethanol and livestock producers for high-starch (and therefore low-grade) wheat production, rather than expansion of wheat acreage.

ETHANOL PRODUCTION AND AGRICULTURAL PRICES

Another key element of the food versus fuel issue is the impact of ethanol production on crop prices. Agricultural prices can be influenced by changes in the prices of any and all inputs as well as by changes in market demand or consumer preferences. The relationship between ethanol demand and agricultural prices is complex. Ethanol producers have been credited with increasing corn prices, particularly in regions where ethanol plants are located. They contribute to corn basis—the differential between regional corn prices. Higher prices for corn result in upward pressure for other crops to the extent that higher prices are required to prevent farmers from

9 (U.S. Department of Agriculture June 30, 2009, Table 7.2)

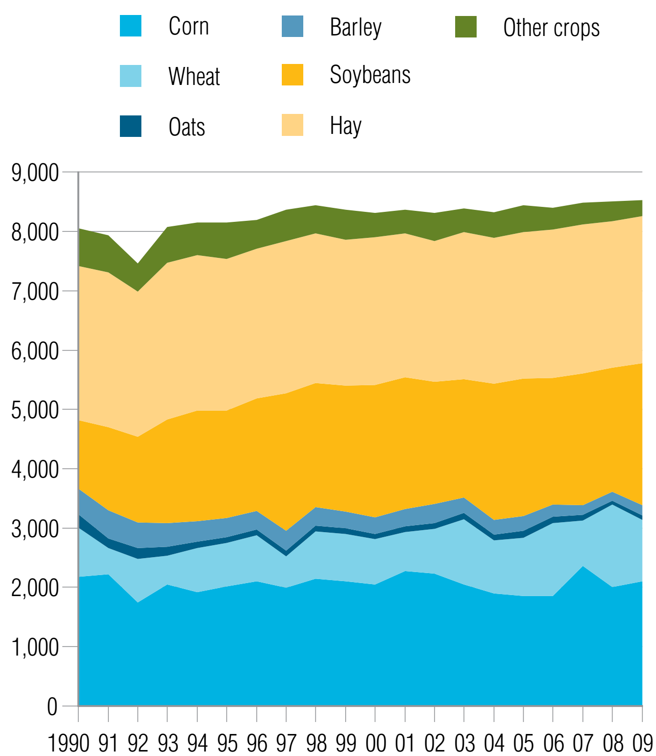
10 (U.S. Department of Agriculture June 30, 2009, Table 7.3)

switching from other crops to corn. Ethanol demand for corn also influences livestock feed prices in a very complex way, as described in Chapter 2. Finally, the link between ethanol demand, crop prices, and land-use impacts has been considered by several analysts.

A careful evaluation of the food versus fuel linkage between feedstock demand for ethanol and agricultural prices is therefore an essential starting point. For example, the work done by the OECD is one of the few reports that explicitly tests the impact of crude oil prices versus the impacts of biofuels policy targets, finding that oil prices have a much stronger effect, at least for the cases they examined.[11] Similarly, a U.S. report concludes that ". . . over the same period [April 2007 – April 2008], certain other factors – for example, higher energy costs – had a greater effect on food prices than did the use of ethanol as a motor fuel."[12] Similarly, a U.K. literature review found that economic models predict a long-term upward pressure on agricultural prices from ethanol production, but that ". . . biofuels had a relatively small contribution to the 2008 spike in agricultural commodity prices. . . . "[13] The World Bank considered the relationship between price speculation, growing demand for food, biofuel production, and agricultural prices, concluding that ". . . biofuels played some role too, but much less than initially thought."[14] This corrected a previous preliminary World Bank report that had attributed as much as 75 per cent of the increase in commodity prices to biofuel feedstock demand. The more recent report finds that commodity market speculation and energy prices played more important roles.

The relationship between crop prices in the U.S. and crude oil prices is shown in Table 3. The prices of several major crops are shown after indexing to a base year of 1990. A similar index of crude oil prices is also included

Chart 3
Ontario Area Harvested by Crop
(acres, 000s)



Source: Government of Ontario.

in the graph, using the average price of WTI on an annual basis. As the table shows, although there is a strong correlation between oil prices and crop prices, other factors not shown are also at play. The period from 2006 onward is of particular interest because it is the focus of the food versus fuel debate. A period of rising oil prices began in 2002, ending abruptly in the second half of 2008. Table 3 shows clearly that agricultural prices in 2009 were sharply lower than in 2008 as well, although they had not yet fallen back into the historical range, suggesting the possibility of lagged effects or expectations-driven price responses.

11 (Organisation for Economic Co-operation and Development 2006)

12 (Congressional Budget Office 2009, vii)

13 (Pfuderer, Davies and Mitchell 2010, 3)

14 (Baffes and Haniotis 2010, 18)

Table 4 shows the same price information for crude oil and the major crops from which ethanol can be produced. Of course, corn is the ethanol feedstock of choice in the U.S., but ethanol production also influences soybean demand through the production and sale of distillers grains with solubles. Indices for ethanol production and ethanol feedstock demand are also shown from 1990 onward. From 2000 through 2006 there is an apparent relationship between rising crude prices and rising ethanol production. This relationship did not continue in 2009, as ethanol production continued to rise and crude prices fell. Although crude prices enable ethanol production because higher gasoline prices can make ethanol more profitable, other factors (e.g., government support programs) were clearly at play. Similarly, when crude prices and agricultural commodity prices retrenched in 2009, ethanol production and feedstock demand continued to grow. The long-term trend shown suggests that for the U.S. crude prices are more useful in explaining crop prices than is ethanol feedstock demand.

Table 3
U.S. Crop and Crude Oil Price Indices
(1990 = 100*)

	1990	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09
Barley	100	98	95	93	95	135	128	111	93	100	99	104	127	132	116	118	133	188	251	206
Canola	–	100	102	112	114	114	133	116	106	80	69	90	109	109	110	99	122	188	192	165
Corn	100	104	91	110	99	142	119	107	85	80	81	86	102	106	90	88	133	184	178	162
Oats	100	106	116	119	107	146	172	140	96	98	96	139	159	130	130	143	164	231	276	184
Soybeans	100	97	97	111	95	117	128	113	86	81	79	76	96	128	100	99	112	176	174	165
Wheat	100	115	124	125	132	174	165	130	102	95	100	107	136	130	130	131	163	248	260	186
Sugar cane	100	94	92	93	95	96	92	92	89	83	85	94	93	96	92	93	99	96	96	–
Sugar beets	100	90	97	91	90	89	106	90	85	87	80	93	92	97	86	101	103	98	112	–
Crude oil	100	88	84	75	70	75	90	84	59	79	124	106	107	127	169	231	269	295	406	253

*for canola, 1991 = 100
Sources: USDA; U.S. Energy Information Administration; The Conference Board of Canada.

Table 4
Ethanol Production Versus Crop Prices in the U.S.
(1990 = 100*)

	1990	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09
Canola	–	100	102	112	114	114	133	116	106	80	69	90	109	109	110	99	122	188	192	165
Corn	100	104	91	110	99	142	119	107	85	80	81	86	102	106	90	88	133	184	178	162
Soybeans	100	97	97	111	95	117	128	113	86	81	79	76	96	128	100	99	112	176	174	165
Wheat	100	115	124	125	132	174	165	130	102	95	100	107	136	130	130	131	163	248	260	186
Sugar cane	100	94	92	93	95	96	92	92	89	83	85	94	93	96	92	93	99	96	96	–
Crude oil	100	88	84	75	70	75	90	84	59	79	124	106	107	127	169	231	269	295	406	–
Ethanol prod	100	116	132	154	172	182	130	172	188	196	217	236	286	375	455	522	653	872	1,245	–
Ethanol feedstock	100	115	131	152	169	178	127	168	182	190	210	228	277	360	436	497	620	823	1,171	–

*for canola, 1991 = 100
Sources: USDA; U.S. Energy Information Administration; The Conference Board of Canada.

CHAPTER 6

The Evolution of Technology

Chapter Summary

- Canada's ethanol plants are based on dry milling technologies that use natural gas as an energy source. These technologies are evolving toward more complex biorefineries and are making increased use of biomass as an energy source.
- Thermochemical and biochemical processes are reaching the demonstration plant stage in Canada to produce second-generation ethanol.
- The future biorefinery will produce a broader range of products using a broader range of feedstocks, but is still at the early stages of development.

Ethanol production technologies have advanced considerably in recent years. Conventional production processes, based on converting the starch in corn and wheat into ethanol, have achieved significant progress in both feedstock and ethanol plant yield increases and energy consumption reductions, while developing innovative ways of reusing production waste and creating valuable co-products.

CONVENTIONAL TECHNOLOGIES FOR ETHANOL PRODUCTION

The two primary processes for conventional ethanol production are wet milling and dry milling. Wet milling technology is quite old, developed more than 150 years ago as a method of processing corn starch.[1] In wet milling, a steeping process separates the corn kernel into its main components before the starch portion of the kernel is fermented to produce ethanol.[2] Dry milling, also known as dry grinding, skips this initial step, grinding the entire corn kernel into a corn meal, which is then fermented to produce ethanol. Wet milling plants are larger and more complex, requiring higher levels of capital investment and larger scales of production capacity to achieve the economies of scale necessary for making a profit. Consequently, most new and smaller-scale ethanol plants use the dry milling process.[3]

In dry milling, the entire kernel is ground, then heated and liquefied into a hot slurry, which is then fermented with yeast and enzymes for 50 to 60 hours. This produces a mash that is between 10 and 15 per cent ethanol by

1 (Drapcho, Nhuan and Walker 2008, 118)

2 These production processes are also used for wheat and other feedstock grains.

3 (Drapcho, Nhuan and Walker 2008, 119)

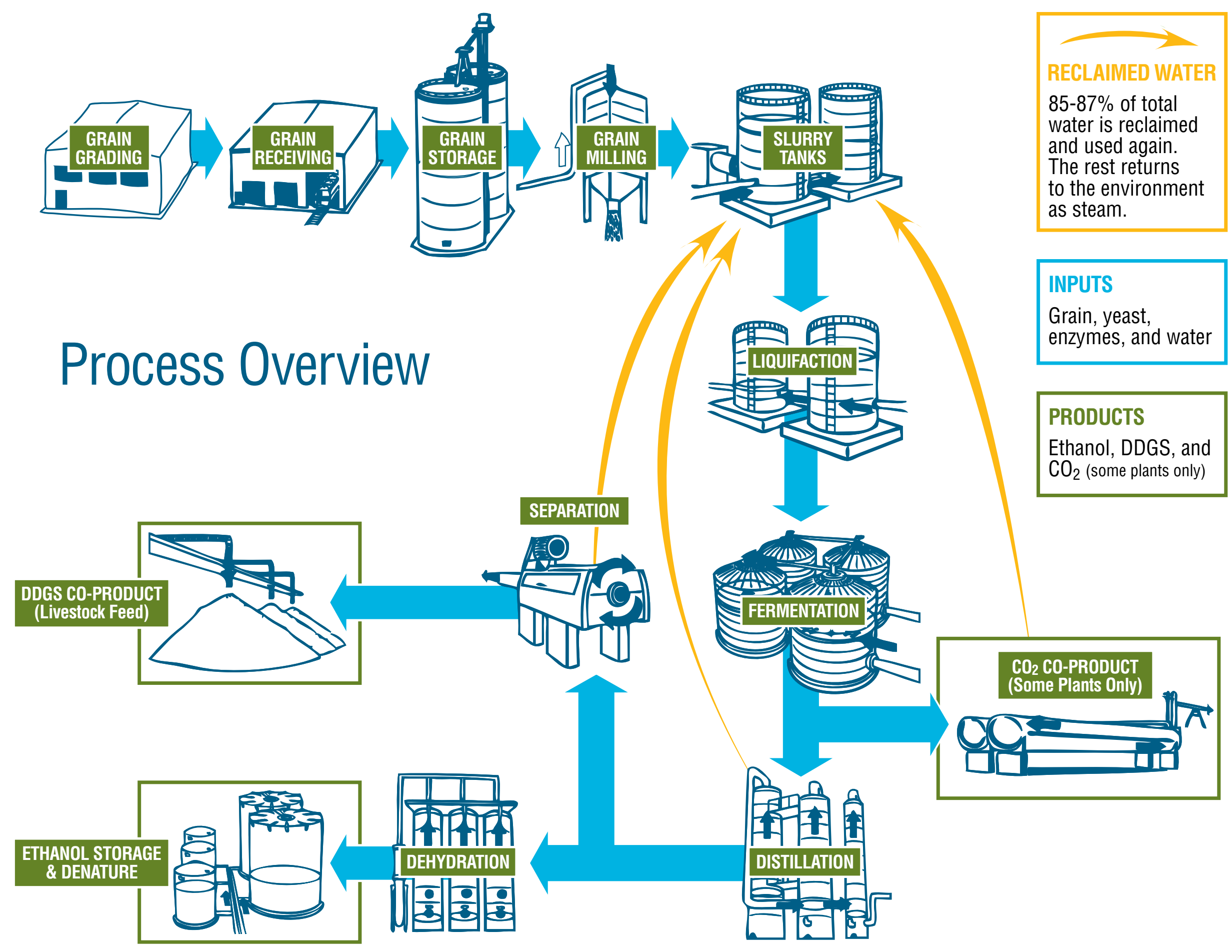
weight, and which also contains grain and yeast solids. The mash is then sent through a distilling process to boil off the water and separate the ethanol into a product that is 95 per cent ethanol by weight and 5 per cent water. The final steps are to dehydrate the ethanol mix to remove the final 5 per cent of water and to add a denaturant (gasoline) to make the ethanol undrinkable. The dry milling process is depicted in Exhibit 1.

Meanwhile, the residues from distilling, made up of non-fermentable solids and water, are called stillage, which is further processed into distillers grains with solubles (DGS). This by-product contains most of the nutritive value of the feedstock, plus the yeast added during production, and can be sold in its wet form (WDGS) to local cattle feedlots and dairies. However, WDGS spoils quickly, so if there is not a sufficient local market for it, the product can be dried (DDGS) and sold as a high-protein ingredient for cattle, swine, poultry, or fish feed.[4]

Another by-product of ethanol production is carbon dioxide (CO_2) gas, which is produced from the corn in large quantities during the fermentation stage. In some

4 (United States Environmental Protection Agency 2010)

Exhibit 1
The Dry Milling Ethanol Production Process



Source: GreenField Ethanol.

plants it is simply released into the air, but in others it is recovered and sold to carbonated beverage bottling companies, or other food processing industries such as vegetable greenhouses.[5,6]

In wet milling, corn kernels are first steeped in a dilute sulfurous acid solution for between 24 and 48 hours. The steeping process allows the kernels to be separated into their main components: germ, fibre, gluten, and starch. Each of these components can then be used to produce various corn products.

While improvements have increased the efficiency of ethanol production, the ethanol industry continues to pursue new technologies to increase the value of co- and by-products and to reduce energy requirements.

Corn oil can be extracted from the germ (either wet milling or dry milling) and sold as feedstock for biodiesel, although most wet milling plants produce food-grade corn oil on site as a co-product. The steeping liquid is concentrated to produce "heavy steeping water," which can be sold alone as a livestock feed ingredient or as a component of "Ice Ban," an environmentally friendly ice removal product for roads. Heavy steeping water can also be mixed and dried along with the corn fibre and sold as corn gluten feed. The gluten from the kernel can also be filtered and dried to produce gluten feed.

Meanwhile, the starch from the kernel and the remaining water is fermented into ethanol, using a process that is similar to the fermenting process in dry milling plants. The starch can also be processed into corn starch or corn syrup.

ADVANCEMENTS IN CONVENTIONAL ETHANOL TECHNOLOGIES

Many improvements have been made over the past 15 years that have increased the efficiency of conventional ethanol production, and profitability. This includes the optimization of cooking, mashing, and fermenting techniques to increase the amount of ethanol that can be produced from a bushel of corn, to reduce the energy required, and to improve production and utilization of by-products.

Still, the ethanol industry continues to pursue new technologies to increase the value of by-products or co-products and to reduce energy requirements. These include:[7]

- **Dry fractionation—**This process involves mechanically separating the corn kernel into the germ, bran, and endosperm[8] before fermentation, to reduce the amount of non-fermentable material and increase the value of production by-products. The endosperm is the only portion used for ethanol production. Meanwhile, the germ is processed into corn oil, and the protein is blended into DGS to create a higher-value livestock feed. The bran can be sold as cattle feed, or as a fibre supplement for humans, or burned as an energy source for ethanol production. The benefits of dry fractionation can be substantial, raising the plant's production capacity, reducing the energy required to dry the DGS, and reducing enzyme requirements by up to 30 per cent. However, this process increases feedstock requirements by about 2 or 3 per cent, because a small amount of starch is lost during fractionation, and it is very capital-intensive.[9]
- **Corn oil extraction—**This is an alternative method of recovering oil from the kernel, by mechanically extracting crude corn oil from the stillage and/or DGS. The recovered oil is lower quality, but it can be used as an additive for cattle feed or as a feedstock

5 (Drapcho, Nhuan and Walker 2008, 122)

6 The life cycle analyses indicate that this is the single largest source of GHG emissions in the ethanol production process. If all of the CO_2 is captured and sold, the direct emissions from the ethanol plant would be reduced by as much as 80 per cent, depending on the plant.

7 These technologies are described in greater detail in United States Environmental Protection Agency 2010.

8 The endosperm contains the starch and protein.

9 For a plant with a capacity of 100 million gallons per year, the capital investment would be about US$35 million.

for biodiesel production. This process improves the plant's energy efficiency, because oil acts as an insulator, so removing it improves the performance of the DGS dryers. Also, DGS that has been de-fatted has a better consistency and is of higher value to the swine and poultry industries. Plus, the capital investment to adopt this process is relatively small.

- **Cold starch fermentation—**This is a patented process of fermentation without the use of heat, developed by POET Biorefining, and using low-temperature enzymes developed by Novozymes.[10] The process reduces energy consumption and releases additional starch from the kernel for conversion into ethanol. This process also produces a higher-quality DGS that is more nutritional. However, there are a number of issues with this process that still need to be addressed; for example, because heat is not used, more enzymes are required to ferment the corn, which can substantially increase operating costs. In addition, the heat used in conventional production methods sterilizes the corn, killing microorganisms and neutralizing toxins. Without this step, microorganisms can interfere with the yeast during fermentation, lowering ethanol yields, and toxins can be passed through to the DGS, contaminating the livestock feed.
- **Membrane replacement—**The ethanol industry continues to explore methods to reduce the energy used during the distillation/dehydration of ethanol, which is the most energy-intensive phase of production. Membrane replacement technology uses a polymeric membrane in place of molecular sieves and rectifier units in a conventional ethanol plant to remove water, potentially reducing the energy consumed during distillation by up to 50 per cent.[11]
- **Combined heat and power—**Some ethanol plants in the U.S. are using combined heat and power technology to reduce the use of water, electricity, and steam during the production process. This involves using a boiler to produce electricity and diverting the waste heat to produce steam. Excess electricity can also be sold to a local utility company. Although this system requires a higher level of thermal heat than a conventional ethanol plant, the plant's overall energy consumption is lower because more waste heat is used. In some cases, a plant using this technology will partner with a utility company to share operational costs.
- **Alternative boiler fuels—**Some ethanol plants are exploring alternatives to coal and natural gas for powering their boilers when using the combined heat and power system, to reduce their carbon footprint. Alternative boiler fuels include biomass such as wood, by-products of ethanol production such as corn bran or stillage, methane from nearby livestock lots, and landfill gas.

Another recent advancement in ethanol production efficiency is the creation of holistic ethanol biorefineries, located, in many cases, near cattle-feeding or dairy operations that consume the WDGS. Particularly when combined with some of the technological advances discussed above, biorefineries have the potential to substantially improve the life cycle emissions profile and energy balance of corn ethanol, while improving production efficiencies.

- **Other—**A study by the University of Nebraska examined the relative efficiency and environmental footprints of various biorefinery configurations used in the United States. The study suggests the most efficient configuration is a "closed-loop" biorefinery; this type of facility is located next to a cattle feedlot, uses a dry milling process, and produces WDGS for the cattle feedlot, thereby avoiding the extra step of drying the distillers grains. Cattle manure and urea are collected from the feedlot and used to produce methane, which becomes a source of energy for ethanol production. The external energy requirements for this type of system are significantly lower than they are for traditional ethanol plant operations. The study determined that ethanol produced in this type of facility achieved a 67 per cent reduction in life cycle GHG emissions compared with the energy equivalent of gasoline, and a net energy balance of 2.23.[12] The study also points out that there have been significant advances in crop genetics and crop yield

10 For more information, see www.poet.com/innovation/producing_ethanol.asp.

11 The Siftek, developed by Vaperma, was once a promising example, although the technology is no longer under development.

12 (Liska and others 2008)

management in recent years that have substantially improved the overall energy balance of corn ethanol. In fact, there are indications of further improvements ahead. The U.S. Department of Agriculture (USDA) expects that over the next 10 years, advancements in corn feedstock optimization will increase the starch content of corn kernels by between 2 and 4 per cent.[13] Progress in other genomics and related science and technology areas may also contribute to further advancements in ethanol production.[14]

NEXT-GENERATION ETHANOL PRODUCTION TECHNOLOGIES

The largest, most significant advancement in ethanol technology will be to commercialize technologies that will broaden the range of feedstocks to include lignocellulosic[15] biomass, corn stover, other agricultural residues, forest products and residues, and grasses, as well as other feedstocks, such as municipal solid waste.

In North America, there is strong interest in the use of cellulosic feedstocks for ethanol, because of their widespread abundance and environmental benefits. Compared with ethanol produced from corn or wheat starch, cellulosic ethanol has a substantially lower life cycle GHG emissions profile and a much more favourable energy balance.[16] However, cellulosic ethanol is more costly to produce, because converting cellulose into fermentable sugars that can then be processed into ethanol is significantly more complex. It requires a new generation of production technologies that have not yet reached the commercial stage of development.[17]

13 (United States Environmental Protection Agency 2010, 15)

14 For a detailed discussion of the potential contribution of genomics to the bioproducts sector, see Biofuels and Bioproducts Genomics Working Group 2007.

15 Lignocellulosic biomass is plant matter composed of cellulose, hemicellulose, and lignin. Cellulose and hemicellulose can be converted into sugars, which can then be converted into ethanol. (Drapcho, Nhuan and Walker 2008, 133)

16 (Greene 2004)

17 (Drapcho, Nhuan and Walker 2008)

Existing processes for converting cellulosic biomass into ethanol fall into two broad categories: biochemical and thermochemical. Both are considered to be advanced, or second-generation, production technologies for ethanol, and are still being developed. Biochemical conversion involves the use of enzymes (or, less commonly, concentrated acid) to convert the carbohydrates in cellulose to sugar, which can then be processed into ethanol. Thermochemical conversion involves the use of extreme heat to break down biomass into a synthesis gas, which is then converted into ethanol.

In North America, there is strong interest in using cellulosic feedstocks for ethanol because of their widespread abundance and environmental benefits.

Thermochemical platforms can use a mix of feedstocks, including cellulosic biomass and municipal solid waste, providing a plant with greater flexibility to change its feedstocks as supplies vary. In contrast, biochemical platforms using enzymes work best with homogeneous feedstock supplies, as specific enzymes are needed for individual feedstocks.

It is unclear when these technologies will be available for the commercial production of ethanol, although there are a number of demonstration plants in North America producing small quantities of cellulosic ethanol. These include Iogen Corporation, a Canadian company that opened the first commercial demonstration plant for cellulosic ethanol in North America, located in Ottawa, Ontario. Iogen uses biochemical conversion to produce ethanol from agricultural residues (i.e., wheat, oat, and barley straw), using its own proprietary enzymes. Iogen has also conducted research on the potential use of other feedstocks, such as corn stover, switchgrass, and miscanthus.[18]

Biochemical conversion is the most common technology used for North American pilot and demonstration projects for second-generation ethanol production, but this may change in the near future. According to the

18 (Iogen Corporation n.d.)

USDA, a number of companies in the U.S. are planning large-scale biofuels projects using thermochemical conversion, as well as other processes.[19]

In Canada, in the summer of 2010, Enerkem started construction of a new biorefinery in Edmonton, Alberta, located at the Edmonton Waste Management Centre, which will convert municipal solid waste (cardboard, plastic, packaging, sawdust, etc.) to ethanol using a thermochemical process.[20] Enerkem has also built a demonstration plant in Westbury, Quebec, that uses thermochemical technology to convert used telephone and electricity poles into several products, including methanol. The company expects to begin producing ethanol at this plant sometime in the near future.[21]

A number of challenges face the commercial-scale production of second-generation ethanol, including high capital and production costs, and the establishment of economical feedstock supplies.

Looking ahead, there are a number of challenges facing the commercial-scale production of second-generation ethanol, including high capital and production costs, and the establishment of economical feedstock supplies. Capital investment costs are considerably higher for second-generation ethanol plants than for conventional ethanol plants—up to three or four times higher, according to the USDA. For this reason, companies pursuing second-generation ethanol production have sought pre-commercial development financing through a number of channels, such as government grants and loan assistance, venture capital investments, and partnerships with large corporations and research institutions.[22] As one example, Iogen Corporation has partnered with Shell Oil to create Iogen Energy, a joint venture in cellulosic ethanol research and development.[23]

19 (Coyle 2010)

20 (Enerkem n.d.)

21 (Enerkem n.d.)

22 (Coyle 2010)

23 (Iogen Corporation June 3, 2010).

Another challenge is the establishment of economic supply channels for second-generation feedstocks. Although cellulosic biomass exists in abundance, it is much bulkier than grains, making it more expensive to transport and store; companies will have to set up efficient supply chains to access feedstocks if plants are not located close to feedstock sources.

The ethanol industry is poised to make a major breakthrough in the development of second-generation technologies.

A 2006 research report by Biocap Canada suggests that cellulosic residues from agricultural and forestry industries could provide significant quantities of feedstock for second-generation ethanol production in Canada. The report focuses on forestry residue in particular, which is produced most abundantly in British Columbia, followed by Quebec, Alberta, and Ontario. It discusses the benefits of forestry-based biorefineries, operated in conjunction with pulp and paper or sawmill operations, which could efficiently and economically produce a range of bioproducts, including ethanol, using wood waste as feedstock.[24]

THE BIOREFINERY

The heart of the ethanol production process is the biorefinery—where a biological feedstock like corn is processed into ethanol fuel. A biorefinery is ". . . a facility that integrates biomass conversion processes and equipment to produce fuels, power, and chemicals from biomass."[25] This definition encompasses a range of facilities, but is based on two fundamentals: a biomass feedstock and multiple products. The feedstock may be corn, wheat, forestry waste, special purpose crops, municipal waste, or something else. The conversion technology may involve fermentation, enzymes, or a thermochemical process. The outputs may include ethanol, DDGS, carbon dioxide, fuels, chemicals, or other materials.

24 (Mabee 2006)

25 (National Renewable Energy Laboratory 2009, 1)

Central to the concept of the biorefinery is an attempt to limit waste as an output. Improving the efficiency of ethanol production has involved either returning waste products to the process or converting them to marketable co-products. At many ethanol plants, carbon dioxide given off during the production process is captured and sold for use in other industrial processes, such as the production of soft drinks, industrial freezers, and greenhouses (where its use increases the output of tomatoes, cucumbers, and lettuce by up to one-third). Distillers grains, which are used as a high-protein animal feed, is another example of a marketable co-product.

Efficiency improvements have also included efforts to reduce the energy consumption within the biorefinery and to reduce the hydrocarbons content of the energy that is used. These combined efforts have the potential to make biorefineries into carbon sinks—a situation where the life cycle GHG emissions reductions from the products produced by the biorefinery are greater than the life cycle emissions of the products displaced.

The ethanol industry is now poised to make a significant breakthrough in the development of second-generation technologies, using alternative feedstocks to produce ethanol with a substantially lower environmental footprint than conventionally produced ethanol. This new generation of technology is expected to reach the commercial stage within the next few years, with a number of Canadian companies at the forefront.

CHAPTER 7

The Policy Environment

Chapter Summary

- Canadian ethanol policy to date has focused on producer incentives to support private investment in ethanol production capacity, and more recently on a renewable fuel standard to ensure a minimum blend level in gasoline.
- Although high-blend service station infrastructure has not been a key focus, it presents a policy opportunity to support increased fuel security and to provide a growing biofuels market.
- Next-generation technologies provide an opportunity to maintain a leadership position. To achieve this, incentives for innovation, commercialization, and production will be required.

Government support of the ethanol industry has been the subject of wide debate around the world. Proponents of the ethanol industry believe ethanol can assist governments in achieving public policy objectives, such as energy security and the diversification of energy resources, reductions in emissions that contribute to climate change, income support for agricultural producers, and contribute to the growth of rural economies.

The Canadian government has maintained a relatively light hand in supporting the ethanol industry compared with the world's two largest ethanol producers, the U.S. and Brazil.[1] This chapter presents a discussion of the Canadian public policies in place to support the growth of the ethanol industry, the main drivers of support, and whether the Canadian ethanol industry is meeting policy objectives.

POLICY ENVIRONMENT IN CANADA

Canadian federal and provincial governments support the ethanol industry through a range of policy mechanisms, including blending mandates, producer incentives, capital grants, loan assistance, and modest financial support for R&D.

At the federal level, the most significant policy implemented in Canada to date has been the Renewable Fuel Standard (RFS), the final details of which were announced on September 1, 2010. The RFS mandated a 5 per cent renewable fuel content in Canada's gasoline pool as of December 15, 2010. Administered by Environment Canada, the main policy objective of the RFS is to reduce GHG emissions in Canada. The rule targets transportation fuel producers and importers, which must prove that the gasoline they sell contains at least 5 per cent renewable fuels, on average. There are some

1 U.S. and Brazilian policies to support ethanol are discussed in Chapter 8.

exemptions, including special purpose fuels,[2] as well as gasoline used in Newfoundland and Labrador, northern Quebec, and the three territories. There is also an opportunity for fuel producers to participate in a compliance unit trading system if they are unable to meet the mandate.

The RFS defines renewable fuel as any fuel produced from a renewable feedstock, including corn, wheat, barley, forestry, woodwaste, and even municipal waste, as long as its biogenic carbon content is at least 50 per cent.

Based on 2010 gasoline consumption, to fully meet 5 per cent renewable fuel consumption, Canada's ethanol plants would need to operate at full capacity.

A notable aspect of the RFS is it could become binding in its first year, immediately forcing an increase in ethanol consumption in Canada. In 2009, Canadian ethanol production capacity was just over 1.4 billion litres,[3] which was roughly 4 per cent of net gasoline sales in the regions of Canada subject to the RFS. Environment Canada acknowledged this potential gap in its regulatory announcement and expects any shortfalls in domestic production to be met through imports from the United States.[4] Based on 2010 gasoline consumption, to fully meet 5 per cent renewable fuel consumption, Canada's ethanol plants would need to operate at full capacity, leaving a shortfall of just under 300 million litres, which would need to be met by imports or by exemptions from the standard.

Environment Canada first announced its intent to implement a national Renewable Fuel Standard in December 2006. Over the next year, the federal government rolled out a number of programs under the umbrella of a Renewable Fuels Strategy to stimulate growth in domestic ethanol production, including:

- **ecoENERGY for Biofuels—**a grant program providing operating incentives for biofuels production, with the aim of promoting domestic biofuels production. Eligible recipients receive fixed rates for each litre produced and eligible for sale, starting at $0.10 in 2008–10, then declining by $0.01 every year after that. The program was launched in December 2007 by Natural Resources Canada, with $1 billion allocated to ethanol and $500 million to biodiesel. The application process closed in March 2010, and contribution agreements have since been signed with 22 companies: 15 ethanol producers and 7 biodiesel producers.
- **eco Agriculture Biofuels Capital Initiative (ecoABC)—**a loan assistance program for agricultural producers to encourage their participation in the biofuels industry. The program has ended, but provided repayable contributions[5] of up to $25 million for the construction or expansion of renewable fuels production facilities, for projects where agricultural producer investments make up at least 5 per cent of total project costs. The program was launched in April 2007 by Agriculture and Agri-Food Canada, with $200 million in total funding over four years.
- **NextGen Biofuels Fund—**a loan assistance program to support the development of large-scale demonstration facilities for the production of second-generation renewable fuels (cellulosic ethanol and biodiesel) and co-products. The program was launched in September 2007 by Sustainable Development Technology Canada (SDTC), with $500 million in total funding. SDTC has positioned this program downstream from the SD Tech Fund, which can act as a "feeder" to this fund. The SD Tech Fund is a grant program, established in 2002, to support the late-stage technology development and demonstration of a wide range of clean technology solutions, including biofuels.

2 Special purpose fuels are defined as those used for aviation, kerosene for heating, lamps or stoves, competition vehicles, scientific research, chemical feedstock, and military combat equipment. (Enviro-Acces inc. 2010)

3 (Canadian Renewable Fuels Association 2009)

4 (Environment Canada, Government of Canada 2010)

5 Loan repayments are contingent upon the profitability of the facility.

The Canadian ethanol industry also benefits from federal government support for research and development through a number of channels, although most federal R&D programs are structured to cover a full range of bioproducts, rather than supporting ethanol research specifically. For example, the Agricultural Bioproducts Innovation Program (ABIP) provides funding for research, development, technology transfer, and commercialization activities for a broad range of bioproducts, including biofuels, other forms of bioenergy, industrial chemicals, biomaterials, and health products. In 2009, ABIP provided $19.9 million to the Cellulosic Biofuel Network, a group of government and university organizations involved in research activities related to the development of cellulosic ethanol and its bioproducts.[6] In addition, the Canadian Biomass Innovation Network, managed by Natural Resources Canada's Office of Energy Research and Development, oversees a number of federal government renewable energy R&D programs that have funded ethanol projects.[7]

At the provincial level, a number of provincial governments have policies in place to promote the production and consumption of ethanol. Saskatchewan, Manitoba, and Ontario already have a renewable fuel standard in place, and many provinces have phased out fuel tax exemptions for ethanol, offering instead a range of tax incentives, grants, and producer subsidies. The most extensive of these is Ontario's Ethanol Growth Fund, which has set aside $520 million in capital grants, producer subsidies, and R&D funding for the ethanol industry. (See Table 5.)

6 (Agriculture and Agri-Food Canada 2009)

7 (Laan, Litman and Steenblik 2009)

Table 5
Summary of Provincial Government Policies to Support Ethanol

Province	Mandate	Tax incentives	Grants/subsidies	Loans
B.C.	5 per cent renewable fuel in gasoline beginning Jan. 2010	Ethanol portion exempt from fuel tax ($0.145) and carbon tax ($0.0445); E85 to E100 fully exempt	**BC Bioenergy Network** $25 million for R&D for all forms of bioenergy	
Alta.	RFS effective Apr. 2011; requires 5 per cent of gasoline pool		**Bioenergy Producer Credit (2011–16)** Up to 150 million litres: • $0.10/l 1st gen. ethanol • $0.14/l 2nd gen. ethanol Over 150 million litres: • $0.06/l 1st gen. ethanol • $0.09/l 2nd gen. ethanol **Bioenergy Grant Program** ran 2007–10, granted $41.5 million **Bioenergy Infrastructure Development Program (expired 2009)** Up to $5 million per project—program includes biofuel blending and storage facilities	

Source: The Conference Board of Canada.

(continued . . .)

Table 5
Summary of Provincial Government Policies to Support Ethanol (cont'd)

Province	Mandate	Tax incentives	Grants/subsidies	Loans
Sask.	RFS 7.5 per cent of gasoline pool; effective in 2006		**Fuel Distributor Grant** $0.15/l produced and sold in Sask.; offsets fuel excise tax	**SaskBio (four-year program now completed)** $80 million in total; up to $10 million per project available to Sask. residents for investments in biofuels facilities
Man.	RFS 8.5 per cent of gasoline pool; effective in 2008		**Ethanol Production Grant** Eight-year program beginning in 2008 2008–09: $0.20¢/l produced and sold in Man. 2010–12: $0.15/l 2013–15: $0.10/l (annual payouts capped by amount of ethanol required to meet mandate)	
Ont.	RFS 5 per cent of gasoline pool; effective in 2007		**Ontario Ethanol Growth Fund** Total of $520 million over 12 years (2005–17): ◆ $32.5 million in capital grants ◆ producer's subsidy of up to $0.11/l to mitigate effects of changing market prices ◆ also includes funding for R&D	
Que.	"Target" of 5 per cent renewable fuel in gasoline pool by 2012	Tax credit for production of ethanol: max of $0.185/l on production up to 126 million l/yr. (available only for months of year when oil prices less than US$65)		

Source: The Conference Board of Canada.

MAJOR DEVELOPMENTS IN CANADIAN SUPPORT POLICIES

Before the establishment of the federal government's Renewable Fuels Strategy, the most significant support for ethanol at the federal level was the Fuel-Tax Exemption for Ethanol,[8] which was phased out in 2008 and replaced by the producer incentives offered under the ecoENERGY for Biofuels program. While the fuel tax exemption was in place, the federal government also offered the National Biomass Ethanol Program, which provided contingent loan guarantees to encourage financing for new ethanol production plants. This program was established to address uncertainty among investors concerned about potential changes to fuel tax exemption for ethanol.[9]

In 2003, the federal government launched the Ethanol Expansion Program, which provided repayable loans[10] for the construction or expansion of Canadian ethanol production facilities. According to Natural Resources Canada, the objective of the program was to increase the domestic production and use of ethanol, and reduce transportation-related GHG emissions. The ethanol plants that benefited from this program represent a collective capacity of about 1 billion litres of ethanol per year.[11]

In addition, the Biofuels Opportunities for Producers Initiative (BOPI), offered by Ag Can, provided grants to agricultural producers for ethanol plant feasibility studies. A precursor to the ecoABC program, BOPI provided a total of $20 million in funding between 2006 and 2008, approximately half of which was allocated to ethanol projects.[12]

8 The ethanol portion of ethanol-blended gasoline was exempt from the $0.10/litre fuel excise tax. Revenues from this tax are collected into the federal Gas Tax Fund, which provides funding for municipal infrastructure projects across the country. (Infrastructure Canada 2010)

9 (Natural Resources Canada 2009)

10 Over the course of the program, a total of $107 million in deferred, conditional loans were provided. Loans were interest free, except in the case of late payments, and repayment terms were based on company profitability.

11 (Natural Resources Canada 2010)

12 (Laan, Litman and Steenblik 2009)

Canada's ethanol industry also benefited from access to modest levels of federal government support for R&D activities prior to the RFS. For example, ethanol research projects could access funding from the Renewable Energy Technologies Program, run by Natural Resources Canada, which provided grants for R&D and commercialization of renewable energy technologies. The program was open to prototype or demonstration projects involving bioenergy, small hydro, solar, or wind energy.

From the beginning, the environmental benefit of using renewable fuels has been a primary motivation for federal support of the ethanol industry.

The federal government has also provided support for the work done by Iogen Corporation to develop cellulosic ethanol technologies. Over the past 30 years, Iogen has received a total of $20.7 million in R&D grants from the National Research Council of Canada, Natural Resources Canada, and Agriculture and Agri-Food Canada. Iogen has also received a total of $26 million in loan assistance from Technology Partnerships Canada to support capital investments in Iogen's demonstration plant.

IMPACTS OF CANADIAN GOVERNMENT POLICY

The Government of Canada states that the purpose of its RFS is to "reduce the greenhouse gas (GHG) emissions resulting from fuel use, encourage greater production of biofuels, accelerate the commercialization of new biofuel technologies, and provide new market opportunities for agricultural producers and rural communities."[13]

The environmental benefit of using renewable fuels has been a primary motivation for federal support of the ethanol industry since the beginning. Environment Canada stated it was implementing a consumption mandate because other federal programs to promote renewable

13 (Government of Canada 2010, 1)

fuels, including the fuel tax exemption, had not achieved significant market penetration for renewable fuels or substantial reductions in GHG emissions. It also noted that market-based measures such as the ecoENERGY for Biofuels and ecoABC programs were more effective when accompanied by regulatory measures such as the RFS.[14]

The reduction in GHG emissions under the Renewable Fuel Standard is expected to reach about 4 million tonnes per year.

The reductions in GHG emissions achieved by the RFS are expected to be about 1 million tonnes per year over the next 25 years, according to a cost-benefit analysis provided by Environment Canada. The combined impact of all programs under the RFS is expected to reach about 4 million tonnes per year, which is just under 7 per cent of 2008 emissions from gasoline-powered vehicles in Canada.

Another issue is the cost associated with achieving this policy objective. For example, the C.D. Howe Institute released a position paper in 2008 estimating the combined cost of federal and provincial programs to support ethanol at 26.8 cents per litre produced in 2007, decreasing over time to 16.7 cents in 2012 as subsidy levels decline.[15] It notes that at that rate, federal and provincial governments in Canada are collectively paying an average of around $368[16] for every tonne of CO_2 eliminated through the use of corn ethanol between 2007 and 2012. The weakness in this type of analysis is that it presents point-in-time results, based on government expenditures each year, divided by the ethanol produced and GHGs saved in that year. Given the downward trend in government payments and the long life of the assets they supported, some form of discounted cash flow or net present value analysis would have been more appropriate. Further, the C.D. Howe work ignores the tax revenues that all three levels of government receive from ethanol producers as well as other benefits related to rural development.

The International Institute for Sustainable Development (IISD) presented similar figures in a 2009 report, calculating total federal and provincial subsidies to ethanol at 21 to 23 cents per litre produced in 2007, decreasing to between 4 and 17 cents in 2012.[17] Even at the lowest end of the estimated cost range, avoiding CO_2 emissions in 2008 was priced at $200 per tonne.

Based on the C.D. Howe and IISD estimates of government support, we can make two important adjustments that result in a more useful estimate of the cost of GHG emissions reductions that result from ethanol. The first adjustment is to update the cost information based on the revised producer support payments that were implemented after the studies were completed. The second adjustment is to extend the time frame of the analysis to include the remainder of the support payment period as well as the full production life of the ethanol plants eligible for support. We assumed that each ethanol plant would produce ethanol for a period of 25 years from its first year of operation. Finally, because the payments are made in the early years of the period examined (2006–33) and the ethanol production continues through the entire period, the time value of money becomes an important factor.

Using the government support identified by the IISD, and a GHG emissions reduction of 496.6 g CO2e per litre of ethanol produced (the value used by the C.D. Howe report), the undiscounted cost of GHG abatement over the full life of Canada's existing ethanol plants would be $94/tonne. If we adopt the Cheminfo estimate

14 (Environment Canada 2010, Regulatory Impact Assessment Statement)

15 (Auld 2008). This calculation took into account producer credits and capitalized costs of research grants at the federal and provincial level, as well as opportunity costs associated with federal loan assistance programs. For example, in 2012, total federal and provincial subsidies are projected to be $383 million, and ethanol production is projected to be 2.302 billion litres, which equals 16.6 cents per litre.

16 The calculation for the cost per tonne of CO_2 avoided was based on GHGenius 3.11 life cycle GHG emissions analysis software.

17 (Laan, Litman and Steenblik 2009). The subsidy per litre is presented in a high–low range, based on two different scenarios: a low-cost scenario, with conservative estimates for accelerated depreciation and R&D support, and in which all government loans are repaid; and a high-cost scenario, with high estimates for accelerated depreciation and R&D support, and in which no loans are repaid.

of the GHG emissions reduction per litre of ethanol (1,253 g CO2e/litre), the abatement cost is reduced to just over $37/tonne. Discounting both the government support payments (to reflect the time value of money) and ethanol production volumes (to reflect the uncertainty of future production) increases the abatement cost because the support payments occur at the beginning of the time horizon and are therefore less influenced by discounting. Using a social discount rate of 6 per cent results in GHG abatement costs of $147/tonne using the C.D. Howe estimate of GHG reductions, and $58/tonne using the Cheminfo value for GHG reductions. Abatement costs over the life of the assets that were constructed under the government support programs are therefore much lower than the near-term estimates prepared by the IISD and C.D. Howe studies.

As ethanol production ramps up and as federal subsidies wind down, the public sector cost attributed to GHG emissions reductions will continue to fall.

In addition, the Government of Canada's regulatory impact analysis statement found that, after reflecting all appropriate benefits and costs, there is a broad range of net benefits or costs associated with the Renewable Fuels Regulation. The analysis was not limited to the cost of government programs, but included costs to consumers and suppliers as well. The finding was that at $25/tonne of GHG emissions abated, the net cost of the RFS would be $1.3 billion, and at $100/tonne of GHG emissions abated, the net benefit would be $363 million.[18] In other words, the Environment Canada analysis finds that at a carbon price of $25/tonne the RFS results in a net cost to the economy, and at a carbon price of $100/tonne the RFS results in a net benefit. The break-even GHG mitigation cost of the RFS based on Environment Canada analysis appears to be something between $25/tonne and $100/tonne (closer to the higher end if we can assume a linear relationship).

The IISD report states that Canada has "done a better job than other countries in targeting and limiting its biofuels subsidies."[19] For example, the shift from tax exemptions to producer incentives has reduced public subsidies for ethanol produced outside of Canada. Additionally, the Ethanol Expansion Program contained a provision limiting government assistance to 50 per cent of total project costs, described as an innovative approach for avoiding "subsidy stacking." The report also notes that many Canadian programs have funding caps, time limits, and subsidy levels that decrease over time.

The IISD and the C.D. Howe reports both calculate the public sector cost of reducing GHG emissions over a limited period of time, when government subsidies are at their highest projected level, and ethanol production in Canada is still growing. As ethanol production ramps up, and as federal subsidies wind down, the public sector cost attributed to GHG emissions reductions achieved by supporting ethanol production will continue to fall—particularly when amortized over the life of the ethanol plants receiving those subsidies. The producer support payments have also been revised since both studies were published, resulting in a much smaller payment to ethanol producers from 2009 onward. Moreover, calculating the government cost of achieving one specific policy objective, such as GHG reductions, does not account for other potential returns of that government investment, such as the positive economic impacts discussed in Chapter 2 of this report.

The question of tariffs has also had an impact on the development of ethanol markets around the world. Although Canada's tariff is smaller than that of the U.S., it does provide potential market distortion. Proximity to a low-cost supplier may not be an appropriate justification. The net impact of import restrictions or tariffs on ethanol or ethanol feedstocks was not examined in the work reviewed for this project. This is an area for further analysis.

18 (Environment Canada 2010, Regulatory Impact Assessment Statement, Table 9)

19 (Environment Canada 2010, Regulatory Impact Assessment Statement)

CHAPTER 8

Energy Security

Chapter Summary

- Although Canada is a net exporter of oil, Ontario, Quebec, and the Atlantic provinces currently import most of the crude oil they refine and most of the transportation fuels they consume.
- In order for high-blend ethanol (E85) to contribute to Canada's energy security, investments would be required in expanded production capacity and high-blend delivery infrastructure.

According to the International Energy Agency, energy security is "the uninterrupted physical availability [of energy] at a price which is affordable, while respecting environment concerns."[1] Energy security is a policy objective often associated with the ethanol industry. Indeed, the U.S. and Brazil, the world's two largest producers of ethanol, have implemented extensive programs to promote the growth of the ethanol industry since the oil supply disruptions of the 1970s and 1980s, with energy independence as a primary goal.

1 (International Energy Agency n.d.)

ENERGY SECURITY IN THE UNITED STATES

Energy security and independence has been a main policy driver for U.S. government support of ethanol, dating back to the 1970s, when oil supply disruptions sparked political interest in alternative fuels.[2] The two other main policy motivations have been its environmental benefits, such as reductions in GHG and carbon monoxide emissions, and the income and market support benefits it provides to the agricultural sector.[3]

Extensive government support has been a crucial element of the strong growth and development of the U.S. ethanol industry seen over the past three decades.[4] Ethanol production in the U.S. grew from 50 million gallons (189.3 million litres) in 1979 to 13.2 billion gallons (51.2 billion litres) in 2010. Currently, the U.S. ethanol industry benefits from public policy mechanisms at all three levels of government, including blending mandates, tax incentives, loan guarantees, capital grant programs, and funding for R&D.[5]

2 (DiPardo 2000); (Duffield, Xiarchos and Halbrook Fall 2008)

3 (Congressional Budget Office 2010)

4 (Yacobucci 2008); (Duffield, Xiarchos and Halbrook Fall 2008); (United States Environmental Protection Agency 2009)

5 A complete list of U.S. federal and state ethanol incentives and laws can be found on the U.S. Department of Energy Alternative Fuels and Advanced Vehicles Data Centre website at www.afdc.energy.gov/afdc/laws/.

At the federal level, three main policy mechanisms support the U.S. ethanol industry:

- **Renewable Fuel Standard—**The U.S. government has set ambitious, mandatory volumetric targets for biofuels consumption, which increases annually to reach 36 billion gallons by 2022. The RFS establishes specific targets for cellulosic ethanol and biodiesel, which fall under the category of "advanced biofuel," and sets stringent GHG emissions thresholds for fuel eligibility for each category.[6] Although the RFS implicitly assumes that corn ethanol will make up all but a small portion of the biofuel content over the next several years, the proportion of advanced biofuel gradually increases over time, reaching 58 per cent of the overall renewable fuel content in 2022.

  The RFS applies to refiners, importers, and blenders of transportation fuels used in the United States. The Environmental Protection Agency administers the program, and, as in Canada, a trading system is in place for fuel producers unable to meet RFS targets. Up until now, the RFS has not been binding; that is, consumption of ethanol has exceeded the targets set by the RFS, and therefore has not been forced up by the rule. However, it is likely to become binding sometime in the near future.[7]
- **Tax credits—**U.S. federal and state governments offer a number of tax credits for fuel producers that blend ethanol with gasoline. The most significant federal tax credit is the Volumetric Ethanol Excise Tax Credit (VEETC), which provides gasoline producers with a $0.45 credit for each gallon of ethanol blended with gasoline. In 2009, this tax benefit alone was worth US$5.6 billion, according to the U.S. Congressional Budget Office.[8] The VEETC was to expire at the end of 2010, but has been extended until the end of 2016.[9] Other federal tax credits supporting the ethanol industry include the Small Ethanol Producer Credit, at $0.10 per gallon up to 15 million gallons per year, and the Credit for Production of Cellulosic Biofuel, at $1.01 per gallon (inclusive of all other available producer credits).[10]
- **Import tariffs—**U.S. Customs and Border Protection levies a 2.5 per cent *ad valorem* tariff on ethanol fuel imports, plus a $0.54 per gallon duty. The duty is waived for imports from countries covered by the Caribbean Basin Initiative, a significant source of ethanol imports, as part of efforts to "promote development and stability" in Caribbean and Central American countries.[11] Still, Brazil has been the largest source of imports since 2006, although the U.S. is not currently importing ethanol from Brazil.[12]

About 98 per cent of ethanol produced in the U.S. uses corn as its feedstock, grown primarily in the American Midwest,[13] and consequently, there are very strong public policy links between the U.S. ethanol industry and American corn producers. Numerous studies show the beneficial impact of ethanol policy incentives on the U.S. agricultural sector;[14] however, U.S. ethanol production has lagged far behind gasoline consumption in the U.S., preventing any significant inroads into energy independence through the use of renewable fuels. In 2010, ethanol accounted for about 10 per cent of the 137.9 billion gallons of gasoline Americans consumed.[15]

In his 2007 State of the Union address, President George Bush announced his "Twenty in Ten" plan to reduce gasoline consumption in the U.S. by 20 per cent within 10 years, mainly through the increased use of alternative fuels and tighter vehicle fuel economy standards.[16] Legislation enacted after this speech revealed a strong emphasis on encouraging cellulosic ethanol

6 To qualify for a biofuel category in the RFS, the life cycle GHG emissions of the fuel must be significantly less than the life cycle GHG emissions of the gasoline or diesel fuel it replaces, based on the production process used. For details about the RFS and EPA's methodology, see www.epa.gov/oms/renewablefuels/420f10007.htm.

7 (United States Environmental Protection Agency 2009)

8 (Congressional Budget Office 2010)

9 (Planet Ark 2010)

10 (Congressional Budget Office 2010)

11 (Yacobucci, Ethanol Imports 2008)

12 (Canadian Renewable Fuels Association n.d.)

13 (United States Environmental Protection Agency 2009)

14 See, for example, Duffield, Xiarchos and Halbrook Fall 2008; Rubin, Carriquiry and Hayes 2008; Yacobucci, Fuel Ethanol, 2008.

15 (U.S. Energy Information Administration 2010)

16 (United States Environmental Protection Agency 2007)

production. President Barack Obama has reiterated the emphasis on renewable fuels through the Blueprint for a Secure Energy Future:

> So today, I'm setting a new goal: one that is reasonable, achievable, and necessary. When I was elected to this office, America imported 11 million barrels of oil a day. By a little more than a decade from now, we will have cut that by one third. . . . If anyone doubts the potential of these fuels, consider Brazil. Already, more than half of Brazil's vehicles can run on biofuels. . . . So there's no reason we shouldn't be using these renewable fuels throughout America. That's why we're investing in things like fueling stations and research into the next generation of biofuels.[17]

Despite the beneficial impact of ethanol policy incentives on the U.S. agricultural sector, U.S. ethanol production has lagged far behind gasoline consumption.

The *Energy Independence and Security Act* (EISA) of 2007 greatly expanded the parameters of the RFS,[18] creating much more aggressive targets for renewable fuels consumption, including specific targets for cellulosic ethanol and other "advanced" biofuels. The Act also contained numerous programs to support advanced biofuels R&D and commercialization.[19] The 2008 Farm Bill contained $1 billion in funding for loan assistance and grant programs supporting advanced biofuels, mainly cellulosic ethanol. The bill also reduced the VEETC from $0.51 to $0.45, and created a production tax credit for cellulosic biofuel.[20] The *American Recovery and Reinvestment Act of 2009*, also known as the "Stimulus Bill," provided nearly $800 million to the Department of Energy for programs to accelerate advanced biofuels research and commercialization.

This shift in public policy reflected the widespread belief that cellulosic ethanol and other advanced biofuels could lead to significantly higher levels of renewable fuel production and make a significant contribution to U.S. energy security, while making a stronger contribution to long-term environmental goals.[21] In fact, a 2010 report by the United States Department of Agriculture suggests that if RFS targets for 2022 are met, the increased use of renewable fuel—including at least 16 billion gallons of cellulosic ethanol—could displace between 16 and 17 per cent of U.S. crude oil imports that year.[22]

FUEL INFRASTRUCTURE AND DISTRIBUTION

A key challenge will need to be addressed if the U.S. is to achieve this increase in ethanol consumption: the so-called "blend wall." Once U.S. ethanol production reaches 15 billion gallons, there will be enough ethanol to account for more than 10 per cent of the U.S. gasoline pool. Increasing consumption beyond that threshold will require higher levels of ethanol to be blended into gasoline, but the EPA currently limits ethanol-blended gasoline for conventional vehicles to concentrations of 10 per cent (E10) in vehicles manufactured in 2001 or earlier and 15 per cent in vehicles manufactured after 2001. There are a number of reasons for this limit, including fuel additive regulations under the *Clean Air Act*, auto manufacturer warranties, infrastructure and distribution impediments associated with ethanol, and municipal and state motor fuel infrastructure codes.[23]

Various stakeholders lobbied the EPA to allow higher levels of ethanol-blended gasoline for use in non-flex-fuel vehicles, such as E15 or E20,[24] and the EPA conducted studies to determine the feasibility of allowing these higher blends. The EPA has approved the sale of

17 (MarketWatch 2011)

18 The RFS was first established by the *Energy Policy Act* of 2005, with much more modest targets for renewable fuels consumption, and with no specific category for advanced biofuels.

19 (U.S. Department of Energy n.d.)

20 (Stubbs 2010)

21 See, for example, Duffield, Xiarchos and Halbrook Fall 2008; Yacobucci 2010; Greene 2004; Gehlhar, Winston and Somwaru 2010; Horelik 2008.

22 (Gehlhar, Winston and Somwaru 2010)

23 (Yacobucci 2010)

24 E15 is a fuel blend containing 15 per cent ethanol and 85 per cent gasoline. E20 is a fuel blend containing 20 per cent ethanol and 80 per cent gasoline.

E15 for vehicles built in 2001 or later, but this could introduce a series of logistical issues with preventing the use of E15 in vehicles built before 2001.[25]

Another option is to promote the use of E85, which requires the use of flex-fuel vehicles that can run on any blend of ethanol and gasoline up to 85 per cent ethanol. E85 is sold at just over 2,100 fuel stations in the U.S.—less than 2 per cent of all fuel outlets—and mainly in the Midwest, where most ethanol is produced. Meanwhile, flex-fuel vehicles represent only 3 per cent of all light-duty passenger cars and trucks on U.S. roads, although the number of flex-fuel vehicles is increasing rapidly.[26]

Establishing a market for ethanol that could take it from a fuel additive to a fuel alternative would require a broad supply infrastructure and strong incentives to make high-blend ethanol attractive to consumers.

So far, the main driver of growth in the production of flex-fuel vehicles in the U.S. has been an incentive included in the EPA's Corporate Average Fuel Economy regulations, which provides fuel economy credits to automobile manufacturers for the production of flex-fuel vehicles. According to the U.S. Department of Commerce, North America's three largest automakers, Ford, Chrysler, and General Motors, are "committed to biofuels" and intend to make 50 per cent of their vehicle fleets flex-fuel by 2012.[27]

Even with a large increase in the supply of flex-fuel vehicles, a broad expansion of ethanol fuel distribution and dispensing infrastructure will be required to ensure those flex-fuel vehicles are not just running on gasoline. For example, fuelling stations require a separate storage tank and dispensing unit for E85 fuel. Federal and state governments offer numerous incentives and grants for the installation of ethanol distribution infrastructure, but the low demand for E85 fuel has hindered the success of these initiatives.[28]

COULD ETHANOL DISPLACE GASOLINE IN CANADA?

The question of whether ethanol could be used to displace gasoline in Canada calls up many of the same issues that exist in the United States. With the exception of four fuelling stations selling or preparing to sell E85,[29] ethanol is available commercially in Canada only at blends of up to E10. Establishing a market for ethanol that could take it from a fuel additive to a fuel alternative would require a broad and extensive supply infrastructure, combined with strong market or policy incentives to make high-blend ethanol attractive to consumers.

As in the U.S., there are fuel infrastructure and distribution challenges that would need to be addressed in Canada to expand the supply and use of higher-blend ethanol fuel. Fuel retailers would need to make significant capital investments in the equipment needed to sell higher-blend ethanol, with the assurance that demand for the product would be strong enough to justify the added costs. It would also be necessary to price high-blend ethanol fuel to reflect its lower energy content.

Although Canada is a net exporter of oil at a national level, most of these exports originate in Western Canada, while central and eastern provinces import oil or refined products to meet their energy needs.[30] Therefore, there are regions of Canada that could benefit from higher supplies of domestically produced transport fuel. And, since 57 per cent of ethanol production capacity is concentrated in Ontario, the most populous province in the

25 (Yacobucci 2010)

26 In 2009, there were 8.35 million flex-fuel vehicles on U.S. roads. Data for E85 availability and flex-fuel vehicle use come from Moriarty and others December 2009 and U.S. Department of Energy 2010.

27 (Office of Transportation and Machinery, U.S. Department of Commerce 2010)

28 (Moriarty and others December 2009)

29 UPI Energy in Guelph, Ontario (UPI Energy n.d.); MacEwan Petroleum Inc. and TopiaGreenStop in Ottawa, Ontario, and Chatham EnviroStation in Chatham, Ontario, are listed at Growth Energy n.d.

30 Canadian pipeline systems that transport crude oil and refined products are designed to accommodate existing flow patterns from Western Canada to Western and Midwestern regions of the U.S., returning crude oil into Southern Ontario.

country, establishing a fuel infrastructure and distribution system could be more cost-effective in Central Canada than in other regions. If the infrastructure for ethanol transport and high-blend retail sales was developed, ethanol could potentially reduce the need for crude oil and gasoline imports in Central and Eastern Canada.

As higher-blend ethanol markets emerge, continuous monitoring is needed to ensure that full economic and environmental benefits are achieved and costs are managed.

In addition, the flex-fuel vehicle market in Canada may receive a boost from the new vehicle emissions regulations announced October 1, 2010, by Environment Canada. Structured similarly as the U.S. CAFE program, the regulations set GHG tailpipe emissions standards for new vehicles sold in Canada starting in 2011. Automobile manufacturers will be obligated to meet fleet average standards, and will have the opportunity to purchase credits to offset CO_2 emissions that exceed maximum levels. And, like the CAFE program, these new regulations include a provision allowing automakers to receive offset credits for flex-fuel vehicles, thus potentially creating an incentive for the production and sale of flex-fuel vehicles in Canada.

Expanded ethanol production based on next-generation technologies could be combined with a growing flex-fuel vehicle fleet and high-blend delivery infrastructure to provide consumers with an alternative to gasoline. Flex-fuel vehicles are already being produced at an incremental cost as low as $100 per vehicle compared with gasoline vehicles. The high-blend infrastructure comes with a modest cost. The future cost of next-generation technologies remains uncertain. As higher-blend ethanol markets emerge, there needs to be continuous monitoring to ensure that the full economic and environmental benefits are achieved and the costs are managed.

CHAPTER 9

Conclusions and Recommendations

Chapter Summary

- Ethanol is a clean transportation fuel that has a positive energy balance, reduces GHG emissions, and contributes to energy self-sufficiency.
- Next-generation technologies will be the key to expanded production, and provide an opportunity for government and industry to partner effectively, keeping Canada at the forefront of ethanol technology progress.
- Coordination among technology development, production growth, climate policies, high-blend infrastructure, and future government programs would strengthen ethanol's contribution to Canada's transportation fuel mix.

This report examines four questions regarding ethanol in Canada:

1. What are the economic impacts of manufacturing and using ethanol in Canada?
2. How green is ethanol?
3. What is the impact of ethanol on Canadian public health?
4. What is the energy balance in producing ethanol?

In addition, the report has examined the policy objectives that underpin government support of the ethanol industry, comparing key elements to other nations.

ECONOMIC IMPACTS

The economic impacts of ethanol production and use come from three primary sources: construction of ethanol plants, operation of ethanol plants, and government financial support of the industry. One might also consider the economic impacts on consumers.

The cost of government support for ethanol has been estimated by several authors, although changes in producer support payments necessitate re-calculation of the costs from 2009 onward. Our finding is that government support in Canada will average approximately $260 million annually from 2006 through 2012 and will decline thereafter unless new funds are allocated. This compares with an estimated $925 million in government revenues during the construction phase for existing ethanol plants, and an annual $240 million in tax revenues during operations. Ethanol production also accounts for most of the more than 1,000 permanent jobs created by the biofuels industry. At a broader scale, ethanol production contributes more than $1 billion annually to Canada's GDP. The contribution will continue to increase through time, while government financial support will decline (in the absence of new programs or program extensions).

The economic impacts of ethanol production on the livestock industry have also been quantified. However, the quantification does not separate the influence of ethanol feedstock demand from the influence of crude oil prices or assumptions regarding corn exports or imports. This makes it impossible to separate the net impact of ethanol on livestock markets in Canada. Further work focused specifically on the volume of corn actually used in Canadian ethanol production versus animal feed, and measuring the impact of oil prices on grain prices, would add clarity.

ENVIRONMENTAL IMPACTS

There has been an active debate regarding the environmental benefits of ethanol, and much of the debate has been linked directly to the cost of ethanol support per tonne of GHG emissions abated. Life cycle analysis indicates that an E10 blend reduces GHG emissions by 4 to 6 per cent relative to gasoline, and E100 (if it were available) could reduce emissions by between 42 and 62 per cent. Life cycle analysis also shows that GHG emissions from ethanol production prior to its delivery to the consumer are larger than GHG emissions from gasoline prior to its delivery to the consumer. The GHG reduction from ethanol occurs in the vehicle where the GHGs in renewable fuels are zero. The evidence also suggests that improvements in current ethanol production technologies, farming practices, feedstock options, and future technologies will improve the GHG balance of ethanol through time.

Perhaps the most significant potential environmental pressures from ethanol production have been identified through potential land-use changes. However, based on Canadian and U.S. harvest data, ethanol feedstock demand has not significantly increased the land allocated to corn production, even though ethanol production absorbs an increasing share of corn production. The volume of corn available for feed remains reasonably constant, primarily because of increasing yield. Higher corn prices result from ethanol production, representing a benefit to all corn producers and an increased cost to corn consumers. However, the link between biofuels production and other crop prices needs further investigation and demonstration. The studies that have examined both biofuels targets and crude oil prices, for example, show that oil prices are a much more important determinant of crop prices than biofuels production. Without the price linkage clearly established, land reallocation and related environmental impacts are difficult to establish.

PUBLIC HEALTH IMPACTS

The public health impacts of ethanol that have been studied relate primarily to tailpipe emissions from vehicles burning ethanol blends rather than gasoline. Some analysis has also been done relating to exposures to pure ethanol and relating to ethanol that is accidentally spilled, leaked, or inhaled as vapours. The evidence for Canada, the U.S., and Australia where detailed studies have been undertaken suggests that replacing gasoline with ethanol blends will have little impact on human health.

THE ETHANOL ENERGY BALANCE

There is a long-standing debate around the energy balance of ethanol production. Opposing sides in the argument focus on what energy is included, what production technology is used, and the sources of electrical and process energy used. The LCAs performed for GHG emissions from ethanol contribute significantly to this debate because they focus on each element of the life cycle and quantify the energy used and GHG emissions, often on a project-by-project basis. These analyses focus on hydrocarbons energy since that is the primary source of GHG emissions. Life cycle analysis clearly demonstrates that ethanol contains more energy than is required to produce it. The hydrocarbons focus of LCA is appropriate because it focuses the analysis on non-renewable energy required to produce a renewable fuel.

ETHANOL AS AN ALTERNATIVE TRANSPORT FUEL

Ethanol has achieved considerable market success as a gasoline extender, blended into gasoline in ratios of up to E10 (with vehicles produced since 2001 now certified to run on up to E15 blends in the United States). This market received an additional boost from the federal government's Renewable Fuel Standard (RFS), which mandates 5 per cent biofuel content in Canada's gasoline pool. Ethanol production in Canada is almost at that level now, and is expected to easily keep pace with overall gasoline demand to fulfill future renewable fuel requirements. There is an opportunity for the federal government to raise the RFS incrementally as Canadian ethanol production ramps up, particularly since other forms of public sector support for conventionally produced ethanol is expected to wind down over the next seven years.

The growth in ethanol production in Canada is evidence that past support programs have succeeded. Expanding the market will create new supply opportunities.

Ethanol's potential contribution to Canada's transportation fuel mix would be greatly enhanced by a breakthrough in second-generation production technologies, which have a substantially lower environmental footprint than the conventional technologies used today. This new generation of technologies is expected to reach the commercial stage of production within the next few years, with a number of Canadian companies at the forefront of this breakthrough.

There is an opportunity for the public sector to act as a catalyst in this breakthrough, through policy mechanisms similar to those used to support the development of first-generation ethanol production. The capital investment support offered through the NextGen Biofuels Fund is certainly a step in the right direction, but other complementary policies may be needed to help bridge the gap.

There are opportunities to improve ethanol policies and support in Canada. The renewable fuels standard mandates ethanol use, but primarily as a gasoline extender. This report cites evidence supporting that use. Ethanol is environmentally advantageous. However, with a growing number of flex-fuel vehicles on the road, there is a missed opportunity that can be captured only through E85 infrastructure. The evidence reviewed indicates that high-blend infrastructure would cost less per litre of fuel delivered than British Columbia's current carbon tax on gasoline. A program to provide financial support for service stations that invest in storage and blending capacity could support E85 infrastructure development. This would contribute to Canada's GHG target at a modest cost. It would also contribute to energy security, particularly if the infrastructure were in Central and Eastern Canada.

The growth in ethanol production in Canada is evidence that past support programs have succeeded. However, the current supply is fully allocated. Expanding the market will create new supply opportunities. Next-generation technologies that are currently at the demonstration stage are expected to meet a large share of market growth. Canadian governments can support clean energy innovation by partnering with the industry to support continued technology development. This partnering can go beyond the current efforts of SDTC and government research labs. The objective would be to ensure that Canadian next-generation technologies are sought after on world markets. There may also be a need to provide support for production facilities, particularly in the early years of commercial availability.

A final area for policy support relates to monetizing the environmental benefits of ethanol. Alberta currently has an offset protocol for ethanol. Offsets can be offered for sale to regulated large final emitters to help them meet their regulatory requirements. GHG offsets are also available in other provinces, but only on a voluntary basis. Several provinces are moving toward mandatory carbon markets, but have not yet implemented them. A formal market for offsets that is linked to regulatory compliance requirements is an option that would establish a price for carbon emissions and provide a potential source of revenue for ethanol producers. This is a policy option that should be carefully integrated within an overall renewable fuels policy framework.

A continued strong and growing ethanol industry in Canada will also provide support for an emerging biorefinery industry. Biorefineries will produce a range of products, one of which will be ethanol. As the industry continues to develop, ethanol will be produced along with a range of high-value products.

APPENDIX A

The Details of Input Versus Output Energy

The energy balance of ethanol production has been studied by numerous authors.[1] This appendix compares results from two primary sources, the U.S. Department of Agriculture and Pimentel. The objective is to compare the information sources and input values used in order to better understand why the reported energy balances differ.

The energy inputs to grow, harvest, and deliver corn to the ethanol producer have been estimated by Pimentel at 27.4 per cent[2] and by Pimentel and Patzek at 26 per cent[3] of the energy contained in the corn. Their estimated ratio of energy outputs to inputs in corn production is therefore between 3.65:1 and 3.84:1, indicating that corn used as an ethanol feedstock contains significantly more energy than is required to produce it. Patzek extends the analysis to include the energy from the sun, soil, and water applied to grow the corn and finds that the resulting net energy balance from corn production is negative.[4]

1 See, for example United States Department of Agriculture 2010; Pimentel 2003; Pimentel and Patzek 2005; Patzek June 2003 (submission date); Durante and Miltenberger 2004; Greene 2004; Tampier and others 2005; Levelton Engineering Ltd. 2000; (S&T)[2] Consultants Inc. 2009; Liska and others 2008; Earley and McKeown 2009; The Delphi Group 2006.

2 (Pimentel 2003, Table 1)

3 (Pimentel 2003, Table 1)

4 (Patzek June 2003 (submission date), Figure 1)

We do not include the energy content of sunshine, rainfall, or soil in our analysis because they are renewable, and have an insignificant opportunity cost in Canadian agriculture.

The U.S. Department of Agriculture[5] reports energy consumption in corn production at just under half of the level determined by Pimentel. The USDA data are based on the Agricultural Resource Management Survey in 2005, which received responses from 1,814 corn producers in 19 states.[6] Table 1 compares the two sources, with the Pimentel data converted to the USDA units for comparison purposes.

Pimentel estimates data in four categories that the USDA does not include, and the USDA shows two categories not reported by Pimentel. Labour inputs account for just under 6 per cent of Pimentel's estimated energy and represent annual energy consumption per worker of 8,000 litres of oil products based on 2,000 hours of work. The machinery category represents the energy required to produce farm machines and implements. The transport category includes machinery, fuel, and seeds that are transported to the farm. Each of these categories is somewhat problematic to estimate accurately,

5 (United States Department of Agriculture 2010, Table 1)

6 (United States Department of Agriculture 2010, 3)

Table 1
Energy Inputs for Corn Production in the U.S.

	Pimentel and Patzek (2005)		USDA (2010)		Converted to BTU/acre	
Input	Unit (all data are per hectare)	Value	Unit (all data are per acre)	Value	Pimentel	USDA
Labour	hours	11.4			741,903	
Machinery	kg	55			1,634,755	
Diesel	litres	88	gallons	5.81	1,610,667	885,281
Gasoline	litres	40	gallons	1.92	650,369	276,885
Nitrogen	kg	153	pounds	133.90	3,931,120	3,268,055
Phosphorus	kg	65	pounds	54.36	433,579	217,440
Potassium	kg	77	pounds	61.26	403,068	183,780
Lime	kg	1,120	pounds	554.36	505,843	309,333
Seeds	kg	21	pounds	18.29	835,042	7,211
Irrigation	cm	8.1			513,872	
Herbicides	kg	6.2			995,627	
Insecticides	kg	2.8	pounds	2.00	449,638	308,300
Electricity	kWh	13.2	kWh	20.41	54,599	191,140
Transport	kg	204			271,389	
LPG			gallons	3.20		274,864
Natural gas			cubic feet	208.90		218,509
Total					13,031,470	6,140,798

Sources: Pimentel and Patzek; USDA; The Conference Board of Canada.

particularly the machinery and transportation entries. The estimates will depend critically on how the energy consumption is allocated over the useful life of the asset being produced or transported. The Pimentel estimates include values for irrigation and herbicide application, neither of which is reported in the USDA data.

The categories shown in the Pimentel data that are not included in the USDA estimates account for approximately 24 per cent of Pimentel's estimated total energy in corn production, or about 46 per cent of the difference between the two sources. These categories are not included in LCA studies for one of two reasons—either they are considered out of scope (labour and machinery categories) or they are considered to be energy inputs and generate GHG emissions that are insignificant or nearly identical to those required to produce gasoline.

The remainder of the gap depends on different estimates of the same energy inputs. Table 2 shows the inputs listed in Table 1 that appear in both the Pimentel and USDA reports, using the physical units as expressed in the USDA data. This allows us to compare application rates for each input. The table also shows the source used by Pimentel and the date of the estimate.

The categories that show the most significant differences in application rates are, not surprisingly, those categories for which the UDSA is not Pimentel's source (oil products and lime application). In every case, the USDA data are based on more current surveys of farming practices and are therefore considered more useful for analytical purposes.

Table 2
Input Assumptions for Corn Production in the U.S.

Input	Unit	USDA value (2010)	Pimentel and Patzek value (2005)	Pimentel source and timing
Diesel	gallons/acre	5.81	9.41	Wilcke and Chaplain 2000
Gasoline	gallons/acre	1.92	4.28	Estimated—n.d.
Nitrogen	pounds/acre	133.39	136.53	UDSA 2002
Phosphorus	pounds/acre	54.36	58.00	USDA 2002
Potassium	pounds/acre	61.26	68.71	USDA 2002
Lime	pounds/acre	554.36	999.45	Brees 2004
Seeds	pounds/acre	18.29	18.74	Pimentel 1996
Insecticides	pounds/acre	2.00	2.50	USDA 2002
Electricity	kWh/acre	20.41	5.34	UDSA 1991

Sources: Pimentel and Patzek; USDA; The Conference Board of Canada.

On balance, the different responses to the energy balance question for corn production reduce to two primary reasons. First, just over half of the difference is accounted for by different information sources, with the more recent data being based on a survey of farmers and showing lower energy inputs per acre and higher corn yields than the older data. The second source of difference relates to the items that are included in the Pimentel versus USDA work and accounts for just under half of the data difference. Further, the items in question are labour energy, energy required to produce machinery, and energy required to transport energy, fuel, and seed. These categories are difficult to estimate accurately, and reported values need to be viewed with caution.

One final step that the USDA takes and Pimentel does not is to allocate 66 per cent of the energy requirements to the ethanol process and the remainder to the animal feed by-product of ethanol. This allocation is based on the starch content of corn, since it is only the starch that can be extracted for ethanol production using currently commercial technologies. The USDA concludes that the total energy required to produce corn is 9,811 BTUs/gallon of ethanol produced, a ratio of 7.75:1 (based on a lower heating value for ethanol of 76,000 BTUs/gallon).[7]

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Pimentel's numbers are less useful, since the energy consumption data reference coal as the energy source for steam and process heat, whereas current ethanol production uses primarily natural gas. Further, the Illinois Corn Growers Association (ICGA) report cited by Pimentel is no longer online. The more recent ICGA data are cited in Chapter 3 of this report, as are the USDA results.

7 (United States Department of Agriculture 2010, Table 2)

APPENDIX B

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