UNIVERSITÉ LAVAL

Faculté des sciences de l'agriculture et de l'alimentation
Centre de recherche en économie agroalimentaire (CRÉA)

CRÉA
CENTRE DE RECHERCHE EN ÉCONOMIE AGROALIMENTAIRE

Research Series **SR.04.08**

Ethanol Industry in Canada

**Olar M., Romain R.,
Bergeron N. and Klein K.**

The authors are respectively :
Graduate student, CREA, Laval University.
Professor and director of the Centre for research in the Economics of Agrifood (CREA), FSAA, Laval University.
Research Associate, CREA, Laval University.
Professor, Lethbridge University.

The *Cahiers du CRÉA*, ***Research Series,*** aim to disseminate the results of research undertaken by members to the scientific community, industry decision makers and governments. These research results are generally submitted to scientific refereed journals for publication. Readers' comments and suggestions are always greatly appreciated. A list of CRÉA publications is available upon request.

ISBN 2-922378-47-0
Dépôt légal - Bibliothèque nationale du Québec, 2004
Dépôt légal - Bibliothèque nationale du Canada, 2004

Centre for Research in the Economics of Agrifood
Faculté des sciences de l'agriculture et de l'alimentation
Laval University

August 2004

Ethanol Industry in Canada

(ouvrage disponible en anglais seulement)

Abstract

The objective of this paper is to provide an overview of today's situation of the ethanol industry in Canada. It points out the main features characterising production, consumption, trade, price, production cost, feedstock, co-products, ethanol plant feasibility and macroeconomic impacts of the development of this industry in Canada. It also presents the provincial and federal policies sustaining the ethanol industry.

The information provided will serve as starting point for further research such as: investigating the sources of biomass available to increase Canadian production of biofuels, assessing the feasibility of the Canadian government's objectives, identifying potential difficulties in trying to reach the targets.

Table of contents

Introduction

The idea of using ethanol as a motor fuel dates back to the early 1800s. In 1826, Samuel Morey developed an engine that ran on ethanol and turpentine. In 1860, the German engine inventor, Nicholas Otto, used ethanol as the fuel in one of his engines. Moreover, in 1908, Henry Ford produced his Model T. car as a flexible fuel vehicle, running on ethanol, gasoline, or a combination of the two (U.S. Department of Energy 2003). But ethanol did not become the fuel used in automobiles because a new fuel, gasoline, emerged dominant in the early twentieth century. Its lower octane rating suited the materials then available for engine construction. There was also a growing, seemingly unlimited supply of low-cost petroleum from oil field discoveries (Canadian Renewable Fuels Association).

The mid 1970`s were the starting point of a growing ethanol industry in Brazil and the United States of America. These governments started to support the development of the ethanol industry as an alternative to the dramatic *escalation of imported crude oil prices* (Gilmour 1986). Later, *environmental concerns* such as climate change (marked by the Kyoto Protocol adoption in 1997) and pollution due to gasoline octane enhancers (lead, MTT) added themselves to the reasons of public support to the development of the ethanol industry (Gilmour 1986). In the case of Canada, federal support for the ethanol industry started mainly because of climate change commitments (Ethanol Expansion Program is part of the Climate Change Plan for Canada, which was conceived in order to meet the Kyoto Protocol engagements). These days, another important reason for governments to support fuel ethanol is the *overproduction in coarse grains markets*. Finding additional markets for the surplus of coarse grains is viewed as a solution to the dependence on international markets or to the increasing financial support to agriculture.

The objective of this paper is to provide an overview of today's situation of the ethanol industry in Canada. The information provided will serve as starting point for further research such as: investigating the sources of biomass available to increase Canadian production of biofuels, assessing the feasibility of the Canadian government's objectives, identifying potential difficulties in trying to reach the targets.

In order to serve these targets, detailed information is offered on the following three aspects: physical-chemical characteristics of ethanol (Ch. 1: Physico-chemistry), federal and provincial policies and programs for developing the ethanol industry (Ch.2: Policies and programs) and economic data such as production, consumption, plant feasibility etc. (Ch. 3: Economics). The first chapter provides the basic notions about ethanol, the environmental advantages and disadvantages of producing and using fuel ethanol, the impacts this fuel has on cars and some evaluations of its energy value. The second chapter presents the instruments used by the federal and the provincial governments in order to give an impulse to the fuel ethanol industry, such as tax exemptions, financial aids or mandates. Finally, in the Economics chapter the reader finds out the level of past, present and future ethanol production capacities in Canada, the level of ethanol consumption, exports and imports, the main distributors and blenders and their tendency to vertical integration with ethanol plants. This chapter also describes the present and potential feedstocks for ethanol production in Canada and the co-products of dry and wet milling production processes and their impacts on the animal feed industry. Concerning ethanol plant feasibility, this paper issues that there are both a lower and an upper limit capacity for an ethanol plant to be feasible. The lower limit appears because of the impossibility to benefit of the economies of scale while the upper limit is due to the increase in the price of grains generated by the additional demand of grains from the ethanol industry. While the lower limit refers to one single plant, the upper limit refers to the whole ethanol industry from a certain region. Finally, the paper concludes that positive impacts of a development of the ethanol industry are expected in terms of employment, GDP and industrial output.

1. Physico - chemistry

1.1. Ethanol main features

Ethanol or ethyl alcohol (CH_3CH_2OH) is a two-carbon alcohol produced either *chemically* from the hydration of ethylene (a petrochemical feedstock) or *biologically* by the fermentation of carbohydrate materials, such as grains. No chemically produced ethanol is made in Canada since Commercial Alcohols closed its facility in Varennes, QC, in 1991 (Cheminfo Services Inc., (S&T)2 Consultants Inc. and Cemcorp Ltd, 2000).

Based on final use, there are two main categories of biologically obtained ethanol: *fuel ethanol* (anhydrous) and *industrial ethanol* (used in the production of vinegar, food extracts, pharmaceutical products, cosmetics, solvents and beverages). Fuel ethanol is traditionally used as a *gasoline extender* and as an *additive* (oxygenates octane enhancer[1]). Examples of combinations of gasoline and ethanol are the so-called E10 (10% ethanol and 90% gasoline) and E85 (85% ethanol and 15% gasoline). The ethanol blend E10 is called *gasohol*. Two other potential uses of fuel ethanol are i) in *fuel cells* (as fuel on board the vehicle, which is necessary to the formation of hydrogen) and ii) as *diesel extender.* A blend of diesel fuel, ethanol (7.5%) and fuel additives known as *e-diesel* was demonstrated in Winnipeg (Government of Manitoba 2002b).

Both industrial and fuel ethanol can be produced from two main categories of feedstock: grains and cellulose. Ethanol is obtained from grains by fermentation of sugars (starch) and from cellulose by conversion of the cellulose into sugars and their fermentation afterwards. *Grain-based ethanol* is mainly obtained from sugar cane, corn, wheat or barley while the *cellulose-based ethanol* is derived from waste bio-mass (ex: straw) or crops/trees specifically grown as feedstock (ex: switch grass). In Canada, the grain-based production process dominates, representing 92% of the actual production capacity. Research is presently conducted to make the cellulose-based production process economically viable (Iogen Corporation is the main Canadian research centre). Because of its environmentally friendly production process (no fossil fuel is used), cellulose-based ethanol obtained by Iogen Corporation is also called *bioethanol or EcoEthanol*, the latter being the trade mark of Iogen Corporation (Iogen Corporation 2004).

There are two general categories of grain ethanol production: *dry milling* and *wet milling*. In the case of dry milling production process, the most important market value is obtained from ethanol, while in wet milling the co-products (gluten, especially) play an equally important role, their market value being superior to those obtained in dry milling. Because ethanol is obtained from the starch component of a grain and the co-products mainly from the protein component, the feedstock used in dry milling generally has high starch content and low protein content while those used in wet milling have low starch content and high protein content.

The co-products of a dry milling ethanol plant are *carbon dioxide* (CO_2) and *distillers grains* (DG). Distillers grains can be used wet (WDG) or dried (DDG) and are almost exclusively used as an ingredient in animal rations. In large plants (more than 50 million litres per year) the collection and selling of the carbon dioxide can be economical. Two of the co-products of wet milling plants are *gluten* and a *low protein animal feed* (Cheminfo Services Inc. et al. 2000).

[1] Another octane enhancer is lead.

1.2. Environmental impacts of fuel ethanol

Full fuel cycle greenhouse gas (GHG) emissions and *criteria air contaminants* (CAC) *tail pipe emissions* are the main studied issues on the impacts of fuel ethanol on the environment.

Canadian fuel ethanol production and use is expected to reduce *GHG emissions* by displacing gasoline (on a volumetric basis). Calculated on a full fuel cycle basis, these reductions achieve 30 - 40% per litre for grain-based ethanol (3-4% for E-10) and 60 - 80% per litre for cellulose-based ethanol (6-8% for E-10) (Natural Resources Canada 2003). Because lignin and not fossil fuel is used to drive the production process, the cellulose-based EcoEthanol produced by Iogen Corporation diminishes GHG emissions by 90% (Iogen Corporation 2004).

Concerning *CAC emissions*[2], ethanol blended with gasoline diminishes carbon monoxide (CO), hydrocarbons (VOCs), particulates (PM) and sulphur (SOx) and it increases nitrogen oxides (NOx) and aldehyde (VOC) (Cheminfo Services Inc. et al. 2000). Aldehyde emissions are mostly handled by vehicle catalytic converters (Government of Manitoba 2002b). The United States Environmental Protection Agency complex model estimates that total *tailpipe emissions* are reduced by 4,08% when using E10 rather then pure gasoline (Manness, Nicholson and Nicolaou 2002).

Other environmental impacts to be considered are *CAC emissions from ethanol plants* and the *environmental impact of agriculture*. Some U.S. reports signalled that emissions from existing U.S. ethanol plants were exceeding U.S. EPA recommended levels. New emission control technologies, which dramatically reduce plant emissions, are currently being fitted in new and existing U.S. facilities (Manness et al. 2002).

Concerning the environmental impacts of agriculture, Pimentel (1991) contends that U.S. corn production is a *non-renewable* resource and consequently so is the corn ethanol production. His main arguments are: i) soil erosion (18 times faster than speed at which soil can be reformed) and ii) groundwater depletion (25% faster than the recharge rate). Another environmental impact of agriculture to consider but not analysed in the literature revised for this paper is the

[2] The National Pollutant Release Inventory (NPRI) considers as Criteria Air Contaminants (CAC) the pollutants emitted predominantly to the air. There are seven CAC : Total Particulate Matter (TPM), Particulate Matter with a diameter less than 10 microns (PM_{10}), Particulate Matter with a diameter less than 2.5 microns ($PM_{2.5}$), Carbon Monoxide (CO), Nitrogen Oxides (NO_x), Sulphur Oxides (SO_x), and Volatile Organic Compounds (VOC).

environmental risk associated with genetically modified plants being developed for ethanol production.

Notwithstanding Pimentel's concerns, ethanol has received the ECOLOGO designation from Environment Canada (Government of Manitoba 2002a).

1.3. Drivability issues

E10 (10% ethanol, 90% gasoline) and pure gasoline can be used alternatively and this is accepted by all car manufacturers selling vehicles in North America. This practice does not void warranties on vehicles (Government of Manitoba 2002a).

Pure ethanol is a *high-octane fuel* (its octane index is 113) particularly valued for use in high-performance engines. It is an *efficient solvent,* cleaning out impurities in the fuel tank and the fuel line and depositing them in the fuel filter (fuel filters have to be replaced after the first full tank). Ethanol helps prevent winter-related problems by acting as a *gas line antifreeze*. Because of its high oxygen content, ethanol *burns more efficiently* than gasoline (Government of Manitoba 2002a, Manness et al. 2002).

Ethanol is *hygroscopic* (attracts water). The first time gasohol is added to a vehicle tank, performance problems can occur if there is water in the tank (Cheminfo Services Inc. et al. 2000).

Gasoline *energy value* (EV) is on average 1.6 times greater than ethanol energy value ($EV_{gasoline}$[3] = 120,000 Btu[4]/gallon, $EV_{ethanol}$[2] = 76,000 Btu/gallon) (Pimentel 1991). As a result, a greater quantity of ethanol must be used to fuel the cars, but because of the more efficient burn of ethanol, the extra ethanol quantity needed is less than 60% (Manness et al. 2002).

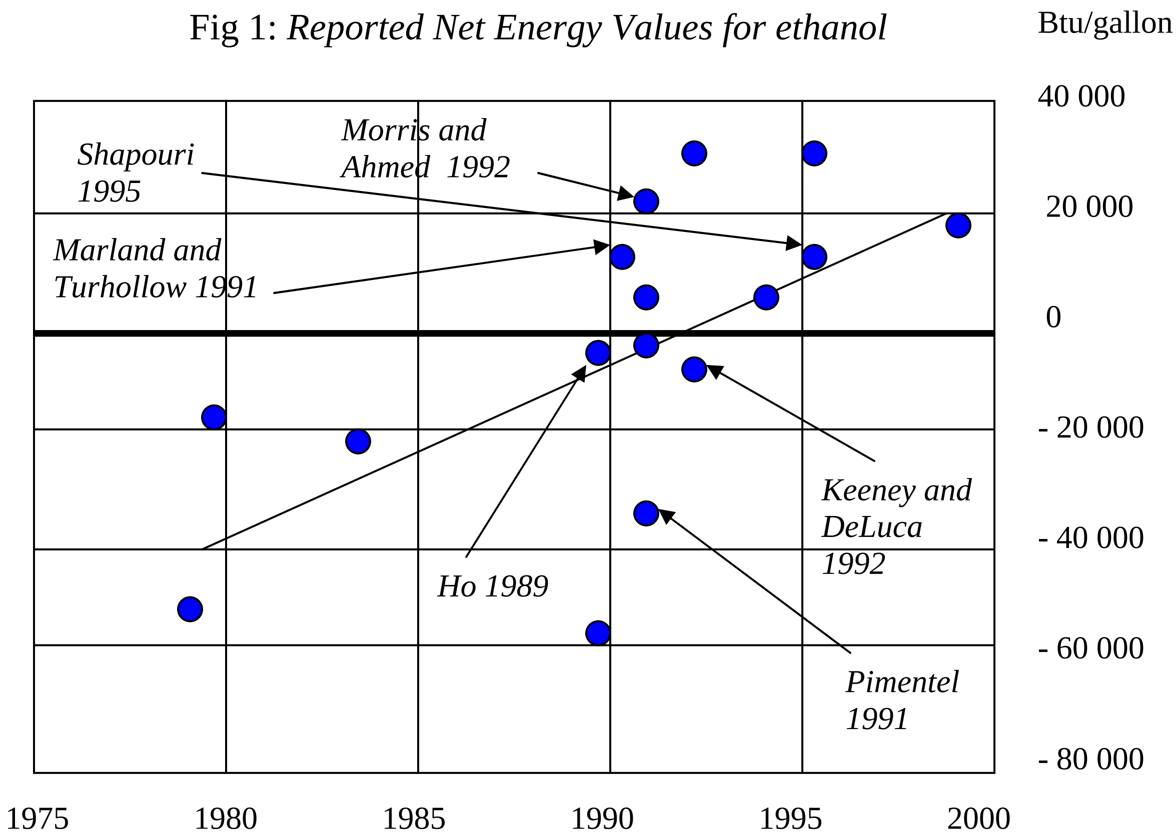
1.4 Net energy value (NEV)

Many studies have been carried out since the 1980's to evaluate the net energy value of ethanol (energy output – energy input). There are important differences in the estimates but the more recent estimates are clearly higher than the earlier ones. Differences are due to several factors

[3] Low heating values.
[4] Btu = British termal unit

such as: the type of heating values considered (LHV[5] vs. HHV), co-products allocation methods, data origins, biases and improvements in ethanol production technology (Lavigne 2001). The different NEV estimations are presented in Fig. 1 :

Fig 1: *Reported Net Energy Values for ethanol*



Source: Lavigne 2001; Shapouri, Duffield and Graboski 1995.

Shapouri, Duffield and Graboski (1995) identified the main factors that determined the net energy values calculated by other researchers to be different of their own evaluation. Thus, the 9460 Btu/gal more net energy value obtained by Morris and Ahmed (1992) is mainly due to the large value they use for co-product energy credits. They are the only authors to use CO_2 as an energy co-product, which adds 4,460 Btu/gal to their NEV. Shapouri et al. (1995) did not include CO_2 in their analysis because they did not have information on how many modern facilities are selling CO_2. On the contrary, the Keeney and DeLuca study reported a negative NEV and that because they used a very low value for energy co-products. The negative NEV value reported by

[5] LHV = Low Heating Value, HHV = High Heating Value

Ho (1989) is generated by an unusually low corn yield of 90 bushels per acre (5658 kg/ha[6]), which represents only the poor years of the 1975 – 1994 period (in U.S.). Finally, Pimentel estimated a NEV which is about 36,000 Btu lower then the average NEV estimated by the six studies. This difference is explained by many factors. For example, Pimentel used the lowest corn yield after Ho. He used the highest fertilizer application rate and the lowest corn ethanol conversion rate. The amount of energy required for ethanol conversion also appears outdated. In addition, he is the only author to include an energy value for steel, cement and other plant materials in the ethanol-processing estimate.

2. Policies and programs

2.1. Federal government

The federal government in Canada sustains the development of the fuel ethanol industry through two main instruments: *an excise gasoline tax exemption* and *an Ethanol Expansion Progra*m (EEP). Beside these two important initiatives, the federal government gives example by its eight E85 (85 percent ethanol) fuelling stations and approximately 800 flexi-fuel vehicles, which can use up to 85 percent ethanol (Government of Canada 2003a).

The *federal excise gasoline tax* of 10 ¢/l is not imposed on the portion of ethanol contained in gasohol, but there is no guarantee on how long this exemption will last. The U.S. government provides an equivalent incentive of $0.23 CDN per litre, almost two times and a half greater than that of the Canadian government. The ethanol industry in the U.S. credits this incentive as being integral to the establishment of an ethanol industry in the U.S. A low federal incentive inhibits inter-provincial trade (Manness et al. 2002). One explanation could be the fact that a low federal incentive lives place for provincial incentives, which generally are heterogeneous (different amounts and periods of tax exemptions). Canadian fuel ethanol exports are eligible for the US federal excise tax exemption or the federal blenders income tax credit, the federal tax credit for pure alcohol fuels and some state road tax exemptions. US fuel ethanol exports, as well as any other country's exports, are eligible for the Canadian federal excise tax exemption on ethanol-

[6] We used the transformation rates 1 bushel of corn = 56 lbs (Prairie Grains Magazine, June 2003), 1 kg = 2.2 lb and 1 ha = 2.47 acres.

blended fuels. The U.S. fuel ethanol exports are also eligible for some provincial excise tax exemptions (Government of Manitoba 2002b).

The Ethanol Expansion Program is part of the Climate Change Plan for Canada, which was created to meet the targets of the Kyoto Protocol[7]. This protocol calls for the reduction of GHG emissions, during the 2008 – 2012 period, to 94% of their 1990 level. The development of the ethanol industry in a specific country is usually motivated by one of the following two reasons: *energy independence* or *environmental concerns*. Canada initiated its federal ethanol programs in response to environmental lobbying.

The Ethanol Expansion Program[8] has a *national mandate* for fuel ethanol consumption in Canada: at least 35% of the Canadian consumption of gasoline must be E10 (10% ethanol and 90% gasoline) by 2010 (mid-point of the 2008 –2012 period targeted by the Kyoto Protocol). In order to achieve this target, estimations are for increasing ethanol production to 1.33 billion litres per year by 2010 (from the existing 0.238 billion litres) (Canadian Renewable Fuels Association December 2002). It is estimated that the associated GHG reductions will be of 2.8 mega tonnes /year compared to the Business-As-Usual (BAU) scenario (Government of Canada 2003b).

The Ethanol Expansion Program provides support on three fronts: *contingent loan guarantees* ($140 million), *public awareness financing* (provides market information to consumers) ($3 million) and *the financing of fuel ethanol production facilities* ($100 million).

The *contingent loan guarantee* program was created under the name of National Biomass Ethanol Program. Its purpose is to counter the reduction or elimination of the excise tax exemption that could affect the viability of new ethanol plants. The program will come into effect if these changes are imposed prior to December 31, 2014 (Farm Credit Canada 2003). In order to qualify for the loan guarantee, manufacturers would have to experience a reduction in cash flow due to a change in the excise tax treatment. Loans would be made directly to lenders in order for ethanol manufacturers to be able to restructure their long-term debts. The contingent loans would be repayable at commercial rates of interest (Government of Canada 2001b).

In addition to loan guarantees, the program adds $3 million over 5 years for a *public outreach component.* Its aim is to provide essential market information to consumers through such

[7] The Kyoto Protocol was signed by Canada on 1998/04/29 but was ratified four years later: 2002/12/17.

[8] The Ethanol Expansion Program includes the Future Fuels Initiative program, which includes the National Biomass Ethanol Program.

activities as public education on fuel ethanol, *analysis* of fuel ethanol markets and producer economics and liaison with provinces and industries interested in ethanol plant expansion (Government of Canada 2001a). The preceding two incentives are expected to reduce GHG emissions by 0,8 Mt CO_2 equivalent/year as compared to the business-as-usual scenario (BAU).

The *contributions for fuel ethanol production capacities* are offered in two rounds of funding, for a total of $100 million over 3 years ($78 million were attributed in the 1st round). The maximum amount payable to any applicant in all rounds of the program is $50 million and cannot represent more than 50% of the total project costs minus other federal, provincial/territorial and municipal governmental contributions. The eligibility criteria include a minimum new or expanded production capacity of 10 millions litres per year and the condition to start production at most 30 months after signing the contribution agreement. Contributions are repayable. Repayments must start 3 years after the date of the final contribution payment and must end 10 years after the date of the final contribution payment (Government of Canada 2003b). The third type of intervention is expected to reduce GHG emissions by 0,9 Mt CO_2 equivalent/year with respect to the BAU scenario.

The total amount invested by the Government of Canada in the ethanol industry is $243 million (100 + 140 + 3), which represents 9% of the $2,700 million invested in climate change over the past 5 years (including the recent allocation of $1 billion) (Government of Canada 2003c). On the other hand, the direct GHG reduction expected from the ethanol industry, 1.7 Mt/year (0.8 + 0.9), represents only 0.7 **%** of the total 240Mt annual reduction needed to meet the targets of the Kyoto Protocol. An immediate question one could raise is: why did the government invest so much in ethanol (9% of the total GHG reduction investments) if this industry contributes so little to GHG reduction (0.7% of all GHG reductions)? Two answers are to be explored: i) GHG reduction was not the unique objective pursued by the federal government when investing into the ethanol industry and ii) the ethanol industry is expected to contribute to the GHG reduction much more on the long term (after 2010) than on the short term.

2.2. Provinces

Provincial policies over fuel ethanol are mainly driven by the specificities of their economies. The governments of Manitoba and Saskatchewan have a conciliatory ethanol expansion policy since they consider expansion of ethanol use as a potential boost for their rural economy. The government of Alberta does not encourage ethanol expansion because of the importance of its oil industry. British Columbia and New Brunswick are analyzing the commercial feasibility of the cellulose-based ethanol production technology; the former because of its forest residues and the latter because of an agricultural base which is not sufficiently large to support an ethanol plant of the scale necessary for economic viability (Government of New Brunswick). Ontario and Quebec have more or less neutral positions, their grain supply and demand being equilibrated. Table 1 shows the *provincial fuel tax exemptions* for fuel ethanol per province:

Table 1: *Tax Exemptions for Fuel Ethanol per Province*

Province	**Provincial Fuel Tax Exemptions for Ethanol** (¢/litre)	**Eligibility for the subsidy**	**Duration**
Alberta	9	No restriction on ethanol source.	5 years after the start-up of an ethanol production plant.
British Columbia	14.5	For E85 to E100 and E5 to E25. Ethanol must be produced in BC.	
Ontario	14.7	No restriction on ethanol source.	Until 2010.
Saskatchewan	15	Ethanol must be produced and consumed in SK.	5 years.
Quebec (under project)	up to 20 (up to 130% of the 15.2 ¢/litre gasoline tax)	Ethanol must be produced in QC.	1999 - 2012
Manitoba	20, until August 2007 15, Sept. 2007 – Aug. 2010 10, Sept. 2010 – Aug. 2013 (in addition, *1.5* ¢/l excise tax reduction for the gasoline blended with 10% Manitoba-made ethanol)	Ethanol must be produced and consumed in MB.	No duration specification.
Federal	10	-	No duration specification.

Source: Cheminfo Services Inc. et al. 2000, Government of Manitoba 2002b, 2003b, Government of Quebec 1996 and 1997, British Columbia Ministry of Provincial Revenue 2004.

The *heterogeneity of the provincial tax exemptions* (amounts, eligibility and duration) represents an important barrier to inter-provincial trade. For example, Alberta's unique ethanol plant exports almost all its production to the U.S. because it does not have access to the Saskatchewan market; Saskatchewan's tax exemption applies only to locally produced ethanol. On the other hand, Saskatchewan ethanol producers can sell their production in Alberta where the tax exemption does not impose any restriction on the source of the ethanol.

Mandates are regulated in Manitoba (E10 to represent 85% of total gasoline consumption in Manitoba by 2005) and Saskatchewan (fuel volumes to contain 7.5% by 2005). Ontario also intends to impose a mandate; all gasoline sold in Ontario is to contain 5% ethanol by 2007, and 10% ethanol by 2010.

Saskatchewan and Ontario are the only provinces offering *financial aids* to investors. The government of Saskatchewan is planning to finance 40% of the plant investment for three projected 80 million litres/year capacities. During the 1991-1993 period it also offered a 40 cents/l subsidy to the Lanigan plant. The Ontario government financed the Commercial Alcohols plant from Chatam with $5 million.

2.2.1. Alberta

The Alberta Ministry of Agriculture, Food and Rural Development has had an "ethanol policy" since 1993. The policy *guarantees* that the exemption of provincial fuel tax payable on vehicle fuel will continue for a period of 5 years after the start-up of an ethanol production plant. The exemption is currently *9 ¢/litre* of ethanol sold in the province. A revision of the policy was considered in 2000 but no modifications were finally made (Cheminfo Services Inc. et al. 2000).

2.2.2. Ontario

Since 1980, Ontario has provided an exemption from its *road and usage tax on gasoline* for the ethanol portion of ethanol-blended fuels sold in the province. The current value of the exemption is 14.7 cents per litre of ethanol (Seaway Valley Farmers Energy Co-operative Inc.).

In October of 1994, it was announced that the province were to enter into project-specific agreements ("Ontario Ethanol Manufacturers' Agreement") with ethanol producers that used renewable feedstock. This *guarantees* that the financial benefit of the 14.7 cent exemption to producers will remain until 2010, even if the tax structure is changed by administrative or legislative action in the interim (Seaway Valley Farmers Energy Co-operative Inc.).

Two other governmental initiatives for sustaining the domestic ethanol industry are the *$5 million grant* to Commercial Alcohols Inc. for building its Chatham plant and the use of ethanol blends in the governmental vehicle fleets (Government of Ontario 2002).

Concerning mandates, both Liberal and Progressive Conservative parties have announced intentions to *mandate* the use of ethanol-blended gasoline, requiring that all Ontario-sold gasoline contain 5% ethanol by 2007 and 10% ethanol by 2010 (Ontario Corn Producers' Association 2003a). On the other hand, Ontario Corn Producers' Association 2003a states that the provincial government doesn't have initiatives to build Ontario's domestic supply.

2.2.3. Saskatchewan

From 1991 to 1993 the government of Saskatchewan subsidised the Lanigan ethanol plant owned by Pound-Maker Agventures Ltd. at the level of 40 cents per litre (Freeze and Peters 1999). The Saskatchewan government's ethanol policy was changed in the March 2000 budget. The province reinstated an exemption of 15 ¢/litre for ethanol blended with gasoline (such an exemption had existed in the early 1990s, but was phased out in the 1994/95 period). The term of the policy is believed to be 5 years, although this is not confirmed (Cheminfo Services Inc. et al. 2000).

The Saskatchewan government announced in March 2002 a plan to develop an ethanol industry (Government of Saskatchewan 2002a).. The plan is called Greenprint for Ethanol Production in Saskatchewan (Government of Saskatchewan 2002b). One component of the plan is the Ethanol Fuel Act established in 2002 and modified in 2004. This act sets a *mandate* imposing that fuel volumes contain 2% ethanol by May 1, 2005 and 7.5% ethanol by November 1st, 2005 (Government of Saskatchewan 2004). A second part of the plan is the obligation for distributors to buy at least 30% of their ethanol from plants that produce 25 million litres per year or less (Briere 2002). The regulation *promotes producer-owned facilities* (apparently because of financing; local communities have more difficulties in finding the necessary money for such investments, even if interested) (Briere 2002).

The government intended to build three $55 m, 80 million litres/year ethanol plants along with Broe Companies of Denver. It was announced that the publicly owned Crown Investments Corp would invest 40% of the cost and Broe Companies the remaining 60%. If there are interested local communities investors, the government intends to sell them part of its 40% share but intends to keep a minimum of 15% (Briere 2002). However, none of the three (3) plants has been built yet because Broe has had difficulty securing its financing. The government and community proponents indicated they expect further developments shortly after the Nov. 6, 2003 provincial election (Briere 2002).

2.2.4. Quebec

There is no fuel ethanol plant for the moment in Quebec, the one in Temiscaming producing only industrial ethanol. But in the very near future a fuel ethanol plant will be built in Varennes, using the federal financial support offered through the Ethanol Expansion Program.

The tax policy for sustaining ethanol industry in Quebec is not yet established. The Fuel Tax Act, article 2, paragraph 5, states that ”in the case of the acquisition of a mixture of gasoline and ethanol, the tax [of $0.152 per litre for gasoline] is reduced in the manner and on the terms and conditions prescribed by regulation”. The Ministry of Finance of Quebec confirmed that regulation establishing the exact terms of fuel tax reduction for ethanol has never been ratified, even if some projects have been made. Thus, the Minister of Finance announced in December 12, 1996 that the reduction in the fuel tax for ethanol could reach 130% of the tax (Government of Quebec 1996). One reason for such a high tax exemption is the competition with the ethanol produced in Ontario. While Quebec applies the provincial sales tax (QST) to fuels too, Ontario does not. This creates a price advantage for the ethanol produced in Ontario and the 130% fuel tax exemption projected for ethanol produced in Quebec tries to eliminate the difference. One year after the announcement of the projected fuel tax exemption, it was also made public the period during which it was guaranteed: January 1st, 1999 – March 31, 2012 (Government of Quebec 1997). But all these announcements were contingent to the construction of ethanol plant in Varennes. Because the construction delayed, ratification of precise regulation concerning the reduction of fuel tax for ethanol was deferred (Government of Quebec 1998). With the new funds obtained from the federal government, the ethanol plant in Varennes should soon start construction and consequently, the tax policy for ethanol in Quebec should clarify.

Quebec doesn't consider a mandatory ethanol composition of its gasoline but is willing to respect the federal mandate of 35% of all gasoline to be E10 until 2010. To reach this objective, 280 million litres of ethanol are needed for the 8 billion litres of gasoline estimated to be consumed in 2010. Jean-Pierre Dubuc, vice-president of the Federation of Commercial Crops Producers of Quebec, estimates that it is possible to double corn production without increasing the cultivated land, due to technology improvements (Coopérative Fédérée de Québec 2004). On the other hand, the Government of Quebec sees an increase in corn production as an automatic increase in the land cultivated: "the corn used [for the plant in Varennes] will mainly come from the surplus of corn already produced rather than from increasing the cultivated areas" (Government of Quebec 1997). What is sure is that the corn needed for producing the 280 million litres per year (710,000 tonnes[9]) overpasses the surplus Quebec has in corn production (around 570,000 tonnes per year (Government of Quebec 1998)). The question is: where will the difference come from? Increasing yield of corn, more corn cultivated land, additional corn imports or other feedstock (wheat, barley, Jerusalem artichoke or agricultural waste)?

Because Quebec imports all its oil (Coopérative Fédérée de Québec 2004), partial replacement of gasoline by locally produced ethanol could have important advantages for its economy.

2.2.5. Manitoba

Manitoba has no oil refineries. Therefore it must import all of its gasoline (Manness et al. 2002). In December 2003, the Government of Manitoba passed The Biofuels and Gasoline Tax Amendment Act. The Act establishes a mandate for ethanol use in the province such that 85% of all gasoline sold must contain 10% ethanol by September 2005. The Act also outlines a gasoline tax reduction for gasohol (E10) of $0.02 per litre of gasohol until August 31, 2007, reduced to $0.015 per litre of gasohol for the next three years and to $0.01 per litre of gasohol for the following three years (Government of Manitoba 2003b). As in the case of Saskatchewan, the

[9] We used the data in Appendix 3 for the plant in Varennes (12 million bushels of corn/year for 125 million litres of ethanol) and the transformation rates 1 bushel of corn = 56 lbs (Prairie Grains Magazine, June 2003) and 1 kg = 2.2 lb.

Manitoba subsidy is available only for the ethanol produced and consumed in the province. As a result, an ethanol producer in Manitoba that is not engaged in the distribution or retail of gasohol does not qualify for the tax preference (Manness et al. 2002). The Manitoba ethanol program also provides a declining tax preference averaging approximately $0.015/litre of gasoline that is blended with 10% Manitoba-made ethanol. This component of the program is scheduled to end in 2013 (Government of Manitoba 2003a).

Despite having the most generous incentive in the industry, the Manitoba ethanol industry has not changed for over two decades. However, the government of Manitoba states that since the announcement of an ethanol mandate in the 2002 Budget, there has been renewed interest by the oil industry and ethanol producers from across North America in building ethanol plants in Manitoba (Manness et al. 2002).

3. Economics

3.1. Alternative transportation fuels

The *1970's oil price increase* prompted research for alternative transportation fuels. At a seminar held in Calgary, Alberta, in 1981, by the Canadian Energy Research Institute (CERI), six alternative transportation fuels were considered: *propane*, *compressed natural gas (CNG)*, *methanol*, *liquefied coal*, *ethanol* and *hydrogen*. Propane and CNG are considered short-term alternatives for Canada (available quantities, distribution systems already in place and low cost compared to gasoline) while methanol and liquefied coal are medium-term alternatives (available quantities but slowly higher cost compared to gasoline). As shown in Appendix 1, propane represented indeed the most widely used alternative fuel in 1995 in Alberta, with 3.9% of total fuel consumption. But projections show its use will diminish by 2010 (0.4%) in favour of increased use of diesel (55% as compared to the 46% in 1995) and of 'other fuels' (0.6%, respectively 0.1%).

Ethanol is seen too expensive and hydrogen uncertain technologically for their expansion to be expected to grow (Canadian Energy Research Institute 1981). In order to reduce the cost of ethanol production, a seminar participant proposes research on use of Jerusalem Artichoke as feedstock (which would yield 4,700 litres of ethanol per ha compared to 1,220 for barley and

2,250 for corn under irrigation). A study from 1990 (Baker, Thomassin, Henning) contradicts the idea of Jerusalem Artichoke being a less costly feedstock for ethanol. This study concludes that the costs of producing ethanol from Jerusalem Artichoke is higher than the cost of producing ethanol from corn as well in Quebec as in Western Canada. This conclusion is true for demonstrated farm level yields (41 tonnes of JA tops/ha in Quebec and 80 tonnes/ha in Western Canada) and conservative conversion rates (90 -110 litres/tonne of JA tops). If these parameters were slightly increased, Western Canada could become a less costly ethanol producer if it used JA tops instead of corn. In the case of Quebec, the increase in these parameters should be more important for JA to compete corn in ethanol production.

3.2. Global ethanol market

The market leader in the international ethanol market is currently *Brazil* with a 14 billion per year production capacity and more than 300 plants (Le Soleil, August 13, 2003). Brazil is also the largest consumer of ethanol: 3 million vehicles a day run on pure ethanol (Briere 2003). The main feedstock used in the production process is sugarcane. The government supported the development of its ethanol industry in the 1970's in order to avoid oil dependency. "From 1990's, the Brazilian ethanol industry is no more subsidised" (Luiz Carlos Correa Carvahlo, director of Canaplan, Brazil).

The *United States* is the second most important ethanol producer and consumer with 10 billion litres per year production capacity, 73 operating plants and 14 plants under construction (Briere 2003). The U.S. intends to increase its ethanol production to 19 billions litres in 2010 (Coopérative Fédérée de Québec, 2004). Ethanol-blended fuels account for 12% of all automotive fuels sold in the United States (Government of Manitoba 2002a). The main feedstock used in the production process is corn and it is estimated that by 2008, 20% of all U.S. corn production is going to be used in the production of ethanol (Briere 2003). At present, 11% of all corn produced in the U.S. is transformed into ethanol (Coopérative Fédérée de Québec, 2004). Oil independency was the first motivation of the U.S. ethanol expansion.

At present, the U.S. government offers an incentive of 1.37 US cents/litre for ten percent or higher ethanol blends sold (E10 to E100) (5.2 US cents/gallon). The incentive for ethanol blends, which is guaranteed until 2007, will change as of 2005 to 1.34 US cents/litre (5.1 US cents/gallon). The US government also offers a parallel income tax credit which allows fuel marketers using ethanol to claim a federal income tax credit in the amount of 13.7 US cents/litre of ethanol used (52 US cents/gallon of ethanol used). But since the amount of income tax credit claimed under this provision must be reduced by any amount of excise tax reduction taken, distributors of ethanol-blended gasoline normally take advantage of the more straightforward and immediate excise tax incentive in lieu of the income tax credit. The income tax credit offers advantages to E85 (85% ethanol blend) suppliers, which receive 13.7 US cents/litre of ethanol used instead of the 1.6 US cents/litre (1.37 * 100/85) of ethanol sold offered by the total excise tax reduction. The greater complexity, longer timetable, and extra requirements for claiming the income tax credit reduce the value and attractiveness of this credit versus the excise tax option. The result is a much stronger overall federal tax incentive for marketing ethanol in gasoline blends of up to ten percent than for marketing of higher ethanol-containing fuels such as E85. (MacDonald et al. 2004).

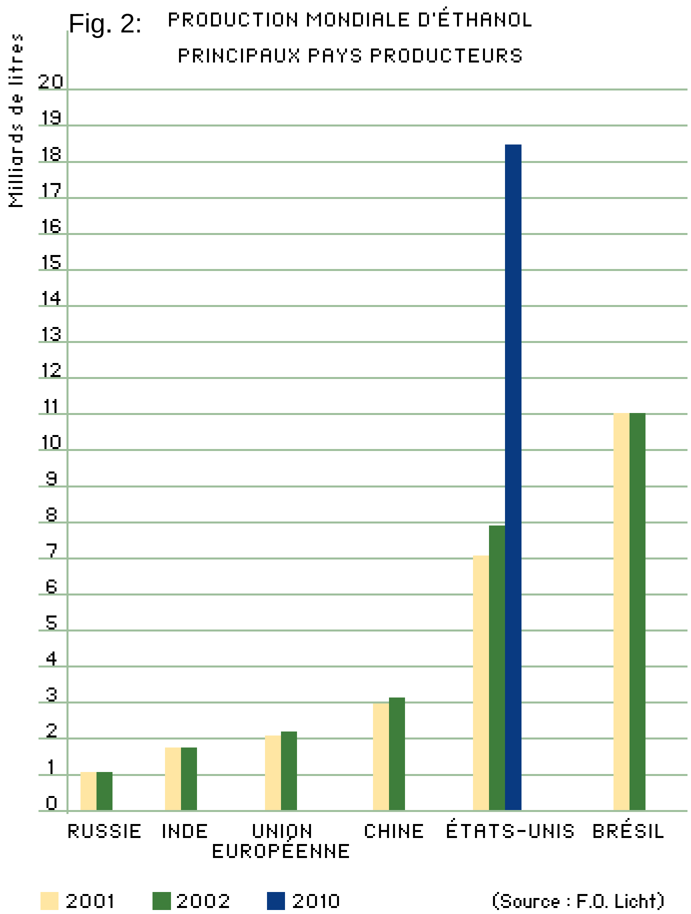
The states also offer important incentives for ethanol. Thus, from the 50 states, 22 have incentives supporting ethanol production ranging from 1.3 US cents/litre (5 US cents/gallon) to 7.9 US cents/litre (30 US cents/gallon) and 32 have incentives supporting applications of ethanol as fuel (MacDonald et al. 2004).

The U.S. imposes an important tariff against ethanol from Brazil of 52 US cents/litre. This tax is due to the fact that Brazilian ethanol, obtained from sugarcane, costs 50% less to produce than American ethanol (Coopérative Fédérée de Québec 2004).

China is the third world producer of ethanol and the largest in Asia with more than 3 billion litres per year capacity, followed by *India* with about 2.7 billion litres of capacity (Cheminfo Services Inc. et al. 2000).

Western Europe has a 2 billion litres per year production capacity but only 5% is fuel ethanol, the rest being industrial ethanol (Cheminfo Services Inc. et al. 2000). Production in Eastern Europe is dominated by the Russian Federation, which has an estimated capacity of 2,5 billion litres/year but with only 1 billion litres of fuel ethanol (Cheminfo Services Inc. et al. 2000).

Fig. 2:



Source: Coopérative Fédérée de Québec 2004

Canada plays a minor role on the international ethanol market with its current 0.24 billion litres/year production capacity. But the federal Ethanol Expansion Program (EEP) recently financed another 0.74 billion litres/year capacities (see Appendix 3) so that Canada's ethanol production capacity will reach 1 billion litres/year in the near future. Canada's main ethanol feedstock is corn with 73% of the current production capacity and 58% of the current plus EEP financed plants. The second is wheat with 17% of the current production capacity and 39% of the current plus EEP financed plants. The main motivation of Canada's Ethanol Expansion Program is climate change concerns, more precisely the ratification of the Kyoto Protocol.

The following table shows that, with ethanol plants financed by the Ethanol Expansion Program included, more ethanol per litre of gasoline consumed can be produced in Canada than in the U.S. for 1 litre of gasoline consumed (0.026 and 0.022, respectively). The quantity of grains needed to produce this ethanol in Canada represented 6% of total cereal production in 2001. The

U.S. would have had to use more of their cereal production (8%) had their entire ethanol capacities been used.

Table 2: *Ethanol Capacities and Motor Gasoline Consumption in 2001*

		Unit of measure	**Canada**	**United States**	**Brazil**
1	Motor gasoline consumption in 2001	Millions of litres	36,902	464,277	16,388
2	Ethanol production capacities in 2003	Millions of litres	238	10,000	14,000
3	Ethanol production capacities with EEP financed plants included	Millions of litres	977	-	-
4	Ratio: x litres of ethanol : 1 litre of motor gasoline	-	0.006 : 1	**0.022 : 1**	**0.85 : 1**
5	Ratio: x litres of ethanol : 1 litre of motor gasoline (EEP financed plants included)	-	**0.026 : 1**	-	-
6	Cereals production in 2001	Millions of tonnes	43.3	325.5	-
7	Cereals needed for ethanol production[10] (EEP included for Canada)	Millions of tonnes	2.6	26.8	-
8	Ratio: cereals for ethanol / total cereals produced	%	6%	8%	-

Source: World Resources Institute 2003a,b, Appendices 2 and 3

[10] We used the conversion rate of 2.68 kg of cereals/litre of ethanol. This was used by Groupe RLD inc. 1998 for ethanol from corn but it is very similar for wheat.

3.3. Fuel ethanol production capacity

Total ethanol production capacity in Canada is 238 million litres per year. Fuel ethanol is the major product with 67% of total capacity while industrial ethanol constitutes the remaining 33% (see Appendix 2). Fuel ethanol is produced in 5 of the 6 existing plants and by 4 of the 5 producers. Production is concentrated in south-eastern Ontario (72%) where Commercial Alcohols holds two plants: a 150 million litres/year production capacity at Chatham and a 22 million litres/year at Tiverton (fuel ethanol represents 65% of total ethanol production of both plants).

The plant in Minnedosa, Manitoba, owned by Husky Energy Inc., was the first Canadian plant to produce fuel ethanol (Agriculture and Agri-Food Canada 2001). This plant started its operations in 1980 with 4 of the current 10 million litres/year capacity. During the 1976 – 1990 period, four other ethanol plants were operating for a total production capacity of 92 million litres/year, but they were producing industrial ethanol only (see Table 3). The most important of the four plants, Commercial Alcohols' Varennes plant (Quebec), will be reconverted to produce fuel ethanol (the plant ceased its production in 1991 after 2 decades of production; it obtained industrial ethanol through chemical procedures). The Ethanol Expansion Program will finance 18 of the total $105 million needed for reconverting the plant. Its capacity will be increased from 70 to 126 million litres/year.

Table 3: *Canadian Ethanol Plant Capacities during the 1976 – 2000 period*

(million litres/year)

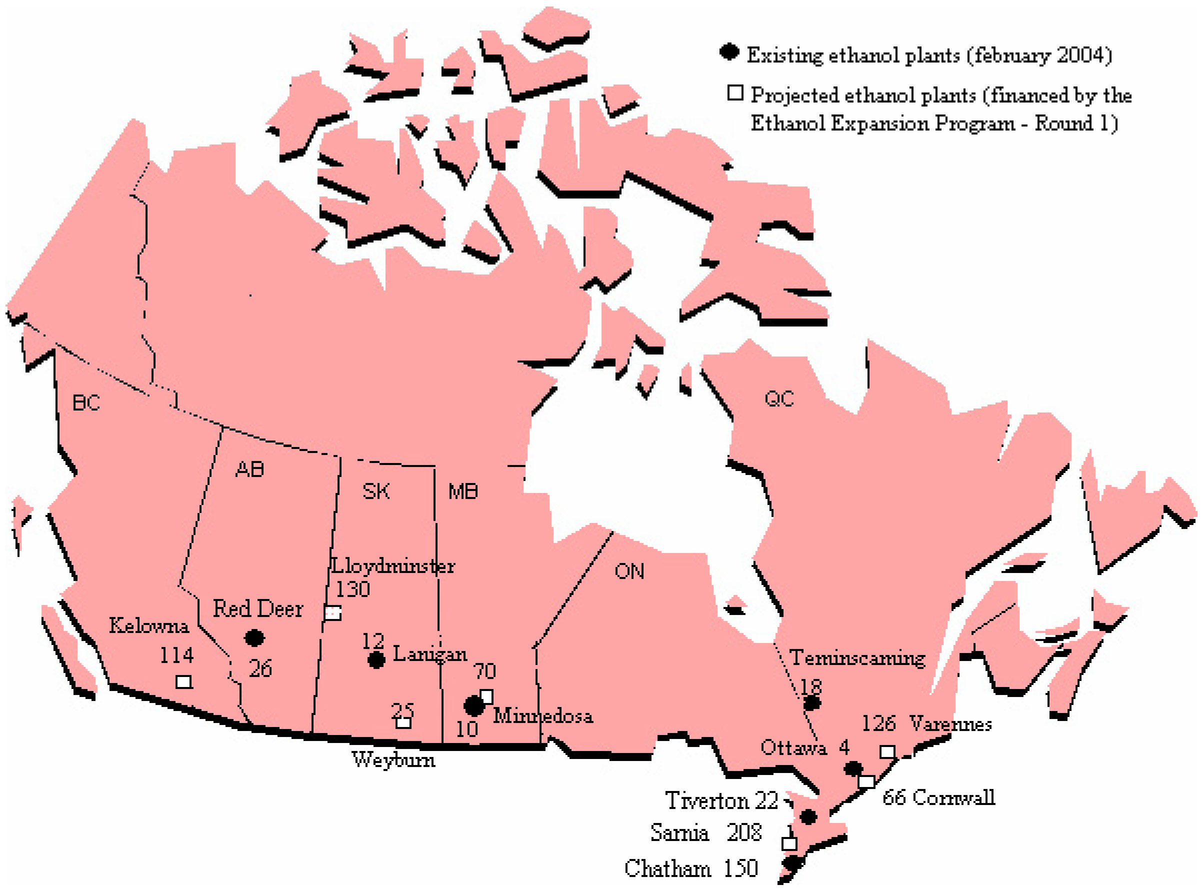
Company	**Location**	**1976**	**1980**	**1990**	**1995**	**2000**
Ontario Paper	Thorold, ON	4	4			
St Lawrence Starch	Mississauga, ON	15	15			
Commercial Alcohols	Varennes, QC	70	70	70		
North West	Kerrobert, SK		3	3		
Mohawk Oil	Minnedosa, MB		4	9	10	10
Commercial Alcohols	Tiverton, ON			12	22	22
Tembec Enterprises	Temiscaming, QC			18	18	18
Pound-Maker Agventures	Lanigan, SK				10	12
API Grain Processing	Red Deer, AB					26
Commercial Alcohols	Chatham, ON					150
Total		89	96	112	60	238

Source: Cheminfo Services Inc. et al. 2000

The Ethanol Expansion Program (EEP) will finance six other plants. The total production capacity financed by the EEP will amount to 739 ml/year and the average production capacity will be of 106 million litres/year. Both total and average production capacities represent important increases with respect to existing capacities, which are of 238 million litres/year (total) and 40 million litres/year (average), respectively. Figure 3 shows the location and the capacity of existing and EEP financed ethanol plants.

Fig. 3: *Existing and Projected Ethanol Plants*

- production capacities in million litres/year -

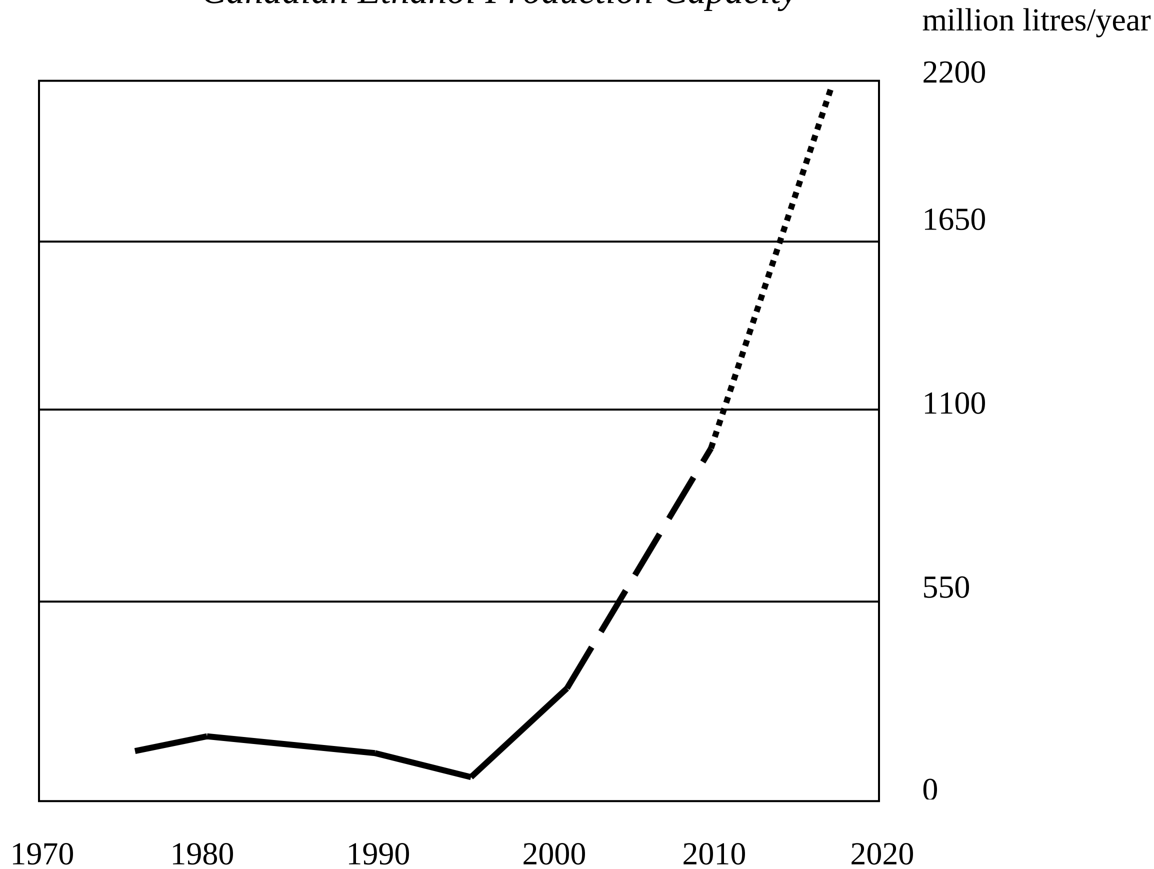


Information is available for 19 other projected ethanol plants for a 1,200 ml/year total production capacity and a 63 ml/year average capacity. Part of these plants are to be sustained financially by provincial governments. For example, the Saskatchewan government announced in 2002 its intention to finance 40% of the construction cost of three 80 ml/year plants located in the province. As of November 2003, this intention had not concretised (Briere 2003).

The diagram in Figure 4 shows the evolution of Canadian ethanol supply from 1976 to present (continued line), and the projected supply for the next 10-20 years (based on EEP financed plants and on information about the capacities of other projected plants). The diagram shows that ethanol production capacities in Canada increased substantially from the mid 90's to present and that this increase will continue exponentially until 2020 due to the construction of plants financed by the Ethanol Expansion Program (dashed line) and to other projected ethanol capacities (dotted line).

Fig. 4: *Existing and Projected*

Canadian Ethanol Production Capacity



Source: Cheminfo Services Inc. et al. 2000, Government of Canada 2004, Appendices 3 and 4

The need for public financing is due to the fact that banks do not believe in the profitability of this industry in the absence of tax exemptions (federal and provincial) and tax exemptions are not harmonized nor guaranteed for a sufficiently long period of time. For example, the federal tax exemption has no duration specification even if the contingent loan guarantee, as part of the Ethanol Expansion Program, offers some financial help if the federal 10 ¢/l gasoline excises tax exemption is eliminated until December 2010. On the other hand, Alberta and Saskatchewan guarantee a 5 year tax exemption period after the start-up of an ethanol plant while Ontario assures it until 2010, Quebec until 2012 and Manitoba has no duration specification (see Table 1). Ethanol stakeholders and potential investors require *longer (8 to 10 years) periods* of guaranteed tax exemptions and *harmonized incentives* (Cheminfo Services Inc. et al. 2000).

Given the high costs of production and the availability of cheaper fuels, ethanol supply is very sensitive to governmental regulations and public funding. Its development is likely to be highly dependent on technology improvements that reduce production costs and increase environmental benefits, as well as on the manifestation of environmental constraints such as climate change or town smog.

3.4. Ethanol demand

Demand for ethanol in North America is concentrated in the *eastern* half of the continent. Demand in the western Canadian provinces, U.S. Pacific Northwest and California constitutes less than 10% of the North American total (Cheminfo Services Inc. et al. 2000). Demand for fuel ethanol averages around *240 million litres* in 2003, representing under *0.7%* of gasoline-type fuels (gasoline and ethanol-blended gasoline) sold in Canada (Natural Resources Canada 2003). Compared to the *3.5%* that was targeted under the Climate Change Plan, the relative part of the fuel ethanol demand in total gasoline-type fuels demand should *increase to 5 times* its present level by 2010 (from 0.7% to 3.5%).

The following table shows the evolution of Canadian ethanol demand during the 1970 – 2000 period:

Table 4: *Canadian Ethanol Demand*

(million litres)

	1976	**1981**	**1990**	**1993**	**1999**
Fuel ethanol	0	4	11	24	150
Industrial ethanol	34	39	34	38	40
Total domestic demand	**34**	**43**	**45**	**62**	**190**

Source: Cheminfo Services Inc. et al. 2000

The substantial jump in Canadian demand for ethanol in the 1998-1999 period (from 62 to 190 ml) was largely a result of Sunoco's decision to blend the oxygenate into the gasoline it retailed in Ontario. Use of ethanol for fuel in the rest of Canada as well as other applications have been growing more slowly (Cheminfo Services Inc. et al. 2000).

Ontario has the largest fuel ethanol demand of all provinces. In the last decade its demand has been multiplied 33-fold and in the last 5 years it has surged 352% (Ontario Corn Producers'

Association 2003c). According to Ontario Corn Producers' Association (2003b, c), Ontario's ethanol demand overpasses 300 ml/yr[11], which cannot be true considering the 240 ml total Canadian demand in 2003. Considering the demand from the other provinces (detailed in the next paragraph), Ontario demand could not overpass 220 ml (240 - 20), still remaining the main ethanol consumer in Canada.

Current estimates of the demand for ethanol to be blended with gasoline are about 5 million litres/year in Alberta and British Columbia while they are of 2.5 million litres/yr in Saskatchewan. The 5 million litres fuel ethanol consumed in Alberta represented less than 0.1% of the total market for gasoline in the province (Cheminfo Services Inc. et al. 2000). In Manitoba, the consumption of fuel ethanol has averaged 7-8 million litres/year over the medium-term past, representing approximately 0.5% of total gasoline sales (Government of Manitoba 2002b).

End consumers are influenced in their choice of alternative fuels by three factors: *price*, *drivability issues* and *environmental impacts*. Environmental impacts dominate the two others in the case of public demand for fuel ethanol (ex: part of the federal and Ontario government fleets use fuel ethanol). The inverse is true for private demand: price and drivability issues primarily influence private consumer's decision to buy fuel ethanol. "Only 5% of consumers buy ethanol blends when their price is higher than that of gasoline" (Dominic Scipio, director of Sonic) (Coopérative Fédérée de Québec, 2004). When both ethanol blends and gasoline are available at the same price, 12 – 15% of all fuel sold is composed of ethanol-blends (Sonic 2004). The price elasticity of demand for ethanol blends seems to be quite high.

3.5. Exports/Imports

The pattern of Canadian trade of ethanol has changed over the years. Canada was a *net exporter* of ethanol in the 1970s, but exports dropped to low levels when Commercial Alcohols closed its synthetic ethanol plant in Varennes, QC, in the 1980s. In 1999 Canada *imported* more ethanol than it exported (see Table 5). Canada is a net importer of *fuel ethanol* also. In 2003, demand of

[11] OCPA gives the information that Ontario routinely imports 100 million litres of U.S. ethanol annually and that Ontario imports over 1/3 of its current demand for ethanol. This would mean the ethanol demand in Ontario is more than 300 ml/yr.

fuel ethanol reached 240 million litres, while fuel ethanol production was less then 155 million litres (only 65% of the total 238 ml capacities produce fuel ethanol). Imports are estimated to 90 million litres for 2003 (Western Producer 2003), which suggests that very few exports of fuel ethanol have been made (most probably coming from API Grain Processors, which exports its production in the U.S.).

Table 5: *Trend in Canadian Ethanol Trade*

(million litres)

	1976	**1981**	**1990**	**1999**
Exports	39	49	8	27
Imports	(0)	(3)	(0)	(75)
Net exports	**39**	**46**	**8**	**(48)**
Total domestic demand	34	43	45	190
Total production capacity	89	96	112	238

Source : Cheminfo Services Inc. et al. 2000

Over 95% of ethanol *imports* in Canada come from the *United States* (Cheminfo Services Inc. et al. 2000). In 2003, imports from the U.S. amounted to 65 ml (Natural Resources Canada 2003) (Briere 2003 gives the information of 90 ml total imports in 2003, which, together with Natural Resources Canada 2003 information could mean that imports from U.S. diminished to 72%). But Canada's ethanol *exports* are not concentrated on the U.S. market (see Table 6). In 1998, the United States accounted for only 30% of exports. The Commonwealth of Independent States (CIS) has recently become major export destinations for denatured and undenatured grades of ethanol (Cheminfo Services Inc. et al. 2000). The difference could come from the type of ethanol traded: fuel or industrial. Industrial ethanol could dominate exports while fuel ethanol could dominate imports.

Table 6: *Canadian Ethanol Exports by Destination, 1998*

	USA	**Georgia**	**Ukraine, Russia**	All Other Countries	Total
Million litres	7.1	**12.3**	**4.1**	0.9	24.4
%	29%	**50%**	**17%**	4%	100%

Source: Cheminfo Services Inc. et al. 2000

Alberta's single ethanol producer exports nearly all its output to the United States (Cheminfo Services Inc. et al. 2000) Quebec's single ethanol producer doesn't export at all, selling all its industrial ethanol to the vinegar industry in Eastern Canada (Tembec 2004).

In 1999 one litre of ethanol exported was more expensive ($1.06/litre) than one litre of ethanol imported ($63/litre) (see Table 7). The difference could come from the structure of exports and imports (fuel or industrial ethanol). Fuel ethanol is usually the cheapest (Government Cheminfo Services Inc. et al. 2000). Exports could mainly consist of industrial ethanol and imports of fuel ethanol. This would be in accordance with the fact that exports are mainly sent to the Commonwealth of Independent States (which are not important fuel ethanol users) and that imports mainly come from the United States (which is an important fuel ethanol producer).

Table 7: *Ethanol Exports/Imports - 1999*

	Quantity (million litres)	Total Value (C$ million)	**Average Unit Value (¢/litre)**
Estimated **imports** 1999	75	47	**63**
Estimated **exports** 1999	27	28	**106**

Source: Cheminfo Services Inc. et al. 2000

Canadian fuel ethanol exports are *eligible* for the US federal excise *tax exemption,* the federal blenders income tax credit, the federal tax credit for pure alcohol fuels and some state road tax exemptions. Similarly, imports of fuel ethanol from the U.S. are also eligible for the Canadian federal excise tax exemption on ethanol-blended fuels and some provincial excise tax exemptions. To date, there has been *no tariff* on ethanol trade between the U.S. and Canada. It is possible, however, that preferential legislation like Manitoba's, and those proposed by Saskatchewan and Quebec, could be anti-NAFTA. While Canadian provinces have no recourse to the barriers imposed by other provinces, the Americans can rely on the NAFTA provisions (Government of Manitoba 2002b).

Ontario is the main ethanol importer and its demand is outstripping the supply. At present, Ontario imports over 1/3 of its current consumption of ethanol (Ontario Corn Producers' Association 2003b).

Inter provincial trade is mainly influenced by provincial tax exemptions, which are very heterogeneous. API Grain Processors (Alberta) exports all its production to the U.S. because of this reason: its ethanol is not eligible for the Saskatchewan tax exemption, which applies strictly to locally produced ethanol. The same restriction applies in British Columbia, Manitoba and Quebec. Alberta and Ontario are the only provinces with no restrictions on tax exemption regarding ethanol source.

3.6. Distribution

In Canada, there is no distribution network for ethanol blends containing more than 10% ethanol, except for a marginal network that provides ethanol blends to the federal E85 poly-fuels fleet (Coopérative Fédérée de Québec, 2004). In 1998, two *bulk distributors* dominated the Canadian market: Husky Energy Inc. and UPI Inc. The former is the unique bulk distributor in the Prairies and British Columbia while the latter is dominant in Ontario. 75% of the 57 Canadian bulk distribution facilities are held by UPI, while Husky holds 23% (see Appendix 6).

Husky Energy is also a monopoly in the *retailing distribution* in the Prairies and British-Columbia, in 1998 holding 31% of the 929 retailing stations in Canada (see Appendix 5). With the Ethanol Expansion Program financing 2 Husky ethanol plants (200 ml/yr capacities beyond the existing 10 ml/yr) its position as distributor in the western Canadian market will strengthen.

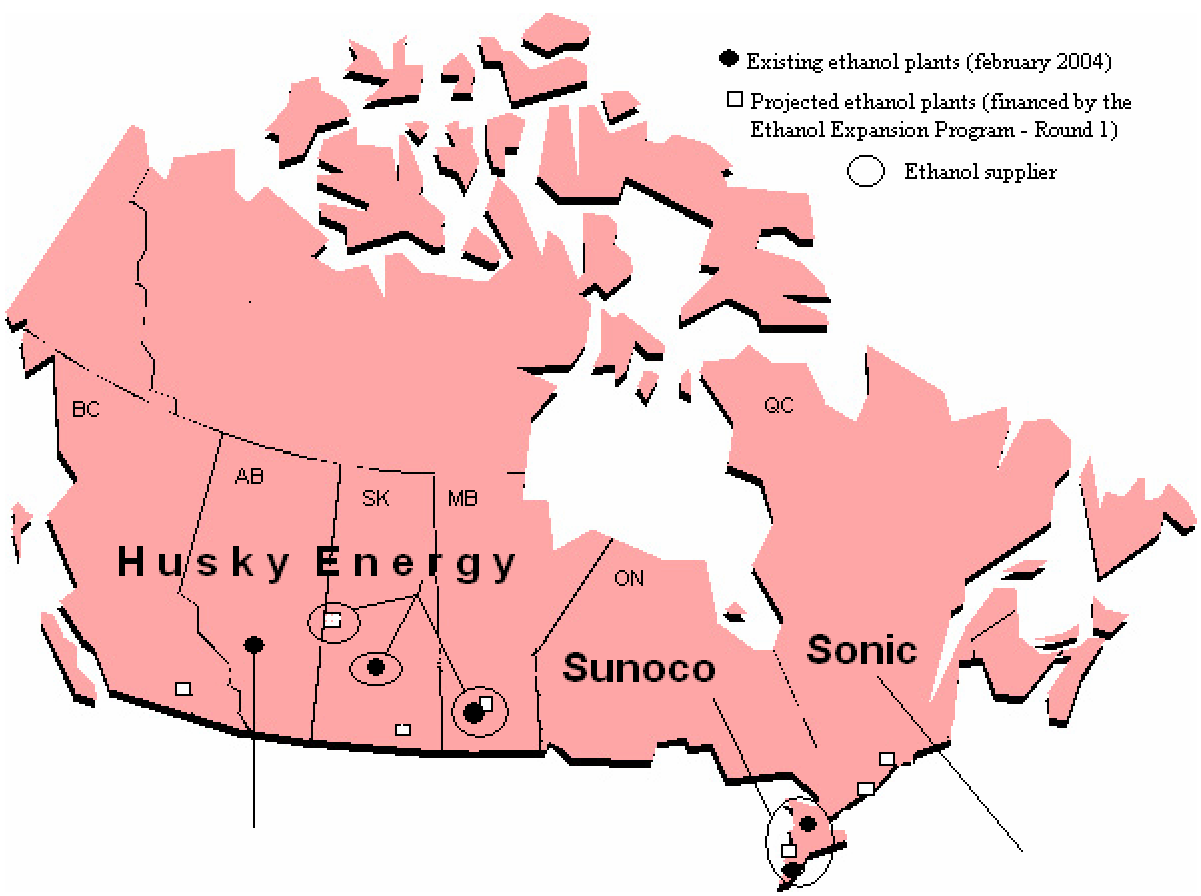
In Ontario, the leader is Suncor Energy Inc. with 29% of the total retailing stations in the country. The following four distributors are much smaller and each holds between 2 and 8% of the retail stations in Canada. Suncor purchases 80% of the fuel ethanol production of Commercial Alcohols` plant located in Chatham (Commercial Alcohols Inc. a). Ethanol is blended with gasoline at Sunoco terminals in London, Toronto and Sarnia (Agriculture and Agri-Food Canada 2000). Its position as distributor in the Ontario will be strengthened, as in the

Husky case, by the EEP, which finances a 208 ml/yr Suncor ethanol plant in the proximity of the plants of Commercial Alcohols. *Vertical integration* is become an interesting option for firms distributing ethanol: 3 out the 13 plants (EEP financed included) are owned by ethanol distributors.

In Quebec, the major retailer is Sonic, with 85% of Quebec's retailing stations, which accounts for 11% of the Canadian retailing stations. Sonic sells only E5 (Sonic 2004) because their ethanol doesn't benefit of Quebec's tax exemption since it is not produced in the province and therefore its price is high compared to gasoline. They buy all the E5 from Pétroles Norcan, which obtains it by blending ethanol to gasoline. Pétroles Norcan most probably buys its ethanol from U.S.

Fig. 5: *Fuel Ethanol Retailing in Canada*

- *February 2004* -



Ontario was the province with the most developed ethanol distribution network in 1998; it hold 56% of the bulk facilities and 77% of the retailing stations (Canadian Renewable Fuels Association 2000). In retailing it is followed by Alberta, British Columbia and Quebec, each of which detains between 11 and 14% of Canadian capacities, while Manitoba and Saskatchewan detain shares of 3 – 4%. In bulk facilities, Ontario's followers are Alberta, BC, Saskatchewan and Manitoba, which each detains between 4 and 9% of Canadian facilities.
Quebec started retailing ethanol only in 1994 (Sonic 2004).

The situation doesn't seem to have changed much from 1998, at least with regard to the total distributing stations in the country. Natural Resources Canada (2003) gives the information of 1041 ethanol distributing stations in 2003, while Canadian Renewable Fuels Association (2000) that of 929 in 1998.

Blending gasoline with ethanol can be carried out at blending racks, which are not necessarily in-line and are not necessarily located at refineries. Truck or rail deliveries of ethanol would be required (Cheminfo Services Inc. et al. 2000). The blending is most probably realised in Canada by *oil wholesalers*. In Ontario this process is probably realised by UPI Inc (Cheminfo Services Inc. et al. 2000: 'in Ontario one major oil wholesaler blends ethanol with its gasoline') and Suncor (Sunoco) (Agriculture and Agri-Food Canada 2000). In Western Canada, blending ethanol with gasoline is most probably undergone by Husky Energy and in Quebec by Pétroles Norcan.

There is a certain *cost* for blenders *to accommodate ethanol* and this cost is mainly determined by the following factors: need for a *low VP* (vapour pressure) base stock gasoline, maintenance of the *drivability index* (DI) specifications, *transportation* and *storage* of ethanol. Ethanol added to gasoline increases vapour pressure. To maintain the required VP, refiners will need to *install facilities to remove butane from gasoline*. These facilities generate *additional investment costs*. Besides the investment costs, the blender may support a decrease in the market value of the butane removed. In the past, the value of butane has typically decreased from gasoline value to fuel value if a suitable market was not found. On the other hand, the installation of additional facilities for butane removal and the valorisation of the butane removed *depend on the specificity of each refinery*. For example, one refiner affirmed that it does not use additional refinery facilities to remove butane from gasoline to accommodate ethanol. This refiner also pointed out that butane can be considered as an additional blending component of the many blending components available to refiners (i.e., a range of different hydrocarbons) to meet product specifications (Cheminfo Services Inc. et al. 2000).

The Canadian Petroleum Producers Institute (CPPI) points out that butane removal makes the *drivability index specification for gasoline more difficult to achieve*. Even if butane is not a factor, ethanol/gasoline blends have poorer drivability than conventional gasoline with the same DI as used for blends. It is more costly to produce blends with the same drivability performance as conventional gasoline. The estimation of the costs of these potential changes would require detailed investigation and optimization of refinery operations and blending operations (Cheminfo Services Inc. et al. 2000).

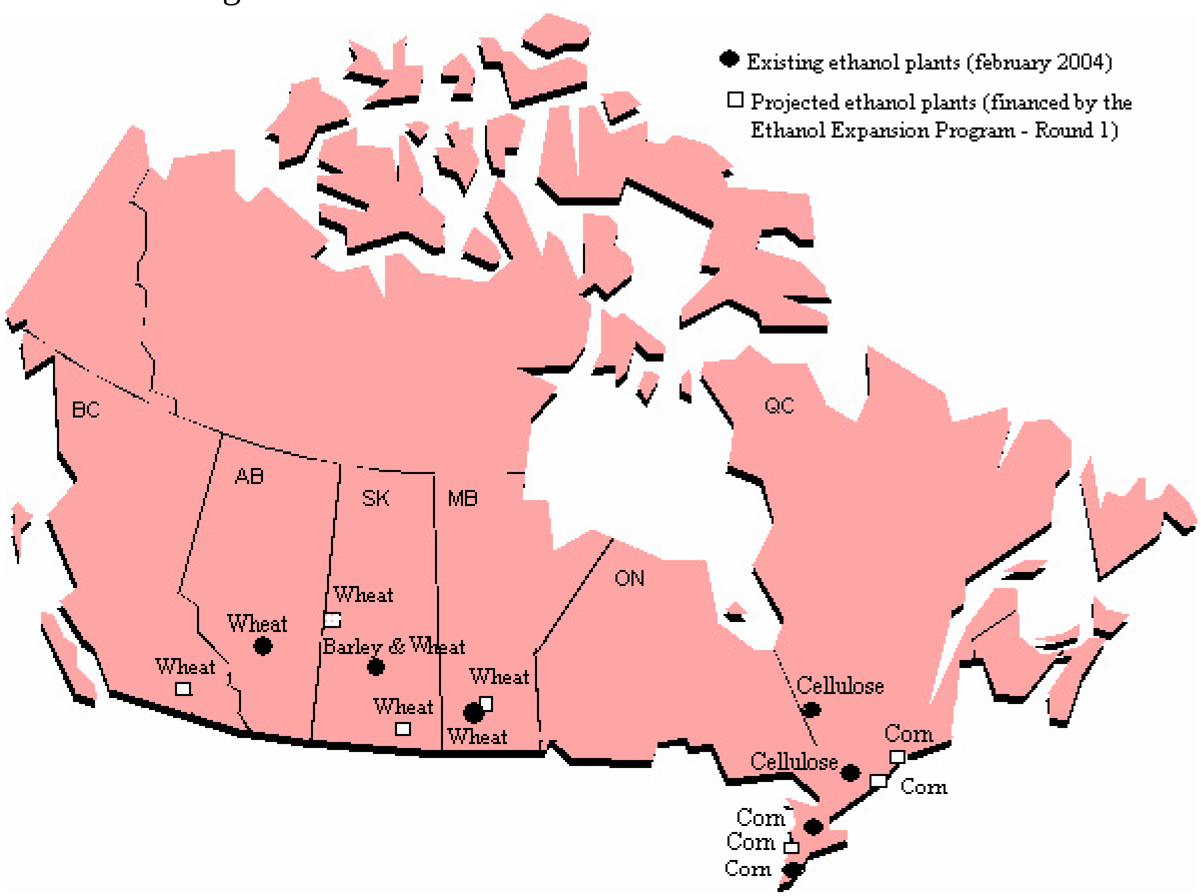
The CPPI points out that ethanol would need to be *shipped by truck or rail*, as opposed to pipeline due to *potential water contamination*. Other potential ethanol contaminants when transported by pipeline would be petroleum products, dirt, grease or oils. A detailed transportation/storage logistics optimization analysis (including potential backhauls, computerized mixing, etc.) is required to determine the actual costs of handling, blending and transporting ethanol. If the distribution/storage systems are properly designed, these *costs can be similar to other gasoline blending components* (Cheminfo Services Inc. et al. 2000).

3.7. Feedstock

Ethanol (industrial and fuel) can be produced from two main categories of feedstock: *grains* and *cellulose*. Ethanol is obtained from grains by fermentation of sugars (starch) and from cellulose by conversion of the cellulose into sugars and their fermentation afterwards. The grain-based ethanol is mainly obtained from sugar cane, corn, wheat or barley and the cellulose-based ethanol comes from waste bio-mass (ex: straw) or dedicated energy crops (like switch grass, prairie grasses and fast-growing trees). In Canada, the grain-based production process dominates, representing 92% of actual production capacity. Research is undergone to make cellulose-based production process economically viable (Iogen Corporation is the main Canadian research centre). Canadian ethanol plants presently use corn (73%), wheat (17%) and barley (3%) as grains (Commercial Alcohols, Husky Energy, API Grain processors, Pound-Maker Ethanol) and agricultural and forestry waste (7%) as cellulose (Iogen Corporation and Tembec). When plants financed by the Ethanol Expansion Program (1st round) will begin their operation, corn-base ethanol will decrease to 58% of the production capacity, wheat-base ethanol will increase to 39% while the use of waste and barley in the production process will decrease to 2% and respectively 1%. Wheat is used for ethanol production in the Prairies and British Columbia while corn and waste are used in Ontario and Quebec. Ontario accounts for approximately 80% of Canada's corn production (Cheminfo Services Inc. et al. 2000).

Other countries, such as Brazil and India, obtain ethanol from *sugar cane*. Ethanol production in North America primarily uses *corn* as feedstock. The exception to this is Western Canada where *wheat* has been the dominant feedstock. This is due to the lack of corn production in the Prairies and wheat provides lower production costs than importing corn into the region. The area generally does not have enough heat degree-days and moisture for corn production. Exceptions are Southern Manitoba and a very small irrigated area of Southern Alberta (Cheminfo Services Inc. et al. 2000). *Barley* is also used for ethanol production in the Lanigan (Saskatchewan) plant.

Fig. 6: *Feedstock Used in Canadian Ethanol Plants*



Wheat

Wheat is the dominant crop in the Prairies. Barley comes on the second place. Barley can also be used for ethanol production but the lower starch content and higher fibre content make it less desirable than wheat. An inconvenient with using barley for ethanol production is the difficulty to hydrolyze and ferment some of its carbohydrates (the beta glucans). Another inconvenient would be the fact that barley hulls can cause erosion of ethanol plant equipment. The lower cost of barley is insufficient to overcome these disadvantages of processing barley and the result is that total ethanol production costs are higher for barley than for wheat (Cheminfo Services Inc. et al. 2000).

Commercial *ethanol yields from wheat* typically vary from 340 to over 500 litres per tonne of wheat. They vary depending on the type of wheat, as well as the ethanol process employed. Yields of ethanol from wheat can exceed 500 litres/tonne for some processes that recycle fermenter broth (Cheminfo Services Inc. et al. 2000).

All classes of wheat are capable of being used for ethanol production but the most likely feedstock for a dry milling ethanol plant is *Canadian Prairie Spring* (CPS) wheat because of its *high starch content.* Indeed, a study published by Freeze and Peters in 1999 finds that CPS wheat cultivated on dark brown and black soils generates the highest revenues for an ethanol plant because of its high starch content and low price. CPS wheat is also profitable for farmers because of its *high yields* per hectare. Indeed, the Canadian Wheat Board (1999) reports a 44% yield advantage over CWRS wheat and only a 14% reduction in price, resulting in an increase in revenue for the producer. Consequently, its production is increasing (Cheminfo Services Inc. et al. 2000).

Hard Red Spring (CWRS) wheat is a potential feedstock for a plant using the wet milling production process because of its high protein content, which increases the market value of the co-products. In wet milling, as opposed to dry milling, co-products (gluten) play a more important role in total revenues because of their higher market value. The reality shows that wet milling also uses CPS wheat, as in the case of the gluten facility in Red Deer (Alberta) (Cheminfo Services Inc. et al. 2000).

The dominant ethanol production process in Canada being dry milling, the most needed wheat varieties are the high starch varieties such as CPS, typically used as animal feed. In the case of Manitoba, although it may appear that it produces more than enough wheat to supply ethanol production, the traditional focus on milling wheat (due to its higher price) has made that animal feed wheat varieties, such as CPS and hard red winter wheat, account for only 6 to 8% of Manitoba's production. At present Manitoba is a net importer of such varieties. In order to develop its ethanol industry, the Manitoba government should support research on feed wheat varieties with *higher yields*. Based on historical prices, a yield advantage of approximately 30% over milling wheat varieties is required to achieve similar returns from feed wheat varieties (Manness et al. 2002).

Jerusalem Artichoke[12]

Jerusalem Artichoke (JA) is a potential feedstock for grain-based ethanol. It is grown commercially on a large scale in the United States and Europe but not in Canada (Baker, Thomassin, Henning 1990). It is used as food (the tubers) or medicinal plant (excellent source of fibres, potassium and high quality proteins). Either its tubers or its tops may be used for ethanol production. This potential feedstock offers several advantages: it can be used as break crop for corn production (a solution to soil degradation in the corn producing regions), it can be cultivated on marginal lands and it diversifies the feedstocks for the ethanol industry (an issue of energy security) (Baker et al. 1990). In addition, in the case of Quebec, there is an abundance of land supporting the need in JA of an ethanol plant such that land for corn won't diminish (Peluso 1998).

A study by Baker et al. (1990) concludes that *JA can compete with corn in terms of feedstock cost (farm level cost) per litre of ethanol* if the tops (but not tubers) are used. In certain conditions described below, this cost is less than the feedstock cost from corn of $0.31/litre of ethanol (estimated by Heath in 1989). In the case of Quebec, Baker et al. (1990) show that there are two groups of conditions for obtaining this lower cost: i) if low-value land is used (675$/ha or marginal land): a yield of 41 tonnes of JA tops per ha (possible at farm level) or more and a conversion rate of at least 100 litres of ethanol per tonne of Jerusalem Artichoke (considered among the lowest); ii) if high valued land is used ($2500/ha): a yield of at least 55 t/ha (only

[12] Jerusalem Artichoke is a member of the sunflower family with tubers being planted as potatoes. Its name is misleading: the plant is not from Jerusalem and is not an artichoke (Ministry of Agriculture and Food of Ontario, 1994). In Europe in the 1600's this crop became known as the Canadian potatoes and there is evidence that Indians were growing it in the 17th century in New England (Baker 1990).

obtained in field trials) and a conversion rate of 90 l/tonne. On the contrary, in Western Canada, the feedstock cost of producing ethanol from JA tops is competitive with the feedstock cost from corn at the lowest yield studied (60 tonnes/ha[13]), the lowest conversion rate (90l/tonne) and both high and low valued land.

The same study concludes that in order to compete with the estimated cost of ethanol from corn of $0.35/l, the *processing cost* (production cost net of feedstock cost) should not be more than *$0.06/l* (after by-product credit) in the case of Quebec, a low-value land, a yield of 41t/ha and a conversion rate of 100 l/tonne (the most probable case for Quebec). In Western Canada, the processing cost should not be greater than *$0.16/l* under the same assumptions (a low-value land, a yield of 80t/ha, the farm level yield in Western Canada, and a conversion rate of 100 l/tonne). Another study by Thomassin (1988) (cited by Baker et al. 1990) estimates the processing cost of ethanol from JA at $0.19/l, which overpasses the targeted $0.06/l for Quebec and the $0.16/l for Western Canada. The conclusion is that JA cannot compete in terms of *total cost per litre of ethanol* with corn neither in Quebec nor in Western Canada for a yield of 41t/ha (80t/ha for Western Canada), a conversion rate of 100 l/tonne and low valued land. It would be competitive in Western Canada for yields of at least 100 t/ha (more than the average at the farm level but still reasonable) and in Quebec for yields of at least 76 t/ha (very optimistic). The author indicates that this result is due to the *conservative conversion rates* (only 90 – 110 litres/tonne) used and to the fact that *only one co-product* (the DDG) was credited.

In conclusion, Jerusalem Artichoke is competitive with corn in terms of *feedstock cost* (farm level cost) *per litre of ethanol* in both Quebec and Western Canada (more competitive in Western Canada) but it is more expensive in terms of *total cost per litre of ethanol*. In the case of Western Canada, the total unitary cost of ethanol from JA only slightly overpasses the total unitary cost of ethanol from corn.

Considering the total cost per litre of ethanol from *JA* used by Thomassin, Henning and Baker (1992), 0.36 $/l for Quebec and 0.20 $/l for Western Canada, and comparing it with the total cost per litre of ethanol from *corn* used in the previous study, 0.35 $/l, the conclusion changes: JA tops are competitive with corn even in terms of total cost per litre of ethanol. Unfortunately, no information on the conversion rates and yields used are available in the study of Thomassin et al. (1992), which takes these estimates from a working paper (Henning 1990).

[13] Yields in Western Canada were evaluated by comparison with those demonstrated for Quebec.

3.8. Co-products/By-products

Valorization of the co-products is essential for an ethanol plant to be feasible, especially in the case of grain-based ethanol.

The main co-product of *cellulose-based ethanol* is *lignin*, which is burned to produce steam for the ethanol production process, with the excess potentially being converted into electricity for sale to the grid (Manness et al. 2002). Iogen Corporation uses the lignin to produce *all* the electricity needed in its ethanol production process (Iogen Corporation 2004).

Only the starch component of the grain is converted to ethanol. The fibre, protein, minerals, carbon dioxide and vitamins remain and are recovered through by-products. The co-products of *grain-based ethanol* may be described under two general categories of ethanol production: *dry milling* and *wet milling*. Dry milling is the dominant process among Canada' ethanol plants. The only wet milling ethanol plant is the one located in Red Deer, Alberta, owned by API Grain Processors /Permolex and integrated with a feedlot. The economics of production favour the dry milling process, in contrast to the large U.S. plants which are able to exploit the scale efficiencies of wet milling technology (Agriculture and Agri-Food Canada 2002).

There are three main co-products of the *wet milling* production process: gluten meal, gluten feed and germ. In the case of wheat (wet milling corn ethanol plant doesn't exist in Canada), the primary outlet for *gluten* is in bakery products (bread, rolls, buns). Other uses are vegetable meat-like products, breakfast cereals etc. Vital gluten *improves* the *quality of the finished product* and gives *flexibility to the production process*. For example, addition of gluten to buns and rolls, like sandwich buns, *improves hinge strength* and produces the type of *crust most desirable in commercial markets* where buns are steamed. Vital gluten also improves the protein content of *breakfast cereals* (Cheminfo Services Inc. et al. 2000).

While *vital gluten market* for *human consumption* is expected to rise only *proportionately to population, s*ignificant growth is anticipated in *pet foods* where it is used as a supplement and/or replacement for meat, due to its very high protein content (e.g., 80%+). Vital gluten is an attractive alternative to pet food processors because of the higher *prices of meat* (based on protein content) (Cheminfo Services Inc. et al. 2000).

Given its composition, the animal feed that is produced (*gluten feed*) is assumed to be able to *replace barley* on a one to one basis in animal rations. The gluten feed is dried and shipped to consumers. It is believed that gluten feed will be used closer to ethanol plant than dry-mill co-products since there is less of this co-product produced and its value is lower. The shipping distance for this material is assumed to be one quarter of the distance for the dry mills and equal to the distance that the feedstock coming into the plant travels (Cheminfo Services Inc. et al. 2000).

The market of wheat gluten in North America is dominated by less than half a dozen of producers. The major Canadian producer of wheat gluten is ADM (Archer Daniels Midland) in Lachine, Quebec. But this facility does not make ethanol. Its capacity is estimated to 20 kilotonnes of gluten per year, representing nearly twice the size of total Canadian demand. ADM exports gluten to the United States. The only ethanol facility in Canada producing wheat gluten as co-product is API Grain Processing in Red Deer, Alberta. Its capacity is assumed to be smaller than ADM's, with a substantial portion of its production potentially used for its enriched flour products (Cheminfo Services Inc. et al. 2000).

The co-products of a *dry milling* ethanol plant are *carbon dioxide* and *distillers grains*. The quantities of each product (ethanol, distillers grain and CO_2) are almost equal on a mass basis, so it is important to insure that there are high-value markets for as much of the co-products as possible. In large plants (more than 50 million litres per year) it may also be profitable to collect *carbon dioxide* (Cheminfo Services Inc. et al. 2000).

Distillers grains (DG) can be used wet or dried and their main use is in *animal rations*. It contains much protein (35% if produced from wheat), fibre and micro-nutrients. It is also very digestible and widely accepted as a premium feed ingredient. The high moisture content (65%) and short shelf life (2-3 days) of wet distillers grains (WDG) require the product to be consumed close to the point of production (need for feedlot integration). On the contrary, dried distillers grains (DDG) are very well fitted to long distance transportation because of their low moisture content (less than 10%) and indefinite shelf life (Cheminfo Services Inc. et al. 2000).

The *price and markets for wheat DG* will depend on *protein content* and the ability of the product to be priced competitively compared to *other protein supplements* currently used in the

livestock industry. Wheat DDG is higher in protein than soymeal and therefore could potentially obtain a premium price, subject to low levels of fusarium (wheat disease) (Manness et al. 2002).
The *potential market for DG* must be evaluated. In Manitoba, for example, it has been estimated that 227 000 tonnes of DG per year may be consumed in the swine, dairy cows/cattle and poultry sectors. The swine sector would consume a half (1/2) of these DG, the dairy cows/cattle sector a quarter (1/4) and the poultry sector 1/20. The 227 000 tonnes of DG greatly exceed the 75 000 tonnes produced from the 80 million litres/year ethanol capacity that will soon be operating in Manitoba (Manness et al. 2002).
Wheat DDG has primarily been used in the beef and dairy sectors in Western Canada and there is little experience with it in the swine and poultry sectors. While in the U.S. there is important research on feeding corn DDG to hogs and poultry, there is a need for this type of research in Canada also for wheat DDG. Meanwhile, it may be possible to find markets in the U.S. where wheat DDG could be established as a unique product (in beef and dairy sectors), in spite of the relative abundance of corn DDG (Manness et al. 2002).
A positive impact of the wheat DDG could be the *diminishment of soymeal imports in Western Canada* by the replacement of the soymeal with wheat DDG (Manness et al. 2002).
Wheat DDG will *replace barley* in some animal feed rations (Cheminfo Services Inc. et al. 2000).

Because both wheat DDG and wheat gluten feed could replace barley in animal rations, the impacts on the consumption of barley should be considered in an analysis of the development of the ethanol industry in Canada.

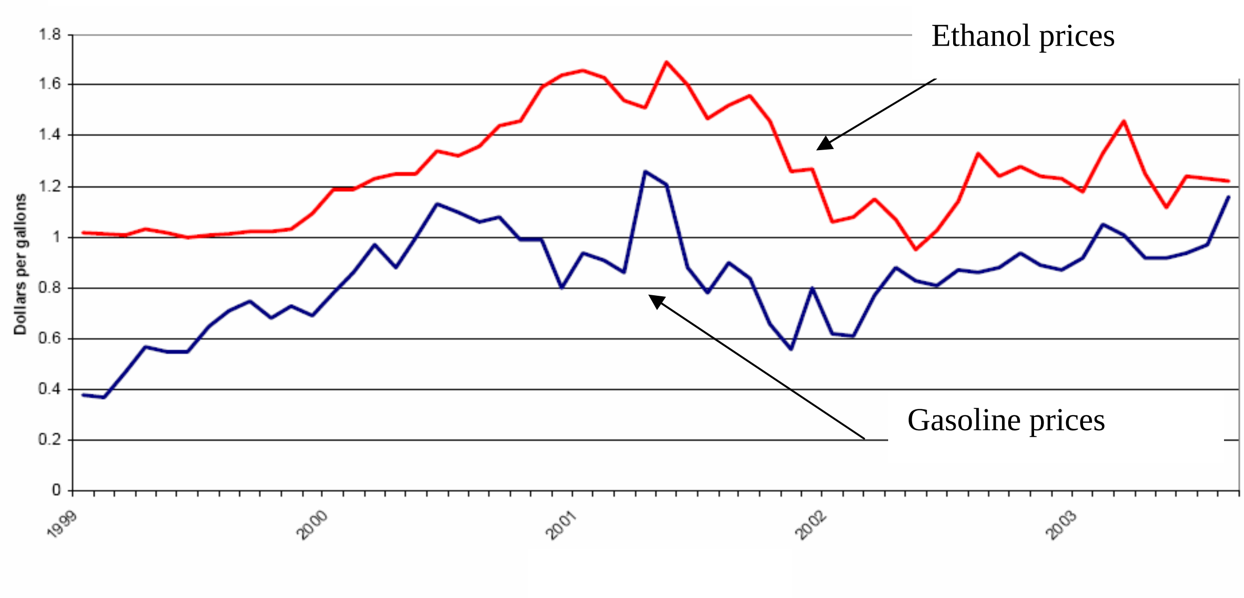
The European Union (EU) was, in 1986, the *largest foreign market for gluten* and *distillers' feeds*. At that time, by-products feeds were exempt from the duties imposed on other agricultural imports but the possibility of introducing them was being discussed (Gilmour 1986).

3.9. Ethanol price and production cost

Canada is a small player on the ethanol market and therefore price taker. The price is set on the U.S. market. As the following diagram shows, ethanol price is higher than the gasoline price.

This difference could be mainly explained by the difference in the production cost. The diagram also shows a positive correlation between the two prices:

Fig. 7*: U.S. Ethanol and Gasoline Prices*
1999 - 2003



The difference in price between regular gasoline and the E5 blend sold by Sonic in the province of Quebec is of 3 - 4 cents per litre. Freeze and Peters (1999) estimated the *long-term price for ethanol* at *$0.428/litre*. They used the long-term average U.S. price for ethanol and converted it into Canadian dollars using the 1978 – 96 average exchange rate (US$0.80165=1$).

Ethanol is *not yet quoted on any exchange* but there are some initiatives on this issue because of the advantages that an international price could generate: information for investors and capitalization of the industry at an international level (Patrick Funaro, broker in energy, cited by Coopérative Fédérée de Québec 2004). But because of the differences in production costs in North America and Brazil (ethanol from corn costs twice as much as ethanol from sugarcane), an international price for ethanol is not yet desired by all countries (Coopérative Fédérée de Québec 2004).

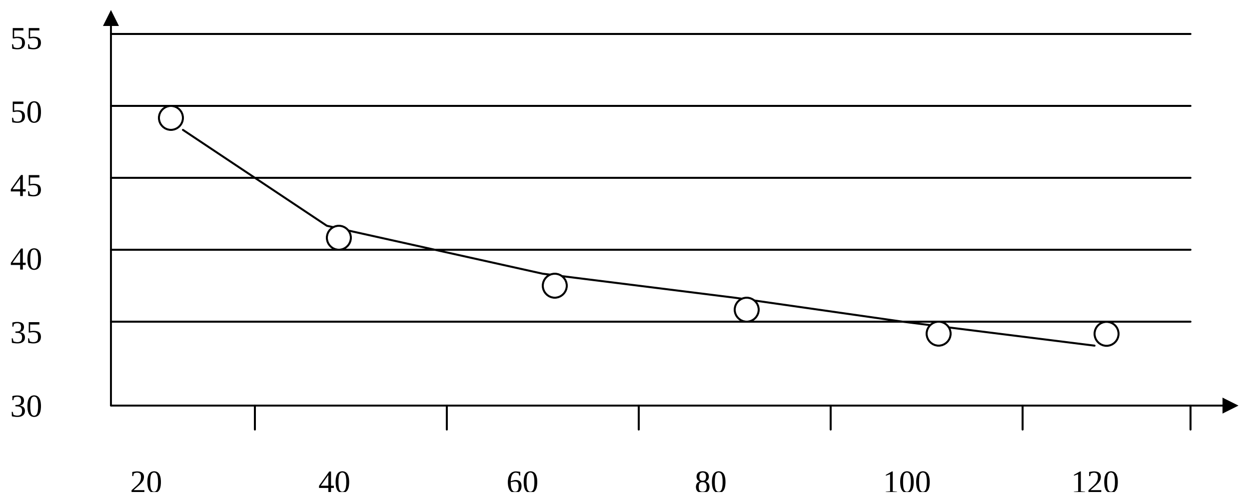
The main factors influencing ethanol price are production costs and tax exemptions. The unitary *production cost* for ethanol is estimated by summing feedstock cost per litre of ethanol and processing cost, and subtracting the price of the co-products per litre of ethanol (Baker et al. 1990). When the cost of production is not diminished by the value of the co-products, it is specified “before co-product credit”. For different types of feedstocks, the per litre cost of ethanol is sensitive to feedstock costs and co-products value (Thomassin et al. 1992). The processing cost (production cost net of feedstock cost) remains almost the same. The major cost component of ethanol production is the feedstock (Thomassin et al. 1992). For example, Thomassin and Baker (2000) estimated the total feedstock cost as representing 57% of the total production cost (for a 200 ml/year corn ethanol plant located in Southern Ontario).

In general, *fuel ethanol and other biofuel production cost is higher than that of petroleum products* (Shapouri 2003). For example, in 1998 fuel ethanol production cost was around *35 – 45 ¢/l* and the petrol production cost around 19 – 24 ¢/l (Groupe RLD inc. 1998).

A study realised for the Government of Alberta in 2000 estimates the breakeven *ethanol price* for a 100 million litres per year facility to approximately 28 cents per litre, much less than the 1998 production costs but still greater than oil production cost. The plant under study uses a raw material (wheat) price of $100 per tonne and a co-product (DDG) price of $160 per tonne (Cheminfo Services Inc. et al. 2000).

Another study realised for the Government of Manitoba (Manness et al. 2002) underlines the economies of scale obtained by big ethanol plants (100 –120 ml/year) compared to small facilities (20 ml/year not integrated with a feedlot). The production cost decreases as the production capacity increases but it doesn’t arrive to the estimated 28 cents per litre obtained by the precedent study (see Fig. 8). In addition, another study estimates the production cost of ethanol from corn at $0.35/l (Baker et al. 1990). The cost of production of ethanol from Jerusalem Artichoke is estimated at about $0.35/l for Western Canada and at $0.48/l for Quebec by Baker et al. (1990), and at $0.20/l and $0.36/l, respectively, by Thomassin et al. (1992).

Fig. 8: *Ethanol Production Costs by Plant Size*



Source: Manness et al. 2002

There isn't much data available on the detailed production costs of a Canadian ethanol facility. For example, for their study on the feasibility of a small ethanol integrated plant to be located in Alberta and using wheat as feedstock, Freeze and Peters use the U.S. adjusted data on labour, energy, ingredients, management and capital costs (Freeze and Peters 1999).

3.10. <u>Fuel ethanol plant feasibility</u>

A study published by Freeze and Peters in 1999 as well as other studies and opinions cited in their article conclude that without government support, the ethanol industry is not commercially viable but has been promoted on the basis of environmental benefits and/or community development benefits. Freeze and Peters estimate the net revenue of a vertically integrated ethanol plant with wheat feedstock suppliers and a beef feedlot using the ethanol plant co-products and conclude that over the long-term it will lose money one-half (1/2) to two-thirds (2/3) of the time when tax exemptions are allowed and two-thirds (2/3) to three-quarters (3/4) when no tax exemption exists. The production process is considered to be dry milling because little data is available on cost structures for other technologies. The capacity of the ethanol plant is little: 10 million litres per year and the average price of ethanol is C$0.428/litre. Manness et al. 2002 also estimated large unitary costs for little ethanol capacities but for plants not integrated with feedlots. Other studies cited by Gilmour (1986) concluded that the economies of scale effectively place a *lower limit* to the size of any viable ethanol operation and the lower limit is of 20 million litres per year. This may be the justification of the fact that the average capacity financed by the Ethanol Expansion Program in its first round was of 106 million litres per year and the minimum capacity of 25 million litres.

If a lower limit exists for an ethanol plant to be profitable, Gilmour (1986) demonstrated that an *upper limit* of the total capacity of ethanol plants in a certain region also exists. The expansion of ethanol production capacities in a specific region is limited by the impact that demand for agricultural feedstocks has on the price level of these feedstocks: the greater the influence, the lower the upper limit. The demand – price dependency is essentially influenced by two factors: the size of the market surplus (net exports) in the region and the degree to which transportation costs and trade barriers isolate the market. In the case of *Ontario,* Gilmour estimated that total initial investments into ethanol production should be kept to a maximum capacity of 74[14] million litres per year in the very next period (1986) and expanded incrementally in tandem with growth in the grain corn industry in order not to determine important local price increase of corn (more than 1%) and thus endanger the solvency of these investments (which compete in price with other fuels and fuel additives). This result was conditioned by the surplus of corn production that Ontario had at the time of the study (1986). Because this surplus was expected to increase considerably from 1986 to 1990, the upper limit for 1990 was estimated at 185 million litres/year.

From 1986 to present, ethanol production capacities in Ontario increased from 0 to 172 million litres/year, as the following table shows:

[14] We used the corn conversion rate of 2.68 kg/litre of ethanol in order to transform the numbers given by Gilmour (tonnes of corn) in litres of ethanol. This corn conversion rate was used by Groupe RLD inc. 1998.

Table 8: *Total Ethanol Production Capacities in Ontario during the 1986 – 2003 period*

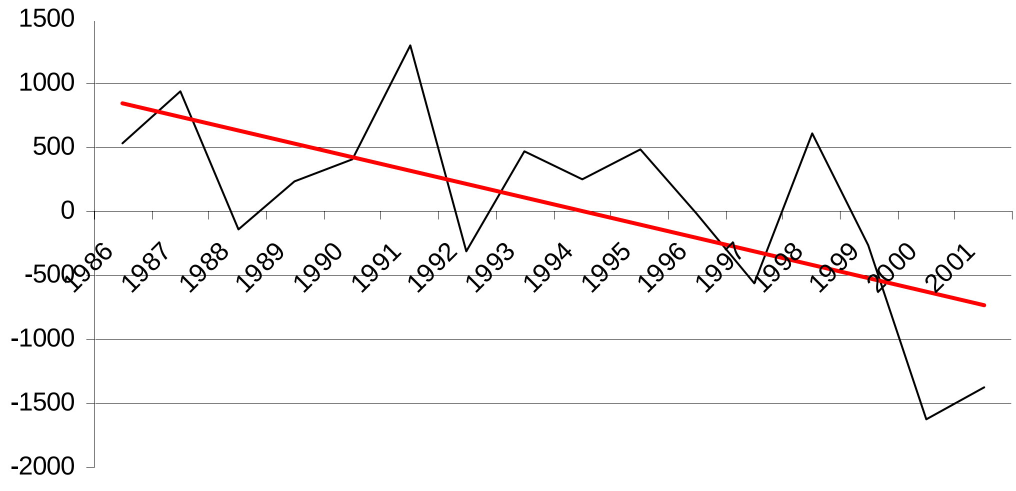
(million litres/year)

	1986	1989	1995	1997	2003
Ethanol production capacities (ml/year)	**0**	**12** (Tiverton plant)	**22** (Tiverton plant)	**172** (Tiverton and Chatham plant)	**172** (Tiverton and Chatham plant)

Source: Commercial Alcohols b, c, Table 3

This increase did not overpass the upper limit of 185 million litres/year estimated by Gilmour as being without danger for corn price increase. But Gilmour's hypothesis, that of an important increase in corn surplus (net exports), is not satisfied. As figure 9 shows, corn net exports had a decreasing trend from 1986 to present, even if in the 1991 – 1992 period they were greater than in 1986. This raises the following question: had the 172 million litres/year increase in ethanol production an impact on the price of corn in Ontario?

Fig. 9: *Ontario Corn Net Exports during 1986 - 2001*



Source: Statistics Canada 2003, Cansim, Table 001-0039

For *Western Canada* it is anticipated that the upper limit is much greater because of the much larger grain surplus, and because the price determination process for Western Canada agricultural feedstocks occurs, for the most part, outside Canada's borders.

The upper limit for total ethanol production capacities in a region also depends on the effects it has on the *price of the by-products*. Gilmour estimated that an 18.5 million litres increase will not significantly influence soybean prices (soybeans are direct competitors of dry distillers grains, DDG, from corn) but that a 185 ml/year increase will cause a decrease of the local soybean price by 5.8% or 6.6%, depending on the elasticity of the demand and supply (high and low, respectively). Decrease in soybean price could determine decrease in DDG price (by-product price), which affects plant's feasibility. In the case of Western Canada it is believed that the canola market (canola meal is a direct competitor of distiller's grains from barley) will not place an upper limit on the development of ethanol plants because the canola meal price formation process is highly independent of Canadian supply (export orientation).

Finally, Gilmour underlined that the solvency of ethanol plants is also influenced by the difference between Canadian and American prices for grains because of the competition between American and Canadian ethanol. The determination of the upper limit of ethanol production capacities should then take into consideration this additional factor.

The Ethanol Expansion Program financed 274 ml/year additional ethanol capacities in Ontario which will be in function in the next maximum 2 – 3 years. An analysis of the impacts this increase will have on the profitability of the whole ethanol sector in Ontario can provide important information.

In order to diminish the influence they have on the *prices of agricultural feedstocks*, firms wishing to invest in the ethanol industry should minimize their relative share of a geographic feedstock market and take advantage of supplies from several sources. With respect to the effects of ethanol plants on the *price of by-products*, the integration with the by-products sector (contracting with local livestock feeders or engaging in livestock production) helps dampening the price depressing effect and also alleviating marketing problems associated with the short life of some of the co-products (Gilmour 1986).

3.11. Economic impacts of a future ethanol industry development

Several studies estimated the impacts of a potential development of an ethanol industry in Canada. Thomassin and Baker (2000) analysed the impact of building a 200 million litres/year fuel ethanol plant located in Southern Ontario. The plant uses the wet milling technology because "other studies suggest that wet milling would be more appropriate and economical in this region"[15] and corn as feedstock (10% of Ontario's corn production in 2000). The model used is a modified version of the 1990 Statistics Canada National Input-Output Model. The agricultural data required for the input-output analysis are generated using the AAFC Ethanol Model (econometric model). None of the two models takes into account the impact on commodities other than corn and barley. Three cases are considered to estimate the macroeconomic impacts of the operational phase of the plant. The first case considers that the only impact on the economy is that generated by the corn demand from the plant and that this additional demand is satisfied only by new corn production. In the second case, more adjustments are made by the agriculture to respond to this new demand (reduced exports to the U.S., reduced feed corn, corn displaced by the ethanol co-products and new production). In the last case, the negative impacts on the petroleum refining sector (decrease in the demand for gasoline equal to the output produced by the fuel ethanol sector) are incorporated into the impacts the ethanol plants has on the economy. The authors believe that case 2 is the most likely scenario. Case 3 is eliminated because it is considered that the decrease in the demand for gasoline will determine a decrease in imports of gasoline and not a decrease in local gasoline supply, Ontario being a major importer of gasoline. Case 1 is also eliminated because land availability and the current corn market structure in Ontario don't permit a sufficient increase in corn production.

The study estimates that the direct, indirect and induced impacts of operating this new ethanol plant in the most probable case are increases in industrial output of 328$.6 million, in GDP at factor cost of $84.2 million and in employment of 1390 jobs. The net direct impact on government (federal and provincial) excise tax and agricultural subsidy level is estimated at – 33.9 million $ but the author suggests that this loss is exceeded by the increased revenue from

[15] All existing ethanol plants in Southern Ontario use the dry milling technology, which is considered more profitable for medium sized plants. On the contrary, large ethanol plants increase their profits with the wet milling technology (Agriculture and Agri-Food Canada 2002).

both personal income and corporate taxes that result from the increase in industrial output. A third category of impacts is on the trade balance: fuel ethanol would replace gasoline imports from the U.S., gluten meal (co-product) would replace imported meal and exports of gluten feed and corn germ would be beneficial to Canada's trade position.

Another study (Cheminfo Services Inc. et al. 2000) confirms the positive impacts on the economy of increasing ethanol capacities. The effects are greater for small scale plants (25 ml/year) than for 100 ml/year capacities. Impacts on oil production and refining are also considered but the loss is not significant because the volume of gasoline displaced by ethanol represents around 0.65% of Alberta's gasoline production. In addition, it is estimated that the volume displaced can easily be exported without losses.

The Government of Manitoba (2002a) estimated the economic impacts of a 140 ml/year demand (the equivalent of the mandate it imposed: E10 to represent 85% of the total gasoline consumed in Manitoba, by 2005). The results found an increase of 200 – 900 jobs (depending on plant size and co-products produced) and a decrease in the economic drain of $57 million per year: $43 million from reduced expenditure for imported gasoline and $14 million from federal excise taxes associated to the reduced gasoline imports.

Trends in Transportation Fuel Demand in Alberta

(million litres)

	1995	**%**	**2000P**	**%**	**2010P**	**%**
Gasoline	4417	50%	5101	47%	6140	44%
Diesel	4046	46%	5597	51.4%	7528	55%
Propane	353	3.9%	137	1.3%	47	0.4%
Natural gas	1	0%	1	0%	1	0%
Other fuels	14	0.1%	31	0.3%	83	0.6%
Total	**8831**	100%	**10868**	100%	**13799**	100%

Source: Cheminfo Services Inc. et al. 2000

Appendix 2

Current Canadian Ethanol Plants

- December 2003 -

Item	Producer	Location	Capacity (million litres/year)	Feedstock	Production process	Co-products	Feedlot integration	Type of ethanol	Fuel ethanol retailer	Markets	Employees	Ownership	Plant investment (million $)
1	*Iogen Corporation*	Ottawa, ON	3 – 4 (demo plant)	Wheat straw (40 t/day)		Lignin	-	Fuel ethanol	Petro-Canada, Shell		20		40
2	*Husky Energy Inc.*	Minnedosa, MB	10	Wheat (2 million bushels/year)	Dry mill	Fibrotein (food-grade co-product)	No	Fuel ethanol	Husky Energy Inc.			An integrated Canadian energy company.	
3	*Pound-Maker Ethanol Ltd.*	Lanigan, SK	12	Wheat (1.5 million bushels/year) Barley (3 million bushels/year)	Dry mill	DG	Yes	Fuel ethanol	Husky Energy Inc.				
4	*Tembec*	Temiscaming, QC	18	Pulping process waste		Lignin	-	Industrial ethanol	-			Forest products company.	
5	*Commercial Alcohols Inc.*	Tiverton, ON	22	Corn	Dry mill	WDG	No	65% Fuel eth; 35% industrial eth	Suncor Energy Inc.			The largest manufacturer of industrial/fuel ethanol in Canada.	(1st year of production: 1989)
6	*API Grain Processors /Permolex*	Red Deer, AB	26	CPS Red Wheat	Wet mill	Wheat gluten	Yes	Fuel (22) and industrial ethanol (4)		USA mainly	40	A partnership jointly owned by Agri Partners International Inc. (API) and the Edmonton Pipe Industry Pension Trust Fund.	
7	*Commercial Alcohols Inc.*	Chatham, ON	150	Corn (15 million bushels/year)	Dry mill	DDG (125 000 t/year) WDG, Syrup CO_2 (100,000t/year)	No	65% Fuel eth; 35% industrial eth	Suncor Energy Inc.		65	The largest manufacturer of industrial/fuel ethanol in Canada.	170 (1st year of production: 1997)
TOTAL (demo plant not included)			**238**	-	-	-	-	-	-	-	-	-	-

Source: Canadian Renewable Fuels Association, Producer's web sites, Iogen Corporation 2004

Appendix 3

Successful Proposals in Ethanol Expansion Program – Round 1

- February 2004 -

Item	Producer	Location	Capacity (million litres/year)	Feedstock	Production process	Co-products	Feedlot integration	Type of ethanol	Fuel ethanol retailer	Markets	Employees	Ownership	Allocated contributions / Plant investment (million $)
1	*NorAmera BioEnergy Corp.*	Weyburn, SK	25	Wheat (67,000 t/year)		High-protein grain residues (23)	No	Fuel ethanol			20	Privately held company founded to produce renewable energy.	3,5 / 20
2	*Seaway Valley Farmers Energy Co-operative.*	Cornwall, ON	66	Corn (6,6 million bushels/year)	Dry mill	DDG CO_2	No	Fuel ethanol		Ontario, NE US markets	40	2800 members and shareholders cooperative.	10,5 / 48
3	*Husky Energy Inc.*	Minnedosa, MB	80 (expansion from 10)	Wheat (210,000 t/year)	Dry mill	Fibrotein (food-grade co-product)	No	Fuel ethanol	Husky Energy Inc.	Western Canada		An integrated Canadian energy company.	6,4 /
4	*Okanagan Biofuels Inc*	Kelowna, BC	114	Wheat (low-grade) (300,000 t/year)	Dry mill	DDG (90)	No	Fuel ethanol			More than 40		10 /
5	*Commercial Alcohols Inc.*	Varennes, QC	126	Corn (12 million bushels/year) (15% of Quebec corn production)	Dry mill	DG (100) CO_2 (90)	No	Fuel and industrial ethanol	Petro Canada Inc		50	Pro-éthanol Inc. – minor shareholder (2.5/105)	18 / 105 (starting year: 2005)
6	*Husky Energy Inc.*	Lloydminster, SK	130	Wheat (350,000 t/year)	Dry mill	DDG (134) Fibrotein	No	Fuel ethanol	*Husky Energy Inc.*	Western Canada		An integrated Canadian energy company.	7,8 / 90 (starting year: end of 2005)
7	*Suncor Energy Inc.*	Sarnia, ON	208	Corn	Dry mill		No	Fuel ethanol	*Suncor Energy Inc.*	Ontario		Canadian integrated energy company.	22 /120
TOTAL			**739**	-	-	-	-	-	-	-	-		-

Source: Government of Canada 2004

Appendix 4

Other Projected Canadian Ethanol Plants

- February 2004 -

Item	Producer	Location	Capacity (million litres/year)	Feedstock	Production process	Co-products	Feedlot integration	Type of ethanol	Fuel ethanol retailer	Markets	Employees	Ownership	Plant investment (million $)
1	*Canadian BioEnergy*	Nokomis, SK	23			(for 20,000 cattle)	Yes						30
2	*Canadian BioEnergy*	Porcupine Plain, SK	23			(for 20,000 cattle)	Yes						
3	*Canadian BioEnergy*	Abbey-Cabri, SK	23			(for 20,000 cattle)	Yes						
4	*Canadian BioEnergy*	Unity, SK	23			(for 20,000 cattle)	Yes						
5	*Manitoba BioRefiners Inc.*	Russell, MB	24			(for 24,000 cattle)						Canadian BioEnergy is also involved.	
6	*Saskatchewan Agrivision Corp.*	5 – 6 plants, SK	25 - 30				Yes					A coalition of farm and business leaders. It planned to create joint ventures with communities (but no financing).	
7	*Metalore Resources, Inc.*	Brooklyn, ON	75 – 80	Hard red wheat (205,000 t/year)	Wet mill	Wheat gluten							
8	*PrairieSun Energy Products*	Belle Plaine, SK	80		Dry mill	DG (for 120,000 cattle)	Yes					*Broe Companies of Denver; Crown Investments Corp*	

Appendix 4 (continued)

Item	Producer	Location	Capacity (million litres/ year)	Feedstock	Production process	Co-products	Feedlot integration	Type of ethanol	Fuel ethanol retailer	Markets	Employees	Ownership	Plant investment (million $)
9	*Broe Companies*	Tisdale, Melville-Yorkton, SK	80									*Crown Investments Corp (CIC) owns 40%*	
10	*Parkland Agricultural Resources Co-operative*	Dauphin, MB	80										
11	*Integrated Grain Processors Cooperative*	Brantford, ON	125	Corn (11.8 million bushels/year)	Dry mill	DDG (96,000 t/year) CO_2 (60,000 t/year)	No				30 -35	**Incorporated co-operative** formed in 04.2002 to explore the possibility of building an ethanol plant.	86 (Should begin construction in **2004.)**
12	*Cypress Agri Energy Inc.*	Shaunavon, SK	150	CPS Wheat (10 bushels/year)	Dry mill	DDG (100,000 t/year; 120,000 cattle)	No			BC, AB, SK, Idaho, Washington, Montana	35	Cypress Agri Energy Inc. is planing the building the ethanol plant. Noble Americas and Com Alcohols are equity partners.	100 (40 from local investors and equity partners)
13	*Iogen Corporation*	Alternative locations (Europe ans/or North America)	225	Straw (714,000 t/year; $5-20 mil to farrmers for straw)					Petro-Canada, Shell		110		100- 200
	TOTAL (approximately)		**1 200**	-	-	-	-	-		-			

Source: Briere 2002, Cheminfo Services Inc. et al. 2000, Producer's web sites, Canadian Renewable Fuels Association

Appendix 5

Ethanol Retailing Stations in Canada (1998)

		Canadian provinces								
Item	Ethanol distributor	**AB**	**BC**	**MB**	**ON**	**QC**	**SK**	**YK**	TOTAL	**%**
1	**Husky Energy Inc.**	110	106	35	4	-	32	1	**288**	**31%**
2	**MacEwen Petroleum Inc.**	-	-	-	56	6	-	-	**62**	**7%**
3	**Mr. Gas**	-	-	-	48	8	-	-	**56**	**6%**
4	**Sonic**	-	-	-	-	106	-	-	**106**	**11%**
5	**Suncor (Sunoco)**	-	-	-	270	-	-	-	**270**	**29%**
6	**Sunys**	-	-	-	12	4	-	-	**16**	**2%**
7	**UPI Inc.**	-	-	-	77	-	-	-	**77**	**8%**
8	**Others**	-	-	-	53	1	-	-	**54**	**6%**
	TOTAL	**110**	**106**	**35**	**520**	**125**	**32**	**1**	**929**	
	%	**12%**	**11%**	**4%**	**56%**	**13.5%**	**3.4%**	**0.1%**		**100%**

Source: Canadian Renewable Fuels Association 2000

Appendix 6

Ethanol Bulk Purchase Facilities in Canada (1998)

		Canadian provinces								
Item	Ethanol bulk distributor	**AB**	**BC**	**MB**	**ON**	**QC**	**SK**	**YK**	**TOTAL**	**%**
1	**Husky Energy Inc.**	5	3	2	-	-	3	-	**13**	**23%**
2	**MacEwen Petroleum Inc.**	-	-	-	-	-	-	-	**0**	**0%**
3	**Mr. Gas**	-	-	-	-	-	-	-	**0**	**0%**
4	**Sonic**	-	-	-	-	-	-	-	**0**	**0%**
5	**Suncor (Sunoco)**	-	-	-	-	-	-	-	**0**	**0%**
6	**Sunys**	-	-	-	-	-	-	-	**0**	**0%**
7	**UPI Inc.**	-	-	-	43	-	-	-	**43**	**75%**
8	**Others**	-	-	-	1	-	-	-	**1**	**2%**
	TOTAL	**5**	**3**	**2**	**44**	**0**	**3**	**0**	**57**	
	%	**9%**	**5%**	**4%**	**77%**	**0%**	**5%**	**0**		**100%**

Source: Canadian Renewable Fuels Association 2000

Bibliography

Agriculture and Agri-Food Canada 2000, *Assessment of Net Emissions of Greenhouse Gases from Ethanol-Gasoline Blends in Southern Ontario*, Available on the internet site http://www.tc.gc.ca/programs/Environment/climatechange/docs/ETOH-FNL-RPTAug30-1999.htm#_Sunoco425, January 2000;

Agriculture and Agri-Food Canada 2001, *Bi-weekly Bulletin - Ethanol*, Available on the internet site http://dsp-psd.communication.gc.ca/Collection/A27-18-14-9E.pdf, May 2001;

Agriculture and Agri-Food Canada 2002, *Bi-weekly Bulletin - Canada: Primary Processing of Grains, Oilseeds, Pulses and Special Crops,* Available on the internet site http://www.agr.gc.ca/mad-dam/e/bulletine/v15e/v15n14e.htm, July 19, 2002;

Baker L., Thomassin P. J., Henning J. C. 1990, *The Economic Competitiveness of Jerusalem Artichoke (Helianthus tuberosus) as an Agricultural Feedstock for Ethanol Production for Transportation Fuels*, Canadian Journal of Agricultural Economics 38 (1990), pages 981-990;

Briere K. 2002, *Ethanol Special Report*, The Western Producer, It was available on the internet site http://www.producer.com/articles/20021121/special_report/media/ethanol_sr.pdf, November 21, 2002, This internet address is no longer available because the site www.producer.ca has recently been changed;

Briere K. 2003, *Ethanol Slow to Fly in Canada,* The Western Producer, http://www.producer.com/articles/20031120/news/20031120news25.html, November 20, 2003, This internet address is no longer available because the site www.producer.ca has recently been changed;

British Columbia Ministry of Provincial Revenue 2004, *Notice to Collectors: Changes to the Taxation of Alternative Motor Fuels,* Available on the internet site: http://www.rev.gov.bc.ca/ctb/notices/SDE-AMF(June%202004).pdf, British Columbia Revenue Programs Division, Victoria, British Columbia;

Canadian Energy Research Institute 1981, *Economic Potential for Alternative Transportation Fuels: Methanol, Ethanol, Propane, Liquefied Coal, Compressed Natural gas and Hydrogen – Proceedings of a Seminar Held on November 17, 1981, Calgary, Alberta*, Lawson Printing, April 1982;

Canadian Renewable Fuels Association, *Henri Ford and Fuel Ethanol*, Internet site http://www.greenfuels.org/ethahist.html;

Canadian Renewable Fuels Association 2000, *Ethanol Awareness Campaign*, Internet site http://www.ethanol-crfa.ca, July 2000;

Canadian Renewable Fuels Association, December 2002, *The Renewable Fuels Report*, Available on the internet site http://www.greenfuels.org/newsletters/dec2002.pdf, December 2002;

Cheminfo Services Inc., (S&T)2 Consultants Inc. and Cemcorp Ltd, 2000, *Ethanol Production in Alberta.* Final report prepared for the Government of Alberta. http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agc6751/$FILE/ethanol%20production%20in%20alberta%20final.doc, April 2000;

Commercial Alcohols Inc. a, *Frequently Asked Questions about Commercial Alcohols Inc. and Ethanol*, Internet site http://www.comalc.com/english/chatham/facts/faq.htm;

Commercial Alcohols Inc. b, *Corporate*, Internet site http://www.comalc.com/english/corporate/main.htm;

Commercial Alcohols Inc. c, *Commercial Alcohols asks our neighbours in Chatham-Kent: CAN WE TALK?*, Internet site http://www.comalc.com/english/ (Press Releases, Archived Press Releases);

Coopérative Fédérée de Québec, 2004, *Éthanol: les enjeux d'un carburant "écolo"*, http://www.coopfed.com/COOPERATEUR/contenu/janv_2004/page34.htm, January 2004;

Cypress Agri Energy Inc., *About us*, Internet site http://www.cypressagrienergy.com/aboutus.htm;

Freeze B.S., Peters T. 1999, *A Note on the Profitability of Wheat-ethanol-feedlot Production in Alberta*, Canadian Journal of Agricultural Economics 47 (1999), pages 67-78;

Farm Credit Canada 2003, *National Biomass Ethanol Program*, Internet site http://fcc-sca.ca/en/products/partnerships/nbep_e.asp, 2003;

Gilmour B. 1986, *Potential Market Impact of a Corn/Ethanol Plant to be Located in Southern Ontario*, Agriculture Canada, May 1986;

Government of Canada, 2001a, *Future Fuels Program*, Available on the internet site http://oee.nrcan.gc.ca/vehiclefuels/ethanol/ethanol_futurefuels.cfm?PrintView=N&Text=N, September 2001;

Government of Canada, 2001b, *Future Fuels Initiative*, *National Biomass Program,* Internet site http://www.climatechange.gc.ca/english/newsroom/2001/steps/steps_future.asp, 2001;

Government of Canada, 2003a, *Backgrounder - Ethanol Expansion Program*, Available on the internet site http://www.climatechange.gc.ca/english/newsroom/2003/bg_ethanol.asp, October 2003;

Government of Canada, 2003b, *Ethanol Expansion Program Invitation to Proponents – Round 1*, It was available on the internet site http://climatechange.gc.ca/english/publications/announcement/pdf/invitation.pdf, October 20, 2003, This internet address is no longer available because the site www.climatechange.gc.ca has recently been changed;

Government of Canada, 2003c, *Government of Canada Announced $1 Billion Toward Implementation of the Climate Change Plan for Canada*, Available on the internet site http://climatechange.gc.ca/english/newsroom/2003/budget/20030812_budget.asp, August 12, 2003;

Government of Canada 2004, *Government of Canada Announces Successful Proposals in Ethanol Expansion Program*, Available on the internet site http://www.nrcan-rncan.gc.ca/media/newsreleases/2004/200402_e.htm, February 13, 2004;

Government of Manitoba 2002a, *Developing Manitoba's Ethanol Industry (part of Homegrown energy: Manitoba energy development initiative*), Available on the internet site http://www.gov.mb.ca/est/energy/ethanol/ethanol.pdf, April 2002;

Government of Manitoba 2002b, *Ethanol Backgrounder (part of Homegrown energy: Manitoba energy development initiative*), Available on the internet site http://www.gov.mb.ca/est/energy/ethanol/ebckgrder2.html#Benefits http://www.gov.mb.ca/est/energy/ethanol/ebckgrder1.html#Intro , 2002;

Government of Manitoba 2002c, *Ethanol Made in Manitoba*, A report by the Ethanol Advisory Panel to the Government of Manitoba, Available on the internet site http://www.gov.mb.ca/est/energy/ethanol/ethanol2-low.pdf, 2002;

Government of Manitoba 2003a, *Province Introduces Proposed Legislation to Mandate 10 per cent Ethanol Blends by 2005*, Available on the internet site http://www.gov.mb.ca/chc/press/top/2003/11/2003-11-21-03.html, November 2003;

Government of Manitoba 2003b, *The Biofuels and Gasoline Tax Amendment Act*, http://web2.gov.mb.ca/laws/statutes/2003/c00503e.php, December 2003;

Government of New Brunswick, *New Brunswick Energy Policy*, Chapter 3.5 Alternative Energy, Available on the internet site http://www.gnb.ca/0085/alt.htm;

Government of Ontario 2002, *Ontario Supports Clean, Renewable Power Generation*, Available on the internet site http://www.ene.gov.on.ca/envision/news/2002/102401fs.htm, October 2002;

Government of Quebec 1996, Ministry of Finance, *Déclaration ministérielle concernant la réduction de la taxe sur les carburants à l`égard de l`éthanol*, December 12, 1996;

Government of Quebec 1997, Ministry of Finance, *Entente pour la production d`éthanol au Québec*, May 27, 1997;

Government of Quebec 1998, Ministry of Finance, Bulletin d`information 98-8, *Modalités d`application de la réforme de la fiscalité des entreprises et autres mesures fiscales*, Section 12 `Report de la mesure de reduction de la taxe sur les carburants à l`égard de l`ethanol`, December 22, 1998;

Government of Saskatchewan 2002a, *Plan to develop ethanol industry*, Available on the internet site http://www.gov.sk.ca/newsrel/releases/2002/03/21-178.html, March 2002;

Government of Saskatchewan 2002b, *Greenprint for Ethanol Production in Saskatchewan*, Available on the internet site http://www.ir.gov.sk.ca/adx/asp/adxGetMedia.asp?DocID=3288,3286,2937,2936,Documents&MediaID=4734&Filename=Greenprint.pdf, April 2002;

Government of Saskatchewan 2004, *Increased Ethanol in Fuel May 1st, 2005*, Available on the internet site http://www.gov.sk.ca/newsrel/releases/2004/06/10-354.html, June 10, 2004;

Groupe RLD inc. 1998, *La construction d'une usine d'éthanol au Québec – Éléments de réflexion*, March 1998;

Integrated Grain Processors Cooperative (IGPC), Internet site http://www.igpc.ca;

Iogen Corporation, *A Fully Integrated Facility*, Internet site http://www.iogen.ca/2200.html;

Iogen Corporation 2004, *Iogen – Creating a Cleaner Future*, Article published in the directory `Canadian BioProducts from Renewable Resources 2004`, Publisher Contact Canada, pages 5 - 7, 2004;

Lavigne Amanda 2001, Clarkson University, *The Net Energy Value of Ethanol: Critical Issues*, Presentation given at the Workshop on the Increased Use of Ethanol and Alkylates in Automotive Fuels in California, Available on the internet site http://www-erd.llnl.gov/ethanol/proceed/, April 2001;

Le Soleil 2003, *De l'espoir pour l'usine d'éthanol de Varennes*, by Pierre Asselin, August 13, 2003;

Manness G., Nicholson T. and Nicolaou C. 2002, *Ethanol Made in Manitoba*, A report made by the Ethanol Advisory Panel to the Government of Manitoba, http://www.gov.mb.ca/est/energy/ethanol/ethanol2-low.pdf, December 2002;

Natural Resources Canada 2003, *Ethanol Policy and Programs in Canada*, Presentation for the World Summit on Ethanol for Transportation, November 3, 2003;

Ontario Corn Producers' Association 2003a, *Ethanol/Bioproducts*, Available on the internet site http://www.ontariocorn.org/issues/elect2003.html, 2003;

Ontario Corn Producers' Association 2003b, *Ocpa Market Development Committee Annual Report*, Available on the internet site http://www.ontariocorn.org/about/markdev03.html, March 2003;

Ontario Corn Producers' Association 2003c, *Markets - Why Expand Domestic Consumption of Ontario Corn?*, Available on the internet site http://www.ontariocorn.org/ocpmag/magh42003pg8.html, April 2003;

Pimentel D. 1991, *Ethanol Fuels : Energy Security, Economics, and the Environment*, Journal of Agricultural and Environmental Ethics, 0893/4282/91, 1991;

Seaway Valley Farmers Energy Co-operative Inc., *The Project*, Internet site http://www.glen-net.ca/ethanol/project.html;

Shapouri H., Duffield James A., Graboski Michael S. 1995, *Estimating the Net Energy Balance of Corn Ethanol*, Available on the internet site http://www.ers.usda.gov/publications/aer721/, July 1995;

Shapouri H. 2003, Ethanol Production Economics, *Presentation for the World Summit on Ethanol for Transportation*, Quebec, November 2 – 4, 2003;

Statistics Canada 2003, *Harvest Disposition – Average Yield*, Table 001-0010, Available on the internet site http://estat.statcan.ca, 2003;

Tembec 2004, *Éthanol*, Internet site http://www.tembec.com/DynamicPortal?key=web&lng=fr-CA&crit=products_chemical_ethanol&page=tpl_products, 2004;

Thomassin P. J., Henning J. C., Baker L., 1992, *Macroeconomic Impacts of an Agro-Ethanol Industry in Canada*, Canadian Journal of Agricultural Economics 40 (1992), pages 295-310;

Thomassin P. J., Baker L., 2000, *Macroeconomic Impact of Establishing a Large-scale Fuel Ethanol Plant on the Canadian Economy*, Canadian Journal of Agricultural Economics 48 (2000), pages 67-85;

World Resources Institute 2003a, *Resource Consumption: Motor gasoline consumption*, Available on the internet site http://earthtrends.wri.org/text/ENG/variables/291.htm, 2003;

World Resources Institute 2003b, *Agricultural Production: Cereals production, total*, Available on the internet site http://earthtrends.wri.org/text/AGR/variables/183.htm, 2003;