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BIO BASED CHEMICAL IMPORT REPLACEMENT INITIATIVE

CHEMICAL MARKETS AND BIOCHEMICAL OPTIONS FOR ALBERTA

FINAL REPORT

Prepared for:

Enterprise and Advanced Education
Government of Alberta

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1. Executive Summary

1.1 Introduction

Alberta's Enterprise and Advanced Education (EAE) ministry is interested in upgrading bioresources to useful chemicals. Bioresources include, but are not necessarily limited to: wood; wood wastes/residues; wood pulping by-products; wheat; canola; other crops; livestock rendering by-products; manure; and municipal solid waste (MSW). This report provides background market information for chemicals and key market factors to consider with respect to displacing fossil fuel based chemicals that are imported into Alberta, and/or that could be produced from bioresources available in the province.

The report provides insight and analysis on 40 chemicals that were deemed to be of interest from a bio-production and import replacement aspect for Alberta. In addition to individual chemicals, analysis is provided for 10 formulated products industries or chemical market areas. The first phase of the study involved the creation of brief (1 to 4 page) profiles on these chemicals and chemical market areas. These brief profiles generally contain information on the chemical production, use, value, Canadian/Alberta trade, and Alberta bioresources feedstocks. After completing these profiles Cheminfo Services in consultation with EAE selected the 10 most promising areas as candidates for further study. This selection was made based on an established set of criteria that is detailed in the *Summary of Findings* section. The ten selected areas for phase II of the study are listed in the table below.

Table 1: List of Selected Chemicals and Market Areas for More Detailed Analysis

Alpha-olefins	Guar gum
Glycerol carbonate	Isopropanol (IPA)
Carboxymethylcellulose (CMC)	Hexane
Surfactants	Oilfield chemicals
Solvents	Lubricants

This report is intended to inform Alberta Enterprise and Advanced Education on selected potential opportunities for biochemicals development in Alberta and to highlight some areas of further study for the development and growth of biochemicals in Alberta. The analysis on each chemical and market area represents a scan of the market factors. Further and more detailed research on each chemical and market area would be required to assess the feasibility for further development or investment in Alberta.

1.2 Overview of Bioresources

Alberta possesses a wealth of bioresources. Agricultural crop products occupy the second largest export category in Alberta behind only bitumen and petroleum products. Cereals and oil seeds make up the largest category of exported crop products. The majority of these exports are destined for the United States where they are used in the production of animal feed and food for humans. In addition to agricultural crops, Alberta possesses biomass resources such as forestry products and agricultural residue.[1,2] In general, Alberta possesses sufficient bioresources for a variety of bio-based chemicals examined in this report. For example:

- Agriculture crops: wheat, barley, other grains, beets, oilseeds. These may be used to produce oleochemicals (e.g., for surfactants, lubricants), starches for thickeners (for drilling fluids), and sugar sources for fermentation (IPA, xanthan gum);
- Agricultural and Forest Residue: plant matter left after crop or timber harvest such as foliage, tree limbs, and straw from wheat, barley and oats. This largely cellulosic material may be used for the production on modified cellulose (CMC, cellulose ethers), or polysaccharides for fermentation (IPA, xanthan gum); and
- Whole forest biomass: hardwood or softwood lumber obtained through conventional logging. This cellulosic material can provide pulp for specialty cellulose chemicals like CMC and other cellulose ethers. Some processes may also use polysaccharides from the wood in fermentation processes.

Bioresources can be attractive feedstocks for some chemicals and energy due to better sustainability compared to the use of finite petroleum and natural gas resources. Although this report may highlight certain issues pertaining to feedstock requirements, these were not the focus of the study and therefore merit further study. While there are large amounts of feedstocks available in Alberta, detailed analysis of availability to match the required production scale and yields for each chemical of interest is required.

1.3 Overview of the Chemical Industry

The chemicals market in Alberta is large and complex, though not as diverse as in the eastern part of the United States and eastern Canada. The oil and gas and agricultural industries represent large chemical markets in Alberta, while markets for such products as cosmetics, cleaners, printing inks, adhesives, sealants, pharmaceuticals, and lubricants tend to be smaller than in the eastern part of the Canada where there is a larger population and greater manufacturing activity. A brief overview of some key aspects of Canada's and Alberta's chemical markets is provided below.

[1] Statistics Canada, Canadian International Merchandise Trade Database. http://www5.statcan.gc.ca/cimt-cicm/home-accueil?lang=eng

[2] Jacobs Consultancy, (2013). *Final Report: Identification of Opportunities for the Production of Bio-Products from Waste Bio-Mass in Alberta.*

Canada's chemicals manufacturing industry is included in the North American Industrial Classification System (NAICS) code 325. The industry is large and very diverse in terms of products and manufacturing processes. Manufacturing shipments for the Canadian chemical sector totalled $42.5 billion in 2010 with commodity products such as petrochemicals, polymers, fertilizers, inorganic chemicals, and gases making up 58% of the total value. Specialty chemicals, formulated products, and pharmaceuticals made up 42% of manufacturing shipments in 2010. Excluding pharmaceuticals, total manufacturing shipments were close to $33 billion, with approximately 73% being industrial and polymer products.[3]

Alberta's chemical industry is largely comprised of petrochemical, polymer (i.e., polyethylene) and fertilizer production. Its products are largely exported to the Far East and United States. In comparison to Ontario and Quebec, where the great majority of the rest Canadian chemical industry resides, there are lower levels of manufacturing of formulated products and specialty chemicals (FPSC) in Alberta. In general, FPSC tend to be made in eastern Canada, closer to larger manufacturing and consumer markets in Canada and the northeastern part of the United States. However, as an exception, Alberta has a large upstream oil and gas industry, which has attracted FPSC formulators servicing regional demand.

Table 2: Manufacturing Shipments for Canadian Chemical Sector, 2010
($ billion)

Grouped Industry Segments	Canada Manufacturing Shipments	% of Total	Estimated Alberta Portion of Canada Total
Petrochemicals, organic chemicals and polymers	$16.6	39%	High (>70%)
Fertilizers and other agricultural chemicals	$4.0	9%	High (>70%)
Inorganic chemicals and gases	$4.1	10%	Low (<20%)
Formulated products and other chemicals	$9.2	22%	Low (<15%)
Pharmaceuticals	$8.7	20%	Very Low (<5%)
Total chemical sector	$42.5	100%	

Source: Industry Canada, Available at: http://www.ic.gc.ca/eic/site/chemicals-chimiques.nsf/eng/bt01203.html.
High means over 70% Medium is 20% to 70%, and low means less than 20% of Canada total.

The most attractive markets for Alberta bio-based chemicals production would be oil and gas production (including oilsands mining and bitumen production), agriculture and petrochemicals. Future bio-based chemical producers should consider focusing their market efforts on regional customers in and near Alberta in these areas.

[3] Includes Petrochemicals, organic chemicals and polymers, Fertilizers and other agricultural chemicals, and Inorganic chemicals and gases, in the table below.

1.4 Summary of Findings

There are many chemicals that can be derived from bioresources. This study took into consideration key market factors that are typically important to developing chemical businesses in order to select the most attractive chemicals and/or market areas for analysis. The following factors were taken into account.

Regional Market In or Near Alberta
It is preferable to have sizable customers and high demand in and/or near Alberta (e.g., western Canada, northwest United States). These factors contribute to improved technical and customer service, and lower transportation costs. Biochemicals that are used in the large oil and gas, and agricultural sectors are more attractive.

Import Displacement Potential for Alberta
Chemicals that are not produced in Alberta and must be imported are likely to offer more attractive market potential.

Market Potential
Biochemicals produced in Alberta may offer environmental and/or sustainability benefits, or other benefits that may be important to some customers or for niche market segments. Market potential considers uptake by customers interested in these or other benefits associated with biochemicals. This factor was informed through interviews with potential customers for biochemicals.

Supply Activities
This factor considers biochemical supply activities (i.e., Are there companies offering the bio-based chemical?) and the state of development of the bioprocess for production.

A summary assessment for each of the 10 selected[4] chemicals and market areas that were identified as being most attractive for further study is provided in the table below. The 10 chemicals/market areas are presented in descending order of attractiveness with respect to further analysis and development in Alberta. For example, the oilfield chemicals area presents an attractive market for a variety of bio-based chemicals produced in Alberta.

[4] Selected from the 40 chemicals and 10 formulated products market areas.

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Table 3: Summary of Information for the Ten Detailed Profiles in the Study

Chemical	Regional Market (In or Near Alberta)	Import Displacement Potential for Alberta	Market Potential for Biochemical	Bio-based Supply Activities
Oilfield chemicals	• Large regional chemicals market in natural gas, conventional oil, oilsands mining and bitumen production.	• Good potential to displace significant quantities of specialty chemicals imports used in formulated oilfield products.	• Minor customer interest in biochemicals. Low interest since products are not used by consumers, low promotional benefits for using renewable feedstocks. • Some interest due to lower toxicity/worker safety and biodegradability. • Some potential to tie-in with Alberta's GHG offset credit program.	• Wide variety of bio-based chemicals used (e.g., natural gums, starches, lignosulphonates) • Active research in some fields with little activity in others. • Many suppliers of imported bio-based products.
Lubricants	• Use in every type of machinery, automotive lubricants, metal working fluids for cutting, etc. • Large demand for heavy equipment and machinery in oil and gas operations, and drilling wells.	• Competition with local petrochemical refineries. • There is the potential to replace imports of various specialty lubricants and greases.	• Traditional biolubricants such as vegetable oils and their derivatives could find increased use in the oil/gas industry as biodegradable drilling lubricants. • Some interest in remote machinery operation for reduced spill impact on the environment.	• Some small startup firms producing bio-lubricants in North America. • Growing interest in the field with a wide variety of biolubricants for many applications. • Hindered by a lack of standards, accreditations.
Isopropanol (IPA)	• Good regional demand in de-icing fluids. • Minor uses in paints and coatings, printing, inks, adhesives.	• Large production in Ontario by Shell but none produced in Alberta. • Imports could be displaced by a local supplier.	• Pipeline de-icing and other oil and gas solvent uses make up the largest Alberta demand. • Interest in a specifically bio-based IPA for these applications is likely low. • Local bio-based IPA supplier is attractive.	• Mascoma is building a cellulosic ethanol plant in Drayton Valley, AB that is expected to produce IPA as a co-product.
Solvents	• Large number of uses across many sectors. • Consumer/automotive (washer fluid, antifreeze), paints/coatings, adhesives, pesticides.	• Large imported quantities of specialty solvents and consumer products. Potential to displace some imported solvents. • Existing solvents production from domestic petrochemical plants and refineries are competitive sources.	• Consumer products and green cleaners for household market offer better potential. • Improved sustainability, environmental or workplace safety benefits for some industrial uses.	• Methyl ester solvents are being offered in the marketplace. • Some development and research in bio-derived solvents - largely for niche, specialty applications.
Carboxymethylcellulose (CMC)	• Large current demand for CMC in drilling muds for oil and gas production. • Also used as a food thickener, demand for which is expected to be low in Alberta.	• Canada is an importer of CMC and has no domestic production. • Abundant forest resources in Alberta could supply the Canadian market and parts of North America.	• CMC for use in drilling muds is the largest potential use in Alberta.	• Produced exclusively from biomass (cotton linter or wood pulp).

Chemical	Regional Market (In or Near Alberta)	Import Displacement Potential for Alberta	Market Potential for Biochemical	Bio-based Supply Activities
Hexane	• Used as a component in bitumen diluent. High potential for use by in-situ bitumen upgraders that purchase diluent. • Also used in natural oil extraction (ex. canola) for which there is demand in Alberta. • Small uses in adhesives, other formulated products manufacturing.	• Large production at Shell Scotford plant and Imperial Oil in Sarnia, ON. • Relatively small amount (5 kilotonnes) imported to Alberta means import replacement potential is low.	• Potentially large market for bio-naphthas (comprised of hydrocarbons including hexane) for in-situ oilsands facilities. • Several oilseed extraction facilities in Alberta require hexane.	• No current bio-production but some research is being conducted on sugar fermentation pathways. • Bio-naphtha are being produced via Neste Oil's process as well as other renewable naphtha technologies for use in diluents and commercial solvents.
Surfactants	• Good demand for oilfield chemicals and mining in Alberta and other western provinces. • Smaller uses in cleaners, pesticides, and coatings. • Other uses in Canada include personal care, formulated cleaners (institutional and household), and in metal mining.	• Lower domestic production is replaced by imports across Canada. • Potential to increase domestic production with a viable product.	• Consumer products and green cleaners for households. • Improved sustainability and wastewater quality for industrial uses. • Complex market and formulated products business is a concern for a new producer. • Consumer preference for biodegradable and bio-based surfactants is a positive factor.	• A large portion of basic surfactants are made from bio-based chemicals. • Variety of research on different types of bio-surfactants and cleaners aimed at household/institutional uses.
Guar gum	• Large current demand for guar in drilling muds for oil and gas production, especially in fracking. • Regional use in potash mining (Saskatchewan). • Minor uses as a food thickener in Alberta, other western provinces.	• Exclusively imported from Pakistan and India with a high potential for import replacement. • Guar plant (crop) not suitable for growth in Alberta. • A domestic supply would have lower shipping costs to customers in western Canada.	• Primarily oil and gas drilling with some use in neighbouring Saskatchewan for potash mining. • Price volatility for imported guar could make domestic production attractive.	• Produced exclusively from biomass (guar bean). • Current research on new varieties of guar, cultivation methods, and replacement substances.
Glycerol carbonate (GC)	• Used as a specialty solvent, intermediate and other applications. • Little use in Alberta. • Total market and uses cannot be easily quantified.	• Some potential to displace some specialty solvent imports. • Potential to provide a use for exported glycerol by-product from biodiesel production.	• No identified current niche market for GC in Alberta. • Some potential use in solvents and degreasers in Alberta requiring low volatility and toxicity.	• Early stage of research, currently produced from petrochemicals. • Little to no new developments identified. • Production is dominated by one US company (Huntsman).
Alpha-olefins	• Large use for C_4, C_6, C_8 comonomers in polyethlylene production. • Some smaller applications for C_{10}+ in lubricants, surfactants	• Alberta imports a large fraction of the Canadian total demand. • Already a large alpha olefin demand for the polyethylene industry in Alberta.	• No interest in bio-based alpha olefins for use in polyethylene. • Low volume applications: for surfactants, lubricants, and oilfield chemicals. • Low potential for niche applications in oil and gas.	• No identified producers. • Little research in this field.

1.5 Suggestions for Advancement and Promotion of Opportunities

This study provides an overview of many chemicals spanning a variety of markets in Canada, the United States, and globally. It identifies developments in multiple areas of biochemical production and market factors affecting a number of chemicals, which are in many cases at early (and not very well defined) stages of development. Given the broad scope of chemicals and market areas examined, there are uncertainties and information gaps. This section provides some suggestions for addressing these and advancing bio-based chemical opportunities in Alberta. These are:

- **Regional Market Focus:** Focus on regional markets such as oil and gas, agriculture, and oilsands mining rather than more distant specialty chemical markets such as paints, inks, adhesives, cosmetics, and pharmaceuticals.

- **Detailed Market Research**: Conduct detailed and extensive market research focused on specific chemicals to identify customer purchase volumes, specific customer needs, level of interest in the benefits of biochemicals, product functional requirements, quality standards, prices, existing supplier positioning, etc.

- **Feedstock Supply Matching to Biochemicals Production:** Abundant feedstocks available in Alberta include agricultural resources and glycerol (by-product from biodiesel production). These might be available at a low cost and present an opportunity for biochemicals that can be made with them. Further analysis is suggested to match potential chemical production volumes with the bioresources available. A study focused on the bioresource requirements for specific biochemical plant sizes might better define production opportunities or issues for resource availability in Alberta.

- **Incentive Strategies:** An analysis of financial incentives, tax treatments, greenhouse gas offsets or credits, and other mechanisms to encourage biochemical developments in Alberta is suggested. Other jurisdictions have been able to attract biochemical investors using a variety of mechanisms.

- **Technical Properties of Biochemicals:** Accreditation by international standards organizations is an important step in acceptance of some biochemicals (e.g., lubricants, some solvents). (This has been the case for biofuels – especially biodiesel.) A more detailed understanding of technical properties and functionality of biochemicals and the related needs of potential users would provide a good basis for matching the quality of products offered to customer needs.

2. Introduction

2.1 Background

Alberta's Enterprise and Advanced Education (EAE) ministry is interested in upgrading bioresources to useful chemicals. Bioresources include, but are not necessarily limited to: wood; wood wastes/residues; wood pulping by-products; wheat; canola; other crops; algae; livestock rendering by-products; manure; and municipal solid waste (MSW).

2.2 Purpose of the Report

This report provides background market information for chemicals and key market factors to consider with respect to displacing fossil fuel based chemicals that are imported into Alberta, and/or that could be produced from bioresources available in the province. The focus of the study is on chemicals and thus it does not analyze biofuels such as biodiesel and bioethanol. The report does not describe potential technology advancements that might be required to feasibly produce the biochemicals. Recent work (Jacobs Consultancy, 2013) conducted for Alberta Innovates has examined some bioprocesses for making chemicals in the province.[5] That work also examined the availability of bioresources in the province, which is briefly summarized in this report.

This report provides market information to inform potential biochemical suppliers regarding the nature of the markets in which drop-in substitutes or bio-based chemicals with suitable functionality might compete. The report does not assume or ignore the potential situation that bio-based processes may not be available to make identical or "drop-in" replacements for chemicals made with conventional technologies. Although there may be no currently available bio-based technologies to make certain chemicals analyzed in this report, market information is provided for perspectives.

2.3 Methodology

The following section provides an overview of the research methodology applied to prepare this report, which involved two phases. The rationale and selection process to identify chemicals for analysis in these phases is provided below.

[5] Jacobs Consultancy (March 2013) *Identification of Opportunities for the Production of Bio-Products from Waste Bio-Mass in Alberta.* Prepared for Alberta Innovates – Energy and Environmental Solutions

2.3.1 Phase I

The study was conducted in two phases. The first phase was the establishment of 40 chemicals[6] and 10 market areas for brief market profiles in order to better understand potential bio-based chemical opportunities in Alberta. The following is the list of 40 chemicals developed in collaboration with EAE that are analyzed in this report.

Table 4: List of Chemicals Analyzed in this Study

Selected Chemicals for Detailed Analysis	
Alpha-olefins	Guar gum
Glycerol carbonate (GC)	Isopropanol (IPA)
Carboxymethylcellulose (CMC)	Hexane
Chemicals with Brief Profiles	
Ethylene oxide and ethylene glycol	Epichlorohydrin
Polyethylene	Ethylene
Polystyrene	Polylactic acid
Methanol	Alkyl polyalkyloglycosides
Hydrogen	Acrylic acid and acrylate polymers
Ammonia	Acetone
Urea	Naphthas
Carbon black	Toluene
Carbon and graphite anodes	Xylenes
Polyols	Ethanol
Phenol	Heavy aromatics
Ethanolamines	Methyl ethyl ketone
Morpholine	Methyl isobutyl ketone
Xanthates	Ethers, esters and acetates
Acetic acid	Hydrogen peroxide
Isoprene	Sulphuric acid
1,4 butanediol	Diluent for bitumen transport

In addition to individual chemicals, this report provides analysis for 10 formulated products industries or chemical market areas, listed in the table that follows. Manufacturers involved in these industries use some of the chemicals analyzed as well as many other chemicals and ingredients. Understanding these industries is useful when considering the markets in which biochemicals might compete.

[6] There were 39 chemicals in phase 1. Diluent for bitumen pipeline transport was added during the course of phase 2 analysis, and included in the Appendix.

Table 5: Chemical Market Areas Analyzed

Selected Market Areas for Detailed Analysis
Surfactants
Solvents
Oilfield chemicals
Lubricants
Market Areas with Brief Profiles
Paints and coatings
Soaps and cleaners
Adhesives and sealants
Toiletries and cosmetics
Pesticides
Explosives
Pigments and dyes

The process for selecting the chemicals and market areas for analysis in phase I was based on EAE's interest to better understand the markets for chemicals that are used in Alberta and/or markets in which bio-based chemicals produced in Alberta can be sold in markets outside the province. There are a great many chemicals made in North America and used in Alberta. Furthermore, pure chemicals and polymeric resins can be blended to make a very large number of formulated products. A preliminary review of literature sources and application of the consultant's knowledge and judgement were used to develop an initial longer list of chemicals to investigate. Additional chemicals and revisions to the initial list were identified by EAE. EAE on conjunction with the consultant selected the 40 chemicals and 10 market areas for further analysis in phase I. The key factors considered in selecting the chemicals were: whether the chemicals were used in Alberta; imported and/or made in Alberta; and whether their production was based on non-biomass based raw materials. Information applied to inform these criteria was based only on limited or preliminary research. More detailed research to better inform these criteria and other elements was conducted once the chemicals and market areas were selected.

2.3.2 Phase II

After completing brief profiles for 40 chemicals and 10 formulated products markets, Cheminfo Services, in consultation with EAE, selected the ten most promising areas as candidates for further analysis in phase II of the study. In order to objectively select ten chemicals or chemical market areas for more detailed market research, a decision matrix method was applied to the list of 40 chemicals and 10 chemical market areas profiled. The chemicals were scored from 1 to 10 by EAE on the basis of four criteria. The higher the score, the more attractive the result. No differentiated weighting factors were applied to the criteria. The raw scores were summed and the total scores were ranked. The higher the total score the more attractive the chemical/area opportunity. The four criteria are described below. The matrix was used as a decision making tool for EAE and its review committee but some review committee respondents chose to provide input in other forms such as a list of preferred chemicals. All input, regardless of format, was considered.

Regional Market In or Near Alberta
This criterion takes into account the relative size of demand and presence of customers for the chemicals in and/or near Alberta (e.g., western Canada). Rankings will typically be higher for oilfield and agricultural chemicals since there are relatively large markets and there are many customers in and around Alberta.

Maturity of Bio-Based Production Process
This criterion considers the maturity of the bio-based production processes. In some cases there are multiple processes, each with varying degrees of maturity. Chemicals with full scale production will score highest followed by those in the pilot plant stage, planned pilot plant, lab scale demonstration, and at theoretical or practical research stages.

Import Displacement Potential for Alberta
This criterion considers import displacement potential. Chemicals that are not currently produced in Alberta and must be imported are likely to offer more attractive potential. Scores are higher for chemicals that are not produced in Alberta, but are heavily imported.

Niche Market Potential
Since the majority of bioprocesses identified are not currently able to compete with conventional processes in terms of scale or production cost, some consideration is given to the potential uptake by smaller niche markets, which may provide higher prices for biochemicals. Niche market potential could include uptake by customers concerned with product sustainability or remote customers suitable for small modular plants.

Bio-resource availability in Alberta was not considered as one of the criteria. Scoring on this criterion may change the relative attractiveness of certain chemicals. For example, there may not be bioresources available in Alberta to produce guar gum, which would reduce its attractiveness.

The ten selected areas for phase II of the study are listed in the table below.

Table 6: List of Selected Chemicals/Market Areas for More Detailed Analysis

Alpha-olefins	Guar gum
Glycerol carbonate	Isopropanol
Carboxymethylcellulose (CMC)	Hexane
Surfactants	Oilfield chemicals
Solvents	Lubricants

The above ten chemicals are almost all used in the oil and gas industry, which is the largest industry in Alberta. Surfactants, solvents, lubricants, oilfield chemicals, guar gum, CMC, and alpha-olefins all have applications in the oil and gas sector in Alberta. The degree to which some of these chemicals could feasibly be produced from bioresources varied greatly but research usually indicated a handful of start-up companies producing a bio-based chemical at a small scale with no widespread adoption. CMC, guar gum and glycerol carbonate are already bio-based (glycerol carbonate is partially bio-based) but were analyzed for other reasons (rather than as substitutes for petroleum-based chemicals). Guar gum and CMC are both imported in large quantities for use in drilling fluids and a local supply could be valuable to Alberta drilling mud suppliers. Glycerol carbonate is a value-added product relative to the low value glycerol feedstock (a co-product of biodiesel) from which it is derived.

2.3.3 Research Methodology

The focus of the research was on collecting market and related information (e.g., production, suppliers, trade data). This information was analyzed and brief profiles were prepared based on readily available information. With 40 chemicals to profile and 10 industries, the study allocated and applied a limited amount of research resources to cover each area. The availability of public information for the chemicals varies. In general, more information is available for high volume commodity chemicals, as opposed to low volume specialty chemicals. This is also the case for Canadian trade data. As a result, the information on the 40 chemicals and 10 chemical markets/industries varies with respect to comprehensiveness, accuracy and consistency of information provided.

The research methodology included:

- literature / Internet searches;
- review of public databases (e.g., trade data, Statistics Canada publications, etc.);
- review of the consultant's library files; and
- interviews with selected industry participants.

Most of the information in the profiles is from public literature/Internet sources and the consultant's library of information, which for some chemicals was sufficiently extensive for brief profile development. A variety of chemical industry trade magazines, journals, newsletters and other public sources were consulted for supply and market information. Information sources are referenced within the report and a list of references is provided in the *References* section of the report. In general, information that is not referenced can be considered to be based on the consultant's knowledge of the industry, and/or Cheminfo's library of information.

Publicly available trade data at the 6-digit harmonized system (HS) code level was downloaded from the Canadian International Merchandise Trade Database. Additional trade data at the 10-digit level for imports and export data at the 8-digit level (only available at 8-digit) were purchased from Statistics Canada for Alberta and the rest of Canada and summarized. Import data for chemicals that are not produced in Canada (or Alberta) are a good source of information to establish the size of the market in Canada or Alberta. For chemicals produced in Canada or Alberta, available production and trade data were sometimes applied to estimate the domestic market. This was carried out using the following approach:

- Production + Import – Exports = Domestic Consumption.

In the field of chemicals market research it is generally the case that there is more information available on commodity chemicals and polymers, and much less information available on specific specialty chemicals, low volume chemicals, and formulated products (e.g., quantities of inks, adhesives, etc.). For many individual chemicals and formulated products, information is available on the value of products, but little or no corresponding information on the quantities produced or used in the market. Furthermore, quantitative information for all of Canada is generally more available than for individual provinces, including Alberta. Canadian and Alberta chemical trade data were available from Statistics Canada and Industry Canada for many chemicals. However, there are no data for interprovincial trade. Where no data were available, when reasonable, order-of-magnitude estimates for chemical demands were made for Canada and Alberta. These estimates have a high level of uncertainty associated with them, and further detailed market research beyond the scope of this project would be required to reduce such uncertainties.

2.3.4 Industry and Government Consultations

For the more detailed analyses of the 10 potential opportunities examined in this study, important sources of information and perspectives were obtained through consultations with industry representatives. Information was collected from chemical users and suppliers on quantities used, technical requirements, functionality, prices, interest in using or distributing biochemicals, seasonal demands, existing suppliers, packaging, handling and other market elements. Consultations with marketing personnel to obtain perspectives regarding the market benefits and price premiums associated with formulated products that are made with biochemicals from renewable / sustainable resources.[7]

2.3.5 Research Gaps

In general, there is a lack of comprehensive market data (e.g., size, value, suppliers) available for Alberta and Canada for the 10 selected biochemical opportunities examined in phase II. In this situation, in some cases order-of-magnitude estimates were developed - often based on anecdotal input from customers or suppliers regarding actual or potential markets. Some of these estimates may have a high uncertainty associated with them, and further detailed market research (e.g., contacting many or all potential customers) may be required, which was beyond the scope of this project.

[7] The list organizations and individuals contacted has been provided to EAE, as a separate electronic Appendix.

Given the large number of chemicals/market areas covered in this study, some profiles have gaps regarding certain subjects. Also due to the limited time and research resources that could be allocated to each chemical or market area, there are variations in the level of information available in the chemical profiles presented in this report. Some chemicals were new or emerging and thus had little to no market information available. For other specialty chemicals, production was restricted to very few suppliers, which were in some cases reluctant to disclose information on their markets.

2.4 Rest of This Report

The rest of this report is comprised of the following sections and appendices. Section 3 consists of the summary of of bioresources available for use in Alberta. Section 4 provides an overview of Canada's and Alberta's chemicals industry and markets. These sections are intended to provide context and a framework for better understanding bioresources available in Alberta and the chemicals and market areas analyzed. Section 5 consists of the profiles for the 10 chemicals and market areas that were selected for more detailed research in phase II of the work. Section 6 contains the references used for the report. Appendix A (Section 7) contains brief profiles for the remaining six (6) chemical market areas and 34 chemicals, which were developed during phase I of the study but were not selected for further analysis in phase II. Appendix C (Section 8) contains the decision matrix used to help in selecting the 10 market areas and chemicals for further analysis in phase II of the work. The matrix table shows the list of chemicals/market areas and criteria considered to identify the 10 best chemicals/market areas for phase II analysis.

2.5 Acknowledgements

Cheminfo Services would like to acknowledge the guidance provided by Mr. Morley Kjargaard and Ms. Lynn Martinez of EAE. Their help in coordinating a review by the guidance committee and feedback throughout the study process were greatly appreciated.

3. Bioresources for Biochemicals Available in Alberta

3.1 Introduction

This section provides a brief summary of bioresources available in Alberta. Some of the information is borrowed from a recent study conducted for Alberta (Jacobs Consultancy, 2013).[8] One purpose of the information in this section is to provide perspectives with respect to the quantities of bioresources available in Alberta. These quantities can be compared with the size of markets and the size of existing production facilities for chemicals provided later in the report. Production process yields and other factors would need to be taken into consideration to determine the availability and sufficiency of Alberta bioresources to support biochemicals production.

3.2 Agricultural Crops

Alberta possesses a wealth of bioresources owing to its large agricultural sector. Crop products occupy the second largest export category in Alberta behind only bitumen and petroleum products. Cereals and oil seeds make up the largest category of exported crop products. The majority of these exports are destined for the United States where they are used in the production of animal feed and food for humans.[9] The following table summarizes Alberta's export statistics from 2012.

Table 7: Major Agricultural Crop Exports from Alberta
(tonnes)

Commodity	2012 Export Quantity
Wheat and meslin, other than durum wheat	6,071,600
Low erucic acid rape or colza seeds, whether or not broken	2,997,400
Durum Wheat	644,000
Barley	596,900
Low erucic acid rape (canola) or colza oil and its fractions, crude	510,500
Oats	420,100
Low erucic acid rape (canola) or colza oil and its fractions, refined	134,000

Source: Canadian International Merchandise Trade Database.

[8] Jacobs Consultancy, (2013). *Final Report: Identification of Opportunities for the Production of Bio-Products from Waste Bio-Mass in Alberta.*
[9] Statistics Canada, Canadian International Merchandise Trade Database. http://www5.statcan.gc.ca/cimt-cicm/home-accueil?lang=eng

Crops already grown in Alberta as well as new crop varieties have the potential to be used in the production of chemicals. Some examples of the types of biochemical that might be produced from harvested crops and forests include: wheat, barley, other grains, beets, and oilseeds. These may be used to produce oleochemicals (e.g., for surfactants, lubricants), starches for thickeners (drilling fluids), and sugar sources for fermentation (IPA, xanthan gum).

3.3 Biomass

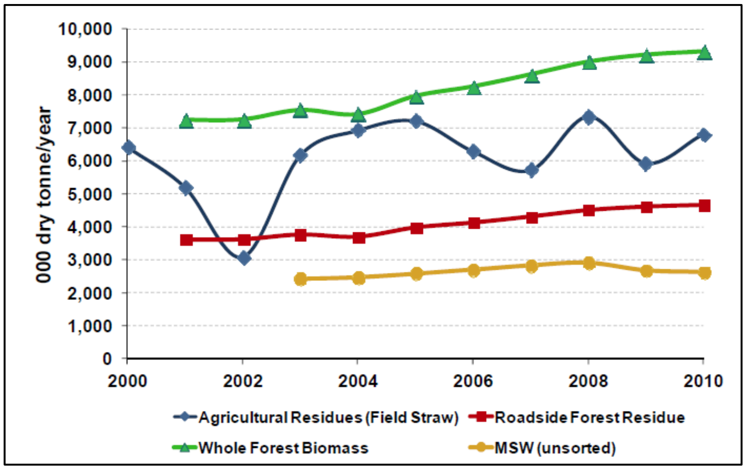
The definition of biomass typically excludes agricultural products and typically includes agricultural/forestry wastes, forestry products, and municipal solid waste (MSW). Biomass can be attractive as a feedstock for chemicals and energy due to better sustainability compared to the use of finite petroleum and natural gas resources. Waste biomass is even more attractive since it is often discarded. An advantage of using some waste streams as feedstock is the low cost of the raw material. However, low costs may be offset by high transportation costs and costs associated with addressing impurities, which can make the use of such materials expensive. Municipal solid waste is also included as a bioresource since it can be processed under some conditions to yield methane and other chemicals. In general, Alberta possesses sufficient bioresources for a variety of bio-based chemicals examined in this report. For example, the following biomass resources may be available to make biochemicals in Alberta:

- Agricultural and forest residue: plant matter left after crop or timber harvest such as foliage and tree limbs, and straw from wheat, barley and oats. This largely cellulosic material may be useful for the production on modified cellulose (CMC, cellulose ethers), or polysaccharides for fermentation (IPA, xanthan gum); and
- Whole Forest Biomass: hardwood or softwood lumber obtained through conventional logging. This cellulosic material can provide pulp for specialty cellulose chemicals like CMC and other cellulose ethers. Some processes may also use polysaccharides from the wood in fermentation processes.

The figure below (Jacobs Consulting, 2013) shows the quantities of biomass available on a yearly basis. Whole forest biomass is the most abundant bioresource category with an availability of between 7,000 and 9,000 kilotonnes per year. While this figure is high, it is worth noting that it is the only category currently used for other applications (e.g., wood pulp, lumber, etc.). Agricultural residues, roadside forest residue and MSW are all largely discarded or burned and might be more attractive biochemical feedstocks.[10]

[10] Jacobs Consultancy, (2013). *Final Report: Identification of Opportunities for the Production of Bio-Products from Waste Bio-Mass in Alberta.*

Figure 1: Biomass Resources Available in Alberta



Source: Jacobs Consultancy, (2013). *Final Report: Identification of Opportunities for the Production of Bio-Products from Waste Bio-Mass in Alberta.*

According to the recent Jacobs study, the agricultural residues yield for wheat, barley, and oat straw in Alberta is on average 0.54 dry tonnes per hectare. The number is based on an estimate of total straw produced along with a number of correction or availability adjustment factors. The final figure on availability takes into account losses in storage and handling from biomass decomposition and spoilage. A correction factor is also applied since a portion of the straw is left on the field to decompose and act as fertilizer for the following crop. Based on this figure, the total yearly crop residue available for use as feedstock for a chemical plant is 6,200 kilotonnes. Detailed studies in plant locations are required to determine an ideal biochemical facility site but the cost of transportation is a key concern for sourcing bio-based feedstock.[11] The waste generated by livestock in Alberta may also constitute a sizeable bio-resource. It is estimated that straw and plant waste make up 46% of agricultural residues while manure and livestock processing waste (from slaughterhouses) make up the remaining 54%. Much like waste straw, some portion of manure is retained and used as a land fertilizer but it may be possible to harvest some portion of manure to be processed in a digester or bioreactor for the production of biochemicals.[12]

Roadside forest residue refers to the leaves and branches discarded after the valuable lumber has been recovered from forestry operations. It is estimated that 0.25 dry tonnes per hectare per year of forest residue are available in Alberta. Currently, logging companies typically pile and burn these residues to reduce the risk of forest fires. In order to be used as biomass feedstock, the piled residues would need to be either chipped onsite and hauled to a facility or baled then chipped offsite. Mill residue is also included in this category and is the residual

[11] Jacobs Consultancy, (2013). *Final Report: Identification of Opportunities for the Production of Bio-Products from Waste Bio-Mass in Alberta.*
[12] Alberta Environment Information Centre. *Waste Facts : A Companion Document For Too Good To Waste: Making Conservation A Priority*

wood left over after cutting and processing. Unlike forest residue, mill residue is currently used by pellet manufacturers (for combustion) or landscaping companies (for mulch). The Alberta mill residue surplus in 2005 was estimated to be 480 kilotonnes after accounting for domestic consumption.[13]

The amount of available whole forest biomass available for biochemicals is unclear. The province has allocated various contracts to forestry companies and has over 24 million hectares of non-reserved forest land available for harvesting. There are various quotas for areas and volume of wood that can be cut each year. Any new biorefinery or chemical production plant would need to negotiate prices and supply arrangements with existing forestry companies. It is unclear how much additional wood is available to be harvested below the provincial quotas.[14]

There are three classifications of municipal solid waste in Alberta:

- Residential waste: waste generated by apartments and homes collected by municipalities. It consists largely of yard waste/organics (38%), food waste (23%), paper/cardboard (17%) and plastic/textiles (10%);
- Industrial, commercial, and institutional (ICI): waste generated by businesses. It consists largely of organics (30%), paper (30%), and plastic (10%); and
- Construction, demolition, renovation (CRD): It consists largely of wood (27%), asphalt/drywall/concrete (22%), and roofing material (12%).

Significant efforts are underway to divert some of the waste generated in Alberta from landfill. Wastes that could be targeted for the production of biochemicals are organic wastes such as food waste, yard waste, paper, cardboard, and wood. A portion of the paper and cardboard is already diverted to recycling centers but paper that is not deemed suitable for recycling could be send to an anaerobic digester with the other organic waste. A digester can produce methane for chemical synthesis or fuel use from organic wastes and could be integrated with the established organics diversion programs in Alberta. In addition to anaerobic digestion, mixed wastes can be gasified to produce hydrogen and carbon monoxide that could be used in chemical synthesis. Another option is the use of a certain waste stream as a feed to another biological digester for the production of chemicals other than methane. According to the Jacobs study, MSW diversion has increased in recent years and approximately 230 kilotonnes of organics, and 300 kilotonnes of paper are being diverted. Increased diversion rates might be possible given another use for the wastes such as the production of biochemicals.[15]

Biomass can be attractive as a feedstock for chemicals and energy due to better sustainability compared to the use of finite petroleum and natural gas resources. Despite an abundance of

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[13] Jacobs Consultancy, (2013). *Final Report: Identification of Opportunities for the Production of Bio-Products from Waste Bio-Mass in Alberta.*
[14] Ibid.
[15] Ibid

potential feedstock, a detailed analysis of resource availability to match the required production scale and yields for each chemical of interest is still required. For example, forestry residue may be relatively abundant but its isolation might make it uneconomical to harvest as a biochemical feedstock. Although this report may highlight certain issues pertaining to feedstock requirements, these were not a central focus and therefore merit further study.

4. Canada's and Alberta's Chemicals Industry and Markets

4.1 Overview

The chemicals market in Alberta is large and complex, though not as diverse as in the northern eastern part of the United States and eastern Canada. The oil and gas, and agricultural industries are large chemical markets in Alberta, while cosmetics, soaps, cleaners, inks, adhesives, sealants, pharmaceuticals, and other specialty chemical market segments tend to be much smaller. New bio-based chemical producers in Alberta may have to compete with some larger, well established suppliers of low-priced petroleum-based chemicals. An overview of some key aspects of Canada's and Alberta's chemical markets is provided below. This overview is intended to provide some insights on the market segments in which future biochemical producers in Alberta might compete.

Canada's chemicals manufacturing industry is included in the North American Industrial Classification System (NAICS) code 325. The industry is large and very diverse in terms of products and manufacturing processes. It is often useful to distinguish between commodity and/or pseudo-commodity chemicals (including polymers) and formulated products and specialty chemicals (FPSC). The industry contains many unique segments and thousands of chemical products in pure and mixed form. It also encompasses synthetic resins (polymers) production. Details of the definition and economic statistics for the industry and its segments can be obtained by linking to Industry Canada's website (www.ic.gc.ca/chemicals), as shown in the table below.

Table 8: Statistical Data Sources for Canada's Chemical Sector

(Click on the hyperlinks below to access economic statistics)

Total Sector: NAICS 325 - Chemicals and chemical products (total)	
Basic Petrochemicals, Polymer, Fertilizers, Inorganic Commodity and Pseudo-Commodity Products	**Formulated Products and Specialty Chemicals (FPSC)**
NAICS 32511 - Petrochemicals	NAICS 32532 - Pesticides and other agricultural chemicals
NAICS 32512 - Industrial gases	NAICS 3254 - Pharmaceuticals and medicines
NAICS 32513 - Synthetic dyes and pigments	NAICS 32551 - Paints and coatings
NAICS 325181 - Alkali and chlorine	NAICS 32552 - Adhesives and sealants
NAICS 325189 - Other basic inorganic chemicals	NAICS 32561 - Soaps and cleaning compounds
NAICS 32519 - Other basic organic chemicals	NAICS 32562 - Toilet preparations
NAICS 32521 - Synthetic resins and rubbers	NAICS 32591 - Printing inks
NAICS 32522 - Synthetic fibres and filaments	NAICS 32592 - Explosives
NAICS 325313 - Chemical fertilizers (except potash)	NAICS 325991 - Custom compounding
NAICS 325314 - Mixed fertilizers	NAICS 325999 - Other chemical products

4.2 Size and Trends

Manufacturing shipments for the Canadian chemical sector totalled $42.5 billion in 2010 with commodity products such as petrochemicals, polymers, fertilizers, inorganic chemicals, and gases making up 58% of the total value. Specialty chemicals, formulated products, and pharmaceuticals made up 42% of manufacturing shipments in 2010. Excluding pharmaceuticals, total manufacturing shipments were close to $33 billion, with approximately 73% being industrial and polymer products.[16]

Alberta's chemical industry is largely comprised of petrochemical, polymer (i.e., polyethylene) and fertilizer production. Its products are mostly exported to the Far East and United States. In comparison to Ontario and Quebec, where the great majority of the rest Canadian chemical industry resides, there are lower levels of manufacturing FPSC in Alberta. In general, FPSC tend to be made in eastern Canada, closer to larger manufacturing and consumer markets in Canada and the northeastern part of the United States. However, as an exception, Alberta has a large upstream oil and gas industry, which has attracted FPSC formulators servicing regional demand (see *Oilfield Chemicals*, for example, later in this report).

Table 9: Manufacturing Shipments for Canadian Chemical Sector, 2010

($ billion)

Grouped Industry Segments	Manufacturing Shipments	% of Total	Estimated Alberta Portion of Canada Total
Petrochemicals, organic chemicals and polymers	$16.6	39%	High (>70%)
Fertilizers and other agricultural chemicals	$4.0	9%	High (>70%)
Inorganic chemicals and gases	$4.1	10%	Low <20%
Formulated products and other chemicals	$9.2	22%	Low <20%
Pharmaceuticals	$8.7	20%	Very Low (<5%)
Total chemical sector	$42.5	100%	

Source: Industry Canada, Available at: http://www.ic.gc.ca/eic/site/chemicals-chimiques.nsf/eng/bt01203.html.
High means over 70% Medium is 20% to 70%, and low means less than 20% of Canada total.

The Canadian chemical industry grew steadily in the early part of the previous decade. Between 2002 and 2006, average annual growth in the value of manufacturing shipments was high at 5.1%.[17] However, much of this growth was the result of increasing prices. The growth in the mass quantity of sales during this period was lower.[18] The value of shipments between

[16] Includes Petrochemicals, organic chemicals and polymers, Fertilizers and other agricultural chemicals, and Inorganic chemicals and gases, in the table below.
[17] Industry Canada. http://www.ic.gc.ca/eic/site/tdo-dcd.nsf/eng/Home. Excludes pharmaceuticals.
[18] No statistics are available for total sales volume of chemicals due to the large number of diverse products.

2006 and 2008 was flat, and in 2009, the industry performance reflected the effects of the economic downturn in North America and around the world. The value of shipments in 2009 was about 20% below 2008 levels. Industry shipments declined as prices and sales volumes dropped for many petrochemicals, polymers and other chemical products. Some plants closed in Canada during the last five years. In 2010, the Canadian industry began to recover along with increases in North American and global demand.

Canada's chemical industry has had a large trade deficit for many years. It totalled $13 billion in 2010.[19] Canada enjoys a trade surplus for some petrochemicals and polymers, inorganic chemicals (e.g., sodium chlorate, sulphuric acid), and fertilizers, a large portion of which are produced in Alberta. These chemicals are competitive in export markets due to raw material (e.g., natural gas) and energy price competitiveness, and are made in large-scale plants with good economies of scale. However, there are trade deficits for practically all formulated products and specialty chemicals, including pharmaceuticals that accounted for the largest trade deficit contribution in the industry in 2010 - at approximately $7 billion.

Table 10: Trends in Chemical Industry Shipments, Trade, Establishments and Employment

Year	Shipments	Imports	Exports	Domestic Consumption(1)	Trade Balance	Establishments	Employment
	($ billions)	($ billions)	($ billions)	($ billions)	($ billions)		
2000	$37	$29	$19	$48	-$11	2,061	83,252
2001	$38	$31	$20	$50	-$11	2,067	87,861
2002	$41	$33	$20	$53	-$13	2,145	88,129
2003	$43	$33	$20	$56	-$13	2,122	87,166
2004 [20]	$47	$36	$24	$58	-$11	3,315	84,091
2005	$49	$37	$27	$59	-$11	3,049	81,882
2006	$50	$39	$29	$60	-$10	2,955	79,990
2007	$49	$40	$32	$57	-$8	2,945	78,709
2008	$50	$42	$32	$60	-$10	2,834	80,934
2009	$41	$40	$27	$54	-$14	2,734	79,087
2010	$43	$41	$28	$55	-$13	2,734(2)	77,670

Source: Industry Canada, http://www.ic.gc.ca/eic/site/chemicals-chimiques.nsf/eng/bt01203.html. Based on Statistics Canada.
Notes: Includes Pharmaceuticals.
(1) Domestic Consumption is calculated as shipments plus imports less exports.
(2) Industry Canada estimates.

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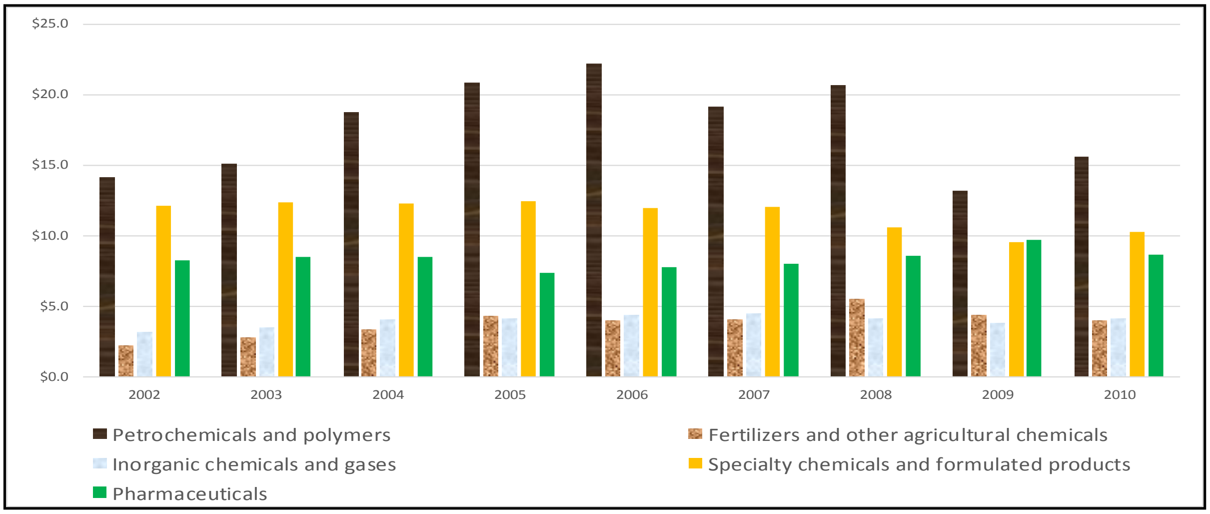
[19] Industry Canada, Available at: http://www.ic.gc.ca/eic/site/chemicals-chimiques.nsf/eng/bt01203.html. Accessed: January 26, 2011.

[20] Prior to 2004, data covers incorporated establishments with employees, primarily engaged in manufacturing and with sales of manufactured goods equal or greater than $30,000. This applies to all other similar tables in this report. Source: Industry Canada.

Figure 2: Manufacturing Shipments by the Canadian Chemical Industry
(C$ Billions)



Source: Industry Canada. http://www.ic.gc.ca/eic/site/tdo-dcd.nsf/eng/Home.

Most of the chemical industry establishments are located in Ontario and Quebec. However, relatively few – i.e., about 20 large facilities in Alberta account for a large share of total Canadian production. There are many small firms located in all provinces of Canada to serve region and/or niche chemical markets.

Table 11: Number of Establishments in Canadian Chemicals Industry

Province or Territory	Employers	Non-Employers/ Indeterminate	Total	% of Canada
Alberta	229	126	355	11.7%
British Columbia	230	132	362	11.9%
Manitoba	63	26	89	2.9%
New Brunswick	27	7	34	1.1%
Newfoundland and Labrador	10	2	12	0.4%
Northwest Territories	2	0	2	0.1%
Nova Scotia	32	9	41	1.4%
Nunavut	1	0	1	0.03%
Ontario	804	425	1,229	40.5%
Prince Edward Island	20	3	23	0.8%
Quebec	632	202	834	27.5%
Saskatchewan	36	15	51	1.7%
Yukon Territories	1	1	2	0.1%
CANADA	**2,087**	**948**	**3,035**	**100%**
Percent Distribution	68.8%	31.2%	100%	

Source: Statistics Canada, Canadian Business Patterns Database, December 2011.

Tens of thousands of chemical customers in Canada obtain products from distributors and sub-distributors. Some of the major Canadian chemical distributors are Univar, Brenntag, Canada Color and Chemicals, and L.V. Lomas. There are many more distributors, some focused on regional markets or market segments (e.g., oil and gas, cleaning chemicals, etc.).

4.3 Basic Chemicals and Polymers

Generally, basic chemicals and polymers are commodity and pseudo-commodity products that include: petrochemicals, polyethylene and other polymers, fertilizers, inorganic chemicals such as acids and bases, and industrial gases. Basic chemicals are: made and sold in large volumes (e.g., thousands of tonnes per year); largely shipped by short distance pipelines, marine vessel, rail and truck; sold at relatively low prices (e.g., $0.1 to $3 per kilogram or $100 to $3,000 per tonne); capital and energy intensive to manufacture; and are made in very large plants by relatively few firms. In Canada, basic chemicals plants are mostly owned by foreign entities.

The Canadian basic chemicals and polymers industry had manufacturing shipments of approximately $21 billion in 2009, which were 30% lower than the previous year. Prices for many petrochemicals and polymers declined sharply in 2009 because of poor economic conditions in North America and many other countries. Canadian production quantities also dropped, but by lesser percentages. For example, Canada's 2009 ethylene production was only 4% lower than in 2008, and ethylene glycol production was only about 7% lower.[21] The industry rebounded in 2010, with shipments up 13% to about $24 billion.

Table 12: Canadian Shipments of Basic Chemicals and Polymers

($ billion)

Shipments	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Petrochemicals	$4.0	$4.6	$6.1	$6.7	$7.4	$6.8	$7.7	$4.1	$6.2
Industrial gases	$0.4	$0.5	$0.6	$0.8	$1.0	$0.9	$0.9	$0.9	$1.0
Synthetic dyes and pigments	$0.6	$0.6	$0.6	$0.5	$0.5	$0.5	$0.4	$0.4	$0.5
Chlor-alkali	$0.5	$0.6	$0.7	$0.6	$0.6	$0.7	$0.4	$0.4	$0.4
Other inorganics	$2.3	$2.4	$2.7	$2.7	$2.8	$2.9	$2.9	$2.6	$2.8
Other organic chemicals	$3.6	$3.7	$3.9	$2.2	$2.2	$2.6	$3.8	$2.8	$3.2
Synthetic resins and rubbers	$6.5	$6.8	$8.7	$11.9	$12.6	$9.7	$9.1	$6.3	$6.2
Synthetic fibres	$0.9	$0.8	$0.8	$0.8	$0.8	$0.7	$0.6	$0.5	$0.5
Chemical fertilizer (excl. potash)	$1.5	$1.8	$2.2	$2.9	$2.6	$2.9	$3.9	$2.9	$2.5
Mixed fertilizers	$0.4	$0.5	$0.6	$0.7	$0.7	$0.5	$0.7	$0.5	$0.6
Total basic chemicals and polymers	$20.8	$22.3	$27.0	$29.9	$31.2	$28.1	$30.5	$21.3	$23.8
% change from previous year		7%	21%	11%	4%	-10%	9%	-30%	12%

Source: Industry Canada, http://www.ic.gc.ca/eic/site/chemicals-chimiques.nsf/eng/bt01203.html. Based on Statistics Canada.

[21] Cheminfo Services (J. Cummings Editor) *Canadian C2+ Petrochemical Report* (March 2010)

The Canadian and US markets for basic chemicals and the great majority of commodity polymers can be considered mature. Most of the products, which are broadly used, have reached saturation penetration levels in the economy. For example, polyethylene replaced other materials in packaging (e.g., paper bags, glass bottles), construction (e.g., metal pipes), and many other applications from the 1960s through the 1980s. As a result, Canadian sales volumes for commodity chemicals and polymers tend to track overall economic activity. Demand for some products may even be in slow decline as they are under pressure due to environmental factors. For example, solvents have been under environmental pressure in a variety of formulated products (paints, adhesives, etc.) since they are a source of volatile organic compounds (VOC)[22], which contribute to ground level ozone concentrations (smog). In this category, toluene, for example, has been losing sales in the paints, coatings and adhesives markets, which have been trending toward water-based products. Given market maturity in North America, chemical and polymer markets, investors have been more interested in locating new plants to serve faster-growing markets – as in Asia.

4.3.1 Petrochemicals and Polymers

Major petrochemicals include ethylene, propylene, butylenes, butadiene, ethylene glycol, styrene and methanol. Some of these are used to make polymers, such as polyethylene, polypropylene[23], rubber, polyethylene terephthalate (PET), and polystyrene.

Most of Canada's petrochemicals and polymers industries are located in Alberta. This is home to most of Canada's largest and newest plants. These plants rely on access to relatively low-priced natural gas and ethane (which is extracted from natural gas) available in the province. There are also petrochemical and polymer plants in Ontario and Quebec, but practically none in other provinces. In the 1970s and 1980s, Ontario and Quebec had more prominent petrochemical and polymer industries. However, some plants in these provinces that did not have access to competitively priced feedstocks and low energy prices did not grow, could not maintain competitiveness, and eventually closed. Examples of plants that closed over the last five to ten years are: Petromont's ethylene and polyethylene facilities in Varennes, QC; and Basell's polypropylene plants in Sarnia, ON and Montreal, QC.

[22] VOCs are a precursor to formation of ground level ozone or smog.
[23] There is no polypropylene made in Canada.

Alberta's petrochemical ethylene plants are the most competitive in Canada. The major reasons for Alberta's competitive advantage over producers in Ontario as well as some US producers are:

- access to low-priced natural gas for fuel and feedstock;
- ethylene plants have access to ethane, which is a very cost competitive, energy-efficient, high ethylene-yielding feedstock;
- larger plant capacities versus plants in Ontario;
- proximity to large markets in northwest part of North America;
- relatively new plants; and
- presence of salt caverns for storage (also available in Ontario's Sarnia valley).

Petrochemical plants in Ontario have remained competitive in different ways. Imperial Oil's ethylene plant accesses competitively priced ethane and propane feedstocks; is integrated to the Imperial Oil refinery from which it receives some low cost feedstocks and to which it can transfer some co-products for upgrading; and is integrated to value-adding polyethylene production. Nova has relied on: relatively good economy of scale; integrated relationships with Sarnia area refineries (Shell Canada, Suncor, and Imperial Oil); and forward integration to polyethylene and styrene production. More recently it has been investing to access and utilize more competitively priced natural gas liquids (ethane, propane) from the Marcellus region, in the northeast United States.

Also, eastern Canadian plants are closer to large markets in the densely populated and heavily industrialized north-eastern part of North America. Plants in Ontario and Quebec can reach customers in these provinces as well as customers in the northeast US states with relatively low transportation costs. Their transportation costs to reach this large regional market would be lower than western Canadian and offshore producers.

4.3.2 Inorganic Chemicals

The inorganic chemicals segment encompasses a very broad range of products with unique production processes, supply and market structures, and competitive environments. It is beyond the scope this study to delineate all of the chemical-specific information. Major inorganic chemicals made in Canada include: chlorine, caustic, carbon black, sulphuric and other acids, sodium chlorate, and hydrogen peroxide. The markets for most of these products in North American are mature. Similarly, the production technologies are mature, so the R&D associated with supply of these chemicals is relatively low. More "applications" research may be occurring where these chemicals are used (e.g., pulp and paper, mining). Major siting factors in the commodity inorganic chemicals industry usually include: low priced electricity; proximity to large customers in the pulp and paper industry and other markets; and proximity to low priced raw materials.

Table 13: Examples of Inorganic Chemical Producers in Alberta

Company	Location		Products	Major Markets
Orica Canada	Carseland	AB	Nitric acid, Ammonium nitrate	Explosives for coal, other mining
Erco Worldwide	Bruderheim	AB	Sodium chlorate	Kraft pulp mills
Erco Worldwide	Grande Prairie	AB	Sodium chlorate	Kraft pulp mills
National Silicates Partnership	Whitecourt	AB	Sodium silicate	Mechanical pulp mills
Cancarb Ltd.	Medicine Hat	AB	Carbon black	Global
Marsulex Inc.	Fort Saskatchewan	AB	Sulphur products (e.g., acid)	Regional

Sources: Cheminfo Services. Company websites.

Alberta has some large inorganic chemical markets. These include pulp and paper manufacturing, water treatment, mining (e.g., coal), and oil and gas production.

4.3.3 Fertilizers

Commodity fertilizers include ammonia (liquid), urea, ammonium nitrate, ammonium phosphate, ammonium sulphate, potash[24] as well as mixtures of these and other chemicals. Ammonia, which is one of the key basic commodity fertilizers, is made from natural gas. It can be used to make nitric acid, which may be combined with ammonia to make ammonium nitrate. Ammonia can also be combined with sulphuric acid to make ammonium sulphate and phosphoric acid to make ammonium phosphate fertilizers.

Most of Canada's fertilizer production facilities are located in Alberta due to the availability of low priced natural gas raw material. The plants are also close to the large western and mid-west North American crop growing markets. Canadian producers offer competitive pricing in the large US market – their major export market, where US and offshore imports compete with Canadian exports. Western Canadian ammonia and urea facilities are more production cost competitive than Canada's eastern plant (i.e., Terra in Courtright, ON). Western Canada plants enjoy lower cost natural gas relative to most other plants in North America.

[24] Potash production is not included as part of the chemicals sector. It is including the mining sector.

Table 14: Canada's Major Fertilizer Producers and Their Products

(X denotes production capability)

Company	Plant Location	Ammonia	Urea	Nitric Acid	Ammonium Nitrate	Ammonium Phosphate, Sulphate
Agrium	**Redwater, AB**	**X**	**X**		**X**	**X**
Agrium	**Fort Sask. AB**	**X**	**X**	**X**		
Agrium	**Carseland, AB**	**X**	**X**			
Agrium	**Joffre, AB**	**X**				
Canadian Fertilizers	**Medicine Hat, AB**	**X**	**X**			
Orica	**Carseland, AB**			**X**	**X**	
Saskferco	Belle Plaine, SK	X	X			
Koch	Brandon, MB	X	X	X	X	X
Terra Industries	Courtight, ON	X	X	X	X	

Camford Information Services, Product Profiles. Company websites.
Additional fertilizer products or mixtures may also be produced at the facilities shown.

4.3.4 Other Basic Organic Chemicals (NAICS 32519)

The Other Basic Organic Chemicals (NAICS 32519) segment is comprised of establishments, not classified in any other chemical segment, and primarily engaged in manufacturing organic chemicals. Some of the larger products of this segment include: ethanol, other alcohols, acyclic hydrocarbon, esters, and biodiesel. Producers of these chemicals are mostly located in Ontario, Quebec and Alberta. Many are located close to petroleum refineries and petrochemical plants, which provide feedstocks. However, new bioethanol and biodiesel plants are being located in regions where renewable raw materials are available. These include: corn for bioethanol in Ontario and Quebec; wheat for bioethanol in western Canada; canola in western Canada for biodiesel; and tallow (animal fats) and used cooking oils in various parts of Canada for making biodiesel.

Most of the markets for these chemicals are mature. An exception has been the Canadian renewable fuels (i.e., ethanol and biodiesel) market, where numerous new plants have been installed or are in the process of being installed. The ethanol and biodiesel fuel markets have been driven by government requirements for minimum levels of renewable fuels in gasoline, diesel and heating oil. The Government of Canada announced its Renewable Fuels Regulations in September 2010 requiring gasoline fuel producers and importers to have average annual renewable fuel content equal to 5% of the volume of gasoline that they produce or import. The 5% requirement for gasoline came into force on December 15, 2010. The Regulations also include provisions requiring an average 2% renewable fuel content in diesel fuel and heating distillate oil based on annual volumes.[25] The Canadian biofuels and other biobased chemicals have been supported by financial assistance from governments and their

[25] Environment Canada, http://ec.gc.ca/energie-energy/default.asp?lang=En&n=828C9342-1

agencies. There have also been biofuel tax exemptions by provinces and the federal government.

4.4 Formulated Products and Speciality Chemicals

Formulated products and speciality chemicals (FPSC) products are typically sold in lower volumes (e.g., grams, kilograms, tonnes) at relatively high prices (e.g., $3 to $5,000+ per kilogram, $3,000 to $5,000,000+ per tonne), require low amounts of energy to make, and often involve formulation and blending by small and medium-sized facilities. Formulations are often custom blended to meet diverse user needs. Products are typically packaged in drums, cans, pails, and bags, and usually delivered to customers in trucks.

A summary table provides context regarding key elements of these segments of the chemicals industry.

- Surfactants;
- Soaps and cleaners;
- Paints and coatings;
- Adhesives and sealants;
- Toiletries and cosmetics;
- Pesticides;
- Explosives;
- Dyes and pigments;
- Oilfield chemicals; and
- Lubricants.

These segments represent some of the larger markets in which biochemicals might compete. There may be additional potential markets that have not been reviewed in this report.

It should be noted there are no publicly-available data from Statistics Canada was identified that provide the economic size of the Canadian surfactants, oilfield chemicals and lubricants industries. Statistics Canada includes economic activity for these industries within other chemical segments or other industries.

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Table 15: Summary Characteristics of the Formulated Products and Specialty Chemical Segments

	Pesticides and other agricultural chemicals	Pharmaceuticals and medicines	Paints and coatings	Adhesives and sealants	Soap and cleaning compounds	Toilet preparations	Printing inks	Explosives	Custom compounding of resins	Other chemicals (e.g., Oilfield chemicals)
NAICS→	**32532**	**3254**	**32551**	**32552**	**32561**	**32562**	**32591**	**32592**	**325991**	**325999**
Market structure	Many segments, types of products, customers.	Many segments, types of products, customers.	Many segments, types of products, customers.	Many market segments, types of products, customers.	Many market segments, types of products, customers.	Many market segments, types of products, customers.	Many market segments, types of products, customers.	Mining, construction.	Many market segments, types of resin products, customers.	Many market segments, varied types of products, customers.
Ownership	Mostly foreign. Some Canadian.	Mostly foreign. Some Canadian.	Mostly Canadian. Some US firms.	Mostly Canadian. Some US firms.	Mostly Canadian. Some US firms.	Mostly Canadian. Some US firms.	Mostly foreign. Some Canadian.	Mix of foreign and Canadian.	Mostly Canada. Some foreign	Mix of foreign and Canadian.
Production processes	Liquid and solids blending. Packaging. Little chemical synthesis for active ingredients in Canada.	Liquid and solids blending. Packaging. Little chemical synthesis for active ingredients in Canada.	Liquid and solids blending. Packaging.	Liquid and solids blending. Packaging.	Liquid and solids blending. Some spray drying. Packaging.	Liquid and solids blending. Packaging.	Liquid and solids blending. Packaging.	Liquid and solids blending. Packaging.	Resins, fillers, additives mixing, extrusion. Packaging	Organic chemical synthesis. Liquid and solids blending. Packaging. Miscellaneous
Upstream linkages	Synthetic chemicals Research and development organizations.	Synthetic chemicals production for active ingredients. Research and development organizations.	Synthetic resins. Pigments and dyes. Inorganic chemicals. Organic chemicals. Other chemicals. Packaging.	Synthetic resins. Pigments and dyes. Inorganic chemicals. Organic chemicals. Other chemicals. Packaging.	Inorganic chemicals. Organic chemicals. Other chemicals.	Inorganic chemicals. Organic chemicals. Other chemicals. Packaging.	Synthetic resins. Pigments and dyes. Inorganic chemicals. Organic chemicals. Other chemicals. Packaging.	Inorganic chemicals. Organic chemicals. Other chemicals. Packaging.	Synthetic resins. Other organic chemicals. Inorganic chemicals. Minerals. Packaging.	Synthetic resins. Pigments and dyes. Inorganic chemicals. Organic chemicals. Packaging.
Downstream linkages	Agricultural products wholesalers, distributors, Retailers, farmers, Consumers, commercial establishments.	Pharmacies, Hospitals, doctors, veterinarians.	Wholesaling. Retailing. Manufacturing (auto, rail, furniture, etc.). Construction. Consumer. Maintenance (traffic markings, bridges, etc.)	Industrial manufacturing. Construction. Consumer.	Industrial. Commercial. Consumer. Institutional.	Consumer. Institutional. Commercial.	Publishing. Packaging. Manufacturing. Commercial. Consumer.	Coal mining. Other mining.	Plastics processing.	Formulated chemical products. Resins. Petrochemicals. Refineries. Bitumen upgraders, Oil and gas production.

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	Pesticides and other agricultural chemicals	Pharmaceuticals and medicines	Paints and coatings	Adhesives and sealants	Soap and cleaning compounds	Toilet preparations	Printing inks	Explosives	Custom compounding of resins	Other chemicals (e.g., Oilfield chemicals)
NAICS→	**32532**	**3254**	**32551**	**32552**	**32561**	**32562**	**32591**	**32592**	**325991**	**325999**
Annual capacity, production, capacity utilization, use	No available quantity data. Estimated at 50 to 100 kilotonnes of active ingredients production per year.	No available quantity data	About 300-400 kilotonnes of production per year.	No available quantity data. Estimated at ~230 kilotonnes per year.	No available quantity data. Hundreds of kilotonnes of product.	No available quantity data. Hundreds of kilotonnes of product.	No available quantity data. Tens of kilotonnes of product.	No available quantity data. Hundreds kilotonnes of product.	No available quantity data. Thousands of kilotonnes of product.	No available quantity data. Thousands of kilotonnes of product.
Competitive environment	Canada relies largely on foreign active ingredients.	Canada relies largely on foreign patented active ingredients.	Canada lacks production of many unique industrial coatings types.	Canada lacks production of many unique industrial adhesives and sealants.	Canadian plants are smaller with poorer economies of scale.	Canadian plants are smaller with poorer economies of scale.	Canadian plants are smaller with poorer economies of scale.	Canadian plants in good location to serve Canada's mining sector.	Canadian plants are smaller with poorer economies of scale.	Canadian plants are smaller with poorer economies of scale.
Imports as % of domestic demand (2010)	58%	84%	38%	64%	75%	108%	41%	108%	30%	69%
Provincial and regional importance in Canada	Blending, packaging carried out across Canada. Large demands in Western Canada	Blending, packaging carried out mostly in Ontario and Quebec.	Manufacturing spread out across Canada.	Manufacturing more important to Ontario and Quebec.	Manufacturing more important to Ontario and Quebec.	Manufacturing more important to Ontario and Quebec.	Manufacturing more important to Ontario and Quebec.	Products important to western and northern Canada.	Manufacturing more important to Ontario and Quebec.	Manufacturing more important to Ontario, Quebec, Alberta.

Sources: Cheminfo Services estimates.
Statistics Canada for trade data.

5. Selected Biochemical Opportunities for Alberta

5.1 Introduction

The following section contains profiles for the ten most promising chemicals and/or market areas where biochemicals could be sold. These were selected from the initial 40 chemicals and 10 market areas investigated in phase I of the study. These 10 profiles were developed using industry input from telephone consultations and analysis of available public literature. The profiles are intended as a scan market factors. Further research would be required to determine market and business feasibility.

5.2 Solvents

In this report, the term "solvents" refers to low molecular weight, organic substances that have the ability to dissolve other organic substances. Most of these organic substances begin in a liquid state at room temperature and pressure[26] but evaporate to air due to their high vapour pressure. This section describes the Canadian solvents market, in which biosolvents would need to compete, and then provides examples of activities related to the market potential for biosolvents.

The 2012 demand for solvent-type hydrocarbons in Canada is estimated to be between 400,000 and 500,000 tonnes per year. A central estimate of 450,000 tonnes is used in this report. The estimates contained in this section are intended to provide the order-of-magnitude of quantities involved, the structure of the market and its various segments. Further research would be required, beyond the scope of this study, to develop estimates with low uncertainties.[27]

Some of the solvents that comprise Canadian demand are also used as fuels and for reactive uses, which account for the majority of total demand. Example of solvents used as fuels and reactive uses in Canada include: ethanol used in gasoline; methanol used for formaldehyde production; and ethylene glycol used in polyethylene terephthalate (PET) resin production. The focus of this analysis is on the market for solvent uses, which comprise the minor portion of total demand for these hydrocarbons.

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[26] Propane and butane are notable exceptions, requiring higher pressure to keep in a liquid state.

[27] Estimates provided in this report are largely based on previous analysis of the Canadian solvent markets conducted by Cheminfo Services. These studies prepared estimates for supply and demands through review of publicly available production and trade (import and export) data, input from industry sources and some solvent users, and literature sources. For this report, anecdotal input from some solvent industry participants was obtained regarding the trends in the industry as well as the position of and interest in bio-solvents.

Table 16: Estimated Total 2012 Canadian Demand for Solvent-Type Chemicals

Use	Estimated Demand	% of Total
	(kilotonnes)	
Fuel and reactive uses	3,000-3,500	85-90%
Solvent uses	400-500	10-15%
Total	3,400-4,000	100%

Source: Cheminfo Services estimates.

There are eight types of solvents that comprise the great majority (i.e., greater than 90%) of total demand in Canada. Alcohols, such methanol, ethanol, and isopropanol (IPA) account for about one third of the total use. Aliphatics, such as naphthas, hexane, and pentanes[28] are the next most heavily used, with naphtha accounting for most of the demand for this type. Aromatics include toluene, xylenes, styrene and heavy aromatics. Ethylene glycol and propylene glycol are usually included as solvents since they are blended into paints and coatings, and other formulations. However, they are also used in heat transfer fluid formulations (e.g., antifreeze) and other applications. There are a variety of esters, ethers, ketones, halogenated and nitrogenated solvents that in total comprise about 10% of Canadian demand.

[28] Pentanes, natural gas condensates and other chemicals used as bitumen diluent in Alberta is excluded from this analysis. There are substantial and increasing quantities of diluent used and further focused analysis would be required to ascertain specific products used and demand for this "fuel" use.

Table 17: Estimated Canadian Demand Pattern by Solvent Type

Solvent Type	Percent of Total Canadian Demand	Specific Solvents
Aliphatics	22%	• Propane • Butanes • Pentanes • Hexane • Naphthas (C_7-C_{10})
Aromatics	17%	• Toluene • Xylene • Heavy aromatics (Aromatic 100, 150 and 200) • Styrene
Alcohol	32%	• Methanol • Ethanol • Isopropanol (IPA) • Butanols (n-butanol, isobutanol) • Methyl isobutyl carbinol (MIBC)
Ketones	5%	• Methyl ethyl ketone (MEK) • Methyl isobutyl ketone (MIBK)
Glycols	17%	• Ethylene glycol • Propylene glycol
Ethers and Esters	7%	• Glycol ethers, glycol ether esters • Ethyl acetate • Propyl acetate • Butyl acetates (n-butyl acetate, i-butyl acetate) • Other esters
Halogenated	<1%	• Trichloroethylene
Nitrogenated	<0.5%	• Ethanolamines • Morpholine

* List is not exhaustive of the many solvents within each category.
Source: Cheminfo Services estimates.

The market for solvents is quite fragmented. There are hundreds of thousands of industrial (including construction), manufacturing, commercial (e.g., restaurants, auto repair garages) and institutional (e.g., hospitals, academic and government laboratories) users, plus millions of households that use solvents in pure form or in mixtures.

Table 18: Major Canadian Market Segments for Solvents

Market Segments	Application examples	Estimated 2012 Use	% of Total
		(kilotonnes)	
Consumer and commercial auto and similar products	Windshield washer fluid, antifreeze, various packaged products	150	33%
Paints and coatings	Architectural, industrial/manufacturing, automotive, maintenance (bridges, building, etc.) uses (includes spary gun washes, other cleaners, diluents)	99	22%
Other industrial, manufacturing, construction	Adhesives, general cleaning, vegetable oil extraction	90	20%
Printing	Flexography, rotogravure, lithography, photocopy	44	10%
Household products	Household cleaners, air fresheners, sanitizers, degreasers, glues, polishes	36	8%
Pesticides	Liquid pesticides	9	2%
Personal care products	Hair care products, fragrances, nail care products	8	2%
Other	Dry cleaning, miscellaneous	13	3%
Total solvent uses		450	100%

Source: Cheminfo Services estimates.

Naphtha solvents, which are composed of a mixture of hydrocarbons, are used in a variety of application areas and are incorporated in great number of formulated chemical products, including: architectural paints and protective coatings; printing inks and printing press cleaners; other cleaning compounds; pesticides; degreasing formulations; and household products. Sales to households or commercial (e.g., construction, commercial building cleaning contractors, garages, etc.) applications can use naphtha in "pure" form or as part of formulated products. Naphthas are often referred to as mineral spirits, Stoddard solvents, ligroine as well as popular brand names such as Varsol®, Iosol®, and ShellSol®. One reason for their broad base of use is that naphtha solvents are relatively inexpensive compared to many single component solvents.

The largest solvent use for methanol is in windshield washer fluid (WWF) formulations, most of which are used in the winter as de-icers. Methanol is also used in a variety of other de-icing applications and formulated products (paints and coatings, adhesives and sealants, etc.). In these applications, it offers high efficacy (melting ice and snow), evaporates quickly, and is usually the lowest cost solvent option. Ethanol and isopropanol are typically more expensive options for some applications.

Ethylene glycol is used for automobile antifreeze, winter plumbing freeze protection formulations, and similar applications. Approximately 10% is used in de-icing fluids used at airports. Aromatic solvents such as toluene, xylenes and heavy aromatics have a variety of applications including paints and coatings, adhesives and sealants, pesticides, printing (especially on plastic substrates), and in various formulated products. Other higher volume solvents and example of applications are provided in the table below.

Table 19: Estimated Use for Major Solvents in Canada

Solvent	Examples of Use	Estimated 2012 Demand	% of Total
		(kilotonnes)	
Naphtha	Cleaning, paints and coatings, adhesives, asphalt cutbacks, printing, household products	80	18%
Methanol	Windshield washer fluid, de-icing fluids, adhesives	75	17%
Ethylene glycol	Antifreeze, paints and coatings	72	16%
Ethanol	Personal care, household products	36	8%
Xylene	Cleaning, paints and coatings, adhesives, printing	30	7%
Isopropanol	Printing, de-icing, adhesives, household products	30	7%
Toluene	Cleaning, paints and coatings, adhesives, printing	25	6%
Heavy aromatics	Pesticides, wood treatment, paints and coatings	24	5%
Hexane	Oilseed extraction, oil and gas, adhesives and sealants, resin manufacturing	9	2%
MEK	Cleaning, paints and coatings, adhesives, printing	10	2%
Other	Above applications and many others	59	13%
Total		450	100%

Source: Cheminfo Services estimates.

The 2012 solvents market in Alberta is roughly estimated at 37,000 tonnes, or about 8% of the national total.[29] Uses in Alberta include paints and coatings, oil and gas industry applications, de-icing formulations, and cleaning applications. Ontario and Quebec with larger populations and manufacturing industries in total account for close to 70% of total Canadian demand. In comparison to these provinces, Alberta has a smaller manufacturing sector (e.g., lack of automobile manufacturing, smaller furniture industry, smaller printing industry, etc.).

[29] This excludes diluent for bitumen, which is be much larger than all other solvent applications.

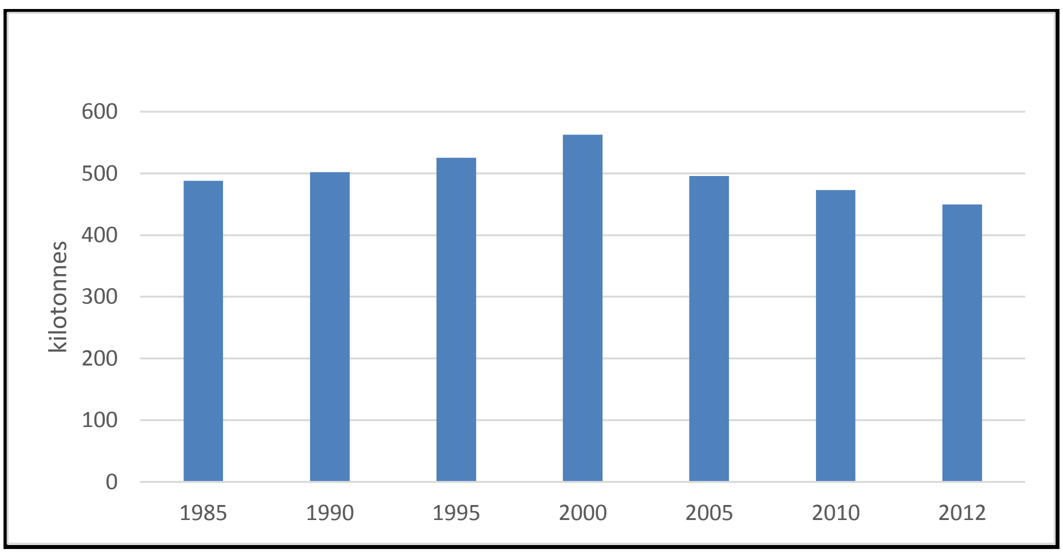
Table 20: Regional 2012 Demand for Solvents in Canada
(kilotonnes)

Market Segments	BC	AB	SK	MB	ON	QC	NB	NS	PE	NF	TR	Total
Consumer and commercial auto and similar products	20	**15**	5	5	58	35	4	4	1	2	0	150
Paints and coatings	8	**7**	2	2	54	21	2	2	0	1	0	99
Other industrial, manufacturing, construction	8	**7**	1	3	47	22	2	2	0	0	0	90
Printing	4	**1**	0.2	3	26	9	0	1	0	0	0	44
Household products	5	**3**	1	1	13	9	1	1	0	1	0	36
Pesticides	0.4	**2**	3	1	2	1	0	0	0	0	0	9
Personal care products	1	**1**	0.2	0	3	2	0	0	0	0	0	8
Other	1	**1**	0.1	0	7	3	0	0	0	0	0	13
Total solvent uses	46	**37**	12	17	210	102	9	11	1	4	1	450

Source: Cheminfo Services estimates.

The solvents market is mature. Total Canadian use has been declining over the last decade. Environmental pressures and associated regulatory limits on volatile organic compound (VOC) content for formulated products have been key drivers in the solvents market. VOCs are precursors to ground level ozone (smog) formation, which is hazardous to human health. Solvent industry sources indicate that total Canadian demand in 2012 is about 15-20% lower than a decade ago. The general trend has been toward water-based and high solids formulated products (lower solvents). As a result, solvent use in paints and coatings, adhesives and sealants, inks and many other formulated products has been reduced. Manufacturing facilities using solvents have also faced pressures to reduce VOC emissions, and as a result have installed VOC control and/or lowered solvent use.

Figure 3: Trend in Total Estimated Canadian Solvents Demand
(kilotonnes)



Source: Cheminfo Services estimates.

The pressures to reduce solvents that are VOCs contributing to ground level ozone formation has resulted in greater use for some solvents that are exempt from regulatory limits for formulated products and/or have low VOC-ozone formation potential. Examples of exempt solvents include: acetone, various fluorinated and chlorinated solvents (some of which have other environmental issues associated with them). In the United States, methyl acetate and methyl esters may be exempt - depending upon state regulations.

5.2.1 Solvent Supply and Distribution

Solvents are used in hundreds of thousands of industrial, commercial and institutional facilities across Canada in pure form and in formulated products. A complex distribution system exists to provide products to end-users. The distribution system features suppliers that can be grouped in five categories, namely: (i) solvent producers, (ii) primary solvent distributors, (iii) sub-distributors, (iv) product formulators, and (v) recyclers. A new producer of biosolvents in Alberta would most likely need to establish a relationship with one or more distributors to access customers in the market. Some of the key characteristics of solvents distribution structure in Canada are as follows.

- The great majority of solvents production is sold to end-users through primary distributors, sub-distributors, recyclers and formulators.
- A few large primary distributors handle the majority of solvent sales. Primary distributors sell to large accounts, formulators and sub-distributors.
- Regional sub-distributors handle smaller accounts and specialty niche markets.
- Chemical product formulators use solvents to make products (paints and coating, inks, adhesives, cleaners, etc.), which are sold directly to end-users or through other distribution channels.
- Solvent recycling companies reclaim, purify and re-distribute solvents to numerous accounts at a lower price than virgin solvent.

Canada's production of hydrocarbon solvents is mostly from petroleum refineries and petrochemical plants. In addition to making solvents, petroleum refiners provide a variety of fossil fuels, while petrochemical producers sell a range of commodity chemicals and polymers. Solvent sales are therefore usually a minor portion of the total sales of petroleum refiners and petrochemical producers. Petroleum refineries as well as petrochemical facilities are capable of making different aliphatic (e.g., naphtha) grades, toluene, xylenes as well as heavy aromatic solvents. Shell Chemicals Canada is a producer of hexane and isopropanol. In some cases, petrochemical producers process raw materials that are upgraded to solvents. Examples include: use of methane to make methanol; and propylene use to make isopropanol. Methanol is derived from natural gas in western Canada, while isopropanol is made from propylene in Ontario at one facility. Solvent ethanol is made in fuel bioethanol plants, through additional processing of fuel ethanol to remove components that can result in undesirable odours for solvent applications. Not all bioethanol plants have the capability to make ethanol for solvent applications.

Table 21: Canada's Sources of Commercial Solvents

Main Canadian Supply	Examples of Key Solvents Production
Crude oil refineries and petrochemical plants	Naphthas, toluene, xylenes, heavy aromatics, hexane
Dedicated solvents plants	Methanol, isopropanol, ethanol
Mostly imported	Ketones, packaged propane and butane, pentanes, butanols, ethers, esters, nitrogen solvents

Source: Cheminfo Services

Canada's major solvent producers are shown in the table below.

Table 22: Major Canadian Solvent Producers

(May not include all Canadian solvent producers)

Company	Locations	Main Solvents Produced
Shell Chemicals Canada	Corunna, ON Scotford, AB	Naphthas, toluene, xylenes, hexane, isopropanol
Imperial Oil Ltd.	Sarnia, ON	Naphthas, toluene, xylenes
Suncor Inc.	Montreal, QC Sarnia, ON	Naphthas, toluene, xylenes
Greenfield Ethanol	Chatham, ON	Ethanol
Methanex Inc.	Medicine Hat , AB	Methanol
Brenntag Canada Ltd.	Ajax, ON	Ether

Source: Cheminfo Services

Primary distributors are companies that purchase most of their solvents from domestic and foreign producers. The larger primary national distributors that handle solvents in Canada are Univar, Brenntag Canada Limited, Canada Colors and Chemicals (CCC), and Ashland. These companies supply a broad slate of solvents for many applications. There are also smaller distributors such as Apco Industries, Comet Chemicals and Quadra Chemicals that mostly focus on supplying certain regions. Distributors typically have established distribution agreements to resell the products of Canadian and foreign solvent producers.

Table 23: Major Primary Distributors of Solvents

Company	Head Office Location
Apco Industries Co	Toronto, ON
Ashland	Mississauga, ON
Brenntag Canada Ltd.	Toronto, ON
Canada Colors and Chemicals (CCC)	Toronto, ON
Comet Chemicals	Thornbury, ON
Univar	Burnaby, BC

Source: Cheminfo Services estimates.

Sub-distributors are companies that purchase the majority of their supply from the primary Canadian distributors. Most are small, single-site operations, which often purchase in drums and may re-package in pails or bottles and distribute to smaller accounts within a region. Some specialize in supplying selected market segments or niche markets such as oil and gas sector, laboratory chemicals, metal working shops, asphalt-paving companies, hospitals, auto garages, maintenance shops, food companies, etc. There are dozens of solvent sub-distributors in Canada. This would not include suppliers of other products and services, which purchase and/or may supply solvents for their customers.

The solvents market also includes solvent product bottlers. This group includes companies that will formulate their own products or custom blend for customers. Bottled products include: windshield wiper fluids, paint thinners, cleaners; various aerosols and a great many other products. Some of the larger firms (e.g., Recochem, Vulsay) make their own plastic bottles. Major bottlers in Canada are listed below. Most are located in eastern Canada. Recochem, which is the likely the largest of the bottlers, has a facility in Nisku, AB to supply its western Canadian and US market.

Table 24: Major Canadian Solvent Product Bottlers

Company	Locations
Recochem Inc.	Milton, ON; Nisku, AB; Montreal, QC
Vulsay Industries Ltd.	Brampton, ON
K-G Spray-Pak Inc.	Vaughan, ON; Mississauga, ON
Assured Packaging Inc.	Mississauga, ON

Source: Cheminfo Services Industry Interviews

5.2.2 Bio-solvent Market Potential

Environmental pressures on the solvents industry have resulted in some suppliers offering "environmentally-friendly", "green" and/or "bio-based" products. These can feature one or a combination of the following environmental benefits:

- Low VOC or ground level ozone formation potential;
- Low VOC content (for mixed solvents);
- Low vapour pressure VOC (LVP-VOC) – which may be exempt from VOC regulatory requirements;
- Exempt VOC status under government regulatory requirements;
- Carbon content from renewable resources (plant, animal);
- Carbon content from plant resources (plant based – which may be preferable for some customers to animal based carbon);
- Biodegradability (to carbon and water within short period of time –e.g., one month); and
- non-hazardous to human health or the environment (not necessarily a VOC).

Many solvent industry suppliers, and particularly chemical formulators that use solvents have adopted certain principles of "Green Chemistry". The US EPA documents 12 such principles, which are available on following website (http://www2.epa.gov/green-chemistry). Some of these principles help increase the potential use of biosolvents, namely:

- **Use renewable feedstocks**: Use starting materials that are renewable rather than finite. The source of renewable feedstocks is often agricultural products or the wastes of other processes; the source of finite feedstocks is often fossil fuels (petroleum, natural gas, or coal) or mining operations.
- **Design chemicals and products to degrade after use**: Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment.[30]

However, it should be noted that some of the other Green Chemistry principles may deter use of solvents and other chemicals altogether.

[30] US EPA, *Basics of Green Chemistry*. http://www2.epa.gov/green-chemistry/basics-green-chemistry#definition

Many solvent customers making formulated chemical products have developed "green" product lines including biosolvents. (Other products may be "green" for other reasons.) This would include bioethanol, which is well established in the Canadian solvents market. Other examples of biosolvents include:

- Soy methyl esters;
- Corn oil methyl esters;
- Canola oil methyl esters;
- Palm oil methyl esters;
- Ethyl lactate (ethyl alpha-hydroxy propionate);
- Glycerol carbonate;
- Succinic acid;
- 1,4-butanediol; and
- Polyhydroxyalkanoates (PHAs).

The Canadian demand for these biosolvents is very low in comparison to conventional petroleum-based solvents. Challenges that might be preventing greater sales in Canada include:

- Higher prices than conventional solvents;
- Lack of specific performance needed in various applications (e.g., evaporate rate, solvency for polymers, etc.).
- Lack of technical data on performance for various applications;
- Odour issues;
- Lack of sufficient supply;
- Lack of customer awareness of biosolvent product attributes;
- Lack of final end-user demand for products containing biosolvents;
- Established relationships with existing conventional solvent suppliers; and
- Reduced solvent demand in favour of water-based, high-solid products.

Although there are market challenges for biosolvents, from a small base, demand has been growing. Various suppliers have been active in providing biosolvents. Most of the biosolvent suppliers are new to the solvents industry. Suppliers of conventional petroleum-based solvents have been reluctant to develop biosolvents as this would further reduce sales and production from existing petroleum refineries and chemical plants.

Examples of activities by some identified biosolvents producers, solvent distributors, bottlers and product formulators in the industry are provided below. These provide anecdotal, but useful information on pricing, applications, promotional activities and product development. This material, which is largely borrowed from company websites may be promotional in nature, and therefore not fully descriptive of the product features and their suitability to the various applications identified.

Vertec Biosolvents, based in Illinois USA produces ethyl lactate (C_5 - ethyl alpha-hydroxy propionate) from lactic acid derive from corn. Ethyl lactate is a clear and colourless liquid of low volatility with a natural distinctive odor. Vertec sells ethyl lactate as a pure solvent, but also blends it with other biosolvents (e.g., soy methyl esters) as well as conventional solvents to meet specific customer needs. Vertec promotes its biosolvents as offering the necessary performance, safety and environmental benefits (e.g., organic origin, very low toxicity, and biodegradability). Some of its products are sold at prices comparable to petrochemical solvents, although usually they are higher priced. The company was once solely offering products for high-performance applications such as medical products and electronics cleaning where there might have been less sensitivity to higher prices versus conventional solvents. It is now selling to a broader market, including specialty coatings, inks and cleaners. After more than a decade, the company has not reached sales volumes to sell in truckload quantities. Products are shipped in less than truckload (LTL), in drums pails and gallon bottles.

BioAmber – through its Bluewater Biochemicals subsidiary – based its first North American biosuccinic acid plant in Sarnia, Ontario. The $80 million plant was to be commissioned late (November) in 2013. Using corn as raw material, it will have an initial capacity of 17,000 tonnes per year, later producing 35,000 tonnes/year of biosuccinic acid, some of which will be converted to produce 23,000 tonnes/year of 1,4-butanediol (BDO) using technology licensed from DuPont.

Canadian provincial and federal governments provided the company with $35 million in grants and loans to locate in Sarnia. Support was secured from the Ontario Ministry for Economic Development and Trade, Sustainable Development Technology Canada and the Canadian Sustainable Chemistry Alliance.[31,32,33]

Succinic acid is a naturally-occurring dicarboxylic acid that is used for many products and to make BDO. Examples of succinic acid applications BioAmber is promoting are as follows:

> **De-icing:** Use of succinate salts as ingredients in de-icing solutions. BIO-SA™ brand succinic salts have a far better corrosion profile than potassium acetate, potassium formate and brine (sodium chloride) for use on roads, bridges, runways and walkways.
> **Solvents:** BIO-SA™ brand bio-based solvents offer economical, environmentally-friendly alternatives without compromising performance. They can be used as a drop-in substitute in inks, varnishes and paints.

[31] BioAmber, http://www.bio-amber.com/
[32] Camford Chemical Report, Volume 43 Number 35 September 5, 2011
[33] Tyler Kula, The Observer (October 2011) New bioindustrial plant announced for Sarnia. Available at: http://www.theobserver.ca/ArticleDisplay.aspx?e=3277325&archive=true.

Heat Transfer Fluids: Heat transfer fluids or coolants formulated using bio-based succinic acid are water-based fluids, which include bio-derived dipotassium succinate in concentrations of up to 50%.
Lubricants: Bio-based succinic esters are promoted as environmentally friendly solutions for the lubricants market as base oils and additives in industrial lubricants and metal-working fluids, with improved flowability in cold temperatures and better prevention of oxidation and corrosion.
Personal Care: BIO-SA™ brand succinic esters are effective, all-natural emollients and surfactants. Emollients are used in lotions, liquid soaps and cleansers to improve and moisturize skin, while surfactants are used in soaps, body washes and shampoos to allow easier spreading.[34]

Gamma-butyrolactone (GBL): The BioAmber licensed hydrogenation catalyst technology from DuPont that can convert succinic acid into bio-based GBL. GBL is used to produce a number of value added specialty chemicals, including 2-pyrrolidone, n-methyl pyrrolidone and n-vinyl pyrrolidone. Pyrrolidones are generally produced from the reaction of GBL with amines. GBL and the pyrrolidones can be used as extraction solvents in petroleum processing, coatings and possibly other applications. These materials are also intermediates used in the manufacture of pharmaceuticals, fine chemicals and agrochemicals. Polyvinyl pyrrolidone (PVP) polymers are used in pharmaceuticals, food, agrochemicals, cosmetics and personal care and detergent applications.

The major uses of bio-based 1,4-butanediol are in the production of tetrahydrofuran (THF) and polybutylene terephthalate (PBT). THF is used to produce spandex fibers and other performance polymers, resins, solvents and printing inks for plastics. PBT is a high quality thermoplastic used in automotive, electronics and other industries. [35]

Recochem Inc. is one Canada's largest bottlers of windshield washer fluid, antifreeze and solvent products. The great majority of its solvents sales are conventional products, however, it offers its Bio Green Products line that includes:

- windshield washer (ethanol based);
- de-icer fluid;
- car wash cleaner, auto glass cleaner;
- tire shine, rim & tire cleaner;
- carpet & upholstery cleaner;
- all purpose concentrate pressure washer fluid;
- vehicle & boat concentrate pressure washer fluid; and
- multi-purpose degreaser.[36]

[34] BioAmber, http://www.bio-amber.com/
[35] BioAmber, http://www.bio-amber.com/
[36] Recochem Inc., http://www.recochem.com/

It is assumed that these Recochem products contain higher concentrations of bioethanol (versus methanol) and/or have other environmentally friendly features or ingredients. Retail sales of these products, some of which are higher priced than conventional solvents, have been challenging. Major retail product-line buyers are very price sensitive, and reluctant to place new products on retail shelves to complete against traditional products.

Brenntag conducted a market analysis of sustainability and green chemistry in Europe, which indicated a "green" trend in all areas and industries. Brenntag offers its Green Product Line, which features environmentally friendly products for a range of applications. The distributor claims that it is not content to merely follow this trend, but wishes to set new standards in green chemistry. Brenntag in Europe has chosen to orient its service and product offering to follow five (5) of the US EPA's 12 principles of Green Chemistry. As such, at least one of the following five basic principles has to be fulfilled for its products so that they can be included in the European Green Product Line. The majority of products fulfill between three and five of our basic principles.

Five Principles of Green Chemistry Adopted by Brenntag, Europe

1. Use of renewable feedstocks
2. Safer solvents and auxiliaries
3. Less hazardous chemical syntheses
4. Design for biodegradation
5. Design for energy efficiency.[37]

Brenntag in Canada has yet to document a following of the European standard.

Univar claims it is proactive in sourcing 'green' and natural ingredients for customers that wish to offer more sustainable solutions in their product ranges.[38]

Stepan, based in the Northfield, Illinois is a large producer of surfactants, some solvents and other chemicals. It has plants across North America, including a surfactants plant in Longford Mills, Ontario. Stepan provides products for a broad set of industries. In oilfield chemicals, it has products for drilling, production and stimulation. Stepan oilfield chemicals include:

- Bio-based solvents;
- Surfactants: anionic, cationic, nonionic and amphoteric; and
- Biocides: quaternary ammonium compounds and triazine.

[37] Brenntag Europe. http://www.brenntag.com/en/pages/umwelt/Europa/index.htmlBrenntag, (2013) *Adding Value, Sustainability Report Brenntag AG.* http://www.brenntagnorthamerica.com/en/downloads/120075_BRE_BROSCH__RE_ADDINGVALUE_final.pdf
[38] Univar, http://www.univar.com/canada

Stepan offers the following vegetable-derived methyl ester biosolvents that it claims can be used in heavy duty degreasing.[39] It will also make chemicals to meet specific customer requirements.

Table 25: Stepan's Vegetable-Derived Methyl Ester Biosolvents

Trade Name	Biosolvent Type	Cloud Point (C)	Freezing Point (C)
STEPOSOL® ROE-W	Canola methyl ester	2	-24
STEPOSOL® SB-W	Soya methyl ester	1	-6
STEPOSOL® SC	Soya methyl ester / Ethyl lactate blend	-3	-15

Source: Stepan, http://www.stepan.com/default.aspx

Bio-Solvents Inc. based in Cedar, MI is a small company that offers C_{14}-C_{24} fatty acid methyl ester solvents with applications in the asphalt industry. Some product features include:

- boiling point: 204 C;
- vapor pressure (mm Hg): <5 mm HG @ 22 C;
- evaporation rate: less than 0.005 versus (butyl acetate = 1);
- insoluble in water;
- appearance: light to dark yellow clear liquid; and
- odor: light musty odor.[40]

The Canadian biosolvents market features significant use of bioethanol, but relatively low demand for other biosolvents. Environmental pressures and the interest in green chemistry is encouraging some customers to use more biosolvents. Market segments for biosolvents include oil and gas applications, asphalt industry, coatings, inks other formulated products, degreasing, and cleaning applications. Various biosolvent suppliers are trying to compete against the conventional petroleum-based products. While their products offer some environmental benefits, there are a number of market challenges that biosolvents need to overcome to increase their market penetration, including price competitiveness and performance.

Additional information for some specific solvents examined in phase I of this study is available in the Appendix.

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[39] Stepan, http://www.stepan.com/default.aspx
[40] Bio-Solvents, http://www.bio-solventsinc.com/

5.3 Glycerol Carbonate

Glycerol carbonate (CAS 931-40-8), also known as 1,3-dioxolan-2-one, 4-(hydroxymethyl)- is a clear, mobile liquid at room temperature. Glycerin carbonate is a relatively new substance among other organic carbonates. It is claimed to be 73% bio-based due in large part to the glycerol used as a feedstock. It has the unique characteristic of being a hydroxyl-functional carbonate with both carbonate and hydroxyl reactive sites. It is readily biodegradable and non-toxic.[41] Unfortunately, there are no harmonized system (HS) trade data codes available for glycerol carbonate, and therefore there data on imports or other methods for estimating annual Canadian or Alberta demand. Similar synthetic products include propylene carbonate (made from all synthetic material) and other alkyl carbonates.

5.3.1 Uses

Among the chemicals derived from glycerol, glycerol carbonate is a high added-value derivative that demonstrates low toxicity, good biodegradability, and high boiling point. With these properties, it finds use in several applications in different industrial sectors, such as: a polar high-boiling solvent/degreaser or intermediate in organic syntheses (i.e., synthesis of polycarbonates and other polymeric materials; intermediate for making glycidol, which is employed in textile, plastic, pharmaceutical, and cosmetics industries); as a precursor in biomedical applications; and as a protection group in carbohydrate chemistry.[42] Glycerol carbonate is also used as a non-volatile solvent in coatings, adhesives, paints and detergents.[43/44/45] GC and other carbonates produced by Huntsman can be used as more environmentally sustainable replacements to products such as methylene chloride, acetone and aromatic solvents.

Glycerol carbonate finds use as a component in membranes for gas separation, instead of ethylene and propylene carbonates, in the synthesis of polyurethanes and in the production of surfactants. As a chemical intermediate, it reacts readily with alcohols, phenols, and carboxylic acids with loss of carbon dioxide as well as with aliphatic amine with carbon dioxide recovery. Glycerol carbonate and its derivatives can also be used as electrolytes

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[41] Kob, Nicholas., et. al., *Application of Glycerine Carbonate in Novel One-Component Polyurethane Blocked Systems*.
[42] Chiappe, Cinzia & Rajamani, Sunita. (October, 2011), *Synthesis of Glycerol Carbonate from Glycerol and Dimethyl Carbonate in Basic Ionic Liquids,* published in Pure and Applied Chemistry.
[43] Wang, Liguo., et. al. (2011), *Efficient Synthesis of Glycerol Carbonate From Glycerol and Urea with Lanthanum Oxide as a Solid Base Catalyst*, published in *Catalysis Communications*.
[44] Herseczki, G., et. al. (2011), *Enhanced Use of Renewable Resources: Transesterification of Glycerol, the Byproduct of Biodiesel Production*, published in the Hungarian Journal of Industrial Chemistry.
[45] Reuters (March 9, 2009), *Huntsman Launches New Bio-Based Glycerine Carbonate Product*.

and solvents in lithium ion batteries, and it is considered to be a green substitute for important petro-derivative compounds (ethylene carbonate or propylene carbonate).[46]

Due to its low toxicity, low evaporation rate, low flammability, and moisturizing ability, glycerol carbonate is used as a wetting agent for cosmetic clays, in personal care products and as a carrier solvent for medical preparations.[47/48]

5.3.2 Canadian and Alberta Markets

There are no known producers of glycerol carbonate in Canada. The small Canadian market is supplied by imports, likely primarily from the United States. According to the Chemical Data Reporting website (www.epa.gov/cdr) of the U.S. EPA, the only producer of glycerol carbonate in the US appears to be Huntsman Corporation. Total aggregated glycerol carbonate production in the US in 2010 was withheld. Huntsman, which is one of the world's largest producers of alkylene carbonates, can meet 50% of the global requirements for this alternative to volatile and hazardous solvents.[49] In March 2009, Huntsman Performance Products (a division of Huntsman Corporation) announced the commercial availability of JEFFSOL® Glycerine Carbonate. It is manufactured by Huntsman using the glycerine co-product of biodiesel.[50] China and Japan appear to be the only other producers of glycerol carbonate in the world with the following companies listed as suppliers: Hangzhou Dayangchem Co. (China), Andexin Industrial Co. (China), Nanjing Chemlin Chemical Co. (China), and UBE Industries (Japan).[51]

As glycerol is a major input into the production of glycerol carbonate, the availability of this raw material from current and future biodiesel production facilities might provide some incentive to establish a glycerol carbonate facility in Alberta. Archer Daniels Midland (ADM) is in the process of building the largest North American biodiesel plant (265 million liters per year) near Lloydminster.[52] Another biodiesel production facility in Alberta being constructed is Kyoto Fuels Corporation's 66 million liters per year facility in Lethbridge. There are other biodiesel plants that have been proposed in Alberta, however they have not progressed to the construction phase.

If a glycerol carbonate facility were established in Alberta, the main market for the product is expected to be as an oxygenated solvent for use in a variety of industrial applications. Although there are many applications cited by Huntsman Chemicals for GC, solvents is

[46] Chiappe, Cinzia & Rajamani, Sunita. (October, 2011), *Synthesis of Glycerol Carbonate from Glycerol and Dimethyl Carbonate in Basic Ionic Liquids*, published in Pure and Applied Chemistry.
[47] Oprescu, Elena-Emilia., et. al., *Synthesis of Glycerol Carbonate over Hydrotalcite Catalyst*, published in Chemistry Magazine.
[48] Huntsman Corporation, *Technical Bulletin – Jeffsol® Glycerine Carbonate*.
[49] Accessed at the website of Huntsman Corporation (http://www.huntsman.com/performance_products/a/Products/Carbonates).
[50] Reuters (March 9, 2009), *Huntsman Launches New Bio-Based Glycerine Carbonate Product*.
[51] Accessed at the website of GuideChem. Available at: http://www.guidechem.com/cas-931/931-40-8.html
[52] Archers Daniels Midland (November 14, 2011), *ADM to Build Biodiesel Plant in Lloydminster, Canada*.

expected to be the highest volume potential use. There may be some demand for the other GC applications such as curing aids and specialty reagents but they are not expected to be high volume and a large facility would need a large potential market to be viable. GC is a highly polar molecule and is likely to compete with other polar solvents. Polar, oxygenated solvents that might be displaced by glycerol carbonate include acetone, MIBK, MEK, and methylene chloride. The solvents profile in this study can provide more perspective on solvents markets in Canada. Contrary to all the solvents listed below, GC has very low volatility, which would limit its use in many paints and coatings and other applications where volatility is required. The table below shows some estimated demand for solvents that might be replaced by glycerol carbonate. Glycerol carbonate might displace a fraction of the quantities shown.

Table 26: Estimated Demand for Potential Market Niches for Glycerol Carbonate in Canada

Solvent	Examples of Use	Estimated 2012 Use	% of Total Solvents Market
		(kilotonnes)	
Ethanol	Personal care, household products	36	8%
Isopropanol	Printing, de-icing, adhesives, household products	30	7%
Acetone	Chemical synthesis, industrial solvent, household product	12	2%
MEK	Cleaning, paints and coatings, adhesives, printing	10	2%
MIBK	Paints and coatings, printing, adhesives	1	>1%
Other	Above applications and many others	59	13%

Source: Cheminfo Services estimates.

5.3.3 Supply and Value

In terms of its production, crude glycerol (raw material for the production of glycerol carbonate) is a considerable by-product of biodiesel production. Glycerine byproduct occurs at approximately 0.9 kg/litre yielding a rough glycerine production estimate of 284 kilotonnes of crude glycerine per year. Crude glycerine must be refined for use in the cosmetics, pharmaceutical, and other specialty applications. Refining the glycerol generally involves separation, neutralization, and washing. These additional processing steps increase total biodiesel production costs, simultaneously reducing the quality of the glycerol obtained as a by-product. As glycerol is a key co-product of biodiesel manufacturing, increasing use of biodiesel may lead to much greater glycerol availability and lower cost. Much of the produced Canadian glycerol is currently shipped to the US to be processed into various products such as propylene glycol (a replacement for antifreeze). Other biodiesel producers may elect to sell their waste glycerol to anaerobic digesters to produce methane. As a result, there would be significant interest in a simple method to transform waste glycerol into a saleable product (e.g. glycerol carbonate).[53]

There are several methods for the preparation of glycerol carbonate, based on the reaction of glycerol with phosgene, dialkyl carbonate or alkylene carbonate, urea, carbon monoxide and oxygen. Traditionally, cyclic carbonates have been prepared by reaction of glycols with phosgene, but due to the high toxicity and corrosive nature of phosgene, alternative routes such as transesterification reaction of dialkyl or alkykene carbonates to obtain cyclic carbonates have been explored.[54] However the more attractive methods are those utilizing glycerol as a renewable and cheap raw material. A typical method of obtaining carbonate derivatives of glycerol is its transesterification with ethylene carbonate or dialkyl carbonate. Promising methods of glycerol carbonate preparation comprise the reaction of glycerol with carbon dioxide or carbon monoxide and oxygen in the presence of Cu(I) catalysts. This method is of particular interest for Alberta and Canada since it would present a potential use for waste glycerol produced by the biodiesel industry. Another method for synthesizing glycerol carbonate is from glycerol and dimethyl carbonate using potassium carbonate as a catalyst.[55] The use of dimethyl carbonate can be considered an increase in the sustainability of the process. Dimethyl carbonate can be manufactured by environmentally safe industrial methods (potentially from carbon dioxide and renewable resources), avoiding the formation of the high-boiling ethylene glycol. However, the proposed potassium carbonate (or calcium oxide) -catalyzed process always requires the final neutralization step where an acid (e.g. phosphoric acid, sulphuric acid, benzenesulfonic acid) must be added to the system to neutralize the catalyst, which produces significant quantities of salts as by-products. [56]

Although there may be potential for use of GC in Alberta, the current use is expected to be very low in Canada and the US. It should be considered a chemical under development with significant research still required to determine a viable pathway to producing it from glycerol. Adding to the complications of GC, the market in North America appears to be dominated by Huntsman Chemicals making it highly unlikely that a new plant in Alberta could capture enough of a market share to be considered viable. There may be potential in the future if a use for GC can be demonstrated and if it can be easily produced from glycerol.

[53] Herseczki, G., et. al. (2011), *Enhanced Use of Renewable Resources: Transesterification of Glycerol, the Byproduct of Biodiesel Production*, published in the Hungarian Journal of Industrial Chemistry.
[54] Oprescu, Elena-Emilia., et. al., *Synthesis of Glycerol Carbonate over Hydrotalcite Catalyst*, published in Chemistry Magazine.
[55] Herseczki, G., et. al. (2011), *Enhanced Use of Renewable Resources: Transesterification of Glycerol, the Byproduct of Biodiesel Production*, published in the Hungarian Journal of Industrial Chemistry.
[56] Chiappe, Cinzia & Rajamani, Sunita. (October, 2011), *Synthesis of Glycerol Carbonate from Glycerol and Dimethyl Carbonate in Basic Ionic Liquids, published in Pure and Applied Chemistry*.

5.4 Lubricants

Lubricating oil is a general term that refers to liquid fractions produced at crude oil refineries that are heavier than liquid fuels and of a viscosity that is desired for providing lubricating performance for machinery and other equipment. The majority of lubricating oils are directed towards lubricants production, which is known as the base oil (or lubricants) market. The following profile provides a brief description of the base oil (or lubricant) market in Canada. Information is provided on Canadian lubricant production and sales, and the major applications for lubricants in Canada. There is also an analysis of the challenges limiting the markets adoption of bio-lubricants and a description of some opportunities where the strengths of bio-lubricants might be better exploited. Lastly, details on legislative tools utilized in other jurisdictions that encourage or mandate the use of bio-lubricants for certain environmentally sensitive applications are discussed, as are some potential strategies for bio-lubricant market development.

5.4.1 Lubricants Market in Canada

There are two main segments to the lubricants market – automotive and industrial.[57] Automotive oils are not limited to consumer engine oil applications, but are used in a variety of mobile equipment. Automotive oils include:

- motor oils for gasoline powered cars;
- heavy duty diesel oil for diesel powered on-road and off-road trucks, buses and heavy duty equipment;
- automatic transmission fluids for light duty cars and trucks, universal tractor fluids commonly used in farm tractors and other off-highway mobile equipment, and hydraulic oils used in power steering pumps and shock absorbers; and
- heavy duty gear oils used in trucks and off-highway equipment.

Industrial lubricants include:

- hydraulic oils used in manufacturing plants and in supplementary equipment mounted on trucks, construction, and forestry equipment;
- turbine, bearing and circulating oils, used in steam turbine bearings, and in steel manufacturing equipment;
- industrial gear oils;
- lubricants used in range of manufacturing plant equipment, such as compressors, refrigeration units, rock drills/air tool, and greases;
- natural gas engine oils (natural gas compression and transmission);
- marine and railroad engine oils; and
- metalworking fluids used for rolling sheet metal, treating casted metal parts, and lubricating metal drilling, cutting, and grinding operations.

[57] MTN Consulting Associates, *Lubricating Oils Study*, 2009.

The remaining portion is consumed in non-lubricant applications, such as chemicals or solvents. These applications are referred to as the process oil market. Base oils and process oils are essentially identical, but may be produced to slightly different specifications and sold under different brand names into the two different markets. The majority of the demand for lubricant products in Canada is for automotive lubricants.

Table 27: Canadian Lubricating Oils Consumption, By Type

(million litres)

	2006	% Total
Automotive	724	65%
Industrial	286	25%
Process Oil	120	11%
Total	1,130	100%

Source: MTN Consulting Associates, *Lubricating Oils Study*, 2009.

The major market segments using lubricants are shown below. These segments include automotive, industrial, and process applications, and show the widespread use of lubricants in the economy.

Table 28: Major Uses for Lubricants in Canada

(million litres, 2006)

Market Segment	Use	% Total
Transportation	204	18%
Mining, Oil and Gas	130	12%
Manufacturing	303	27%
Forestry	24	2%
Construction	24	2%
Agriculture	47	4%
Public Administration	5	0.4%
Commercial and Other	393	35%
Total	1,130	100%

Source: MTN Consulting Associates, *Lubricating Oils Study*, 2009.

5.4.2 Lubricant Supply

There are four lubricating oil production plants (petroleum refineries) in Canada, indicated in the table below, with a total production capacity of 1.46 billion litres of lubricating oil annually.

Table 29: Canada Lubricating Oil Production Capacity (2008)

(million litres)

Company	Production
Imperial Oil, Edmonton	119
Imperial Oil, Sarnia	356
Petro-Canada, Mississauga	843
Shell, Montreal	146
Totals	1,464

Source: 2008 Lubes 'N' Greases Guide to Global Base Oil Refining

The lubricants market has remained generally flat in North America over the last decade.[58] Canadian lubricants production in 2006 was 1.29 billion litres, with domestic consumption of 1.13 billion litres. Canadian demand in 2012 was virtually the same as in 2006 at 1.104 billion litres. A total of 192 million litres or 17% of 2012 Canadian sales were in Alberta.[59,60] Alberta's relatively high lubricant consumption is in large part due to demand for lubricants in oil and gas production applications. A very small fraction of the total market is supplied with bio-lubricants.

The lubricant industry is relatively consolidated, with major brands such as Petro Canada (Suncor), Shell, Imperial Oil and a couple of other brands accounting for the majority of the market. These are largely sold through distributor networks that are contractually committed to selling only the products produced by their parent brand.

5.4.3 Bio-Based Lubricants

Bio-lubricant products can be divided into two main categories: traditional bio-lubricants and modern bio-lubricants. Traditional bio-lubricants are usually vegetable oil based, and are known to have issues with oxidative stability and cold operating temperatures. Many of the first bio-lubricant products on the market were reportedly imported from Europe by parties largely involved in seed crushing and who did not have a detailed understanding of the lubricant market.[61] This unfortunately contributed to a negative image regarding bio-lubricant reliability.

Modern bio-lubricants are typically either based on synthetic esters or on vegetable oils containing additives. The additives may or may not be bio-based. Modern bio-lubricants

[58] National Petrochemical and Refiners Association (US), www.npra.org
[59] Statistics Canada Catalogue #57-003-X (2006) Table 5-1. http://www.statcan.gc.ca/pub/57-003-x/57-003-x2006000-eng.pdf
[60] Statistics Canada (2013) *Supply and Disposition of Petroleum Products in Canada*
[61] Cheminfo Services based on industry sources.

are typically priced two to three times higher than their conventional oil counterparts.[62] However, they do not suffer from the same oxidative stability/cold temperature issues associated with traditional bio-lubricants, and can be formulated for use in many applications. These applications include industrial lubricants, hydraulic fluids, turbine oils, cutting oils, machining oils, assembly oils, corrosion inhibitors, high temperature lubricants, a variety of greases, automotive engine oils/transmission oils, food grade lubricants and fuel additives. Industry has indicated that bio-lubricant technology has progressed to the point where bio-lubricants can be synthesised to replace any petroleum-based lubricant currently in use.[63]

Bio-lubricant products are deemed to have high future potential in the traditional lubricants market according to bio-lubricant producers.[64] The traditional lubricants market is so large, and the current market penetration of bio-lubricants so low, that it is not yet possible to assign any kind of a market penetration figure or accurately size the bio-lubricant market in Canada.

5.4.3.1 North American Bio-Lubricant Producers

This section provides information on the major North American players in the bio-lubricants market, identifies challenges to further market adoption faced by bio-lubricant products, and provides some of the potential strengths or opportunities that could be exploited by bio-lubricants.

There are several major oil refining companies that are selling "green" product lines or single products. Some of these products are conventional petroleum oil-based lubricants that contain limited quantities of biologically derived substances (such as canola oil) in concentrations that can be as low as 5%.[65] Additionally, major oil companies are promoting hydrogen-treated petroleum-based products that are biodegradable – as an environmentally preferred product.[66] Beyond large petrochemical companies, the businesses that are distributing bio-based lubricants are mostly smaller companies that are focused on bio-lubricant products. This review describes some companies distributing or researching predominantly bio-lubricant products in North America.

Renewable Lubricants, based in Ohio, is one of the largest bio-lubricant producers in North America. It produced vegetable oil based lubricants - relying on patents that utilize bio-based additives to overcome some of the oxidative stability and cold weather issues generally associated with vegetable oil based bio-lubricants. Several of the products claim to be usable at -40 C temperature, and some of their specialty cold weather bio-lubricant

[62] Cheminfo Services based on industry sources.
[63] Ibid.
[64] Ibid.
[65] Personal interview with DM's Bio-Based Fluid Supply Inc., October 22, 2013.
[66] Industry Sources.

products claim pour points of -60 C. They currently produce a range of lubricants that are used in on/offshore drilling, in hydraulic applications, in a wide variety of industrial applications (drilling fluids, compressor and vacuum pump oils, metal working fluids, greases, turbine fluids etc.), in high performance engines, in transmissions and in a variety of other applications. Their products are distributed in Canada by DM's Bio-Based Fluid Supply Inc., who in turn supplies several other companies (such as Linnaeus Plant Sciences) with bio-based lubricant products.[67] DM's Bio-Based Fluid Supply Inc. also owns the Canadian manufacturing rights to Renewable Lubricants products in Canada, but does not believe the market is yet large enough to begin production.[68]

Linnaeus Plant Sciences of Vancouver, BC proposes to develop and demonstrate an integrated process to produce value-added, renewable, biodegradable industrial oils and feedstock from camelina and safflower. The oils would be used for production of lubricants and feedstocks for polymers used in foams and coatings. Linnaeus has been developing industrial applications for oil seeds for more than a decade. The company has focused its efforts on uses beyond fuels – including production of hydraulic fluids, greases and polymers.[69]

Rustlick, a chemicals formulator (makes cleaners, lubricants, etc.) in Illinois USA, makes vegetable-based lubricants for metalworking applications. Its water-soluable oil product branded ULTRACUT® Green CF is a chlorine free (i.e., not using toxic chlorinated parrafins for flame retardancy), vegetable-oil based, bioresistant product suited for heavy-duty metalworking applications. It is USDA Certified as 81% bio-based. Rustlick combines vegetable oils with emulsifiers and performance additives to produce a concentrate that can be added to water before application in metal working applications.[70]

Ballard Biofuel in Seattle, WA offers a biodegradable anti-wear hydraulic oil that is a fully formulated, thermally stable, non-zinc containing hydraulic oil made from soy oil. The company claims it can be used in both high and low pressure hydraulic systems for industrial and mobile application in and around environmentally sensitive areas, such as national parks, streams or lakes, where use of oil containing toxic-heavy metals is restricted. It was developed as a top–tier replacement to crude oil based hydraulic oils where good low temperature properties, improved oxidation stability, low-toxicity and biodegradability are required or preferred.[71]

Amyris Inc. of Emeryville, California (NASDAQ: AMRS) (formerly Amyris Biotechnologies, Inc.) develops and provides renewable compounds for a variety of markets. The company is seeking to provide alternatives to petroleum-sourced products

[67] Cheminfo Services based on industry sources.
[68] Cheminfo Services based on industry sources.
[69] Camford Chemical Report, Process would make lubricants, plastic feedstocks from oilseeds. Volume 45 Number 14 April 15, 2013
[70] Rustlick, http://www.itwfpg.com/rustlick/biobased.html?gclid=CIDTwNSO-7gCFTFgMgodYxQAYg
[71] Ballard Biofuel. *Bio-Clear Bio Hydraulic Fluid*. http://www.ballardbiofuel.net/

used in specialty chemical and transportation fuel markets worldwide. It is targeting the cosmetics, lubricants, flavors and fragrances, polymers, consumer products and transportation fuel markets. The company recently announced its intent to establish a joint venture with U.S. Venture Inc for the production, marketing and distribution of finished lubricants for the North American market. The joint venture would market and sell lubricants employing Amyris' renewable base oils derived from *Biofene*. *Biofene* is Amyris's brand of a long-chain, branched hydrocarbon molecule called farnesene (trans-ß-farnesene). It is a tailor-made pure hydrocarbon. *Biofene* is one of thousands of renewable isoprenoid molecules made using a microbial platform.

Amyris is working on the production of a complete line of renewable lubricants, including hydraulic, compressor, turbine and gear oils and greases, as well as oils for 2-cycle and 4-cycle engines. The product line would be designed to provide *No Compromise* performance and equipment protection equal or superior to that of existing synthetic lubricants, while offering such environmental benefits as improved biodegradability and low toxicity compared to traditional petroleum-based lubricants. The company reported revenues of $74 million in 2012, with a net income loss of $205 million. The company had substantial research and development expenses.[72,73,74]

Greenland Corporation is a Calgary based company that produces vegetable oil based bio-lubricants. They currently have approximately 14 products for applications such as turbine fluids, release agents, chain saw oils and pneumatic equipment lubricants. The majority of their sales occur in B.C. and Ontario, and their business is focused largely on their hydraulic oils. Greenland has indicated that their customers buy their products because they are working on environmentally sensitive land or near watercourses, and Greenland products are both biodegradable and non-toxic.

BioBlend High Performance BioBased Lubricants is a U.S. company that manufactures and sells vegetable oil based lubricants and hydraulic fluids. They currently have original equipment manufacturer (OEM) approval from ThyssenKrup Elevator and sell into that niche market, as well as the drilling, mining, construction, agriculture, and marine market segments. Their products are vegetable oil based as opposed to synthetic ester based.

5.4.3.2 Challenges and Opportunities for Bio-Lubricants

Bio-lubricants may have inherent disadvantages or advantages that affect their marketability in certain applications. Issues such as price, reliability, and supply consistency become factors in whether or not a bio-lubricant may suitably replace a petroleum-based lubricant in any given application.

[72] CIBC Investor's Edge: *Amyris Inc, Company Overview.*
[73] Camford Chemical Report, May 23, 2011
[74] Amyris Inc., http://www.amyris.com/Innovation/155/BreakthroughScience

Input from industry representatives and a review of available literature indicate that there is currently a very limited market for traditional bio-lubricants. These products are priced higher and often do not have the performance characteristics of petroleum-based lubricants. Consumers and industrial customer are reluctant to pay premium prices for a product that does not perform to the same standards as less expensive products with a history of reliability, even though it may have some environmental benefits. While modern bio-lubricants do not suffer from the same disadvantages, and by some accounts have performance benefits, they are still priced approximately two to three times higher than petroleum-based lubricants, and have therefore achieved very limited market penetration.

The bio-lubricant industry is largely made up of smaller businesses trying to compete against large, entrenched, multinational corporations that are marketing lower priced products that have proven to be reliable over a very long period of time. Many of the challenges experienced by bio-lubricant producers are therefore typical of the challenges generally faced by small businesses trying to make an impact in a large and highly competitive market. These types of challenges include relatively limited advertising budgets, significant development/testing/certification costs, cost issues associated with small-scale production and costs related to patenting and protecting their investments.

The consolidated nature of lubricants supply, as well as the current distribution structure for lubricant products also pose difficulties to bio-lubricant suppliers. Most of the bulk lubricant distributors in Canada are contractually required to distribute only a certain brand of product. Any given distributor will be either a Petro-Canada (Suncor) distributor, an Imperial Oil distributor or a distributor for another major brand. Therefore, when entities such as mining companies, vehicle fleets, forestry companies or other major businesses look for lubricants from bulk distributors, the bio-lubricant products produced by the smaller companies are typically not available.

It is also challenging for bio-lubricant companies to bid on contracts released by businesses with vehicle fleets (such as large bus companies) due to how the bid structure for lubricants are often organized. Vehicle fleets structure bids for fuel/lubricant companies, and therefore require any companies bidding on their lubricant contracts to submit a bid that offers to fulfill both their lubricant and fuelling needs. Since small bio-lubricant companies do not produce fuels, they are immediately shut out of the bidding process for many vehicle fleet lubricant contracts.[75]

Additionally, there is currently some confusion regarding exactly what differentiates bio-lubricant products from petroleum-based products or “biodegradable” lubricant products based on petroleum. There is little standardization regarding the amount of biodegradable product content a lubricant must have before a manufacturer can call it “bio-based”, or simply give the product a name with the word “bio” in it. Bio-lubricant producers expressed

[75] Cheminfo Services based on industry sources.

concern regarding programs such as "EcoLogo®",[76] which they felt were accepting of products that were damaging to the environment.[77] Bio-lubricant manufacturers point out the existence of products in the market that contain non-biodegradable additives or contain very little (as low as 5%) biodegradable content and are marketed as "bio-based" products.[78, 79] These products are priced lower than bio-lubricants that meet recognized ASTM, OECD and CEN standards for biodegradability. This situation makes it more difficult for bio-lubricant producers to market their products, and also makes it problematic for legislators when considering tools that might recognize the increased environmental benefits offered by bio-lubricant products.

Another challenge for the bio-lubricants industry is that it is difficult to obtain OEMs approve or use of bio-lubricant products. "Many OEMs prefer tried and tested lubricants from mineral oil sources; these OEMs represent the biggest consumers in the lubricant market. When such OEMs are reluctant to use bio-lubricants because of performance and cost concerns, end users, who purchase products directly from these OEMs, tend to think likewise."[80] While a situation in which a bio-lubricant producer has managed to be adopted by an OEM has occurred (and will be discussed below), this situation is not typical. The challenge or lack of OEM approval is doubly problematic due to warranty voiding issues for OEM products. The use of a bio-lubricant as opposed to a product or lubricant type approved by an OEM manufacturer may void the warranty on a product. This is a significant concern for vehicle fleet management, farming, or mining or forestry market segment work. Wider acceptance and use of bio-lubricants in the lubricants market are unlikely to occur until OEMs start approving more bio-lubricant products for use in their equipment.

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[76] EcoLogo® is now part of UL Environment, a business unit of UL (Underwriters Laboratories),, http://www.ecologo.org/en/inthenews/pressreleases/
[77] Cheminfo Services industry sources.
[78] Ibid
[79] Ibid
[80] Lubes 'n' Greases Magazine, Apu Gosalia – Head of Global Competitive Intelligence and Chief Sustainability Officer, Fuchs Petrolub SE, *Biolubes: Hope or Hype?,* October 2013.

In summary, literature sources and input from bio-lubricant producers and potential bio-lubricant users/distributors have highlighted the following challenges or issues for wider adoption of bio-lubricant products:

- High price – often two to three times higher due to economies of scale, development/certification costs etc.;
- Limited access to traditional distributor networks and bidding processes – difficulty getting products to bulk distributors or large scale customers;
- Lack of common standards – there are no universally accepted or government recognized standards for both biodegradability and hazardousness to the environment that accurately show, in an easily understandable and quantifiable fashion, the environmental benefits of bio-lubricant products;
- Lack of spill cleanup cost advantages to using bio-lubricants – regardless of whether a large scale or bulk consumer utilizes a bio-lubricant product or traditional petroleum-based product, the current regulatory climate dictates that cleanup costs are identical, which leaves no quantifiable cost advantage for using bio-lubricants; and
- Lack of OEM acceptance or use – OEMs, which are large consumers of lubricants, are reluctant to use or recommend/allow (due to warranty issues) bio-lubricant products in their equipment.

The challenges listed above have restricted bio-lubricants from achieving greater market penetration despite continuing technological development and a presence in the market spanning over 20 years. Two market studies (a 1997 and follow up 2008 study) on bio-lubricants for the United Soybean Board both concluded that there is little market presence and there has been low growth for bio-lubricant products in North America.[81]

5.4.3.3 Opportunities/Strengths of Bio-Lubricant Products

Bio-lubricants have two primary advantages. The first is that many are biodegradable and non-hazardous to the environment and could therefore offer benefits to users in environmentally sensitive areas where petroleum-based lube spills could be costly to clean up. However, this strength is often negated due to current spill clean-up regulations that do not recognise ASTM standards on biodegradability and/or low danger to the environment. The associated challenge for regulators is a lack of coherent standards on which to base regulations distinguishing clean-up requirements for bio-lubricants and petroleum-based lubricants. Regardless of whether or not a lubricant is biodegradable and non-hazardous to the environment, the same procedures (and therefore the same cost) are typically applied when cleaning up the spill in order to avoid costly fines. However, input from distributors revealed that bio-lubricants are most often used by businesses that are operating around watercourses or have heavy machinery operating within water, indicating that users are

[81] Omni Tech International Ltd., for the United Soybean Board, *Bio-Based Lubricants – A Market Opportunity Study Update,* 2008.

cognizant of the damage that petroleum-based lube releases to water bodies can cause and are willing to pay a premium for safer alternatives (where it may not be possible to clean up the spill).[82/83/84]

Second, modern bio-lubricants can have lower volatility and flammability than petroleum-based products, and are therefore better for high temperature applications that require these superior performance attributes.[85] Some consumers have also indicated that some of the better bio-lubricant products can last longer than traditional mineral oil products in non-high-performance applications. The University of Guelph tested soy based motor oils and found that they extended the oil change life of each vehicle where it was used from 5,000 km to 8,000 km.[86]

Discussions with bio-lubricant producers have indicated that some of their main customers are governments - primarily municipal governments in Canada, and universities.[87] Additionally, in the United States, the US military remains a high volume customer due to their operations in environmentally sensitive areas and their desire to lessen their dependence upon foreign oil.[88] Universities (especially Guelph in Ontario and Penn State in Pennsylvania) also have agricultural programs (and vehicle fleets, landscaping equipment, etc.) that have been making the switch to bio-lubricants.[89] Initiatives such as the USDA's Bio-Preferred program (which requires federal government agencies to preferentially select products that have met certain requirements and have therefore been labelled as "bio-based") may increase the traction with which bio-lubricant products are sold to government.

5.4.3.4 Potential Strategies for Market Development

As discussed previously, one of the main market challenges has been difficulty in getting the largest consumers of lubricants, namely OEMs, to adopt bio-lubricants. A single OEM adopting a bio-lubricant for use in their products can make a large impact on a typically small bio-lubricant company. A case in point for BioBlend was obtaining OEM approval by ThyssenKrupp Elevator. BioBlend worked with ThyssenKrupp for two years to test and validate products for their elevator systems. This was an example of a focus on one customer, one product, and one niche application that translated into several hundred

[82] Cheminfo Services based on industry sources.
[83] Ibid.
[84] Ibid.
[85] Lubes 'n' Greases Magazine, Tyler Housel - Vice President of Lexolube Division, Inolex Inc., *Biolubes: Hope or Hype?*, October 2013.
[86] Ontario Grain Farmer, *Bio Based Lubricants – Building a Market That's Good for Farmers, Good for the Environment.*
[87] Cheminfo Services based on industry sources.
[88] Cheminfo Services based on industry sources.
[89] Penn State University, *Penn State Experiences: Bio-Based Lubricants, B100 and SVO – New England Farm Energy Conference March 15-16, 2010*, 2010.

thousand gallons of annual sales in the U.S. alone.[90] Programs that encourage OEMs to work with bio-lubricant producers to test and certify bio-lubricants for their equipment could potentially make a significant impact for bio-lubricant production/use in Alberta. Alberta bio-lubricant producers might consider identifying and focusing on some niche segments of the market – e.g., specific oil and gas applications.

Establishing standards for both biodegradability and hazardous/toxicity (as a product can be biodegradable but still be hazardous/toxic) for bio-lubricants could also help to address the lack of progress bio-lubricants have made into the market. As it stands, there is an array of ASTM, OECD and other standards that address biodegradability, but not environmental hazardousness. The existing standards are also designed specifically for petroleum products.[91] The standardization would need to be accompanied by regulatory changes or legislation that in some way recognizes the difference in between a release of a relatively benign biodegradable/non-toxic lubricant and a mineral oil lubricant.

Lastly, simply mandating the use of bio-lubricants in certain high risk or release applications is a strategy that is being increasingly applied in other jurisdictions. The Vessel General Permit Rule, for example, requires all ships operating in U.S. waters to use environmentally acceptable lubricants in all oil-to-sea interfaces.[92] Similarly, Sweden has regulations requiring "environmentally adapted" hydraulic fluids[93] and greases[94] for certain applications.

Further focused research would be required to identify and assess niche applications in Western Canada where environmentally friendly bio-lubricants might be able to offer value and an alternative to conventional lubricants. The oil and gas industry, which is concentrated in Western Canada, may be an attractive segment for further investigation. There is already some vegetable oil use as lubricants in the industry (See *Oilfield Chemicals* elsewhere is this report). Another market segment that may warrant further investigation is the agriculture market segment. Growers of canola and other crops may have interest to use products that are derived from their market segment – as this can contribute to increased prices for their produce.

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[90] Lubes 'n' Greases Magazine, (October 2013) *Biolubes: Hope or Hype?* Witten by Bill Smith - Vice President, Sales and Marketing, Biosynthetic Technologies

[91] Cheminfo Services based on industry sources.

[92] U.S. EPA, Vessel General Permit Rule.

[93] SP Technical Research Institute of Sweden, *Hydraulic Fluids Which Meet Environmental Requirements According to Swedish Standard SS 15 54 34.* http://www.sp.se/en/index/services/Lubricanting%20grease/Sidor/default.aspx

[94] SP Technical Research Institute of Sweden, *Lubricating Greases Which Meet Environmental Requirements According to Swedish Standard SS 155470.* http://www.sp.se/en/index/services/Lubricanting%20grease/Sidor/default.aspx

5.5 Surfactants

Surface active agents (or surfactants for short) are chemicals that reduce the surface tension of a solvent (usually water) or the interfacial tension between two phases (such as water and oil or grease). Surfactants are organic chemicals with hydrophilic (polar) and hydrophobic (non-polar) parts, and as such are made from non-polar hydrocarbons and polar chemicals. Chemicals that can contribute polar elements may contain sulphur, nitrogen, phosphorus, and oxygen atoms. These polar species may be part of alcohols (O), thiols (S), ethers (O), esters (O), acids (S, N, O), sulfates (S), sulphonates (S), phosphates (P), amines (N), amides (N) and various metal complexes. The non-polar portion of surfactants contain mostly hydrocarbons (e.g., 70%+), which can be derived from bioresources, crude oil and natural gas. The type and size (e.g., carbon chain length) of chemicals used to make the surfactants are among the factors that determine their functionality, production cost, and potential environmental footprint.

The surfactants "industry" does not have one specific NAICS code. As such, there are no public or other readily available statistics regarding the size and economic importance of surfactant manufacturers and blenders in Canada. Manufacturers of these chemicals may classify themselves as belonging to the following or possibly other NAICS codes.

- NAICS 32519 - Other basic organic chemicals;
- NAICS 32561 - Soaps and cleaning compounds;
- NAICS 32562 - Toilet preparations; and
- NAICS 325999 - Other chemical products.

Raw materials for surfactants are petrochemicals and petroleum refinery products, as well as oleochemical (natural) products. The basic oleochemical feedstocks are typically vegetable seed oils and animal tallow. In the United States about 60% of the feedstock for surfactants is oleochemicals.[95] This percentage is unknown in Canada - one reason being Canada's heavy reliance on imported surfactants. A large portion of oleochemicals are soy, coconut, and palm oils while canola may constitute a relatively minor portion. The industry has moved away from using tallow.

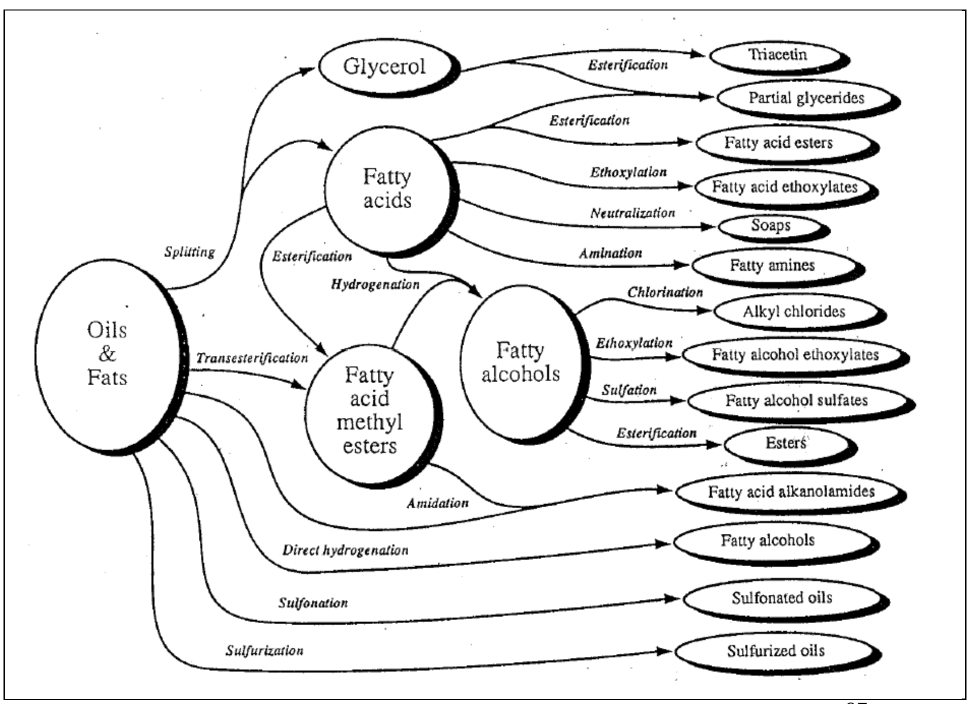
According to one Canadian industry source, an important issue related to using canola oil as a raw material is that the constituent molecules are different than soy oil. As a result, derivative chemicals made with canola oil are often not registered on the Government's Designated Substance List (DSL). The DSL is an inventory of approximately 23,000 substances manufactured in, imported into or used in Canada on a commercial scale. The DSL is the sole standard against which a substance is judged to be "new" to Canada. With few exemptions, all substances not on this list are considered new and must be reported prior to importation or manufacture in order that they can be assessed to determine if they

[95] Omni Tech International (2008), *Surfactants: A Market Opportunity Study Update.* Cheminfo Services.

are toxic or could become toxic to the environment or human health. It is crucial that notifiers determine whether the substance to be imported or manufactured in Canada is listed on the DSL or on the Non-domestic Substances List (NDSL). Substances not appearing on the DSL are considered to be new to Canada and are subject to notification. Substances listed on the NDSL are subject to notification but with reduced information requirements.[96] Reporting to the Government of Canada and obtaining registration for new products can involve high costs, which in some cases prohibits the use of new raw materials in the surfactant industry.

Examples of petrochemicals and refinery feedstocks are: ethylene (from petrochemical plants), n-paraffins and benzene (from petroleum refineries). Ethylene is used to make ethylene oxide (EO), which is used to make ethoxylated surfactants - for example. Dow Chemical makes EO at its Fort Saskatchewan, AB chemicals complex, the great majority of which is used to make ethylene glycol. Ethylene can also be oligomerized (joined together) to make paraffin feedstock for the non-polar portion of surfactant molecules. Benzene and n-paraffins are reacted (for example) to form linear alkylbenzene (LAB), which can be sulphonated to make linear alkylbenzene sulphonate (LAS). LAS is used to make detergents. The figure below provides some illustration of the pathways to producing biosurfactants.

Figure 4: Bio-Based Feedstocks for Biosurfactants



D. J. Burden, Center for Crop Utilization Research, Iowa State University, Ames, Iowa.[97]

[96] Environment Canada, http://ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=5F213FA8-1
[97] Omni Tech International (2008), *Surfactants: A Market Opportunity Study Update*

Surfactants are usually classified as being anionic, cationic, non-ionic, and amphoteric. This relates to the charge on the head of the surfactant molecule (as opposed to the hydrophilic tail). Anionics are negatively charged, cationics positively charged, non-ionics have no charge, and amphoterics can have positive or negative charge depending on the water conditions (e.g., pH) in which they are used. Examples of applications for these types of surfactants are provided below. The charges and their magnitude, which depends on the chemicals used to make them, affect surfactant functionality and cost to produce.

There are a great many surfactants available. They are used in a variety of formulated products, including but not limited to: soaps and cleaners; toiletries and cosmetics; paints and coatings; inks; oilfield chemicals; and many other applications. The end-use market for formulated products containing surfactants is quite fragmented featuring millions of household users, tens of thousands of institutions, and hundreds of thousands of industrial and commercial facilities.

The industry includes large primary hydrophobe producers, secondary producers that may react hydrophobes with polar chemicals, and a broad base on formulator or blenders. Some Canadian surfactant suppliers are listed in the table below. Most of the surfactants industry is located in Ontario and Quebec, while demand is spread out across Canada

Table 30: Canadian Surfactant Suppliers

Company	**Location**	
CEPSA Canada (Lineal alkyl benzene - LAB producer)	Becancour	QC
Chemtura Canada Co. Cie.	Elmira	ON
Colgate-Palmolive Ltd.	Mississauga	ON
Diversey Canada Inc.	Candiac	QC
Diversey Canada Inc.	London	ON
Emery Oleochemicals Canada Ltd.	Mississauga	ON
Evonik Oil Additives Canada Inc.	Morrisburg	ON
Markham Chemicals	Markham	ON
Nalco Canada Co. (An Ecolab company)	Burlington	ON
Rohm and Haas Canada LP	Toronto	ON
Schering-Plough Canada Inc.	Pointe-Claire	QC
Sialco Materials Ltd.	Delta	BC
Stepan Company	Longford Mills	ON
The Procter & Gamble Company	Brockville	ON
Tri-Tex Co. Inc.	Saint-Eustache	QC

Note: Some of these companies may be surfactant product formulators rather than suppliers. Some may not be producing surfactants in Canada.

There have been some plant closures in the industry over the last 10 years, and some suppliers may now only be importing basic or more complex surfactants from affiliates for their own use and/or resell. The most recent case in point is Emery Oleochemicals Canada, which closed it Mississauga, ON plant in September 2013.

The annual demand for basic surfactants in Canada is estimated to be between 300,000 and 400,000 tonnes per year.[98] This excludes the quantity of formulated products that use surfactants and formulated products that are imported that contain surfactants. (These would contain water and other ingredients.) Household laundry detergents, dish washing formulations, other household and personal care products have always represented the largest end-use market segments for surfactants. The pattern of demand and some of the larger end-uses in each market segment along with application examples are provided in the table below.

Table 31: Estimated Pattern of Canadian Demand for Surfactants

Market Segment	% of Total Canadian Demand (quantity basis)	Examples of Major Products
Household products	30-40%	Laundry detergents, light-duty dish washing formulations, shampoos, conditioners
Personal-care products	15-20%	Hand soaps (bars and liquid), shampoos, creams & lotions, shaving creams
Institutional, industrial, commercial	5-10%	Janitorial supplies, commercial laundry products, rug cleaners, carwashes
Oil/gas industry	5-10%	Drilling muds, corrosion inhibitors, demulsifiers, paraffin dispersants, well servicing chemicals
Mining	5-10%	Flotation chemicals, coal processing chemicals, extractive metallurgy aids
Pesticides	5-10%	Pesticide emulsions, wettable powders, spray products
Pulp & paper	1-5%	Digester aids, defoamers, browstock washing, pitch dispersants, slimicides, deinking chemicals, felt washers
Metalworking	1-5%	Cutting fluids, forming compounds, metal plating chemicals.
Construction	1-5%	Asphalt emulsions, cement and concrete additives, wallboard additives
Polymers and plastics	1-5%	Plastics processing aids, polymerization additives (rubber, latex, etc.)
Miscellaneous	5-10%	Food additives (e.g., lecithin), water treatment, textile softeners, lubricants, dyes formulation, paints and coatings, adhesives and sealants.

Source: Cheminfo Services estimates.

[98] Cheminfo Services, based on: Omni Tech International (2008), *Surfactants: A Market Opportunity Study Update*

The quantities of surfactants produced in Canada are not available from public sources, such as Statistics Canada. It is reasonable to assume that production in Canada has been decreasing over the last 20 years, as a number of surfactant plants have closed. Generally, Canadian surfactant production plants that closed were smaller than US facilities, which had better economy of scale. Formulators in Canada have increased their use of lower-priced surfactants made in large-scale US plants. As a result, Canadian imports of the main basic surfactants have been growing in Canada, as shown in the table below. Since 1990 total Canadian imports of surfactants have been increasing at an average annual rate of 4.4%. However, imports into Alberta have increased faster - at 7.2% per year on average, reaching 14.2 kilotonnes in 2012.

Table 32: Trend in Canadian and Alberta's Imports of Main Surfactants

		Canada	Canada	Canada	Canada	Canada	Canada	Canada
		1990	**2009**	**2010**	**2011**	**2012**	**2012**	**2012**
Canada	**HS * Code**	(kilotonnes)	(kilotonnes)	(kilotonnes)	(kilotonnes)	(kilotonnes)	($ million)	($/kg)
Anionic	340211	15.2	52.5	54.6	57.0	59.6	$120.1	$2.02
Cationic	340212	2.0	5.9	7.5	7.4	8.1	$27.7	$3.41
Non-ionic	340213	24.0	45.5	49.1	48.9	47.2	$152.7	$3.23
Other (NES)*	340219	7.8	9.3	9.5	12.1	12.6	$33.2	$2.63
Total Canada		49.0	113.2	120.6	125.5	127.5	$333.6	$2.62
		Alberta	**Alberta**	**Alberta**	**Alberta**	**Alberta**	**Alberta**	**Alberta**
Alberta	**HS Code**	**1990**	**2009**	**2010**	**2011**	**2012**	**2012**	**2012**
Anionic	340211	0.95	3.4	4.6	6.0	7.0	$19.1	$2.74
Cationic	340212	0.09	0.3	0.6	0.6	0.6	$1.9	$3.40
Non-ionic	340213	1.43	4.4	4.9	5.2	3.4	$10.5	$3.06
Other (NES)*	340219	0.61	0.9	1.2	2.7	3.2	$9.7	$3.02
Total Alberta		3.1	8.9	11.3	14.4	14.2	$41.2	$2.90
% of Total Canada		6%	8%	9%	12%	11%	12%	

Source: Statistics Canada, http://www.statcan.gc.ca/trade-commerce/data-donnee-eng.htm
* HS stands for harmonized system. NES stands for "not elsewhere specified".

The total demand for basic surfactants in Alberta is unknown – as the sales quantities by Canadian producers to customers in Alberta is unknown. Another issue in estimating Alberta demands is that many of the shipments from other provinces are in the form formulated products. Surfactants would be contained in partially or fully formulated products such as cleaners, pesticides, oilfield chemicals, coatings, etc. The great majority of imports come from the United States (i.e., over 90%). European and Asian countries account for a relatively small portion of Canadian imports. It is interesting to note that the average unit value ($/kilogram) of surfactants imported in Alberta in 2012 was higher than the Canadian average, by about 10%. This may in part be a result of transportation costs from distant US producers.

The major importers of surfactants in Alberta include oilfield chemical suppliers – such as Baroid, Champion Technologies Ltd/Nalco Energy, M-I Drilling Fluids Canada, Engenium, and Baker Hughes. Agricultural chemical suppliers (e.g., Agrium and Dow Agrosciences), and the major chemical distributors such as Univar and Dow Chemical also import surfactants. There are many additional importers in Eastern Canada, which are involved in a broad spectrum of end-uses including: cosmetics, asphalt mixtures, rubber compounding, coatings, consumer products, metal working fluids, etc.

Table 33: Major Canadian and Alberta Surfactant Importers

Company Name	City	Province
Agrium	Calgary	Alberta
Baker Hughes Canada Company	Calgary	Alberta
Baroid	Calgary	Alberta
Champion Technologies Ltd/Nalco Energy	Calgary	Alberta
Dow Agrosciences Canada Inc.	Calgary	Alberta
Dow Chemical Canada Ulc	Calgary	Alberta
M-I Drilling Fluids Canada, Inc.	Calgary	Alberta
Smith Chem Solutions Inc.	Calgary	Alberta
Engenium (Synerchem International Inc,/Brine-Add Fluids)	Calgary	Alberta
Talisman Energy Canada	Calgary	Alberta
Univar Canada Ltd.	Edmonton	Alberta
Other Provinces		
Akzo Nobel Chemicals Ltd	Mississauga	Ontario
Apollo Health And Beauty Care	Concord	Ontario
Ashland Canada Corp.	Mississauga	Ontario
BASF Canada Inc.	Mississauga	Ontario
Bayer Cropscience Inc.	Toronto	Ontario
Cambrian Chemicals Inc	Oakville	Ontario
Canada Colors And Chemicals Limited	Toronto	Ontario
Charles Tennant & Company (Canada) Limited	Toronto	Ontario
Chemiqa Inc.	Sudbury	Ontario
Chrysler Canada Inc.	Windsor	Ontario
Cognis Canada Corporation	Mississauga	Ontario
Colgate-Palmolive Canada Inc	Toronto	Ontario
Croda Canada Limited	Concord	Ontario
Cytec Canada Inc.	Niagara Falls	Ontario
Debro Chemicals Inc.	Brampton	Ontario
Dempsey Corporation	Toronto	Ontario
Diversey Canada, Inc.	Oakville	Ontario
DSM Nutritional Products Canada Inc.	Ayr	Ontario
Ecolab Co.	Mississauga	Ontario
Estee Lauder Cosmetics Ltd	Toronto	Ontario
Evonik Goldschmidt Canada	Burlington	Ontario
Goodyear Canada Inc.	Toronto	Ontario
Heidelberg Canada Graphic Equipment Limited	Toronto	Ontario
Houghton Canada Inc	Toronto	Ontario
Icynene Inc.	Mississauga	Ontario
Invista (Canada) Company	Kingston	Ontario
Jempak Gk Inc	Concord	Ontario
KIK Canada	Concord	Ontario
L.V. Lomas Limited	Brampton	Ontario
McAsphalt Industries Limited	Toronto	Ontario
Momentive Performance Materials Canada Ulc	Markham	Ontario
Nalco Canada Co.	Burlington	Ontario
Nexeo Solutions Canada Corp.	Mississauga	Ontario

Company Name	City	Province
PK Chem Industries Ltd.	Brampton	Ontario
Rhodia Canada Inc.	Toronto	Ontario
Stepan Canada Inc.	Longford Mills	Ontario
Whin Proprietary Custom Formulas Corp.	Oakville	Ontario
Polyrheo Inc.	Dollard-Des-Ormeaux	Quebec
Quadra Chemicals Ltd	Vaudreuil-Dorion	Quebec
Knowlton Packaging Inc	Knowlton	Quebec
L'Oreal Canada Inc.	Montréal	Quebec
Berger Peat Moss Ltd	Saint-Modeste	Quebec
Entreprise Adtool Electrique	Montréal-Ouest	Quebec
Entretien De Lave-Auto Laval Inc	Laval	Quebec
Quadra Chemicals Ltd	Vaudreuil-Dorion	Quebec
Brenntag Canada Inc	Dartmouth	Nova Scotia
Gea Westfaliasurge Canada Ltd.	Halifax	Nova Scotia

Source: Cheminfo Services

The Canadian market for surfactants includes uses for many products. Some of the higher volume types of surfactants used in or contained in formulated products are listed below, with examples of uses provided in parenthesis:

- linear alkylbenzene (LAB) sulfonates (laundry powders, light-duty liquids);
- fatty alcohol sulfates (personal care products);
- alcohol ether sulfates (light-duty liquids, laundry liquids);
- tall-oil and rosin soaps; (asphalt and latex emulsions);
- tallow and vegetable-oil soaps (toilet bars, laundry soaps);
- ethyloxylates, alkoxylates (pulp & paper, oilfield chemicals, coatings);
- lignosulfonates (concrete mixes, drilling muds);
- fatty alcohol ethoxylates (laundry powders, cleaners);
- fatty amines (metal ore processing, oilfield chemicals);
- ammonium quaternary compounds (fabric softeners, oilfield chemicals); and
- ethanolamides (hair shampoo, light duty liquids)

There are more surfactant types sold in small quantities for many more uses. Some surfactant producers custom make products to meet unique customer needs, which can change. Sialco Materials in Delta, BC is a primary surfactant producer, who finds that it has to change product formulations frequently. It tends to avoid making high volume, low priced products, and sometimes purchases these for custom blends or further processing. It focuses on making specialty surfactants and blends to meet specific customer needs. Sialco also provides customers with production services, such as: vegetable oil polymerization; cosmetic oil refining, bleaching and deodorization; cosmetic oil derivitization; special reactions; and cosmetic ingredient reprocessing.[99]

[99] Sialco Materials, http://sialco.com/.

Stepan in Longford Mills, Ontario is another of Canada's surfactant producers. It can make alkoxylates, amides, sulfonates, sulfates, blends, and phosphate esters. The operations are owned by Stepan, based in the United States.[100]

5.5.1 Potential for Biosurfactants

The surfactant industry and its users have been responding to environmental and health issues and regulations for many years. Some of these pressures have provided opportunity for increased use and production of vegetable-based biosurfactants. However, some regulatory requirements also present marketing challenges for new chemicals. A challenge to new bioresource-based surfactants is the potential requirement for regulatory registration of new chemicals.

In the case of consumer products, ingredients in soaps and detergents, disinfectants, sanitizers, household cleaning products, pest control and other products are governed by various regulations. For example, the Chemicals Management Plan (CMP), announced by the Government of Canada in December 2006, began with the Industry Challenge Program to review 193 highest priority substances. These substances were grouped into 12 "batches" for review, to be completed over five years. The next phase of the CMP was announced October 3, 2011, when the Government of Canada renewed its commitment to Canada's world-leading Chemicals Management Plan. Approximately 1,000 additional substances will be reviewed in the next five years and the rest by 2020, including through the Substance Groupings Initiative. More information on the Chemicals Management Plan, the Industry Challenge and the Substance Groupings Initiative can be found at the Government of Canada website. Other regulations in the consumer products industry include: *New Substances Notification Regulations* (NSNR) under the Canadian Environmental Protection Act, 1999 (CEPA, 1999); the *Food & Drugs Act*; *Pest Control Products Act* (PCPA), administered by Health Canada. The *Consumer Chemicals & Containers Regulations* (CCCR 2001) under the Canada Consumer Product Safety Act (regulating labelling).[101]

[100] Stepan, http://www.stepan.com/default.aspx
[101] Canadian Consumer Specialty Products Association (CCSPA), http://www.healthycleaning101.org/english/QA.html

In addition to consumer products, there are environmental pressures on industrial and other market segments for surfactants and formulated products. These include pressures to:

- reduce air emissions of VOCs;
- reduce releases to water and soils;
- use raw materials from renewable resources;
- reduce animal derived raw materials in certain products (resulting from concerns regarding bovine spongiform encephalopathy (BSE), commonly known as mad cow disease);
- developing a better understanding of the environmental and human safety risks of ingredients;
- reduce workplace exposures to dangerous substances; and
- enhanced product sustainability.

Many of the surfactants are based on vegetable oils, tallow, lignin (e.g., lignosulphonates), and tall oil (from wood biomass), and as such a good portion are already bio-based chemicals. Many of the formulators are offering and promoting a variety of “environmentally friendly”, “environmentally responsible” and/or “green” products. In some cases, this involves branding existing products that were already bio-based. However, in addition to using ingredients that are from renewable sources, they can also offer additional environmental benefits (better biodegradability, lower toxicity, lower VOC, etc.). Some surfactant suppliers have adopted environmental certification programs that brand products. The US EPA's Design for the Environment (DfE) and the European Ecocert are two key examples adopted by some Canadian surfactant industry suppliers.

The US EPA's Design for the Environment (DfE) is a program that works in partnership with industry, environmental groups, and academia to reduce risk to people and the environment by finding ways to prevent pollution. For more than 15 years, through partnership projects, DfE has evaluated human health and environmental concerns associated with traditional and alternative chemicals and processes in a range of industries. These encourage businesses to select safer chemicals and technologies. More recently, DfE has been helping consumers and industrial purchasers make wise choices by identifying safer and effective products. It has evaluated and allowed more than 2,500 products to carry the DfE logo. Its standards cover surfactants in cleaning products, solvents, processing aids and additives, perfumes, and other products. For DfE, surfactants in cleaning products are distinguished by their rate of biodegradation, degradation products, and level of aquatic toxicity. The DfE Criteria for Surfactants combine these hazard characteristics, and requires that surfactants with higher aquatic toxicity demonstrate a faster rate of biodegradation without degradation to products of concern. Surfactants that meet the Criteria are acceptable for use in a DfE-labeled cleaning product; surfactants in products which typically by-pass sewage treatment must meet the Criteria for Environmental Fate

& Toxicity for Chemicals in Direct Release Products.[102] Associated with DeF is CleanGredients, which is a database listing of surfactants, solvents, fragrances, and chelating agents. Key attribute data and the ingredient formulations are reviewed by an approved third-party, and carried out under confidentiality, providing verification of claims for the key ingredient attributes for ingredients without compromising proprietary formulations.[103]

Ecocert is a product and services environmental certification body, created in France and now with subsidiaries in many other countries, including the United States. It has established a set of standards to promote the use of natural ingredients from renewable sources (as opposed to petroleum based materials), reduce greenhouse gas emissions, and reduce environmental impacts for a variety of products and services (e.g., golf courses, spas). Ecocert certifies more than 1,200 products through 150 committed companies. In the surfactants industry, it has established standards for detergents, paints and coatings, cosmetics, and cleaning products. Its cleaning products standard was created in conjunction with stakeholders in the value chain, i.e. suppliers, manufacturers, distributors. Its standards also encourage producers to implement environmentally friendly production practices. Its natural ingredients standard includes: a minimum of 95% of ingredients from natural origin (maximum 5% of synthetic ingredients). There are other standard requirements, including but not limited to specific ingredients to be excluded from products and packaging (biodegradability or ability to recycle).[104]
Below are some examples of suppliers and formulators offering of environmentally friendly or green product lines.

Ostrem Chemical Co. Ltd, headquarter in Edmonton, Alberta formulates a variety of surfactant-based chemicals (e.g., cleaners, auto care products, water treatment, etc.) Its Nature’s Own™ line of environmentally responsible cleaning products consists of products registered with either The EcoLogo Program or Green Seal™ Program. Ostrem promotes its Nature’s Own™ EcoLogo registered cleaning products as not containing:[105]

- petroleum solvents;
- d-limonene;
- alcohols;
- phenol ethoxylates;
- phosphates, silicates, nitrates;
- EDTA (ethylenediaminetetraacetic acid);
- NTA (nitrilotriacetic acid);
- mineral acids; and
- caustic or butyl cellosolve.

[102] US EPA, *Design for the Environment (DfE): A EPA Partnership Program*. http://epa.gov/dfe/pubs/projects/gfcp/index.htm
[103] CleanIngredients, http://www.cleangredients.org/about
[104] EcoCert, http://www.ecocert.com/en/
[105] Ostrem Chemicals Co. Ltd., http://www.ostrem.com/natures/natures.htm

Quadra Chemicals a chemicals distributor based in Vaudreuil-Dorion, QC, with several locations in Alberta, other provinces and China, is committed to the promotion of the principles of sustainable chemistry. With this in mind, it has created its Green Products that are made only with ingredients that are certified by a third party, such as Ecocert, DfE, and/or CleanGredients®.[106]

Table 34: Quadra Chemicals' Green Products

Ingredients for Personal Care and Cosmetics	Ingredients for Household, Industrial and Institutional Cleaning
Algin	Ammonium laureth sulfate
Alpha-Tocopherol	Ammonium lauroyl sarcosinate
Ammonium laureth sulfate	Cocamidopropyl betaine
Ammonium lauroyl sarcosinate	Disodium cocoyl glutamate
Carrageenan	Disodium/sodium cocoyl glutamate
Castor isostearate succinate; Hydrogenated castor	Linear alkylbenzene sulfonate acid
Castor isosteareate beeswax succinate	Sodium laureth sulfate
Cocamidopropyl betaine	Sodium lauroyl glutamate
Disodium cocoyl glutamate	Sodium lauroyl sarcosinate
Disodium/sodium cocoyl glutamate	Sodium lauryl sulfate
Flaxseed oil	Sodium linear alkylbenzene sulfonate
Inulin, oligosaccharide	Sodium xylene sulfonate
Linear alkylbenzene sulfonate acid	
Microcrystalline cellulose	
Octyl dodecanol; Beeswax	
Polyglyceryl-3 ricinoleate	
Sodium alginate	
Sodium alpha olefin sulfonate	
Sodium laureth sulfate	
Sodium lauroyl glutamate	
Sodium lauroyl sarcosinate	
Sodium lauryl sulfate	
Sodium linear alkylbenzene sulfonate	
Tocopherols (mixed)	

Source: Quadra Chemical.
Product brand names and certifications available at website.[107]

Quadra also wanted to highlight certain products that provide tangible environmental benefits despite not being certified by a third party, which is why they created a *Better Choice* list. The company created industry-specific criteria to qualify a product as an environmentally-friendly "better choice". Several criteria (for instance "sustainably produced") are vague and would vary on a product-by-product basis. In these cases, it provided justification (available upon request) for including these products. Its intent has

[106] Quadra Chemical, http://www.quadra.ca/
[107] Quadra Chemical, http://www.quadra.ca/

been to produce a transparent, honest and dynamic list that reflects best industry practices and to add new products over time that will provide customers with a variety of sustainable options.[108]

Croda International is a distributor of surfactants and other chemicals. It believes that the "Green" movement is an important industry trend in cleaning, personal care and other formulated chemical products. Croda points out that while at first, the theme was restricted to the origin of the raw materials (e.g., botanical extracts), it now includes more aspects of a product – e.g., how it is sourced, how it is produced, and ultimately, how it degrades in the environment. Croda is promoting its ability to supply ingredients that fit many aspects of the green trend, such as: botanical extracts with Ecocert qualification; natural oils and butters that are harvested according to Forestry Stewardship Council (FSC) standards;[109] lanolin products and other natural oils that are super refined to remove potential irritating by-products; ingredients with alternative preservative systems; and ingredients that are not petrochemically derived. This list of green attributes is not exhaustive, and Croda continues to grow as it investigates other innovative green technologies.[110]

There are factors favouring the market potential for increased use of biochemicals in the surfactants industry. However, there are also barriers and challenges that need to be overcome. These include:

Positive Factors to Consider

- A large portion of basic surfactants are made from bio-based chemicals, and so are already accepted in the marketplace;
- A large portion of the Canadian market is supplied by low-priced U.S. imports made in large competitive plants, and sold through distributors. Canadian producers might be able to offer competitive prices directly to customers, and pass along a transportation cost advantage – depending on location and distance between customers and production plant;
- The trend to "environmentally friendly" and/or "green products favours increased use of renewable, sustainable resources.

Barriers and Challenges to Consider

- The surfactants market is quite complex, presenting challenges to quantify and delineate with respect to segments and specific products used;
- The market features a few large customers and many small customers, whose needs are constantly changing. This requires custom-made products for small surfactant producers. This requires expertise in surfactant chemistry and production; and
- Government registration of new products made from bioresources may be required, which can involve high costs.

[108] Quadra Chemical, http://www.quadra.ca/
[109] FSC is an international certification and labeling system dedicated to promoting responsible forest management of the world's forests. Forestry Stewardship Council (FSC), https://ca.fsc.org/who-we-are.186.htm
[110] Croda International Plc, http://www.croda.com/home.aspx?s=157&r=400&p=2632

Determining the potential demand in any regional (e.g., western Canada) or market segment (pesticides, oilfield chemicals, etc.) for new or existing bio-based surfactants requires close examination of specific customer needs in the marketplace.

5.6 Isopropanol (IPA)

Isopropanol (also known as isopropyl alcohol, propan-2-ol, and IPA) is a clear, volatile, flammable liquid with a pungent alcohol odor. Most of the product is sold as 99% pure, while higher purity USP[111] grade is also available.

The total Canadian market for IPA is estimated at 25,000 to 32,000 tonnes per year. Close to half of the demand is for a variety of solvent applications in formulated products such as paints and coatings, printing, inks, adhesives, and de-icing fluids. The table below provides rough estimates of the Alberta, Canadian and the global demand patterns for IPA.

Table 35: Estimated Market Demands for Isopropanol, 2012

Industry	Alberta	Canada	United States	Global
Total demand estimates (kilotonnes)	6-8	25-32	600-700	~2,000
Applications	**% of Alberta Demand**	**% Canadian Demand**	**% USA Demand**	**% Global Demand**
De-icing fluids	75-85%	20-25%	40-50%	40-50%
Solvent applications (e.g., coatings, adhesives, printing)	5-10%	40-50%		
Cleaners, disinfectants, personal care products	8-13%	25-30%	10-15%	10-15%
Pharmaceuticals	1-2%	5-10%	3-5%	3-5%
Feedstock for chemicals	0%	0%	30-40%	30-40%
Acetone	0%	0%	1-3%	1-3%

Sources: Cheminfo Services estimates for Alberta and Canada.
For US and global estimates: Dow Chemical, *Product Safety Assessment (PSA): Isopropanol.* http://www.dow.com/productsafety/finder/iso.htm; ICIS, (2009) *Chemical Profile Isopropanol*, http://www.icis.com/Articles/2009/11/02/9259817/Chemical-profile-Isopropanol.html, Markets and Markets, (2013) *Propanol Market worth 2745.8 Kilotons by 2018* (newsline). http://beforeitsnews.com/chemtrails/2013/09/propanol-market-worth-2745-8-kilotons-by-2018-2431208.html

In Canada, IPA is used in a variety of de-icing formulations. One such application is for de-icing natural gas pipelines, especially in Western Canada. IPA for this application may be formulated with other solvents and chemicals, such as methanol, ethylene glycol, and ethyl ether. In this application IPA also competes with methanol, which is the larger

[111] The U.S. Pharmacopeial (USP) Convention is a scientific nonprofit organization that sets standards for the identity, strength, quality, and purity of medicines, food ingredients, and dietary supplements manufactured, distributed and consumed worldwide. USP's drug standards are enforceable in the United States by the Food and Drug Administration, and these standards are developed and relied upon in more than 140 countries. USP sets scientifically developed standards to ensure that over-the counter and prescription medicines or healthcare products are high quality and pure. (Source: U.S. Pharmacopeial Convention: http://www.usp.org/about-usp)

volume de-icing chemical. A good portion of demand for this application is in Alberta, where the majority of Canada's natural gas is produced. Many natural gas pipeline operators have automatic de-icing injection systems to prevent ice formation in their pipeline systems. Demand for IPA and other de-icing chemicals have recently been negatively affected by reduced sales of natural gas (See *Oilfield Chemicals* section). There are other de-icing applications, with low amounts sold in bottles for applying IPA to frozen equipment to melt ice build-up. A portion of the demand for IPA is as a fuel additive to reduce the risk of ice build-up due to water contamination.

As a solvent, IPA is used in such applications as paints and coatings, cosmetics, personal care products, inks, and adhesives. IPA is used in disinfectants and cleaners, sold to industrial, commercial (e.g., restaurants), and institutional (e.g., government buildings, laboratories, hospitals) customers. Cleaners with greater than about 70% IPA have disinfecting properties. In the printing industry, IPA is mostly used in lithographic printing. IPA can be used in higher-priced summer windshield wiper fluid – "bug-wash". Given that it is more expensive than methanol, little if any IPA is used in winter windshield wiper formulations, which use methanol. In pharmaceuticals, IPA can be used as a mixing solvent and in tablet coatings. In Alberta there is also a low amount of premium, very high purity certified food-grade IPA used for sugar beet processing. Other applications include use as a cleaning and drying agent in the manufacture of electronic parts and metals, and as a solvent in medical, consumer products (e.g., rubbing alcohol) and veterinary products.

IPA for food, pharmaceutical, cosmetic, personal care and similar products usually require high purity USP grades. These are typically sold in lower volumes at a premium price to industrial grade IPA.

IPA also serves as a feedstock for chemical synthesis. IPA is used in the production of isopropyl acetate, methyl isobutyl ketone (MIBK) and isopropylamines. None of these chemicals are known to be made in Canada.[112,113]

Alberta demand for IPA is estimated to be 6,000 to 8,000 tonnes per year with natural gas pipeline de-icing use and other applications in the oil and gas industry making up a large portion of demand. Other applications in Alberta include formulation of other coatings, cleaning formulations, printing, sugar manufacturing, and minor other uses.

Given that the IPA market has many applications and customers, distributors such as Brenntag, Univar, Canada Colors and Chemicals, and Altachem play an important role in reaching customer locations.

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[112] Mirasol. F. (2011). *US Chemical Profile: Isopropanol.* ICIS.com, Available at: http://www.icis.com/Articles/2010/03/01/9338188/us+chemical+profile+isopropanol.html
[113] Camford Information Services. (1997). *Isopropanol*. CPI Product Profiles.

5.6.1 Supply and Value

The only Canadian producer of IPA is Shell Chemicals Canada in Corunna, ON. Its plant capacity is 95,000 tonnes per year. It uses an abundant supply of propylene in Canada (much of which is exported) as feedstock. IPA production and sales data are not readily available from Shell Chemicals Canada. Trade statistics indicate that Alberta makes up a sizeable portion of total Canadian imports. It is evident that Shell Chemicals Canada needs to export a large portion of its production from the Corunna plant, as the Canadian demand for IPA is estimated to be about 25-35% of Shell's plant capacity.

Trade statistics show that IPA imports to Alberta are valued ($/kg) somewhat lower than that the average value of all Canadian imports. This may be because the quantities imported into Alberta are purchased in larger quantities by distributors (e.g., Brenntag), as well as Dow Chemical - which has affiliated production capacity in the United States.

Table 36: Canadian and Alberta Imports of IPA

	2009		2010		2011		2012	
Canada	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**
Imports	7,511	$16,074	9,877	$17,988	12,009	$22,655	10,744	$17,984
Value ($/kg)	$2.14		$1.82		$1.89		$1.67	
Alberta								
Imports	2,827	$4,786	4,127	$6,297	5,088	$8,090	4,622	$6,719
Value ($/kg)	$1.69		$1.53		$1.59		$1.45	

Source: Canadian International Merchandise Trade Database. HS: 2905120020: Propan-2-ol.

Table 37: Canadian Exports of Propan-2-ol (IPA) and Propan-1-ol

	2009		2010		2011		2012	
Canada	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**
Exports	68,923	$73,435	65,098	$81,044	72,353	$107,184	75,762	$95,130
Value ($/kg)	$1.07		$1.24		$1.48		$1.26	

Source: Canadian International Merchandise Trade Database, HS: 29051200: Propan-1-ol (propyl alcohol) and propan-2-ol (isopropyl alcohol). No separate export data was available for IPA. Most of the exports are IPA.

The price of IPA is strongly influenced by the price of its propylene feedstock, which is established in the large US petrochemicals marketplace. Propylene prices are in turn affected by raw material prices for natural gas liquids (e.g., ethane) and crude oil, and market demand for other propylene uses, such as polypropylene resin. There have been large changes in IPA prices over the last several years. The U.S. spot export price that was close to $1.15 per kilogram around January 2010 rose by about 50% to $1.70 per kilogram in 2011, and then dropped 30% to about $1.20 per kilogram in the spring of 2012.

Table 38: Examples of Canadian Importers and Distributors of IPA
(Companies marked with an asterisk * were identified as importers IPA)

Company	Type	Location[(1)]	Province
Apco Industries Co. Limited	Distributor*	Toronto	ON
Brenntag Canada Inc.	Distributor*	Calgary	AB
Canada Clean	Distributor for cleaners, etc.*	Ottawa	ON
Colt Chemical	Distributor*	Innisville	ON
Dow Chemical Canada ULC	Distributor*, user	Calgary	AB
Esso Chemical Canada	Distributor*, user	Toronto	ON
Quadra Chemicals Ltd	Distributor* for cleaners	Vaudreuil-Dorion	QC
Univar	Distributor	Vancouver	BC
Canada Colors and Chemicals	Distributor	Brampton	ON
Altachem Ltd.	Distributor, Oilfield & industrial chemicals	Edmonton	AB
Recochem (BC) Inc.	Bottler, formulator, distributor	Nisku	AB

Sources: Canadian Importers Database, http://www.ic.gc.ca/eic/site/cid-dic.nsf/eng/home
Cheminfo Services. Note 1: One location shown. Some distributors have many sales office locations across Canada.

5.6.2 Bio-Production Supply Activities

There was no identified supply or use of bio-based IPA in the Canadian market.

There is considerable research into the bio-based pathway for isopropanol production with Genomatica and Mitsui actively conducting research. Mitsui Chemicals (Japan) received a patent in 2010 for a method to produce isopropanol from a modified bacterium when fed waste plant biomass.[114] This method may prove to be a productive use of Alberta's surplus agricultural waste. California-based Genomatica is also reported to be in the research and development stages for a similar bio-based isopropanol process, but their main focus remains on butanediol and butadiene.[115]

Mascoma Corporation is in the process of developing a cellulosic-based ethanol production facility in Drayton Valley, Alberta. The facility will use Aspen biomass to make

[114] US Patent: 20100311135 A1. (2010) *Isopropyl alcohol- producing bacterium and method of producing isopropyl alcohol using the same.*
[115] Genomatica. (2013). *Broad intellectual property, enabling strong product pipeline*. Available at: http://www.genomatica.com/technology/ip/

ethanol, along with IPA as a co-product. The IPA available from the facility will be approximately 4,300 tonnes per year, while ethanol production will be approximately 80 million litres per year (63,000 tonnes/year). The plant is expected to be in production within several years, contingent upon financing. The plant's production for IPA process is unique, featuring enzymes to break down the cellulosic components of the wood and biological conversion of the by-product acetic acid (a two carbon molecule) to form IPA (a three carbon molecule). The acetic acid by-product that would normally wind up in the waste water, is converted to bio-based IPA, which is an added environmental benefit. A potential technical advantage of bio-based IPA is that the biological synthesis route is specific to making IPA, as such there may be opportunity to obtain high purity IPA with very low concentrations of by-product contaminants.

5.6.3 Market Potential in Bio-Based IPA

Input from a limited number of industry sources involved with distributing and using IPA was generally positive with respect to market factors for bio-based IPA and products containing bio-based IPA. However, they also indicate that IPA is a commodity chemical and as such needs to be priced to be competitive with conventional IPA and solvent alternatives. It is unlikely that bio-based IPA would be able to command a price premium relative to conventional IPA. With price, performance and product quality consistency being equal to conventional IPA, bio-based IPA provided by a reliable local Canadian supplier in Western Canada should be able to attract customers. There would likely be interest in high purity USP grade bio-based IPA for food, cosmetics, personal care and similar products. However, this is a minor portion of the total IPA market in Canada and most of the Canadian USP demand is concentrated in Ontario and Quebec.

Table 39: Industry Input on Factors Influencing Potential Market for Bio-based IPA

Company	Locations	Market Segment, Products	Input on bio-based IPA
Recochem Inc.	Milton, ON, Nisku, AB	Canada's largest bottler of windshield wiper fluid, antifreeze, solvents, mineral spirits, etc.	• Very low amount of IPA used in summer bug-wash formulations. • Bio-based product lines do not sell well to retailers that are very price sensitive. • No price premium likely for bio-IPA. Bio-IPA would be a "tough sell" to retailers. • Environmentally-friendly products can be a positive marketing feature.
Ostrem Chemical	Edmonton, AB	Cleaners, degreasers, industrial, commercial, institutional market	• Good interest for bio-based cleaners for institutional (e.g., government) customers with "green" purchasing policies. • Bio-IPA would be favoured to conventional IPA.

Company	Locations	Market Segment, Products	Input on bio-based IPA
Mike's Oilfield Services	Lloydminster, AB	Oilfield services provider. Distributes and applies de-icing fluids (and other chemicals) for use in customers' gas pipeline systems.	• Low interest in bio-based IPA. • Reluctant to alter ingredients in de-icing formulations.
Altachem Ltd.	Edmonton, AB	Distributor of many oilfield chemicals, cleaners, degreasers, etc.	• Methanol is usually favoured to IPA in de-icing formulations due to methanol's low price and high efficiency. • Environment friendly products (e.g., BioSol product lines) that work as well as conventional products are favoured in the market, even if they are priced slightly higher. • Bio-based may offer cost benefits in related to spills (e.g., may not need to remediate).
Lantic Sugar	Taber, AB	Sugar from sugar beets	• Use low amounts of very high purity IPA that is certified as food-grade. • May be interested in bio-based IPA if it was certified as food-grade.

Cheminfo Services based on industry sources.

5.7 Hexane

Hexane is an alkane of six carbon atoms, and has a chemical formula of C_6H_{14}. The term "hexane" may refer to any of the five structural isomers within the formula, or to a mixture of those isomers. At standard temperature and pressure, hexane is a clear and colourless liquid, with a mild petroleum-like odour detectable at 65 to 248 ppm.[116]

The following profile discusses the hexane market in Canada. It provides information on industries that use hexane (namely the oil and gas industry and the natural oil extraction industry) and the challenges or possible benefits associated with substituting hexane for bio-based alternatives.

[116] Canadian Council of Ministers of the Environment, *Canadian Soil Quality Guidelines for n-Hexane: Protection of Environmental and Human Health – Scientific Supporting Document,* http://www.ccme.ca/assets/pdf/pn_1454_hexane_sqg_supp_doc.pdf.

5.7.1 Hexane Market in Canada

Canadian demand for hexane is estimated between 15 and 20 kilotonnes per year.

Table 40: Canadian Demand for Hexane

Application	% of Total Canadian Demand*
Oil and gas	30-50%
Adhesives and Sealants, Coatings	20-40%
Natural Oil Extraction	15-20%
Resin Manufacturing	10-15%
Tapes	1-5%
Total (kilotonnes, 2010)	15-20

Source: Cheminfo Services estimates, based on industry input.
* Does not include hexane in hydrocarbon mixtures

There are various uses for "pure" hexane in the Canadian oil and gas industry including use in oilfield chemicals. Hexane is also found in bitumen diluents used in Alberta (contained in hydrocarbon mixtures). (A section of the Appendix describes the diluent market.) Other hexane uses are adhesives, sealant, and coatings formulations. Major Canadian adhesives and sealants producers include companies such as 3M Canada, RPM Canada (Tremco), and Helmitin. No producers of adhesives, sealants and coatings that might utilize hexane in their processes were identified in Alberta, although some formulation of these products is likely to exist in the province.

Hexane is used in the extraction of oils from seeds of various types, such as canola, flax, mustard seed, peanuts, safflower seed, and corn. The following table shows the ten major oilseed extraction facilities in Canada, three of which are located in Alberta.

Table 41: Oilseed Extraction Facilities in Canada

Company Name	City	Prov
Canbra Foods Ltd.	**Lethbridge**	**AB**
ADM Agri-Industries	**Lloydminster**	**AB**
ADM Agri-Industries	Windsor	ON
Bunge Canada	**Fort Saskatchewan**	**AB**
Bunge Canada	Altona	MB
Bunge Canada	Harrowby	MB
Bunge Canada	Hamilton	ON
Bunge Canada	Nipawin	SK
Bunge Canada	Dixon	SK
Cargill Limited	Clavet	SK

Source: Environment Canada, Cheminfo oilseed plant interview.

The three oilseed plants in Alberta process primarily canola. ADM Agri-Industries Lloydminster plant processes canola and exports much of the resulting oil to Asia for food applications and Europe as a biofuel feedstock.[117] The Bunge facility claims to be the largest processor of canola in Canada.[118]

Hexane is also used as a solvent in resin production. The only facility in Canada identified as utilizing hexane for resin production was the Lanxess facility in Sarnia, Ontario. They use hexane in the manufacture of halobutyl rubber from butyl rubber. In their process, the butyl rubber is chlorinated or brominated to make halobutyl rubber. The halobutyl rubber reaction uses a solvent that is a mixture of 60% n-hexane and 40% C_6 hexane isomer, likely methyl pentane. However, there are no facilities that use hexane to produce halobutyl rubber in Alberta.[119]

Hexane has uses as a special-purpose solvent and cleaning agent (degreaser) in such industries as textile manufacture, shoe and leather making, and furniture manufacturing. It is used in the printing industry as a cleaner and as a component of some ink formulations. Facilities that use rotogravure printers (facilities that produce catalogues, magazines, “glossy” newspaper inserts, or telephone directories) or similar rotogravure or flexographic technologies (for labels, gift wrap, metal foils, flexible packaging materials, and some floor coverings) are more likely to use hexane.[120] These uses represent a relatively minor share of total Canadian hexane use, and very little demand in Alberta. Further research into facilities making products in Alberta that may or may not use hexane was not pursued. Known hexane demand in Alberta is largely in the oil and gas industry and for oilseed processing. Other demands for hexane in Alberta are assumed to be limited and require further research to confirm.

5.7.2 Hexane Supply in Canada

There are two facilities in Canada that currently manufacture hexane, namely the solvent plants at Imperial Oil in Sarnia and Shell Scotford in Fort Saskatchewan. No data on how much hexane they produce per year was available. Hexane is produced at these facilities through the fractional distillation of raffinate. Raffinate is a by-product resulting from the removal of aromatics from catalytic reformates at oil refineries. Raffinate may be processed further (through fractional distillation) in a solvents plant to produce hexane and other products.

Between 4.5 and 6 kilotonnes of hexane were imported into Canada annually between 2009 and 2012. Alberta constituted between approximately 30% and 78% of total Canadian

[117] ADM Agri-Industries Website, *http://www.adm.com/en-US/worldwide/canada/Pages/default.aspx*.
[118] Bunge Canada Website, *http://www.bungenorthamerica.com/our-businesses/bunge-osp/index.shtml*.
[119] Cheminfo Services, *Volatile Organic Compound (VOC) Emissions from the Use of Solvents in Canada – Inventory Improvement and Trends Compilation*, 2007.
[120] Agency for Toxic Substances & Disease Registry, *n-Hexane – Production, Import/Export, Use and Disposal*, http://www.atsdr.cdc.gov/toxprofiles/tp113-c4.pdf.

imports (1.5 and 4.25 kt). Much of these imports are expected to have been used in Alberta's three oilseed extraction facilities. However, use of hexane as a component of bitumen diluent in Alberta's oil and gas industry might account for some of the hexane imports (this needs to be confirmed through further research).

Table 42: Canadian and Alberta Hexane Imports

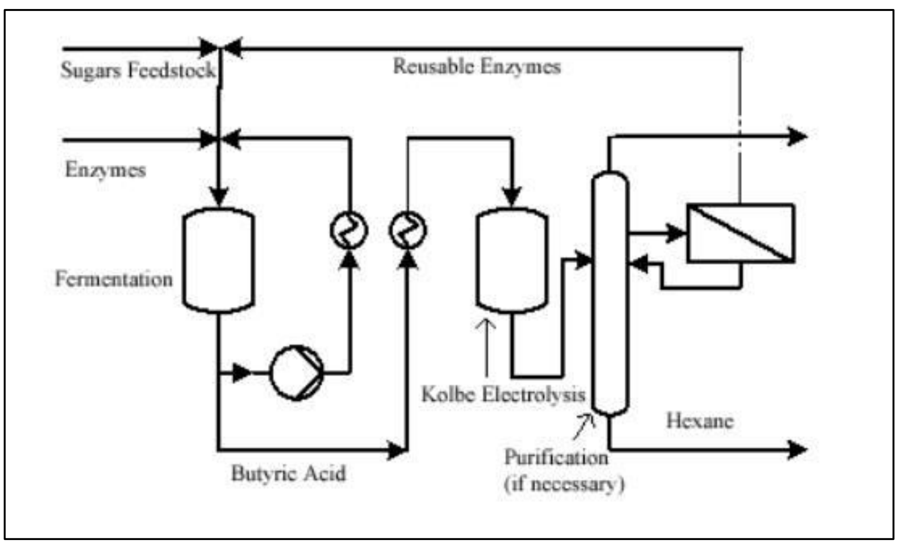
	2009		2010		2011		2012	
Canada	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**
	4,523	$7,897	6,098	$9,530	5,409	$9,380	5,442	$8,414
Alberta								
	3,313	$4,192	4,255	$5,524	3,463	$4,988	1,558	$1,958

Source: Canadian International Merchandise Trade Database, HS 2901100020: Hexanes.

5.7.3 Bio-Based Hexane

No commercial bio-based hexane production was identified, either in Canada or elsewhere. However, one company claims to have developed a method to produce bio-hexane, although it is not commercially producing any. **BGT Biogasoline**, based in Raleigh, North Carolina, has developed a two-step process for manufacturing bio-hexane and bio-heptanone. The first step very closely resembles the traditional production of ethanol through the fermentation of sugars. Instead of ethanol, however, butyric acid is produced. The butyric acid is converted into hexane via Kolbe Electrolysis and heptanone via a packed bed reaction. The following diagram shows BGT Biogasoline's process for producing bio-hexane.

Figure 5: BGT Gasoline's Bio-Hexane Production Process



Source: BGT Biogasoline's Website

5.8 Guar Gum

Guar gum is a powder derived from the ground endosperm of the cluster bean (*Cyanmopsis tetragonoloba),* consisting of a polysaccharide of the sugars galactose and mannose. It is a yellowish-white water soluble powder and forms a thick and viscous solution in water. It is used primarily as a thickening agent and possesses 5-8 times the thickening properties of corn starch. Guar gum is utilized in food processing, oil/gas drilling, paper manufacturing, textiles, printing, metal processing, general emulsifiers, and thickeners. Guar gum is primarily grown in India and Pakistan where it is used as food for livestock and people.[121] The export of guar for use in foreign oil production has made it an important crop in these countries. Other producers of guar include Australia, China, and parts of Africa and the United States. The total demand for guar has been recently growing due to increased demand in oil production, specifically hydraulic fracking.

5.8.1 Uses

In hydraulic fracking and oil drilling, guar gum is used as a viscosity enhancer aiding in lubrication. It also had the added benefit of removing cuttings from the drill bit. It is also used as a “carrying” agent in hydraulic fracking to hold the sand or proppant in suspension and to force it into the fissures in the rock formation. Fracking is expected to be the largest demand for guar along with oil/gas drilling.

In food production, guar gum is referred to as a hydrocolloid and shares similar applications with substances such as cornstarch, xanthan gum, and other plant based gums. Guar functions as a thickening agent, stabilizer, and binding agent. In the US, it has been estimated that 45 kilotonnes of guar gum are used as thickening agents for products such as ice cream, cream cheese, barbecue sauce, and orange juice.[122]

5.8.2 Canadian Market

Canadian demand for guar gum is estimated at 9 kilotonnes for 2012, with two third being used in Alberta – largely in the oil and gas industry. The table below provides some estimated market 2012 demands for guar in Canada, US and globally.

[121] De Guzman, D., (2013). *Developing Guar gum Alternatives.* Green Chemicals Blog. Available at: http://greenchemicalsblog.com/2013/02/20/developing-guar-gum-alternatives/

[122] West Texas Guar Inc. Available at: http://www.westtexasguar.com/

Table 43: Estimated Market Demands for Guar Gum, 2012

Industry	Alberta	Canada	USA	Global
Total demand estimates (kilotonnes)	6	9	270	~480
Applications	**% of Alberta Demand**	**% Canadian Demand**	**% USA Demand**	**% Global Demand**
Oilfield chemicals	80-90%	65-75%	50%	40%
Food processing	5-10%	40-50%	20-30	40-50%
Textiles	~0%	~0%	10-20	10-20%

Source: Canadian International Merchandise Trade Database, HS 1302320010: Guar Gum, Cheminfo Services based on industry sources.

The 2012 global demand for guar gum has been estimated to be roughly 480,000 tonnes; a significant increase since last decade. The largest global importer of guar gum is the US with 270,000 tonnes followed by Germany, Mexico, and Italy at about 25,000 tonnes each. In 2008, the US imports were only 80,000 tonnes. The surge in use is largely due to guar gum use in hydraulic fracking. There are predictions that the guar gum market will regress as companies shift to alternatives but it is still expected to remain much higher than the pre-2000 demand levels.[123,124]

Guar gum's use as a component of drilling fluids for hydraulic fracturing has boomed in recent years causing a number of oil companies to purchase and stockpile large quantities. This led to a large price increase on guar gum in early 2012, forcing India's Forward Markets Commission to close physical guar contracts in 2012 in order to avoid a food shortage. The price for guar gum nearly quadrupled from 2011 to 2012 to $25 per kg. Recently, prices have fallen due to the trade restrictions imposed by India. Some oil and gas exploration companies have sought alternatives to guar gum such as natural polymers, carboxymethylcellulose (CMC), and xanthan-based products in order to avoid this price volatility.[125]

5.8.3 Canadian Supply and Value

There is no known production of guar gum in Alberta or Canada but there is some production in Texas and Oregon. India produces 80-90% of the world's guar with Pakistan as the second major producer and the other countries to contributing ~2% of the global demand. India is by far the largest exporter of guar gum with production estimated to be roughly 1 million tonnes per year and exports in the 400,000 tonne range. Other leading

[123] Agricultural & Processed Food Products Export Development Authority (APEDA). Available at : http://agriexchange.apeda.gov.in/product_profile/prd_profile.aspx?categorycode=0502
[124] De Guzman, D., (2013). *Developing Guar gum Alternatives.* Green Chemicals Blog. Available at: http://greenchemicalsblog.com/2013/02/20/developing-guar-gum-alternatives/
[125] De Guzman, D., (2013). *Developing Guar gum Alternatives.* Green Chemicals Blog. Available at: http://greenchemicalsblog.com/2013/02/20/developing-guar-gum-alternatives/

guar gum exporters include Pakistan, and the US but their exports are dwarfed by India's. The guar grown in the south-western US was reportedly sold at a market price and enjoyed no premium from US companies compared to the guar imported from South Asia. The same scenario is likely to be expected for hypothetical Alberta-based guar producers.

Guar gum is not expected to grow well in Canadian climates due to factors such as a shorter growing season, colder temperatures, soil type, and precipitation. American production of guar is concentrated in the hot, dry regions of Texas, Oklahoma, and New Mexico. Canada imports most its guar gum from India and Pakistan and over 50% of those imports typically go to Alberta. The table below illustrates Canadian and Alberta trade in guar gum for the previous 4 years. The chief application in Alberta is expected to be for drilling fluids.[126]

Table 44: Canadian and Alberta Trade in Guar Gum

	2009		2010		2011		2012	
Canada	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**
Imports	2,873	$8,341	5,582	$13,386	8,631	$30,374	9,254	$97,815
Value ($/tonne)	$2,894		$2,398		$3,519		$10,570	
Alberta								
Imports	1,535	$3,735	3,587	$7,936	5,812	$20,345	6,462	$71,453
Value ($/tonne)	$2,433		$2,212		$3,501		$11,057	

Source: Canadian International Merchandise Trade Database, HS 1302320010: Guar Gum.
Note: Export data was not available for this chemical.

The price for guar gum before 2012 was approximately 2 $/kg. In 2012, due to a boom in futures purchases, the price rose to $10.50/kg with some prices reported to be as high as 25$/kg and forcing the Government of India to put a halt on guar trading. Since then, the price has dropped significantly and has returned to the $2-4 level and appears stable. The price inflation was likely a temporary glitch since the current crop is expected to be enough for a 2 year supply. The inflation was mostly due to speculation by some companies (Halliburton and Baker Hughes) hoarding guar gum in order to secure sufficient quantities to drive the fracking industry in the US.[127]

The following companies are listed by Industry Canada as importers of guar gum into Canada. These six companies represent 80% of Canada's total imports. Alberta imports a large portion of Canada's guar gum, which is used largely for drilling fluids. As expected, half of the companies listed below are oil and gas or related companies.

[126] Cheminfo Services based on industry sources.
[127] Cheminfo Services based on industry sources.

Table 45: Companies Importing Guar Gum to Canada

Company	City	Province	Business Area
Cambrian Chemicals Inc.	Oakville	Ontario	Chemical distributor
Diversity Technologies Corporation	Edmonton	Alberta	Chemical distributor
Economy Mud Products Company	Houston	Texas	Oilfield drilling chemicals
Schlumberger Well Services	Calgary	Alberta	Oilfield drilling chemicals
Synerchem International Inc.	Calgary	Alberta	Oilfield drilling chemicals
Univar Canada Ltd.	Edmonton	Alberta	Chemical distributor

Source: Industry Canada, Canadian Importers Database. HS 1302320010 – Guar Gum

5.8.4 Market Potential in Alberta for Guar Gum

The potential for the domestic production of guar gum in Alberta is limited for two reasons. The first being that since the price of guar appears to have stabilized back to the 2-4$/kg level, competition with production in India or Pakistan would be challenging. Production costs in Canada would likely be much higher than in Asia. Even the guar alternatives such as Exxon's synthetic guar replacement will likely be kept as backup products in the event of another price inflation. The second reason is due to poor expected crop performance in Canada.[128] Guar gum requires a hot arid climate and fares poorly in cold regions and regions with too much precipitation. While it may be that parts of Alberta are dry enough to grow guar, the temperature is expected to be too low. As a general rule, guar beans do not grow well north of the 35th parallel. Some guar is grown in Texas due to its climate. However most areas to the north or east/west of Texas tend to be too cold or wet. It is possible that the plant may grow in other areas such as Alberta however the quality of the finished product will be likely be lower and not competitive with the product from India or Texas. West Texas Guar Inc. is the largest US producer of guar and its farms are concentrated in Texas, Oklahoma, Mexico and New Mexico. Projects have been identified in several states including Missouri, Colorado, North Dakota, South Dakota, and Tennessee but none have shown acceptable results. Even if guar cultivation were possible in Canada, in order to be competitive, a large cultivation area is required. The yields for guar is ½ ton/ha on dry land or 1 ton/ha for irrigated soil. Of the harvested crop, only 30% by weight is guar gum while the remainder is husk and animal feed. For this reason, an economical guar operation needs a large cultivated area coupled with a large processing plant. It is unlikely to be feasible in Alberta despite its growing oil and gas industry. Guar crops also face competition from more lucrative plants such as mung beans in Australia, which is grown as a food crop for sale in India and south Asia.[129]

[128] Cheminfo Services based on industry sources.
[129] Cheminfo Services based on industry sources.

Table 46: Industry Input on Factors Influencing Potential Market for Domestic Guar Gum Production

Industry Contact Description	Input on bio-based Guar
Provincial Government Contact	• There is some interest in academic circles to conduct tests on guar growth in Canada, particularly Saskatchewan and Alberta. The research is in an early stage but there may be interest for a local supply of guar if reasonable prices can be achieved.
Oilfield chemical distributor	• There was some interest in growing guar in Saskatchewan. • The use of guar in Alberta is almost strictly for oil/gas drilling. • Limited potential for production in Alberta due to price stabilization and the expected high costs of production in Canada vs. Asia. • Guar alternatives exist such as CMC, xanthan gum, and other plant based gums. Many are currently being used and the choice depends more on functionality for a specific task. • There would be interest in locally sourced guar but there is no interest in a price premium for it. Guar from the US is competitively priced with guar from India.
Guar Supplier	• The guar plant needs a warm, arid climate in order to grow. US production is restricted to parts of Texas, Oklahoma, New Mexico, and Arizona. • Projects have been set up for guar in a variety of other states such as Missouri, Montana, North Dakota, South Dakota, and Tennessee but none have been successful. The climate in Alberta is likely too cold. • The plant may grow in these regions but the produced guar gum will be of inferior quality. • Guar production requires a large cultivated area. The yield is ½ ton per hectare for dry land and 1 ton per hectare for irrigated soil. Of this, 30% is the guar gum fraction and the rest is husk or animal feed. • Guar gum replacements appear to be inferior in performance compared to guar gum
Industrial gum supplier	• Halliburton is currently conducting research on genetically modified varieties of guar in an effort to discover a modified variety that might grow in North America. • The Guar produced in Texas is of fair quality but it is not on par with guar from India due the climactic variations. Despite this price spike, prices will return to their lower levels. As such, any production in North America will have to be capable of producing a low cost product. • The biggest use for guar gum is for hydraulic fracking.

Source: Cheminfo Services Inc. (2013). *Industry Sources*

5.8.5 Alternatives

Guar gum can be replaced in some applications such as food, mining, and oil and gas by other plant based or bio-derived substances. These substances typically include other plant-based polysaccharides such as CMC and xanthan-based products that exhibit similar waterretention and thickening properties.[130] Some other patented replacements have been developed for use in drilling fluids such as PermStim, a guar replacement developed by Halliburton.[131] The composition of this product remains a guarded secret but the Halliburton factsheet claims that “PermStim™ fluid is based on a derivatized natural polymer that does not contain insoluble residue.”[132] A natural polymer might refer to another type of plant starch/colloid or some cellulose derivative. These replacements are unlikely to compete with guar gum when the price stabilizes but it may provide insulation from another price spike.[133] Costs for these substances have been estimated at around 8$/kg which is double the current price of guar. However, if another guar shortage forces the price to rise above 8-10$/kg, the alternative substance will become competitive and allow drilling companies to avoid paying the exorbitant prices for guar that were seen in 2012.[134] Trican, a Canadian hydraulic fracking and oil drilling company, has developed its own cellulose-based guar replacement called Novum.[135] Despite several guar alternatives in development, the high volume of demand (180-270 thousand tonnes/year in the US) suggests that production of most replacements would not likely be able to match this demand in the short term.

Xanthan gum is a bio-based viscosifier produced by bacterial fermentation of sugars. It can be used as a guar replacement in some applications because it possesses similar properties.[136] It is currently produced in the US by CP Kelco and some other companies but has only recently seen growing use in the oil and gas sector.[137]

5.9 Carboxymethylcellulose (CMC)

Carboxymethylcellulose (CMC) is a derivative of cellulose, the main chemical constituent of plant fibres. Cellulose is a polymer of glucose and is produced solely from biomass by a specialized pulping processes of wood or cotton. It has been speculated that alternative cellulosic crops such as hemp, switchgrass, and willow may be suitable for CMC and cellulose derivative production. These plants are fast-growing crops that grow well in Canada and might be used as feedstock for CMC production instead of the traditional wood pulp.[138] Cotton linter cellulose tends to be used in the production of high purity refined

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[130] Guzman, D.E., (2013). *Developing Guar gum Alternatives.* Green Chemicals Blog. Available at: http://greenchemicalsblog.com/2013/02/20/developing-guar-gum-alternatives/

[131] Halliburton. *PermStim Fracturing Service.* Available at: http://www.halliburton.com/public/pe/contents/Brochures/Web/H09347.pdf

[132] Ibid

[133] DiLallo, M. (2013). *2 Fracking Ingredients You Should Know.* Available at: http://www.fool.com/investing/general/2013/02/05/2-fracking-ingredients-you-should-know.aspx

[134] Cheminfo Services based on industry sources.

[135] Trican Well Services Ltd. (2013). *Novum Fracturing Gel System*. Available at: http://www.trican.ca/Services/technologyfracturing_novum.aspx

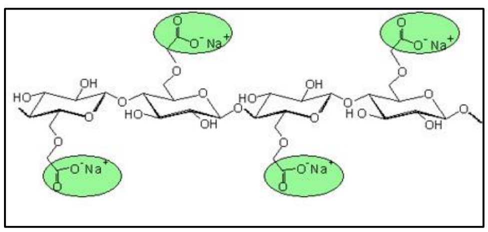
[136] Cheminfo Services based on industry sources.

[137] Cheminfo Services based on industry sources.

[138] Cheminfo Services based on industry sources.

grades of CMC while wood pulp is used for technical grades (such as oil drilling CMC). CMC is usually sold as colourless, odourless, and non-toxic powder. It is soluble in water but insoluble in many organic solvents. When dissolved in water, it forms a gel-like colloidal suspension with thixotropic (shear-thinning) properties. CMC is one of several similar cellulose derivatives referred to as cellulose ethers. Other common cellulose ethers include methyl cellulose, hydroxyethyl cellulose, and hydroxypropyl methyl cellulose. All cellulose ethers tend to have similar properties and all contain a common cellulose backbone. They are differentiated by their functional groups, which in turn change the properties of each ether. The structure of CMC consists of a backbone cellulose chain with 0.4-1.5 sodium carboxymethyl ($-CH_2COONa$) groups in the place of the hydroxyl hydrogen atoms. It is formed by the reaction of alkali cellulose with sodium chloroacetate.[139] The addition of carboxymethyl functional groups increases the polymer's solubility in water. These carboxyl groups also serve to increase the polymer's resistance to bacterial degradation and to increase the fluid's resistance to divalent salts such as calcium (Ca^{2+}). The figure below shows the chemical structure of carboxymethylcellulose.

Figure 6: Structure of Carboxymethylcellulose



Source: The Dow Chemical Company. *Carboxymethylcellulose.* http://www.dow.com/dowwolff/en/industrial_solutions/polymers/carboxymethylcellulose/

5.9.1 Uses

Carboxymethylcellulose has a wide range of uses due to its ability to form colloidal suspensions. Its uses include food manufacturing (e.g., ice cream to control crystal growth and texture), oil drilling fluids, mining, soaps and detergents, textile and paper sizing, latex paints, pharmaceuticals, cosmetics, and adhesives. The Dow Chemical company produces CMC under the brand Walocel™ and lists three specialty applications: adhesives for hard porous surfaces, binder for battery anodes, and as a binder in ceramics.[140] In Canada, a large use for CMC is as a flotation agent in potash mining. Mosaic Potash in Saskatchewan is listed as one of the top ten Canadian importers of CMC according to the Canadian

[139] Rose, A., Rose, E., (1966). *The Condensed Chemical Dictionary, 7th ed.* Reinhold Publishing Corporation.
[140] The Dow Chemical Company. *WALOCEL™ CRT*. http://www.dow.com/dowwolff/en/industrial_solutions/product/walocel.htm

Importers Database. CMC is also used as a flotation aid in other types of mining such as nickel.[141]

In Alberta, the demand is expected to be skewed heavily towards oilfield drilling fluids with some demand in paper sizing. In drilling fluids, CMC is used as a viscosity enhancer and fluid loss prevention aid by forming a film around the outside of the wellbore that prevents fluid from seeping into the well bore.

Globally, there has been a recent increase in demand for CMC from the food sector due to the increase in health conscious consumers and strong demand for low-fat foods. In low fat foods, CMC replaces the consistency and texture imparted by fats and oils. The sector represents the largest and fastest growing application market for CMC but it is not expected to constitute a large demand in Alberta due to the absence of large industrial food products manufacturing facilities.[142]. Interestingly, CMC is touted by some food/cosmetics chemical producers as a good substitute for guar gum users concerned with the volatility of guar prices. Potash mining and drilling fluids may represent potential markets for any CMC plant established in Alberta.[143]

5.9.2 Supply and Value

Bulk purchased CMC is typically delivered as a dry white powder in 50 pound bags (22.6 kg). Drilling fluid suppliers may supply the CMC in powder or as a premixed liquid solution. Premixed solutions are ideal for drilling sites that are remote and may not have appropriate mixing equipment. Some suppliers may also supply CMC in a solution of mineral oil which facilitates homogeneous addition of the CMC to the drilling fluid.

There are no known CMC production facilities in Canada. Although yearly figures have fluctuated significantly, Alberta represents a sizeable portion of Canada's total CMC imports: 20% in 2012 and 50% in 2011. According to industry interviews, the import figures for CMC into Alberta might be misleading. The raw data suggests that Alberta imported 1,381 tonnes in 2012 or 20% of Canada's imports. It is expected that Alberta actually imports roughly 50% or more or Canada's total imports. The reason the declared Statistics Canada numbers appear low may be because some CMC shipments received from overseas are delivered to ports in the US, British Columbia, Quebec, or another port location. This can cause the import data to differ from the actual provincial use figure. The revised demand for CMC in Alberta is likely between 3,500 and 4,500 tonnes per year driven largely by oil and gas drilling.

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141 Cheminfo Services based on industry sources.

142 Global Industry Analysis Inc. (2012). *Global Carboxymethyl Cellulose Market to Reach 892.14 Million Pounds by 2017, According to New Report by Global Industry Analysts, Inc.* Available at: http://www.prweb.com/releases/carboxymethyl_cellulose/CMC_food_beverages/prweb9246544.htm

143 Camford Information Services Inc. (1997). *CPI Product Profiles: Carboxymethylcellulose*

The value of CMC has fluctuated in recent years but tends to remain in the $3,500 to $4,500 per tonne range. The value of the substance appears to be consistently lower in Alberta compared to the rest of Canada. This may be due to the predominant import of alrge volume "industrial" grades of CMC for use in drilling fluids. Other regions in Canada import a higher percentage of food or cosmetic-grade CMC in lower quantities, which are more expensive. The import value of CMC in 2012 was $2,866 per tonne and $3,886 per tonne in 2013 indicating the guar gum shortage did not result in a spike in CMC values (or import quantities). This tends to support the idea that although the two substances are used in a similar manner, they are not necessarily interchangeable. Higher grades of CMC for food/cosmetics can cost up to $10,000 per tonne but tend to be used in small-volume, specialty applications.

Table 47: Canadian and Alberta Trade in Carboxymethylcellulose

	2009		2010		2011		2012	
Canada	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**
Imports	2,935	$13,297	6,659	$23,521	7,495	$27,820	7,075	$24,027
Exports	24	$110	3	$22	32	$102	48	$247
Value ($/tonne)	$4,530		$3,532		$3,712		$3,396	
Alberta								
Imports	503	$1,657	2,452	$8,373	3,672	$13,355	1,381	$3,958
Value ($/tonne)	$3,294		$3,415		$3,637		$2,866	

Source: Canadian International Merchandise Trade Database, HS: 39123100: Carboxymethylcellulose and its salts, in primary forms

Canadian imports of CMC have increased from 2,935 tonnes in 2009 to 7,075 tonnes in 2012. This increase is largely attributed to the increased use in the oil and gas and food industries. According to Statistics Canada, in 2012 CMC was imported primarily from the United States (40%), Italy (15%), the Netherlands (15%), and China (10%). The companies responsible for importing CMC in Canada are mostly split between chemical distributors and oilfield chemical companies. The following companies are listed by Industry Canada as importers of CMC into Canada. These nine companies represent 80% of Canada's total CMC imports.

Table 48: Companies Importing CMC to Canada

Company	City	Province	Business Area
Bio Agri Mix Lp	Toronto	Ontario	Animal feed additives
Cambrian Chemicals Inc	Oakville	Ontario	Chemical distributor
Canada Colors and Chemicals Limited	Toronto	Ontario	Chemical distributor
Canadian Energy Services Lp	Calgary	Alberta	Oilfield drilling chemicals
Chevron Phillips Chemical Canada	Calgary	Alberta	Oilfield drilling
Diversity Technologies Corporation	Edmonton	Alberta	Chemical distributor
FMC Corporation	Houston	Texas	Pesticides
Maxcesyn	Calgary	Alberta	Chemical distributor
Mosaic Potash Colonsay Ulc	Colonsay	Saskatchewan	Potash mining
Univar			Chemical distributor

Source: Industry Canada, Canadian Importers Database. HS 3912310000 - Carboxymethylcellulose and Its Salts- In Primary Forms

5.9.3 Canadian Market

CMC is primarily used in oil and gas drilling (largely in Alberta) and in potash mining (largely in Saskatchewan). There are smaller demands in food, paint, paper, detergents, and pharmaceuticals. Globally, the largest use for CMC is as a food additive/thickener (34%) with other applications each comprising about 10-15% of demand.

Table 49: Global and Domestic Uses for Carboxymethylcellulose

Industry	**Global**	**US**	**Canada**	**Alberta**
Total demand estimates (kilotonnes)	~400	50-60	7-8	5
Application	**% Global Use**	**% US use**	**% Canadian Use**	**% Alberta Use**
Oilfield drilling fluids	18%	25-30%	40-50%	80-90%
Food/beverage	34%	25-30%	10%	5-10%
Detergents	4%	~5%	5-10%	
Paper sizing/textiles	14%	~5%	1-5%	
Pharmaceuticals/cosmetics	10%	~5%	1-5%	
Mining		~25%	25%	
Miscellaneous including adhesive, thickener, paints, mining	20%	1-5%	1-5%	5-10%

Sources: ICIS.com, (2008). *Chemical Profile: CMC.* Available at: http://www.icis.com/Articles/2008/10/20/9164244/chemical-profile-cmc.html; Camford Information Services Inc. (1997). *CPI Product Profiles: Carboxymethylcellulose;* Canadian International Merchandise Trade Database, HS 3912310000 - Carboxymethylcellulose and Its Salts- In Primary Forms; Cheminfo Services based on industry sources.

5.9.4 Market Potential for Alberta Production

CMC is already derived from bio-resources as it is produced from cellulose - a constituent of wood and other plants. Alberta has some pulp and paper mills that produce a variety of products but the cellulose required to produce CMC is referred to as dissolving pulp: a highly purified (>90%) form of cellulose. Dissolving pulp is largely produced by the sulfite process, which has a yield of 30-35%.[144] Production of CMC in Alberta would require either a specialized pulp mill to produce dissolving pulp or the expansion of an existing mill to incorporate a sulfite pulping process (which is unlikely). The total Canadian demand for CMC is roughly 7 kilotonnes and a small mill might produce 10 kilotonnes essentially satisfying all the current domestic demand. This would require a potential mill in Alberta to compete with the much larger ones in Europe, the US, and China.[145] According to some industry contacts, the production of CMC would require a dedicated mill and retrofitting an existing mill would not be feasible.

[144] Biermann, C. J., (1996). *Handbook of Pulping and Papermaking (2nd ed.)*
[145] Cheminfo Services based on industry sources.

The use of CMC as a renewable, bio-based chemical may be of some interest as a marketing tool for end-users. The association of CMC use with a lifecycle greenhouse gas emission reduction could be used to positively promote a process or product. Alternatively, the biodegradability of the substance could be used to improve process safety and to reduce environmental risk compared to a synthetic alternative. Given these potential benefits, a small premium (10 cents per bag) might be acceptable in certain industries compared to an equivalent synthetic substitute for CMC. There may be interest by Canadian purchasers of CMC for a domestic supply if the cost was reasonable. The advantage of locally produced CMC is that the shipping time would be greatly reduced and orders could be completed faster.[146]

By virtue of being a natural polymer, CMC and other cellulose ethers readily biodegrade over time, which makes well closure and environmental cleanup simpler. Synthetic thickening agents and substitutes such as polyacrylamides will not biodegrade in this way. Typically, enzymes are added to the drilling fluid in order to assist in its decomposition after it is no longer required.

Table 50: Factors Influencing Potential Market for Domestic Carboxymethylcellulose Production

Source of Input	Input on CMC Market Factors to Consider
Oilfield chemicals supplier	• CMC production requires essentially a dedicated mill and it not a flexible process. Given that Canada's demand is roughly 7 kt, a small 10 kt plant would replace the entire domestic demand but it would still be small in comparison to plants in Europe, the US and China.
Specialty chemicals, cleaning products supplier	• CMC is purchased from private distributors and the origin of the substance is usually unknown. As a commodity chemical, price is the only real driving force for the company's purchases. This is expected to be a common sentiment especially among smaller users.
Oilfield chemicals supplier	• The might be some interest in a local supply of CMC because it would reduce the shipping delay incurred when purchasing from China or Europe. • The bio-based nature of CMC can be more desirable than a comparable synthetic replacement because CMC is readily biodegradable and contributes to a simple post-drilling cleanup.
Industrial drilling mud ingredients supplier	• Most CMC is produced in the US, Europe, China but there might be potential for a North American production plant to supply the large North American oilfield market. • A plant located in Canada would likely need to produce 15,000-20,000 tonnes per year and supply markets in Canada, the US, South America, and Europe.

Source: Cheminfo Services based on industry sources.

[146] Cheminfo Services based on industry sources.

5.9.5 Alternatives

Other natural viscosifiers such as guar, starches, xanthan gum, and other plant-based gums perform similarly but each has their own niche use. Each type of gum has a particular rheology profile and each has its own particular niche use regardless of the application. For oil drilling, the main criterion tends to be low cost and the most common products are cheap natural viscosifyers such as starches, xanthan gum, and other natural gums. In hydraulic fracking, there are different requirements on the fluid performance. Often, fracking fluids are cross-linked synthetic or natural polymers that have increased viscosity and gelling properties.

Xanthan gum is viscosifyer produced by bacterial fermentation of certain sugars that provides good viscosity at low shear stresses. It was believed to cause formation damage and reduce production effectiveness and thus its use decreased approximately 20 years ago. It is being used increasingly recently as companies have found certain uses for it and can use it more effectively.[147] The table below provides a brief overview of some CMC alternatives for oilfield drilling in particular.

Table 51: Alternatives to Carboxymethylcellulose

Name	Description
Other Celluose Ethers	Similar to carboxymethylcellulose but with different functional groups along the cellulose chain.
Xanthan Gum	Polysaccharide formed from bacterial fermentation of sugars. Produces a viscous, shear-thinning fluid used in food and oil-drilling. Its properties are similar to guar and locust bean gum.
Locust bean gum	Similar to guar gum, locust bean gum is derived from the seed of the carob tree, which is grown mainly around the Mediterranean.
Starches	Starches are a type of polysaccharide that form viscous solutions in water (corn starch is a household example). Many plant-based starches can be used in oilfield drilling operations as a cheap viscosity-enhancer.
Polyacrylamides	Polyacrylamide (PAM) is a synthetic, water-soluble polymer. In its linear form, it forms a viscous solution in water and can be used as a thickening agent for pesticides, oilfield drilling, and water treatment. It can also be sold as a cross-linked form which forms a soft gel in water.
Haliburton PermStim™	A proprietary synthetic thickening agent being marketed as a guar replacement by Halliburton. The Halliburton data sheet for the substance touts it superior performance. The chemical identity of the substance is still a closely guarded secret.

Source: Cheminfo Services based on industry sources.

[147] Cheminfo Services based on industry sources.

5.10 Alpha Olefins

Linear alpha olefins (LAO) are a subset of linear hydrocarbons with one double bond at the terminal (or alpha position on the molecule). They are chemical intermediates that are used as polyethylene comonomers, in detergent manufacturing, specialty lube oil blending and other applications. Alpha olefins can refer to hydrocarbons with carbon chain lengths from C_3 to C_{18}, or even higher. For the purposes of this study, the linear alpha olefins considered are summarized in the table below.[148]

Table 52: End-Use Applications for Linear Alpha Olefins

Name	Carbon chain length	Description
1-butene	C_4	A colourless gas produced by separation from crude refinery C4 streams or by the dimerization of ethylene. It is an important comonomoer in the production of linear low density polyethylene (LLDPE), methyl ethyl ketone, butyl alcohols, and polybutene.
1-hexene	C_6	1-Hexene is a clear, water-white mobile liquid. 1-Hexene enters into all reactions typical of alpha olefins. It can be used as a comonomer in polyolefins and as an intermediate in the production of oxo alcohols, hexyl mercaptans, organic aluminum compounds and synthetic fatty acids.
1-octene	C_8	1-Octene is a clear, water-white mobile liquid. 1-Octene enters into all reactions typical of alpha olefins. It can be used as a comonomer in polyolefins and as an intermediate in the production of oxo alcohols, octyl mercaptans, amines, organic aluminum compounds, synthetic fatty acids and hydrogenated oligomers.
Decene	C_{10}	Polyalpha olefins for synthetic lubricants
Dodecene, tetradecene	C_{12}-C_{14}	Detergents, surfactants
Hexadecane, octadecene	C_{16}-C_{18}	Lubricants additives, drilling fluids

Source: Ineos Oligomers Website. (2013). Available at: http://www.ineos.com/en/businesses/INEOS-Oligomers/Products/#Linear-Alpha-Olefins-LAO

Alpha olefins are predominantly produced by the oligomerization of ethylene (C_2H_4) into C_4-C_{20} and higher linear hydrocarbons. Canada's only LAO manufacturing occurs at the INEOS facility located at the Nova Petrochemical Complex in Joffre, AB. Using ethylene feedstock from Nova, the facility synthesizes a range of linear alpha olefin ($C_6^{=}$ to $C_{20+}^{=}$) liquids. Certain linear alpha olefins are produced at oil refineries or chemical facilities in Canada. These alpha olefins are typically C_7 and higher molecules sold as intermediates in

[148] Ineos Oligomers. (2013). Available at: http://www.ineos.com/en/businesses/INEOS-Oligomers/Products/

the production of lubricants, poly-alpha olefins, and polymer additives. The Imperial Oil facility in Sarnia produces C_7-C_{12} olefins and blends thereof.[149,150]

Table 53: Global Producers of Linear Alpha Olefins

(kilotonnes/year)

Company	Location	Capacity
Shell	Geismar, Louisiana, US	920
ChevronPhillips	Cedar Bayou, Texas, US	705
Shell	Stanlow, UK	330
INEOS	Feluy, Belgium	300
INEOS	**Joffre, Alberta, Canada**	**250**
Sasol	Sasolburg, South Africa	230
Nizhnekamskneftekhim	Nizhnekamsk, Russia	186
SABIC	Al-Jubail, Saudi Arabia	150
Sasol	Sasolburg, South Africa[a]	96
Idemitsu Petrochemical	Ichihara, Japan	63
Mitsubishi Chemical	Kurashiki, Japan	60
Beijing Yanhua	Yanhua, China	50
Dow Chemical	Tarragona, Spain[a]	50
Q-Chem	Mesaieed, Qatar	47

a. Only octane. 1-hexene

Source: ICIS.com (2008) *Chemical Profile: Alpha Olefins.*

The INEOS process for LAO synthesis is based on the chain growth of ethylene on a triethylaluminium (TEA) base to produce a mixture of longer-chain aluminium alkyls. A first-stage reaction of ethylene with TEA in an olefin diluent builds tri-linear alkyl groups on the aluminium base. After flash separation of excess ethylene and diluent, a second-stage reaction with excess ethylene restores the TEA by displacing the linear alkyl groups as a linear alpha olefin mixture. The mixture of linear alpha olefins is separated into component products by distillation and routed to aboveground tanks for final product storage.[151] The figure below shows some typical end-use applications for LAOs of different chain lengths.

There are several other proprietary methods for producing LAO, each licensed by the large producers. Each process typically produces a slightly different distribution of LAO chain

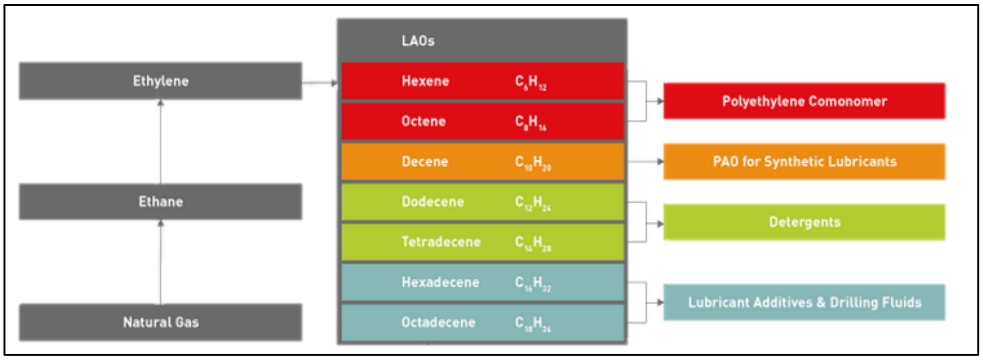
[149] Ineos Oligomers. (2013). Available at: http://www.ineos.com/en/businesses/INEOS-Oligomers/Products/

[150] Camford Information Services Inc. (1999). *CPI Product Profiles: Linear Alpha Olefins*

[151] Chemsystems. (2013). *PERP Program, Developments in LAO Comonomer Technologies for Polyethylene*. Available at: http://www.chemsystems.com/about/cs/news/items/PERP%200607_5_AlphaOlefins.cfm

lengths and some are better suited to different applications. Despite the different process designs and catalysts, virtually all LAOs are produced using ethylene from natural gas as a feedstock.[152] The largest global producers of LAO are Shell, ChevronPhillips, and INEOS. The INEOS plant in Joffre is the fifth largest producer in the world.[153]

Figure 7: Ineos Alpha Olefin End Use Applications by Chain Length



Source: Ineos Oligomers website. http://www.ineos.com/en/businesses/INEOS-Oligomers/Products/#Linear-Alpha-Olefins-LAO. INEOS does not make 1-butene in Alberta.

In Canada, and even more so in Alberta, the end use pattern for LAO is highly skewed towards polyethylene comonomers due to the large polyethylene industry and small customers for other chemical products (e.g., surfactant manufacturing). Another important Alberta-specific use for LAOs is in oilfield drilling fluids.

Table 54: End-use Patterns for Alpha Olefins

Uses	% of Alberta Use	% of Canada Use	% of Global Use
Polyethylene comonomers	95-98%	90-95%	43%
Detergent alcohols			17%
Polyalphaolefins (synthetic lubricants)	1-4%	2-5%	12%
Plasticizer alcohols			7%
Oilfield drilling fluids	1-4%	2-5%	6%
Other uses (including alkylmethylamines, surfactants, fatty acids, mercaptans)	1-4%	2-5%	15%

Source: ICIS.com (2008) *Chemical Profile: Alpha Olefin* for global. Cheminfo Services estimates for Canada and Alberta.

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[152] Chemsystems. (2013). *PERP Program, Developments in LAO Comonomer Technologies for Polyethylene*. Available at: http://www.chemsystems.com/about/cs/news/items/PERP%200607_5_AlphaOlefins.cfm

[153] ICIS.com (2008) *Chemical Profile: Alpha Olefins.* Available at: http://www.icis.com/Articles/2008/02/18/9101114/chemical-profile-alpha-olefins.html

There are several polyethylene producers in Canada that use LAOs, namely: Nova Chemical in Joffre, AB, and Corunna, ON; Dow Chemicals in Fort Saskatchewan, AB; and Imperial Oil Ltd. In Sarnia, ON. (see *Polyethylene* section in Appendix). INEOS production in Alberta exceeds domestic demand, so a high portion of its production is exported.

The following table describes the Canadian trade in LAO and it is evident that the most important chemicals are 1-butene, 1-hexene, and 1-octene. The vast majority of these LAOs are imported into Alberta where the dominant use is comonomer in the production of polyethylene. Export data in the table are for Unsaturated Acyclic Hydrocarbons nes - HS 29012900. The great majority of these are from Alberta, and it is reasonable to assume these are largely from the INEOS LAO facility.

Table 55: Canadian and Alberta Trade of Alpha Olefins

	2009	**2009**	**2010**	**2010**	**2011**	**2011**	**2012**	**2012**
Imports	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**
1-Butene								
Canada	39,300	$47,402	38,529	$55,914	37,807	$62,517	34,110	$56,085
Value ($/kg)		$1.21		$1.45		$1.65		$1.64
Alberta	35,402	$42,761	33,691	$49,234	33,178	$54,999	28,045	$45,852
1-Hexene								
Canada	50,825	$74,994	35,515	$59,227	31,591	$60,712	32,143	$59,912
Value ($/kg)		$1.48		$1.67		$1.92		$1.86
Alberta	46,432	$67,239	33,156	$55,685	28,392	$54,541	12,686	$23,173
Nonenes								
Canada	7,630	$4,080	3,366	$4,094	8,972	$17,376	6,521	$10,086
Value ($/kg)		$0.53		$1.22		$1.94		$1.55
Alberta			1	$1				
1-Octene								
Canada	16,692	$19,037	31,874	$35,885	32,947	$45,432	25,213	$37,773
Value ($/kg)		$1.14		$1.13		$1.38		$1.50
Alberta	16,688	$19,033	31,712	$35,722	31,591	$43,415	17,149	$25,618
Other Linear Alpha Olefins								
Canada	4,141	$5,639	5,892	$9,112	3,314	$6,162	4,468	$8,583
Value ($/kg)		$1.36		$1.55		$1.86		$1.92
Alberta					380	$596	1,225	$2,202
	2009	**2009**	**2010**	**2010**	**2011**	**2011**	**2012**	**2012**
Exports: **Unsaturated Acyclic Hydrocarbons, nes**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Canada	115,028	$139,723	140,543	$195,225	133,451	$197,678	142,180	$200,195
Value ($/kg)		$1.21		$1.39		$1.48		$1.41
Alberta	109,222	$133,971	134,550	$189,126	124,944	$182,531	137,763	$195,303

Source: Canadian International Merchandise Trade Database, HS 2901290019: Linear Alpha Olefins, unmixed, nes. HS 2901290019: Other Linear Alpha Olefins, unmixed. Canadian International Merchandise Trade Database, HS 29012911, nonenes. Canadian International Merchandise Trade Database, HS 29012991, nonenes. Canadian International Merchandise Trade Database, HS 29012912, 1-hexene. Canadian International Merchandise Trade Database, HS 29012310, 1-butene. NES stands for not elsewhere specified.
Note: Export data are for Unsaturated acyclic hydrocarbons, nes - HS 29012900

Since about 1990, the oil and gas extraction industry has been developing new oleaginous (oil-like) base materials from which to formulate high performance drilling fluids. A general class of these fluids is called synthetic materials, which include linear alpha olefins, polyalphaolefins (POA), synthetic paraffins, ethers, vegetable esters, other esters, linear alkylbenzenes, and others. Other oleaginous materials have also been developed for this purpose, such as special grades of mineral oils and non-synthetic paraffins. Industry developed synthetic-based fluids with these synthetic and non-synthetic oleaginous materials as the base to provide the drilling performance characteristics of traditional oil-based fluids but with the potential for lower environmental impact and greater worker safety. Synthetic based muds (SBM) have lower potential toxicity, lower polycyclic aromatic hydrocarbons content, faster biodegradability, lower bioaccumulation potential and in some drilling situations decreased drilling waste volume.[154] Similar to oil-based muds (OBM), SBM can be reconditioned for reuse. Synthetic muds have been adopted for offshore drilling in Canada and are used at a small portion of onshore wells drilled. Water-based muds (WBM) and OBM are predominant types used for onshore drilling.

5.10.1 Potential for Renewable Alpha Olefins

There has been some interest in producing alpha olefins from renewable resources. One such process uses oleic acid to produce olefins via a selective ethenolysis process.[155] Another produces linear alpha olefins from lactones and unsaturated acids derived from biomass.[156] No pilot plants or test facilities producing bio alpha olefins were identified and it appears that this technology is in the very early stages of development. As such, there is no current market for linear alpha olefins derived from renewable resources in Canada.

Bio-LAO would be challenged to achieve sales in the Canadian polyethylene industry. In Canada, this industry requires high purity 1-butene, 1-hexene and 1-octene, which needs to be purchased at low prices. Deliveries are made to Nova Chemicals in Joffre via pipeline, while other customers receive LAO in railcars and trucks.

There may be better market potential in low volume LAO applications, such as surfactants, lubricants, and oilfield chemicals. Some of these application areas may make products that are more interested in environmentally friendly products and associated raw materials from renewable sources. Identifying small LAO customers in these areas and providing products to meet their specific needs is expected to be challenging since the market is fragmented. Most of this market is located in Eastern Canada, although the oilfield chemicals segment is concentrated in Alberta and other Western provinces.

[154] U.S. Environmental Protection Agency (2000), *Profile of the Oil and Gas Extraction Industry*, Prepared by the Office of Enforcement and Compliance Assurance.
[155] Van der Kils, F., et al. (2012). *Renewable linear alpha olefins by selective ethenolysis of decarboxylated unsaturated fatty acids.* European Journal of Lipid Science and Technology
[156] Wang, D., (2013). *A highly selective route to linear alpha olefins from biomass-derived lactones and unsaturated acids.* Chemical Communications.

5.11 Oilfield Chemicals

The oil and gas industry is quite large and important to the Canadian economy, especially in the western part of Canada. The value of oil and gas production from Canada's industry was approximately $110 billion in 2007.[157] The industry is also an important market for chemicals used in exploration and production, including bitumen and synthetic crude oil (SCO) production. The industry is concentrated in Western Canada, much of it in Alberta. Over 70% of the natural gas, and all of the bitumen and SCO production are in Alberta. In 2012, 43% of conventional crude oil was produced in Alberta. Demand for oilfield chemicals is tied to well drilling activity and production. Since 2008, Canada's conventional oil and natural gas production have decreased, while bitumen and SCO have increased substantially.[158,159,160]

Table 56: Trend in Canadian and Alberta's Oil and Gas Production

Canada	**Units**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Crude oil	Million M3	81	80	84	85	82	79	78	81	78	71	71	73	76
Bitumen and Synthetic Oil	Million M3	35	38	43	50	57	56	65	69	70	78	84	93	101
Natural gas	Billion M3	206	209	208	202	205	206	208	204	196	182	177	174	169
Alberta														
Crude oil	Million M3	44	42	38	37	35	33	32	30	29	27	27	28	32
Synthetic oil	Million M3	35	38	43	50	57	56	65	69	70	78	84	93	101
Natural gas	Billion M3	167	164	161	158	159	160	159	158	149	138	132	123	120
Alberta % of Total Canada														
Crude oil		54%	52%	46%	43%	43%	42%	40%	38%	37%	38%	37%	39%	43%
Synthetic oil		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Natural gas		81%	78%	77%	78%	77%	77%	76%	77%	76%	76%	74%	71%	71%

Source: Canadian Association of Petroleum Producers (CAPP) (September 2013) *Statistical Handbook for Canada's Upstream Petroleum Industry*.http://www.capp.ca/library/statistics/handbook/pages/statisticalTables.aspx?sectionNo=3

Oilfield chemicals can be split into two groups, namely: exploration chemicals used for drilling, hydraulic fracturing, completion, etc.); and production chemicals that are applied after the oil and gas is flowing to the surface.

[157] This total includes production from conventional and unconventional oil wells, and oil sands production.
[158] Canadian Socio-economic Information Management System (CANSIM), Table 281-0024, NAICS 2111.
[159] Statistics Canada (2009), *Oil and Gas Extraction - 2007*, Table 4.
[160] Canadian Association of Petroleum Producers (CAPP) (September 2013) Statistical Handbook for Canada's Upstream Petroleum Industry.
http://www.capp.ca/library/statistics/handbook/pages/statisticalTables.aspx?sectionNo=3

Demand for oilfield exploration chemicals is related to drilling activities. Since 2000, an average of about 19,000 wells have been drilled annually in Canada with an average of about 22,000 kilometres drilled per year.[161]

Table 57: Trends in the Oil and Gas Wells Drilled and Depths

	BC	BC	AB	AB	SK	SK	Canada	Canada
	Wells	Metres	Wells	Metres	Wells	Metres	Wells	Metres
2000	846	1 351 010	13 543	14 821 473	3 839	3 759 404	18 480	20 257 318
2001	934	1 572 371	14 975	15 435 493	3 571	3 520 662	19 752	20 889 321
2002	580	994 700	12 989	13 543 517	3 401	2 937 711	17 182	17 768 812
2003	1 032	1 880 562	17 873	17 855 802	4 179	3 409 918	23 365	23 536 884
2004	1 117	1 923 003	19 365	19 538 053	4 104	3 576 631	24 874	25 399 670
2005	1 202	2 211 953	21 599	24 211 705	3 781	3 873 079	26 951	30 701 467
2006	1 313	2 349 465	19 800	21 971 316	4 029	4 299 405	25 811	29 339 526
2007	827	1 682 655	16 238	16 079 296	3 689	4 336 664	21 210	22 649 323
2008	805	1 951 670	14 969	15 060 899	4 037	5 327 344	20 203	22 879 946
2009	667	1 778 962	6 894	7 780 524	2 126	3 401 060	9 987	13 498 463
2010	554	1 868 013	8 537	11 889 897	2 669	4 308 180	12 343	19 073 418
2011	568	1 941 488	9 651	15 519 241	3 275	5 273 750	14 041	23 705 455
2012	363	1 400 055	8 862	14 225 233	3 243	5 237 672	13 080	22 010 762

Source: Canadian Association of Petroleum Producers (CAPP), (2013). Available at http://www.capp.ca/Pages/default.aspx

In 2012, nearly two thirds of drilling activity occurred in Alberta. Almost 9,000 wells were drilled, with a total depth of more than 14,000 km. The depths drilled relate to the quantities of drilling fluids and other chemicals needed. Deeper wells require more fluids due to the volume of the boreholes. There are differences in terms of the average depth per well drilled on a regional basis. In Alberta, the average well depth drilled was 1.6 km in 2012. The deepest land-based wells are found in British Columbia with an average depth of 3.6 kilometres.[162]

Oilfield production chemicals are used at a great many oil and gas sites. There are nearly 200,000 wells producing crude oil and natural gas in Canada, and 10,000 to 30,000 wells are drilled every year. Producing wells feed approximately 22,000 batteries where an initial separation of water, oil, gas, condensates, and other well components is carried out – often using chemicals. The crude oil is transported via pipeline or by bulk trucks to petroleum refineries for processing into gasoline, diesel, other fuels and other products (e.g., lubricants, asphalt). Gaseous components flow to about 5,500 natural gas gathering system stations and eventually pipelined to about 700 gas processing facilities where sulphur is removed, and natural gas liquids (i.e., NGLs - ethane, propane, butane) and heavier

[161] Canadian Association of Petroleum Producers (CAPP) (September 2013) *Statistical Handbook for Canada's Upstream Petroleum.*
[162] Canadian Association of Petroleum Producers (CAPP) (September 2013) *Statistical Handbook for Canada's Upstream Petroleum Industry.*

components – i.e., condensate (C5+) are separated for transportation via pipeline or truck for sale.[163]

5.11.1 Overview of the Oilfield Chemicals Industry

The exploration group of oilfield chemicals includes a broad set of organic chemicals, minerals (e.g., bentonite, barite), water-soluble polymers, mineral oils and synthetic oils, and other chemicals that are used in the drilling process (i.e., drilling fluids or muds), hydraulic fracturing (also called "fracking") processes, and other activities involved with exploration and stimulation of oil and gas wells. Oilfield production chemicals includes formulated or specialized organic and inorganic chemicals that are largely used at oil and natural gas production facilities, after the wells have been drilled and completed, and the oil and gas are flowing.

The total Canadian demand for all oilfield chemicals used in the upstream oil and gas industry is roughly estimated at $1.0 to $1.4 billion per year.[164] Demand has changed over time largely in line with the number and depths of wells drilled, and oil and gas production levels. Over the last several years, demand in the natural gas segment of the industry has been lower as a result of reduced gas production. Chemical demands at bitumen and SCO facilities have increased.

Oilfield production chemicals are largely purchased by the oil and gas producing companies, which use these chemicals as part of on-going daily production of oil and gas at or near well sites. Some oil and gas producers use the oilfield service companies to purchase and apply chemicals as well as provide other services (e.g., maintenance). Exploration chemicals are also eventually paid for by the oil and gas exploration companies, while they may be ordered and handled by drilling mud suppliers, drilling contractors, and well service companies on behalf of the oil and gas companies.

The industry supplying oilfield exploration chemicals is fragmented, as there is a larger number of distinct chemicals needed for drilling, completion, stimulation, fracturing, workovers and other uses. A range of chemicals are made by a large number of manufacturers and delivered to well sites by the manufacturers themselves, distributors (sometimes referred as wholesalers in the industry) and/or mud suppliers. Water-based muds are often formulated at the well sites by mud suppliers or the oil and gas companies. Oil-based and synthetic-based muds are more likely to be delivered already blended (or mostly blended) to the drilling site. Oil-based and synthetic based muds are more expensive and a portion of them is reused. In addition to mud suppliers, well drilling and service companies can also be involved in supplying these chemicals. These firms can also provide special formulations (e.g., unique drilling muds, or drilling mud additive packages, etc.) as

[163] Canadian Association of Petroleum Producers (CAPP), *National Oil and Gas GHG Inventory 2000*, Volume 1, Table A and Table 11.1
[164] Cheminfo Services estimate based on industry sources.

well as some oilfield production chemicals. The table below provides some key market features for Oilfield Chemicals in Canada.

Table 58: Summary of Key Market Features for Oilfield Chemicals

Typical features – there can be exceptions.

	Exploration Chemicals (Examples for ingredients)	Oilfield Production Chemicals
Main customers	• Oil and gas production companies. • Well service providers.	• Oil and gas production companies. • Well services providers
Product price levels (with exceptions)	• Lower priced • (e.g., 0.01-4 $/litre or kilogram)	• Higher priced • (e.g., 3-10 $/litre).
Main products, ingredients	• Water-based muds (WBM): water, bentonite, barite, water-soluble polymers. • Oil-based muds (OBM): mineral oils, water, barite, emulsifers, other additives. • Synthetic-based muds (SBM): Alpha-olefins, water, barite, surfactants. • Completion and fracturing: water, hydrochloric acid, potassium chloride, etc…	• Demulsifiers • Corrosion inhibitors • Scale inhibitors • Biocides. • Surfactants • Hydrocarbon solvents
Location and type of manufacturing chemical site	• On-site blending of WBM (at well sites). • Central facility blending of OBM, SBM • Chemicals, polymer, etc. manufacturing facilities across North America shipped to well sites for use.	• Central blending (formulating) facility close to oil and gas production wells in Western Canada.
Level or type of technical services provided	• Lower level of technical support provided by chemical manufacturers or distributors. Technical formulating provided by "Mud Engineers", well service specialists.	• Higher level of technical service to support sale of blended products
Main manufacturers or suppliers (i.e., These are customers for bio-based ingredients in oilfield chemicals)	• Mud suppliers. • Wholesalers, distributors for manufacturers. • (Minor role for oilfield production chemical manufacturers and other formulators.)	• Baker Petrolite, • Champion/Nalco (Ecolab)
Ability to quantify market size	• Market is difficult to quantify due to lack of central manufacturing sites, multitude of chemicals that can be used, and many suppliers.	• Market can be quantified through major manufacturers.
Changes in demand	• Demand changes with drilling activity, and strongly influenced by crude oil and natural gas prices.	• Changes with oil and gas production and reflects aging wells with increased produced water.
Supply structure	• Numerous companies involved in supplying a variety of drilling muds and other chemicals.	• Relatively few companies account for the great majority of supply.

*Typical features of exploration and oilfield production chemicals, however there can be exceptions.
Source: Cheminfo Services Inc.

The above and additional complexities result in difficulties for delineating and estimating the size of the oilfield chemicals market. Some very rough estimates are provided below.

Table 59: Total Annual Estimated Demand for Oilfield Chemicals, 2008

(order-of-magnitude estimates, includes water in formulations)

	Quantity	**Value**
	(cubic metres)	($ million)
Oilfield production chemicals	110,000-150,000	$500-700
Exploration chemicals		
Water-based drilling muds (mostly composed of water)	600,000-1,000,000	$500-700
Oil-based drilling muds	70,000-90,000	
Synthetic-based drilling muds (includes water)	10,000-12,000	
Fracturing fluids (mostly water, proppant-sand)	8,200,000-10,000,000	
Acidizing chemicals (mostly water, hydrochloric acid)	200,000-300,000	
Completion fluids (mostly water – brines, excludes wells using only water as completion fluid)	90,000-130,000	
Total	**9,250,000-11,682,000**	**$1,000-$1,400**

Sources: Cheminfo Services files based on industry input.

5.11.2 Drilling Mud and Other Exploration Chemicals

Following is a list of the drilling mud chemical functional groups identified on the Petroleum Services Association of Canada's (PSAC's) "Mud List".

Table 60: Typical Functional Groups in Drilling Muds

Weighting Materials	Foaming Agents	Defoamers
Lubricants	Alkalinity (pH) Control	Biocides
Surfactants	Filtrate Reducers	Calcium Removers
Viscosifiers Surfactants	Shale Control Inhibitors	Corrosion Inhibitors
Emulsifiers	Lost Circulation Material	Polymer Stabilizers
Thinners / Dispersants	Flocculants	Polymer Breakers

Source: Petroleum Services Association of Canada (2005), *Drilling Fluid Product Listing for Potential Toxicity Information*.

Generally the ingredients of drilling muds include:

- water (used for all water-based muds (WBM), most oil-based muds (OBM) and synthetic-based muds (SBM));
- hydrocarbon medium (e.g., mineral oil, synthetic chemicals) (in all OBM and SBM);
- weighting materials (in most muds all types)
- viscosifiers (in most muds – all types);
- corrosion inhibitors;
- surfactants (in most muds - all types); and
- variety of other additives (in most muds – all types).

Examples of chemicals used for these functions, some of which might be derived in part or in whole from renewable sources are provided below. Chemicals from renewable sources compete with other organic chemicals, and in some case minerals and inorganic chemical options.

Providing lubrication to the drill bit and drillstring[165] is critical to the success of the drilling operation. Common lubricants, mostly used in aqueous-based drilling fluids, include oils, other hydrocarbon mixtures, glycols, modified vegetable oils, fatty-acid soaps and surfactants.[166,167,168] A typical dosage for lubricants in water-based muds is 5 kg/m^3 of mud, although the requirement can vary.[169]

Viscosifiers provide viscosity to the fluids and keep weighting agents suspended. Bentonite clay (sodium montmorillonite) is commonly used as a viscosifier for water-based muds. Special grades of bentonite can be used in oil-based muds. Without sufficient viscosity, a weighting agent will not stay suspended in the drilling mud, and the mud will be less effective in removing cuttings from the wellbore. Both of these situations can lead to severe drilling problems, such as a clogged wellbore.[170] Viscosifiers, such as bentonite, can be added at 0 to 40 kilograms per cubic meter of mud made.[171] Bentonite has a high affinity for water and when dispersed in fresh water, swells as much as 20 times its dry state. High molecular-weight, water-soluble polymers have been substituted for clays in some situations and are effective at concentrations of 0.1-0.5% in the drilling mud.[172] Sodium

[165] The combination of the drillpipe, the bottomhole assembly and any other tools used to make the drillbit turn at the bottom of the wellbore. Source: Schlumberger: www.glossary.oilfield.slb.com/Display.cfm?Term=drillstring
[166] Schlumberger, *Oilfield Glossary* (http://www.glossary.oilfield.slb.com/).
[167] Canadian Association of Petroleum Producers (2001), *Technical Report - Offshore Drilling Waste Management Review*.
[168] Schlumberger, *Oilfield Glossary* (http://www.glossary.oilfield.slb.com/).
[169] Industry source.
[170] Canadian Association of Petroleum Producers (2001), *Technical Report - Offshore Drilling Waste Management Review*.
[171] Cheminfo Services based on industry sources.
[172] Canadian Association of Petroleum Producers (2001), *Technical Report - Offshore Drilling Waste Management Review*.

carboxymethylcellulose, attapulgite clays, and subbentonites (all colloids) are also used as viscosity builders for fluids to assure a high viscosity-solids relationship.[173]

A water-mud emulsifier is a chemical used in preparation and maintenance of an emulsion mud, which is a water-based mud containing dispersed oil (or a synthetic hydrocarbon). Numerous types of emulsifiers will disperse oil into water muds, including sulfonated hydrocarbons, ethyoxylated nonylphenols, alkali-metal fatty-acid soaps, lignosulfonate, lime, lignite and lignin at high pH. Even clays, starches and carboxymethylcellulose can aid emulsion mud stability. An oil-based mud emulsifier is a chemical used in preparation and maintenance of an oil- or synthetic-based drilling fluid that forms a water-in-oil emulsion (invert emulsion). An oil-mud emulsifier lowers the interfacial tension between oil and water, which allows stable emulsions with small drops to be formed. Emulsifiers can be calcium fatty-acid soaps made from various fatty acids and lime, or derivatives such as amides, amines, amidoamines and imidazolines made by reactions of fatty acids and various ethanolamine compounds. These emulsifiers surround water droplets, like an encapsulating film, with the fatty acid component extending into the oil phase.[174]

Thinners and dispersants act to modify the relationship between the viscosity and percentage of solids in a drilling mud. Tannins, various polyphosphates, lignite and lignosulfonates materials are chosen as thinners, or as dispersants, since most of these chemicals also remove solids by precipitation or sequestering, and deflocculation reactions.[175,176] Chemical thinners may be required to lower the viscosity and maintain the required flow properties of a drilling fluid. In aqueous-based drilling fluids it is common for drill cuttings to hydrate, resulting in high viscosity (thick) drilling mud. Drilling muds that become too viscous require more pump pressure to circulate, thus increasing the hydraulic pressure on the formation. In some situations, the combination of drilling mud density and hydraulic circulating pressure can exceed the fracture gradient of the formation, propagating the loss of whole mud. Dispersing agents, which typically are anionic polymers (highly negatively charged) with a molecular weight under 50,000 atomic mass units, or lignosulfonates, are used to control mud viscosity in water-based drilling muds.[177]

The hydration of drill cuttings and the wellbore surface that occur with aqueous-based drilling fluids does not transpire in non-aqueous invert emulsions (an emulsion of water droplets in the non-aqueous base mud) because the drill cuttings are exposed to the base mud and not water. Thus, thinners are not required for these systems. On the other hand, cuttings may be ground mechanically into fine particles, which can build up to an

[173] Resource Technology, Incorporated (1986), *Drilling Time and Cost Evaluation - User Manual*.
[174] Schlumberger, *Oilfield Glossary* (http://www.glossary.oilfield.slb.com/).
[175] Resource Technology, Incorporated (1986), *Drilling Time and Cost Evaluation - User Manual*.
[176] U.S. Environmental Protection Agency (2000), *Profile of the Oil and Gas Extraction Industry*, Prepared by the Office of Enforcement and Compliance Assurance.
[177] Canadian Association of Petroleum Producers (2001), *Technical Report - Offshore Drilling Waste Management Review*.

unacceptable level in the mud system. When this occurs, the fine-solids mud system must be diluted to an acceptable range using additional base mud even in non-aqueous muds.[178]

5.11.2.1 Foaming Agents

Foaming agents are sometimes used to reduce fluid loss from drilling fluids in relatively shallow, low-temperature formations. They do this by reducing drilling fluid density and thus the hydrostatic pressure exerted by the drilling fluid, which facilitates product flow to the surface. Foams can also reduce erosion of poorly consolidated formations and increase borehole stability. The high apparent viscosity of foams makes them effective in lifting drill cuttings (as well as product during production) to the surface. Commonly used foaming agents include alpha-olefin sulfonates and alcohol ethoxysulfates.[179]

Oil-based and synthetic-based drilling muds are two product areas where hydrocarbons from renewable resources may find use. Oil-based drilling muds are used when formation stability is important, since it is unlikely to be absorbed by hydroscopic clays (i.e., clays that easily absorb water) or wash away sensitive shale formations. Oil-based muds need to provide good lubrication to the drill bit and reduce the likelihood of a stuck drill-pipe. These drilling fluids are typically more expensive than water-based mud. They can also be more difficult to dispose of, since they are based on petroleum products.[180] Operators reuse OBM that is not lost during drilling operations and separation/removal of rock cuttings. (Mud losses are typically in the range of 5 to 30%, or more for some wells.) The OBM can be cleaned, oil added to attain the suitable oil/water ratio, and more additives can be added to achieve the function and physical properties required. The “reconditioned” OBM can then be reused one or more times (usually less than five times).[181]

Since about 1990, the oil and gas extraction industry has developed many new oleaginous (oil-like) base materials from which to formulate high performance drilling fluids. A general class of these fluids is called synthetic materials, such as linear alpha olefins, poly alpha olefins, synthetic paraffins, ethers, vegetable esters, other esters, linear alkylbenzenes, and others. Other oleaginous materials have also been developed for this purpose, such as special grades of mineral oils and non-synthetic paraffins. Synthetic-based fluids were developed with these synthetic and non-synthetic oleaginous materials as the base to provide the drilling performance characteristics of traditional oil-based fluids but with the potential for lower environmental impact and greater worker safety. Synthetic based muds (SBM) have lower potential toxicity, lower polycyclic aromatic hydrocarbons content, faster biodegradability, lower bioaccumulation potential and in some drilling

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[178] Canadian Association of Petroleum Producers (2001), *Technical Report - Offshore Drilling Waste Management Review*.
[179] E&P Magazine, *Oilfield Chemicals - A Reference Guide*.
[180] Kireev, Marat (2008), *Uses and Disposal Methods for Challenge & PSSA Substances found in Drilling Mud Additives/Oil Recovery Agents/Oil Well Treating Agents*, prepared for Environment Canada’s Oil, Gas & Alternative Energy Division.
[181] Cheminfo Services based on industry sources.

situations decreased drilling waste volume.[182] Similar to OBM, SBM can be reconditioned for reuse. Synthetic muds have been adopted for offshore drilling in Canada and are used at a small portion of onshore wells drilled. Water-based (WBM) and OBM are the predominant types used for onshore drilling.

5.11.3 Chemicals Used for Oilfield Production Formulations

Oilfield production chemicals include demulsifiers, corrosion inhibitors, paraffin/wax and asphaltene control agents, scale inhibitors, de-icing fluids, biocides, foaming agents, antifoam agents and a variety of other chemicals. Crude oil production/separation processes usually require more chemical treatment than natural gas production processes. Reasons for this are: water content is higher in crude oil; crude oil emulsions with water are harder to break; and crude oils contain more solids, paraffins and asphaltenes. Processing the water/oil mixtures as they are produced requires chemicals such as demulsifiers, scale inhibitors, corrosion inhibitors, clarifiers, and other chemicals. While most crude oil production requires all types of oilfield chemicals, natural gas production mostly requires the use of corrosion inhibitors, scale inhibitors and de-icing chemicals. Natural gas separation requires lower use of other chemicals and rarely any use of demulsifiers.[183] However, chemical consumption is dependent on the conditions of the oil and gas field, individual wells, and batteries.

Table 61: Estimated Demand for Oilfield Production Chemicals Used in Canada, by Type of Product, 2008

	Natural Gas	Oil	Total Quantity	% of Total Quantity	Total Value
	(million litres)	(million litres)	(million litres)		($ million)
Corrosion inhibitors	24	8	32	26%	$175
Demulsifiers (emulsion breakers)	1	30	31	25%	$125
Paraffin/asphaltene (wax) control	6	12	18	15%	$91
Scale inhibitors	1	9	11	8%	$58
Foamer	5	0	5	4%	$25
Defoamers	0	6	6	5%	$26
Biocides	1	5	6	5%	$51
All other*	9	6	15	12%	$46
Total	**48**	**77**	**125**	**100%**	**$597**

Source: Cheminfo Services files based on industry sources.
* Includes, but is not limited to: hydrogen sulphide (H_2S) scavengers, hydrate inhibitors, de-icing fluids, clarifiers, etc.
Very rough estimates. Estimates shown as zero may be less than 0.5 million litres rounded to zero.

[182] U.S. Environmental Protection Agency (2000), *Profile of the Oil and Gas Extraction Industry*, Prepared by the Office of Enforcement and Compliance Assurance.
[183] Glycols are used in closed loop systems to dehydrate gas streams at batteries or gas processing plants.

Alberta, Saskatchewan and British Columbia account for close to 90% of total use of these chemicals in Canada. Demand for oilfield production chemicals in Newfoundland and Nova Scotia is mostly all for offshore production. Small quantities are used for onshore drilling in that region.

Oilfield chemicals are often custom-formulated for each producing reservoir, well and/or treating facility (i.e., battery) since each site has its own oil/gas product characteristics. Formulations may often change over time due to the changing conditions of the reservoir, well, or mix of flow to the battery. Product characteristics affecting chemical requirements include water content, brine content, condensate content, crude-oil/water emulsion characteristics, hydrogen sulphide content, hydrocarbon constituents of the products and other factors (e.g., solids, paraffins, asphaltenes). Oilfield chemicals are used at thousands of sites where wells, batteries, and pipelines are present. There are therefore thousands of different formulations, which differ with respect to active ingredients, type of carriers/solvents and ratio of ingredients.

5.11.4 Exploration Chemical Suppliers

5.11.4.1 Mud Suppliers

There are about 30 companies in Canada that specialize in supplying drilling muds. Several companies are referred to as wholesalers/distributors, the rest are referred to as retailers. Identified "wholesalers" provide a broad range of mud ingredients. These companies purchase basic chemical from manufacturers, carry inventory, and distribute ingredients to the mud "retailers". Drilling mud "retailers" supply the oil and gas producers (customers). Some of the larger retailers may also be integrated with basic chemical manufacturing. The mud suppliers also provide technical support as well as other products and services (e.g., equipment, etc.). The scope of the products and services these companies can provide varies, and can include (but not be limited to):

- chemicals used in drilling muds and other applications ;
- oils and synthetics used in drilling muds;
- specialized chemical packages for drilling muds;
- partially formulated drilling muds;
- fully formulated drilling muds;
- equipment (for sale or rent);
- preparation of oilfield production chemicals; and
- technical services for mud and other oil and gas activities.

Drilling mud suppliers work closely with oil and gas companies to define drilling mud and other chemical needs. The majority of mud suppliers have Canadian offices in Calgary, AB near their oil and gas customers. However, there are also regional sales offices, technical laboratories, and mixing facilities across Western Canada and on the east coast. The larger drilling mud suppliers, such as Baroid and M-I SWACO, tend to be foreign owned with a global business scope, while the smaller firms operating in Canada tend to be Canadian-based with businesses focused on Western Canada.

For the most part, mud suppliers blend chemicals to make standard or custom formulations for drilling and other purposes. They are not typically involved in any basic chemical manufacturing in Canada. Blending may be carried out at the well site or at central facilities with delivery to the well site via bulk truck. The water-based drilling muds are typically blended at the well site, while oil and synthetic-based muds are typically blended at central mixing plants.

Table 62: Examples of Canadian Drilling Mud (Fluid) Suppliers

Company	Location*
Wholesalers of Mud Ingredients	
Bri-Chem Supply Ltd	Acheson, AB
Di-Corp	Calgary
Federal Wholesale Drilling Mud	Calgary
Mud "Retailers"	
Advantage Mud Systems Ltd	Calgary
Baker-Hughes	Calgary
Blackstone Fluids Ltd.	Calgary
Chem - Add Fluids Ltd.	Calgary
Bronco Mud Inc	Calgary
Canadian Energy Services LP	Calgary
DMK Drilling Fluids Ltd	Calgary
Dynamic Drilling Fluids Ltd	Calgary
Halliburton (Baroid)	Calgary
HiTech Fluid Systems Ltd	Calgary
Marquis Alliance Energy Group Inc	Calgary
Matrix Drilling Fluids Ltd	Calgary
M-I SWACO	Calgary
Mud Master Drilling Fluid Services Ltd	Calgary
Mudco Services Ltd	Calgary
Newpark Drilling Fluids	Calgary
Nalco-Champion	Calgary
Pinnacle Fluids Ltd	Calgary
Prairie Mud & Chemical Service Ltd	Estevan, SK
Q'Max Solutions Inc	Calgary
Rheotech Drilling Fluid Services Inc	Calgary
Southwest Oilfield Products (Alta.) Ltd	Edmonton

Sources: Canadian Oilfield Services and Supply Database: http://www.cossd.com/search.asp. Campages: http://www.canpages.ca/. Industry sources. Petroleum Services Association of Canada (PSCA): https://members.psac.ca/Source/Members/psacDirectorySearch.cfm.* Additional locations may exist.

5.11.5 Oilfield Chemical Suppliers

The Canadian oilfield production chemical market is supplied by two large firms and some smaller companies. The two major Canadian oilfield production chemical suppliers are Baker-Petrolite (resulting from the merger of Baker Hughes and Petrolite), and Nalco-Champion, which was recently acquired by Ecolab. Ecolab is a large US-based supplier of many other chemicals including: cleaners, degreasers, water treatment chemicals, and many other products. It is well known in the industry that together, these two companies are estimated to supply approximately three quarters of the Canadian market, a large portion of the U.S. as well as the global market for oilfield production chemicals.[184] These companies would be major target customers for bio-based ingredients used in oilfield production chemicals.

Table 63: Major Manufacturers of Oilfield Production Chemicals in Canada

Company	Locations*	
Baker-Petrolite Corporation	Eastfield	AB
Baker-Petrolite Corporation	St. John's	NF
Nalco-Champion	Grand Prairie	AB
Nalco-Champion	Calgary	AB
Nalco-Champion	Lloydminster	AB
Nalco-Champion	Nisku	AB
M-I SWACO	Nisku	AB
Caradan Chemicals Inc	Nisku	AB
Chemicals by Sterling Ltd	Estevan	SK
Innovative Chemical Technologies Canada Ltd. (ICTC)	Edmonton	AB
Multichem	Edmonton	AB
Q'Max Solutions Inc.	Calgary	AB
Chemserv Products Inc., A Weatherford Co.	Nisku	AB

* Companies may have additional locations. See company websites.

Oilfield chemicals are often custom-formulated for individual batteries (or processing facilities) as each producing reservoir and associated wells can involve a distinct type of oil or gas stream. Formulations for individual sites often need to be changed due to the changing conditions of the reservoir or well (especially if it is a new field). Product characteristics affecting chemical requirements include water content, brine content, condensate content, crude-oil/water emulsion characteristics, hydrogen sulphide content, hydrocarbon constituents of the products and other factors. Oilfield chemicals are used at

[184] Source: Oilfield production chemical suppliers.

thousands of sites where wells, batteries, and pipelines are present. There are therefore thousands of different formulations, which differ with respect to ratio of active ingredients, carriers/solvents and other ingredients.

5.11.6 Chemical Distributors

There are at least half a dozen large primary chemical distributors in Canada and a much greater number of sub-distributors that purchase from the primary distributors and sell to final users. Canada's major chemical distributors include Univar, Brenntag, and Canada Colors and Chemicals. These and other companies tend to sell commodity products that are not formulated to specific customer requirements (such as would be required for many oilfield production chemicals). They sell thousands of chemical and related products (e.g., polymers). Solvents, minerals, and inorganic chemicals are among the chemicals sold in the oil and gas industry.

5.11.7 Transportation and Storage of Chemicals

The following summarizes transportation and storage information for exploration and oilfield production chemicals.

Exploration Chemicals

- The chemical ingredients to make drilling muds and other exploration chemicals are transported to the well site in bags (25-100 kg), pails (25 L), drums (210 litres), totes (1,100 litres), semi-bulk trucks (e.g., 3-10,000 litres), and bulk trucks (e.g., 20-30,000 litres).
- The chemical ingredients are typically mixed at the well site with water by the mud supplier or "engineer".
- Oil-based muds and other oil-based chemicals are mostly blended at central mixing facilities, and transported to well sites in semi-bulk or bulk trucks. They are stored in large metal tanks at the site.

Oilfield Production Chemicals

- Prepared at central blending facilities of suppliers.
- Transported to the well sites in pails (25 L), drums (210 litres), totes (1,100 litres), semi-bulk trucks (e.g., 3-10,000 litres), bulk trucks (e.g., may have multiple compartments, 20-30,000 litres).
- Stored the well/battery sites in a variety of different size containers.

5.11.8 Biochemicals Used in Oilfield Chemicals

There are a number of ingredients used in oilfield chemicals that are already bio-based. Some suppliers are promoting these and also developing additional bio-based products for this industry and related applications. There is also an increasing awareness of environmental and sustainability considerations in this market. The table below provides a partial list of chemicals used in drilling muds, other exploration chemicals, and oilfield production chemicals that are or could be derived from bioresources. This list and the Chemical Product Category to which the substances belong have been developed from the literatures sources documented at the bottom of the table. Many more non-bio-based chemicals used in this industry are available from these reference sources.

Table 64: Biochemicals Used in Oilfield Chemicals

Chemical Product Category	**Chemical Name**
Surface Active Agents	
Water-Based Fluids	Polyoxyethylene sorbitan mono-tall oil esters
	Rosin amine-alkylene oxides condensation products
Oil-Based Fluids	Refined tall oil fatty acids
	Carboxy modified amines and betaines
	Lecithin
Air Foams	Fatty alcohols and alcohol sulfate salts
	Sulfated polyoxyethylated alcohols
Fluid Loss and Viscosity Control	
Cellulosics and Guar Gum	Polysaccharides and caboxymethylcellulose
	Water-soluble salts of carboxymethylcellulose
	Carboxymethyl-hydroxyethyl mixed cellulose ether
	Celluosics, guar gum, polyacrylamide hydrolyte and vinyl-maleic copolymers
	Modified guar gum
	Polysaccharide cross-linked with polyelectrolyte ligand-metal ion
Starches	Heat modified starches
	Modified starch - dextrin
	Oxidized starch
	Dialdehyde starch and inorganic chromate
	Iodinized starch
	Cyanoethylated starch
Lignin Derivatives	Chromium and iron complexes of sulfite liquor
	Zinc complex of lignites
	Polymeric zinc complex of coniferous tree bark
	Metal sulfate treatment of sulfite liquor
	Sulfoalkylated tannin and chromium salts
	Buffered lignosulfonates

Chemical Product Category	**Chemical Name**
	Phenolation and sulfonation of lignosulfonate
	Sulfonated lignin-alkylolphenol reaction products
	Chlorinated lignin
	Sulfonated lignin from spent sulfite liquor
	Oxidized lignin, polyphosphate and potassium salts
	Fatty alkyl ammonium lignosulfonate
	Humic acid-tall oil-polyamine reaction products
	Lignin-amine reaction products
Acidizing Chemicals	Acetic acid
Other Additives	Castor pomace
	Sulfonated extract oil
	Esters of tall oil pitch and polyoxyethylene compounds
	Chromic gluconate
	Glycerol carbonate
Clay Treatments	Graft copolymers of acrylic acid and modified cellulosics
	Raw fluor
General	Asbestos and water-soluble salts of carboxymethylcellulose
Lost Circulation and Sealing Materials	Flexible flakes, flexible fibres and walnut granules
	Phenolic treated wood fibre or glass fibre
	Oyster shells
	Fibre-nutshell composition
Lubricity Agents Antisticking Additives Extreme Pressure Additives Lubricants	Acrylic acid-acrylamide copolymers and dextran
	Decanal
	Sulfonated tall oil pitch
	Sulfurized tall oil
	Tall oil soaps
	Oleic acid and tall oil
	Aliphatic fatty amines
	Canola oil, other vegetable oils.

Sources: McDermott, J. (1973). *Drilling Mud and Fluid Additives*. Noyes Data Corp: Park Ridge, USA.
Azar, J.J., Samuel, G.R. (2007). *Drilling Engineering*. PennWell Corporation: Tulsa, USA.
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5.11.9 Potential for Bio-Based Oilfield Chemicals

Some of the chemical suppliers to the oil and gas industry in Canada have product lines or products that are marketed as environmentally friendly. Some of these may be bio-based or they may be sold as environmentally friendly products since they do not harm the environment during use, disposal (e.g., on land), or spilled. There has been increasing interest in environmentally friendly products as some consumers and shareholders have begun to value the environmental performance of companies. It is not possible to estimate the size of this demand in Canada due to the wide variety of products, bio-based replacement chemicals, and fragmented nature of the industry. Below are some perspectives regarding bio-based chemicals for the oil and gas industry. These have been gathered from a few industry consultations and company websites.

Di-Corp, based in Calgary is one of the largest wholesalers/distributors of drilling fluid chemicals in Canada. A large portion of its products are imported. The company does see some demand for environmentally friendly or green products. These products can offer environmental benefits and/or worker safety benefits. Part of the drive toward more environmental friendly products in Alberta has been the Government of Alberta's Energy Resources Conservation Board (ERCB) requirement for toxicological data on specific mud additives used by the oil and gas industry. The toxicological data must comply with the most current (May 2, 2012) *ERCB Directive 050: Drilling Waste Management* requirements.[185] Safety is also an important consideration in the upstream oil and gas industry. Companies strive to ensure their workers are not exposed to hazardous chemicals. Environmentally friendly chemicals are generally viewed as being more worker-friendly than conventional chemicals. Part of Di-Corp's marketing strategy will be to re-brand some of its products to position them as being more "worker-safe" and/or environmentally friendly. (Whether these are bio-based chemicals is unknown.)

As a wholesaler/distributor Di-Corp is interested in sourcing more environmentally friendly or green products – possibly made from renewable resources. However, these types of products are viewed as being more expensive, and customers in the oil and gas industry are generally reluctant to pay higher prices – especially during periods of weak oil and gas industry activity. The company has previously examined and would be interested in sourcing locally produced biochemicals that provide appropriate functionality, quality and price. Environmental benefits would be value-added features.

Emery Oleochemicals produces and markets a wide range of oleochemical products derived from natural raw materials, such as palm oil, palm kernel oil, other vegetable oils and tallow. These products are used in the manufacture of oilfield chemicals and in many other industrial applications.[186,187] In Canada, the company was making bio-based fatty acids in Mississauga, ON, until the plant recently shut down in September 2013. Sales in Canada will be supplied by production facilities in the United States, Germany and Malaysia.

Emery's ester-based DEHYLUB® brand is an example of a biochemical product line used in the oil and gas industry. The DEHYLUB® brand, which was developed over many years, is a vegetable ester-based product for drilling fluids (oil well drilling mud conditioner or OMC). It is promoted by Emery as providing outstanding safety and technical performance, even under extreme borehole and formation conditions. Emery claims "It is designed for customers seeking environmentally conscious alternatives… offers

[185] PSAC, http://www.*psac.ca/resources/mud-list/
[186] Emery Oleochemicals, http://www.emeryoleo.com/corporate.php
[187] Camford Chemical Report, July 13, 2009

compliance with EPA regulations and greater environmental protection. Capable of improving solids control, often a major factor in the success of any drilling program - the OMC is credited for its rheology, mitigating toxicity, and is biodegradable. Emery Oleochemicals' drilling fluids is one of the only few natural-based solutions approved for use in the Gulf of Mexico."

In addition to chemicals, Emery offers technical capabilities to customize formulations for specific customer needs. Its services include evaluating production or fracturing challenges to determine the most effective products that enable both environmental protection and improved oilfield production.[188]

Chemfax, based in Calgary, AB offers a range of cleaning and other chemicals to the oil and gas as well as many other industries. Its Enviroline® product line includes a variety of chemical products that are promoted as environmentally friendly. Some contain ingredients that are from renewable sources (e.g., canola oil), while others provide favourable biodegradability or other environmental benefits. There are also benefits associated with worker safety when handling and using these products. The costs for manufacturing Enviroline® products are usually higher than the company's conventional product lines, and as a result they are priced higher. Nevertheless, the sales trend has been positive with increasing customer interest and sales in Enviroline® products over the last several years.

Nalco-Champion, with locations in Alberta, is one of Canada's largest oilfield production chemical suppliers. Oil and gas customers have had some requirements for "environmentally friendly" products, but these have tended to be used in niche applications. It points out that many of the oilfield chemicals use surfactants that are already bio-based. Nalco-Champion points out that "environmentally-friendly" product does not necessarily mean bio-based chemicals. One example is chemicals used for oilsands processing to make bitumen. Some oilsands producers are seeking chemicals that do not accumulate in tailing ponds, water from which is recirculated back into the process. There are also examples of products being used (i.e., for offshore drilling) that provide environmentally benefits (e.g., biodegradability) sometimes with a sacrifice in performance. Government regulations are typically required to force adoption of chemicals that provide the necessary environmentally benefit in the oil and gas industry. These situations involve niche applications. For the most part, oil and gas customers are seeking low-priced chemicals that function as required. One reason is that in the case of oilfield production chemicals, releases to the environmental are low with most of the chemicals contained in the oil and gas streams – in low concentrations.

In general, oilfield chemical users, which are petroleum producing companies or provide services in the industry, are not interested in products derived from raw materials that would replace oil and gas they produce. Furthermore, end-users, which do not sell directly to consumers, have only had minor interest in chemicals from renewable sources from a

[188] Emery Oleochemicals, http://www.emeryoleo.com/corporate.php

promotional perspective. They are generally more interested in purchasing chemicals with suitable functionality and low price. Nalco-Champion indicates that sales of “environmentally friendly” oilfield chemicals are likely to continue to be used in niche applications, especially in the absence of regulations (which would be very difficult to envision) or incentives to encourage adoption of such products.

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7. APPENDIX A: Chemical Market Profiles

This appendix contains the profiles of chemical markets that were not selected for more detailed analysis in phase II of the study.

7.1 Soaps and Cleaners

The soaps and cleaners industry uses surfactants and other raw materials to make products such as laundry detergents, hand soaps, dishwasher detergents, sanitizers, fabric softeners, carpet cleaners, polishes, car wash cleaners, hard surface cleaners, disinfectants, toilet bowl cleaners, polishes, rust removers, window cleaners, and many other chemicals for use on fabrics, personal care, leather, metals, and other surfaces. The broad market segments for these chemicals are consumer (or household), commercial (e.g., restaurants, food stores), institutional (e.g., hospitals, schools, municipalities-water treatment), agriculture (e.g., livestock growing operations), and industry (e.g., food, beverage, pulp and paper).

Table 65: Economic Statistics on the Soaps and Cleaners Industry in Canada

($ millions)

Year	Shipments	Imports	Exports	Domestic Consumption	Net Trade	Establishments	Employment
2003	$1,801	$1,653	$666	$2,788	-$987	232	6,274
2004	$1,675	$1,805	$779	$2,701	-$1,026	364	5,585
2005	$1,490	$1,743	$759	$2,474	-$984	379	5,669
2006	$1,551	$1,819	$795	$2,575	-$1,024	344	5,389
2007	$1,612	$1,848	$734	$2,726	-$1,114	370	5,658
2008	$1,684	$2,049	$755	$2,978	-$1,294	338	5,751
2009	$1,668	$2,253	$783	$3,138	-$1,470	318	5,920
2010	$1,490	$2,183	$769	$2,904	-$1,414	318	5,120

Source: Industry Canada, http://www.ic.gc.ca/eic/site/chemicals-chimiques.nsf/eng/h_bt01181.html

The soap and cleaners industry can be considered mature in that growth in the value of Canadian consumption has been slow – averaging less than 1% per year since 2003. Canadian shipments have been declining, with 2010 value of shipments 17% below 2003, and even lower than shipments in 1995, which stood at $1.6 billion.[189] Canadian producers have lost market share in the domestic market. The trade deficit, largely with the United States, has widened. There have been some plant closures in Canada with production

[189] Industry Canada's, www.ic.gc.ca/chemicals. Also, Cheminfo Services historical files based on Industry Canada. Current dollar values.

migrating to larger U.S. facilities that have lower cost of production. While many of the markets are mature, there have been some products that have grown rapidly over the last decade – hand sanitizers and "environmentally friendly" or "green" products are examples.

Some of the larger firms in this industry are the so-called "soapers" and consumer products producers that make household laundry detergents, consumer cleaners and the like. These companies include Procter & Gamble and Unilever. Companies in this part of the industry are usually backward integrated to manufacturing (not necessarily in Canada) some of their own raw materials, including larger volume surfactants. This usually entails the purchase of a "hydrophobe" such as a petroleum-based alkylate, or bio-based tallow, vegetable oil, coconut oil or other oil. These can be further processed in order to make a hydrophilic component. Important chemical reactions involve hydrogenation, esterification, ethoxylation, sulphonation, sulphation and/or saponification. The next stage in the manufacturing process entails blending the surfactants with various chemicals to yield products that perform according to specific functional requirements in different markets. Products are customized to meet requirements for different substrates being cleaned, water chemistry, temperatures, consumer preferences, and other market factors.

For large firms selling consumer products, in addition to backward integration to raw material supply, key success factors include: building and maintaining brand awareness through large mass-advertising expenditures; maintaining access to shelf space at major mass retailer stores; and good distribution capabilities to meet retailer needs across Canada. In addition to the larger consumer products suppliers, there are many smaller firms that blend surfactants, other chemicals, water or other solvents to a make great variety of products. Some of the more notable firms include Ecolab, Diversey, Sanilab, and Zep Manufacturing.

Most of the soaps and cleaners manufacturing establishments in the industry are located in Ontario and Quebec – close to large manufacturing and consumer markets. There are about two dozen chemical blenders in Alberta that classify themselves as suppliers of soaps and cleaners (NAICS code 32561). With chemical blending capabilities, some of these producers make a variety of formulated products in addition to cleaning compounds. Many are therefore involved in providing oilfield chemicals to the oil and gas industry in the region.[190]

[190] Industry Canada, Company Directories. http://www.ic.gc.ca/app/ccc/srch/cccSrch.do;jsessionid=0001tEvgD-zKccXhj63wyeMbi64:1830KHK28Q?lang=eng&prtl=1&sbprtl=&naics=32561

Table 66: Number of Establishments in Canadian Soaps and Cleaners Industry

Province or Territory	Employers	Non-Employers/ Indeterminate	Total	% of Canada
Alberta	20	22	42	7.0%
British Columbia	54	29	83	13.8%
Manitoba	8	4	12	2.0%
New Brunswick	1	2	3	0.5%
Newfoundland and Labrador	1	0	1	0.2%
Northwest Territories	0	0	0	0.0%
Nova Scotia	3	1	4	0.7%
Nunavut	0	0	0	0.0%
Ontario	154	99	253	42.0%
Prince Edward Island	1	2	3	0.5%
Quebec	128	64	192	31.9%
Saskatchewan	6	2	8	1.3%
Yukon Territories	0	1	1	0.2%
CANADA	376	226	602	100%
Percent Distribution	62.5%	37.5%	100%	

Source: Statistics Canada, Canadian Business Patterns Database, December 2011.

Although the overall soap and cleaners market is mature, there have been technological changes. One of the most important trends has been the drive to offer products that are “greener” or more “environmentally friendly”. This has included reducing fossil-fuel based hydrocarbon solvents that are a source of VOC, and incorporating more “natural” raw materials into formulations.

Soaps and cleaners offer a potential market for solvents, chemical reactants, oils, and surfactants that could be made from renewable bioresources. Alberta has a reasonable number of soap and cleaning products manufacturers, which might serve as product development partners or local customers for Alberta start-up production of biochemicals. However, the Alberta producers are not large (i.e., they are not “soapers”). Therefore, it is likely that the Alberta demand for biochemicals for this market is low and biochemical production would need to be shipped to other Canadian provinces and U.S. markets.

One option for consideration in this industry would be to develop a very large vegetable oil processing facility to make hydrophobes for sale across North America. Alberta offers potential production cost advantages in acquiring vegetable oils, energy and hydrogen production (used for hydrogenation) based on using natural gas. There is also ethylene oxide production in Alberta (Dow Chemical at Fort Saskatchewan), which could be used for ethoxylations. These might provide sufficient advantages to overcome transportation costs to distant markets, since the Alberta market is relatively small. However, a hurdle to consider is that many large “soapers” and other large soap and cleaner producers tend to be backward integrated to production of their own hydrophobes.

7.2 Paints and Coatings

The paints and coatings (NAICS 32551) industry produces architectural (or decorative) paints and protective coatings. Architectural products include interior and exterior house paints, primers, sealers, varnishes and stains. They are sold to contractors and the general public through wholesale and retail outlets as well as direct to large accounts (e.g., construction industry accounts). A large portion of sales to consumers and painter trade is through the major retail chains such as Canadian Tire, Walmart, Home Hardware, Rona, Lowe’s and Home Depot. A portion of these are sold as private-label brands. Industrial products include automotive finishes, metal can coatings, coil coatings, furniture finishes, road-markings, bridge coatings, railcar coatings, marine vessel and boat coatings, and coatings for a great many other applications. Most of these products are sold direct to the end users and often involve custom formulation.[191]

The value of Canadian consumption of paints and coatings was $1,890 million in 2010. The Canadian market is mature, with 2010 domestic consumption slightly lower than the level in 2003. A weakening manufacturing sector has been one of the factors contributing to the lack of growth. Canadian production of paints and coatings has declined, as have imports and exports. Canada continues to have a large and growing trade deficit for these products.

Table 67: Economic Statistics on the Paints and Coatings Industry in Canada

($ millions)

Year	Shipments	Imports	Exports	Domestic Consumption	Net Trade	Establishments	Employment
	($ millions)	($ millions)	($ millions)	($ millions)	($ millions)		
2003	$2,049	$1,012	$414	$2,647	-$598	200	6,288
2004	$1,997	$984	$433	$2,548	-$551	364	6,459
2005	$1,990	$949	$431	$2,508	-$518	283	6,294
2006	$1,998	$962	$463	$2,497	-$499	273	6,184
2007	$2,190	$955	$454	$2,691	-$501	278	6,210
2008	$2,076	$917	$399	$2,594	-$518	273	6,758
2009	$2,062	$884	$257	$2,689	-$627	261	6,737
2010	$1,890	$990	$271	$2,609	-$719	261	5,830

Source: Industry Canada, http://www.ic.gc.ca/eic/site/chemicals-chimiques.nsf/eng/h_bt01181.html

[191] Sources: Paints and Coatings Industry Profile, http://www.ic.gc.ca/eic/site/chemicals-chimiques.nsf/eng/bt01164.html#introduction. Cheminfo Services Inc.

The total volume of paints and coatings sold in Canada is roughly estimated at 400 million litres per year.[192]

Table 68: Major Application Categories for Paints and Coatings for Canada

Paint and Coating Category	Volume Basis	Main Features of the Category[193]
Architectural paints	56%	Sold through major retail chains, large number of small retailers, and to large commercial customers.
Industrial coatings	33%	Fragmented end-use pattern involving tens of thousands of manufacturing facilities and other organizations (governments, maintenance construction firms, etc.)
Automotive finishes	11%	Few suppliers – PPG, DuPont, BASF and Akzo dominate supply. Sold to dozens of car and truck manufacturing facilities, thousands of auto body shops, and some retail consumer sales.

Sources: Canadian Paints & Coatings Association. http://www.cdnpaint.org/. Cheminfo Services

Demand in Alberta for paints and coatings includes architectural paints, industrial/maintenance coatings and vehicle refinishes. There is no automobile manufacturing in Alberta. Overall, Alberta is estimated to account for about 5-10% of the total Canadian demand for paints and coatings.

The table below shows the major paints and coatings suppliers in Canada. Some of these companies have multiple plants in different provinces. There have been a number of corporate ownership and manufacturing facility changes in the industry over the last decade. This has included some consolidation. For example, Akzo Nobel purchased a number of firms including Sico, Chemcraft, International Paints, and ICI Paints. In some cases, Akzo has retained the brand names used by these companies. There has also been some plant closures and product line consolidation between Canadian and U.S. facilities. For example, PPG Canada closed plants in Canada and moved production to its U.S. plants. Additional changes are expected in the landscape of the Canadian industry.

[192] Canadian Paints & Coatings Association. http://www.cdnpaint.org/
[193] Cheminfo Services

Table 69: Major Canadian Paint and Coating Suppliers

Company	City	Province
Architectural		
Cloverdale	Surrey	BC
General Paint	Vancouver	BC
Home Hardware	Burford	ON
Akzo Nobel Canada	Longueuil	QC
Benjamin Moore	Montreal	QC
Sherwin-Williams	Vaughan	ON
Société Laurentide	Shawinigan	QC
PPG Canada	Mississauga	ON
Denalt Paints Ltd.	Saint-Léonard	QC
Industrial Maintenance		
Akzo Nobel Canada	Port Hope	ON
Cloverdale	Surrey	BC
International Paints (Akzo)	Halifax	NS
PPG Canada	Mississauga	ON
Traffic Marking		
Cloverdale	Surrey	BC
General Paint	Vancouver	BC
Ibis Products Ltd	Toronto	ON
Société Laurentide	Shawinigan	QC
Automobile Finishes		
PPG Canada	Mississauga	ON
DuPont Canada	Whitby	ON
Akzo Nobel Canada	Longueil	QC
BASF	Mississauga	ON

Source: Cheminfo Services

Manufacturing paints and coatings involves mixing of polymeric resins (e.g., acrylics, epoxies, alkyds, polyesters, phenolics), organic chemicals (e.g., hydrocarbon solvents, surfactants, dyes, other chemicals), inorganic materials (e.g., pigments, fillers, etc.), functional additives (e.g., UV inhibitors, biocides, plasticizers, curing agents, etc.) and water in large vessels. Coatings are packaged in a variety of containers including metal cans with metal lids, aerosol cans, tubes, drums, plastic containers, and pails.

Alberta is home to about 16% of the paint and coatings manufacturing establishments in Canada. Most of the manufactures are located in Ontario, Quebec and British Columbia. It should be noted that the Canadian Paints and Coatings Association (CPCA)[194] believes that there are only about 130 to 150 paints and coatings manufacturers in Canada, so the total provided by Statistics Canada in the table below might be overestimated, and may include

[194] Personal conversation with CPCA.

companies that carry out painting/coating services or are providing raw materials to paints and coating manufacturers.

Table 70: Number of Establishments in Canadian Paints and Coatings Industry

Province or Territory	Employers	Non-Employers/ Indeterminate	Total	% of Canada
Alberta	**35**	**32**	**67**	**16.4%**
British Columbia	26	38	64	15.7%
Manitoba	12	5	17	4.2%
New Brunswick	2	1	3	0.7%
Newfoundland and Labrador	0	1	1	0.2%
Northwest Territories	0	0	0	0.0%
Nova Scotia	3	3	6	1.5%
Nunavut	0	0	0	0.0%
Ontario	108	79	187	45.8%
Prince Edward Island	1	0	1	0.2%
Quebec	46	13	59	14.5%
Saskatchewan	1	2	3	0.7%
Yukon Territories	0	0	0	0.0%
CANADA	234	174	408	100%
Percent Distribution	57.4%	42.6%	100%	

Source: Statistics Canada, Canadian Business Patterns Database, December 2011.

There continues to be environmental pressures on the paints and coatings industry. The drive to reduce VOC and hazardous/toxic chemicals contents to low levels in paints and coatings has resulted in the development and sale of new formulations, which in turn have required development of new ingredients. For example, new grades of resins have been developed for water-based products. High solids liquid coatings (with 60-70% solid content), which have been gaining in popularity, require resins with lower molecular weight (so they can be dissolved with less solvent). Radiation cured coatings are also a higher growth segment, albeit on a small base of demand. There has also been good growth for powder coatings (i.e., almost 100% solid resin). The introduction of new products can result in incorporation of new polymer and additive substances. There has also been interest to incorporate more bio-based chemicals in paints and coatings formulations.

Some examples of activities involving increased use of renewable materials in paints and coatings are provided below.

- In 2013, AkzoNobel and Solvay have signed a three-year agreement whereby AkzoNobel will increase the use of renewable raw materials in its paints and coatings. AkzoNobel intends to increase its use of Solvay's bio-based "*Epicerol"* epichlorohydrin, which is already contained in many of the company's resins for its coatings products. The agreement underlines the commitment of both parties to play a key role in sustainable development and to expand the use of renewable raw materials. *Epicerol* is a Solvay patented process to make bio-based epichlorohydrin from renewable glycerol. By 2016, AkzoNobel intends to source 20% of its total epichlorohydrin supply as bio-based material. Epichlorohydrin is a chemical intermediate to make epoxy resins, which are base ingredients for certain coatings.[195]
- In 2012, Lignol Inc. (a Canadian company firm based in British Columbia) reached agreement with a leading global coatings manufacturer for the sale of up to ten tonnes of its proprietary *HP*-L lignin. The product was to be used for product trials. The sale was the culmination of a multiyear joint development program, during which Lignol provided test quantities of a variety of lignin derivatives for various epoxy coating formulations. Lignol drew on its unique technology that tailors lignin properties for specific end uses, a capability which it intends to leverage into commercial opportunities to sell *HP-L* lignin into a wide range of applications.[196]
- In 2008 Cargill and Novozymes announced a joint agreement to develop technology enabling the production of acrylic acid via 3-hydroxypropionic acid (3HPA) from renewable raw materials. The collaboration aims at enabling fermentation of sugar into 3HPA using a bioengineered microorganism. The 3HPA can subsequently be transformed into a range of valuable chemical derivatives, including acrylic acid that can be used to make polymers for use in a range of applications, including coatings.[197]

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[195] Camford Chemical Report, June 24, 2013
[196] Lignol Inc. http://www.lignol.ca/news/News-2012/Lignol%20Press%20Release%20HP-L%20sale%20Apr%2024%20final%20for%20Fasken.pdf
[197] Camford Chemical Report, January 28, 2008

7.3 Adhesives and Sealants

Adhesives, sealants, adhesive primers, and sealant primers are used in manufacturing, packaging, construction, and by consumers. They are used on a range of materials such as metal, wood, rubber, plastic, ceramics, fiberglass and composites. Adhesives are used for joining surfaces in assembly and construction of a large variety of products. A sealant is a material with adhesive properties that is used primarily to fill and seal durably, openings between two surfaces to prevent the passage of liquids, solids or gases.[198]

Adhesives and sealants are formulated by compounding (mixing) the base polymeric materials with fillers, pigments, stabilizers, plasticizers and other additives to yield a product with the desired end-use characteristics at an acceptable cost. Low-to-medium performance products are based on natural substances (e.g. starch, dextrin, natural rubber or protein) or synthetic polymers. High performance products have enhanced properties including bond strength, elongation capacity, durability or environmental resistance. These products, based on such polymers as epoxy, polyamide, polysulphide, polyurethane, cyanoacrylate and silicone, are mostly imported, because current Canadian domestic demand is not sufficient to justify domestic production.

The adhesive and sealant industry on a raw material basis is linked to suppliers of resins, starches, rubber, dextrins, synthetic rubbers, pigments, solvents and packaging suppliers. There are many different resins used by adhesive and sealant formulators. For instance, polyvinyl chloride (PVC), ABS, EVA, polyvinyl acetate (PVA), styrene-butadiene rubber (SBR), polyethylene, epoxy, epoxy hardeners; phenolic resins, styrene ethyl butylene styrene, polybutylene, chloroprene; bisphenol resin,. natural rubber, acrylics, asphalt, hydrocarbon resins, silicone, neoprene, and block co-polymers are used. Most large adhesive and sealant manufacturers are backward integrated, at least for a portion of their raw materials. Smaller firms rely on purchased raw materials, lacking the size to justify vertical integration. Both large and small producers purchase significant resin quantities.

The trend within the adhesive and sealant manufacturing sector has been an evolution away from volatile organic solvent (VOC)-based technology to lower emission alternatives (e.g. water based and hot melts). Generally, adhesive manufacturers are continually searching for alternatives to solvent-based formulations that are cost effective and provide equal performance.

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[198] Industry Canada, *Adhesives and Sealants*, accessed at http://www.ic.gc.ca/eic/site/chemicals-chimiques.nsf/eng/bt01165.html on December 22, 2008. This industry does not include production of wood panel adhesives that are typically made at wood panelboard facilities from basic raw materials (e.g., formaldehyde, phenol, urea, etc.). This industry is included in NAICS 3212: Veneer, Plywood and Engineered Wood Product Manufacturing

Table 71: Manufacturing Technologies for Adhesive and Sealants

Technology	Solvent Content
Water-based	0-30%
Hot melt	Negligible
Solvent based	30-90%
Other (i.e. reactives, UV radiation)	Negligible

Source: Cheminfo Services Inc.

Adhesive and sealants manufacturing facilities in Canada typically involve small, batch operations. Due to unique Canadian conditions (e.g. geography, population, climate), Canadian plants usually produce a wide array of products in order to serve the spectrum of Canadian market demands. Most Canadian adhesive formulators have determined it is necessary to be diversified in their product lines because seldom is there a single domestic market segment large enough by itself to support a company's overhead in R&D, technical service and selling expenses. In contrast to Canadian operations, U.S. manufacturing facilities are more likely to concentrate production on specific products in order to maximize benefits of higher-volume operations.

The apparent domestic market for adhesives and sealants in Canada in 2010 was $928 million. The Canadian market (domestic consumption) for adhesives and sealants declined over the last decade. One of the reasons has been the reduction in manufacturing activity in Canada. This has included reduced automobile production. In fact, Canadian manufacturing shipments of adhesives and sealants dropped 38% between 2003 and 2010, the trade deficit grew, and employment declined.

Table 72: Economic Statistics on the Adhesives and Sealants Industry in Canada

($ millions)

Year	Shipments	Imports	Exports	Domestic Consumption	Net Trade	Establishments	Employment
2003	$759	$478	$190	$1,047	-$288	69	2,458
2004	$770	$489	$216	$1,043	-$273	81	2,425
2005	$672	$520	$248	$944	-$272	76	1,983
2006	$611	$532	$241	$902	-$291	73	1,756
2007	$609	$557	$236	$930	-$321	74	1,810
2008	$588	$568	$205	$951	-$363	77	1,971
2009	$519	$589	$165	$943	-$424	66	1,704
2010	$470	$596	$138	$928	-$458	66	1,470

Source: Industry Canada, http://www.ic.gc.ca/eic/site/chemicals-chimiques.nsf/eng/h_bt01181.html

It is roughly estimated that there are 230 kilotonnes of adhesives and sealants consumed in Canada each year.[199] The demand for adhesives and sealants in Alberta is estimated to be between 3-5% of the total or about 10 kilotonnes. Demand is concentrated in Ontario and Quebec, where there is greater manufacturing activity, including packaging and automobile assembly. Demand in Alberta would be more dependent on construction, consumer and woodworking.

Table 73: Canadian Adhesives and Sealants Demand by Market Segment

End-Use Segment	% of Total Demand
Packaging paper, board & related products	30-40%
Construction	20-25%
General manufacturing, tires, etc.	15-20%
Woodworking	5-10%
Vehicle assembly	5-10%
Consumer/do-it-yourself (retail)	5-10%
Footwear, leather	1-3%
Miscellaneous	1-10%

Source: The Adhesives and Sealants Council, *2007-2010 North American Market Study for Adhesives and Sealants with a Global Overview – 2008 Edition*, published in 2008.
Cheminfo Services estimates

There are approximately 69 adhesive manufacturing facilities in Canada, primarily located in Ontario and Quebec. Only several are located in Alberta.

Table 74: Number of Establishments in Adhesive and Sealants Industry

Province or Territory	Employers	Non-Employers/ Indeterminate	Total	% of Canada
Alberta	2	1	3	4.3%
British Columbia	4	0	4	5.8%
Manitoba	2	0	2	2.9%
Nova Scotia	1	0	1	1.4%
Ontario	26	10	36	52.2%
Quebec	18	3	21	30.4%
Saskatchewan	2	0	2	2.9%
CANADA	55	14	69	100%
Percent Distribution	79.7%	20.3%	100%	

Source: Statistics Canada, Canadian Business Patterns Database, December 2011.

[199] Cheminfo Services Inc.

Adhesives and sealants offer a potential market for solvents, chemical reactants, and some polymers that might be able to be made from renewable bioresources. Alberta has only a few adhesives and sealant manufacturers, so Alberta production of such biochemicals would need to be shipped to other provinces and U.S. markets.

Some of the developments to incorporate more biochemicals and biopolymers into adhesives and sealants are similar to those for coatings – as the resin used as similar.

7.4 Toiletries and cosmetics

The toiletries and cosmetics industry (NAICS 32562)[200] is comprised of establishments primarily engaged in preparing, blending and compounding products such as shaving preparations; deodorants, anti-perspirants, colognes, hair dyes, face creams (e.g., cleansing, moisturizing), foundations, lipsticks, nail polishes, perfumes, sunscreen lotions and oils, suntan products, and many other consumer items.

Similar to soaps and cleaners, the value of Canadian manufacturing shipments of toiletries and cosmetics have been declining, imports have been increasing and the trade deficit has been widening. Generally, manufacturing of products has migrated – mostly to the United States, where parent companies of Canadian subsidiaries operate large efficient facilities. After the free-trade agreement took effect in the late 1980s, many firms rationalized operations and in some cases Canadian operations were given North American or global product mandates. One example was S.C. Johnson. However, medium-sized Canadian manufacturing facilities of U.S. parents that could not attract a product mandate or were not competitive were closed and the Canadian market was supplied with imports.

Table 75: Economic Statistics on the Toiletries and Cosmetics Industry in Canada

($ millions)

Year	Shipments	Imports	Exports	Domestic Consumption	Net Trade	Establishments
2003	$1,451	$1,582	$1,016	$2,017	-$566	170
2004	$1,387	$1,654	$1,159	$1,882	-$495	328
2005	$1,375	$1,707	$1,245	$1,837	-$462	320
2006	$1,433	$1,801	$1,242	$1,992	-$559	286
2007	$1,330	$1,864	$1,309	$1,885	-$555	272
2008	$1,270	$2,011	$1,388	$1,893	-$623	269
2009	$1,270	$2,079	$1,342	$2,007	-$737	258
2010	$1,250	$2,111	$1,414	$1,947	-$697	258

Source: Industry Canada, http://www.ic.gc.ca/eic/site/chemicals-chimiques.nsf/eng/h_bt01181.html

[200] Industry is also referred to collectively as "toiletries".

Some of the key success factors in this industry include: developing and maintaining brand awareness through large expenditures in mass advertising; custom formulations to meet regional demands; good distribution capabilities to service distance markets from central manufacturing facilities.

Close to three quarters of the establishments are located in Ontario and Quebec. About 5% of the establishments are in Alberta and most of these are involved with supplying toiletries rather than cosmetics.

Table 76: Number of Establishments in Canadian Toiletries and Cosmetics industry

Province or Territory	Employers	Non-Employers/ Indeterminate	Total	% of Canada
Alberta	**6**	**8**	**14**	**4.9%**
British Columbia	32	13	45	15.9%
Manitoba	3	0	3	1.1%
Nova Scotia	0	1	1	0.4%
Nunavut	0	0	0	0.0%
Ontario	67	54	121	42.8%
Prince Edward Island	0	0	0	0.0%
Quebec	59	36	95	33.6%
Saskatchewan	1	2	3	1.1%
Yukon Territories	0	1	1	0.4%
CANADA	168	115	283	100%
Percent Distribution	59.4%	40.6%	100%	

Source: Statistics Canada, Canadian Business Patterns Database, December 2011.

7.5 Pesticides

The Pesticide and Other Agricultural Chemical Manufacturing industry (NAICS 32532) includes establishments primarily engaged in manufacturing agricultural chemicals, except fertilizers. Establishments engaged in manufacturing household pest control products are included. Examples of products manufactured by these establishments, include:[201]

- fungicides
- herbicides
- insecticides
- pesticides
- rodenticides
- plant growth regulators
- soil conditioning preparations
- tick powder or spray

In 2010 manufacturing shipments for pesticide manufacturing industry were $880 million, with total domestic consumption of $1,866 million. The trade deficit was $986 million, with only $104 million of exports, and $1,090 million of imports. The great majority of the trade in pesticides is with the United States, although Canada also imports from Germany, the United Kingdom, France and other countries.[202]

Table 77: Economic Statistics on the Pesticides Industry in Canada

($ millions)

	Shipments	Imports	Exports	Domestic Consumption	Net Trade	Establishments	Employment
2003	$496	$816	$161	$1,151	($655)	27	702
2004	$597	$868	$153	$1,312	($715)	39	681
2005	$596	$861	$134	$1,323	($727)	36	479
2006	$598	$940	$129	$1,409	($811)	36	482
2007	$682	$965	$110	$1,537	($855)	32	581
2008	$869	$1,147	$108	$1,908	($1,039)	37	699
2009	$970	$1,302	$119	$2,153	($1,183)	35	745
2010	$880	$1,090	$104	$1,866	($986)	35	640

Source: Industry Canada, http://www.ic.gc.ca/eic/site/chemicals-chimiques.nsf/eng/h_bt01181.html

Herbicides account for the majority of the value and volume of pesticides sales in Canada. Fungicides and insecticides are much lower. Pesticides are used in all regions of Canada. However, the large crop growing areas in Western Canada account for a sizable portion of Canadian demand.

[201] These example activities are provided under the North American Industry Classification System. It is recognized that "pesticides" is a broad term and that "soil conditioning preparations" may not include pest control products.
[202] Industry Canada, *Trade Data Online*, Trade by Industry, NAICS 32532.

Table 78: Sales of Pesticide Types in Canada

Type of Pesticide	% of Total Sales in 2009
Herbicides	76%
Fungicides	13%
Insecticides	3%
Other products	8%
Total	100%

Source: CropLife Canada[203]

Active ingredients are contained in powder and liquid concentrate forms. They are blended with other ingredients (inert chemicals) prior to application. Pesticide products may include surfactants (e.g., wetting agents, dispersants), emulsifiers, anti-freeze, defoamers, stabilizers, pigments/dyes, buffers, hydrocarbon solvents, other specialty chemicals, and water. Products are applied in different forms, such as: dry, sprayable powders and dispersible granules; liquid sprayable concentrates, emulsions and microencapsulated particles; and dry spreadable granule on inert or fertilizer carrier.[204]

The key business success factors include: the ability to design, make and test active complex ingredients; obtain and protect patents; register products with suitable government authorities (i.e., Health Canada's Pest Management Regulatory Agency- PMRA in Canada); and establish distribution channels to access agriculture, household (retail) and other markets. The development of active ingredients is an expensive process involving large investments.

The production of pesticide active ingredients in North America is a concentrated industry. There are about a dozen firms that account for most of the production of complex pesticide organic active ingredient chemicals in North America. These include companies such as Monsanto, Dow AgroSciences, Chemtura, BASF, Bayer and Syngenta CropScience. Only Chemtura, which makes a type of fungicide at the Elmira, ON facility, is a known producer of active ingredient in Canada. The great majority of active ingredients are imported as concentrate solutions, which can be blended, diluted, and packaged for distribution in Canada.

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[203] CropLife Canada (2011), *Croplife Canada 2009/10 Annual Report*.
[204] Terry Gouge (Formulations Development at Bayer ES) (2010) Understanding Pesticide Formulations. Presentation. Available at:
http://www.cdpr.ca.gov/docs/emon/surfwtr/presentations/gouge_formulation_050510.pdf

There were 39 pesticide manufacturing establishments in Canada in December 2011. Almost 40% of the sector was located in Ontario, with a large portion of the remainder located in western Canada. There are four establishments Alberta, two of them are non-employers/indeterminate establishments.

Table 79: Number of Establishments in the Pesticides Manufacturing industry

Province or Territory	Employers	Non-Employers/ Indeterminate	Total	% of Canada
Alberta	2	2	4	10.3%
British Columbia	2	4	6	15.4%
Manitoba	2	1	3	7.7%
New Brunswick	1	0	1	2.6%
Newfoundland and Labrador	0	0	0	0.0%
Northwest Territories	0	0	0	0.0%
Nova Scotia	0	0	0	0.0%
Nunavut	0	0	0	0.0%
Ontario	11	4	15	38.5%
Prince Edward Island	1	0	1	2.6%
Quebec	3	2	5	12.8%
Saskatchewan	3	1	4	10.3%
Yukon Territories	0	0	0	0.0%
CANADA	25	14	39	100%
Percent Distribution	64.1%	35.9%	100%	

Source: Statistics Canada, Canadian Business Patterns Database, December 2011.

There have been a variety of business pressures on the pesticide industry, including environmental pressures. These are influencing the industry to reduce the negative environmental impacts of products and develop new products, some of which are biological pesticide agents. There has also been a trend to reduce VOC and hazardous/toxics ingredient content of pesticide formulations. With interests to enhance sustainability and demonstrate a move toward “greener” technologies, there may be interest for pesticide formulators to incorporate more bio-based chemicals in their formulations.

7.6 Explosives

The primary explosives manufacturing industry produces explosives and related demolition products. The North American Industry Classification System (NAICS) 325920 classifies the following as primary explosive products: azides explosive materials; blasting powders; nitroglycerin explosive materials; and TNT (trinitrotoluene); gunpowder; and dynamite. The industry also supplies fuses, detonating, safety and other items. It should be noted that producers of ammonium nitrate, which is a chemical (and a fertilizer) that can be combined with hydrocarbons (e.g., diesel) and other ingredients to produce a primary explosive, may not be classified as part of the explosives industry under NAICS 325920. They may be included under other chemical NAICS (e.g., 3253 – Chemical Fertilizers). Nevertheless, they are included as part of this section since some primary explosives producers are also involved in making raw materials, such as ammonium nitrate.

Explosive products are mostly used by the coal mining industry, which consumes 67% of primary explosives products. Smaller end-uses of primary explosive products are non-metal mining and quarrying, construction and demolition, metal mining, and miscellaneous industries.[205]

Manufacturing revenues in the explosives industry were $360 million in 2010. Total revenues, which include sale of imported and resold products, were $461 million. Total revenues have increased from $270 million in 2001 or by 6.1% per year on average. Canada exports much of its primary explosive products. Its largest trading partner is the United States. The trade surplus, which was small in 2003, has grown at an average rate of 35% per year, from 2003 to 2012.[206]

Table 80: Trends in Explosives Imports for Canada
($ million)

Imports	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2012 % of Total
United States	$72	$95	$102	$103	$103	$107	$83	$111	$127	$124	70%
Mexico	$9	$7	$6	$7	$15	$19	$17	$23	$28	$30	17%
Sweden	$0.1	$0	$1	$2	$0.5	$4	$6	$30	$4	$9	5%
Germany	$11	$19	$23	$24	$31	$22	$17	$14	$5	$3	2%
Japan	$0	$0.1	$0	$23	$0	$0	$0	$1	$2	$3	2%
Norway	$0.3	$0.4	$1	$0.4	$1	$1	$2	$1	$2	$2	1%
United Kingdom	$0	$0	$0.3	$1	$1	$2	$1	$1	$1	$2	1%
Spain	$2	$2	$3	$1	$1	$1	$1	$1	$2	$1	1%
France	$0.4	$1	$1	$0	$0	$541	$741	$292	$1	$1	1%
Italy	$0	$0	$0	$0	$0	$0.1	$0.4	$0.3	$1	$1	1%
Others	$8	$11	$14	$11	$6	$12	$8	$6	$3	$2	1%
Total All Countries	**$103**	**$136**	**$151**	**$148**	**$159**	**$169**	**$136**	**$189**	**$175**	**$177**	**100%**

[205] Source: US Geological Survey: Commodity: Explosives - http://minerals.usgs.gov/minerals/pubs/commodity/explosives/explomyb04.pdf
[206] Industry Canada, Explosives Manufacturing, http://www.ic.gc.ca/cis-sic/cis-sic.nsf/IDE/cis-sic32592tabe.html

Table 81: Trends in Explosives Exports for Canada
($ million)

Exports	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2012 % of Total
United States	$99	$125	$124	$141	$125	$133	$142	$167	$147	$162	65%
Chile	$0	$0	$0	$0	$2	$2	$8	$11	$15	$19	8%
Mexico	$0	$0.2	$1	$2	$5	$7	$8	$8	$11	$14	6%
Australia	$0.8	$0.8	$0.5	$0.6	$1	$6	$11	$8	$20	$12	5%
Peru	$0	$0	$0	$0	$0	$0	$0.9	$3	$7	$8	3%
Colombia	$0	$0	$0	$0	$0	$0	$0.9	$5	$5	$6	2%
China	$1	$2	$2	$1	$3	$4	$3	$3	$4	$5	2%
Sweden	$0	$0	$0	$0	$0.3	$1	$3	$5	$5	$4	2%
Brazil	$0.1	$0.2	$1	$0	$0	$1	$1	$3	$2	$4	2%
Zambia	$0	$0	$0	$0	$0	$0	$0	$0	$0	$3	1%
Others	$5	$6	$6	$6	$5	$6	$5	$10	$16	$12	5%
Total All Countries	**$106**	**$134**	**$135**	**$151**	**$142**	**$158**	**$183**	**$224**	**$231**	**$249**	**100%**
Total Trade Surplus	**$4**	**-$2**	**-$16**	**$2**	**-$18**	**-$11**	**$47**	**$35**	**$55**	**$72**	

Source: Industry Canada Trade Data Online – NAICS 325920

There are upwards of 56 manufacturing establishments in the Canadian explosives industry. Most of these not primary explosives manufacturers. They purchase primary explosives and other items to make products. Seven such establishments are in Alberta. Alberta's large coal mining industry represents an important market for explosives.

Table 82: Number of Establishments in Explosives Manufacturing Industry

Province or Territory	Employers	Non-Employers/ Indeterminate	Total	% of Canada
Alberta	7	0	7	12.5%
British Columbia	9	0	9	16.1%
Manitoba	1	0	1	1.8%
New Brunswick	2	0	2	3.6%
Newfoundland and Labrador	3	0	3	5.4%
Northwest Territories	2	0	2	3.6%
Nova Scotia	1	0	1	1.8%
Nunavut	1	0	1	1.8%
Ontario	10	2	12	21.4%
Prince Edward Island	0	0	0	0.0%
Quebec	15	1	16	28.6%
Saskatchewan	1	0	1	1.8%
Yukon Territories	1	0	1	1.8%
CANADA	53	3	56	100%
Percent Distribution	94.6%	5.4%	100%	

Source: Statistics Canada, Canadian Business Patterns Database, December 2011.

There are three major primary explosives manufacturing companies in Canada. Orica Canada (OC) operates an ammonium nitrate production facility in Carseland, Alberta. The company also manufacturers blasting caps, detonation cord, and delaying elements.[207] General Dynamics Ordinance and Tactical Systems – Canada Valleyfield Inc, (GDOTS-CV), which was founded in 1940, is a Canadian branch of an American manufacturer of ammunition and explosives for military applications. It has one facility in Canada is in Sallerberry-de-Valleyfield, QC.[208] Dyno Nobel Canada (DNC) is the largest North American producer of ammonium nitrate (a major raw material of explosive products). In Canada, the American-owned company, specializes in producing prepared explosives that do not include propellant powder (e.g., gunpowder or smokeless powder).[209]

Table 83: Canadian Explosives Manufacturing Facilities

Company	Location	Employees
Dyno Nobel Canada	North Bay, ON	20
	Lower Sackville, NS	10
	Ormstown, QC	20
	Sainte-Sophie, QC	15
	Garson, ON	10
	South Porcupine, ON	10
General Dynamics	Sallerberry-de-Valleyfield, QC	380
Orica Canada	Brownsburg-Chatham, QC	700
	Tappen, BC	23
Total		1,188

Source: Environment Canada, National Pollutant Release Inventory
Excludes ammonium nitrate production facilities.

It might be possible to make some explosive products using bio-based chemicals. For example, producers of ANFO, which is largely a blend of ammonium nitrate (e.g., 90%) and fuel oil (or diesel, kerosene) (e.g., 10%), might consider the use of a bio-based hydrocarbon source. This would reduce greenhouse gas emissions related to use of the explosive.

[207] Source: Company Website, Industry Canada: Explosives: Company Directory
[208] Source: Company Website, Industry Canada: Explosives: Company Directory
[209] Source: Company Website, Industry Canada: Explosives: Company Directory

7.7 Dyes and Pigments

The dyes and pigments industry is part of the chemicals industry and included under NAICS code 32513.[210] This industry is comprised of establishments primarily engaged in manufacturing organic and inorganic colouring agents that are pure or mixed with solvents, substrates, and other ingredients.

Working definitions for pigments and dyes for the purposes are as follows. Pigments are coloured particulate organic and inorganic solids. They are usually insoluble in, and essentially physically and chemically unaffected by, the vehicle (e.g., solvent) or substrate (e.g., polymer, paper) in which they are incorporated. They alter appearance and colour by selective absorption and/or by scattering of light. Pigments are usually dispersed in vehicles or substrates for application, as for instance in inks, paints, plastics, or other polymeric materials. Dyes are applied to substrates (e.g., textiles, paper, plastics, hair) as liquids in which they are totally or at least partially soluble. As opposed to pigments, dyes have an affinity for the substrate.[211, 212]

There are a great many dyes and pigments, differing in chemical composition. Over the last 145 years, there have been several million colourants produced, while about 15,000 have been made on an industrial scale.[213] The number in current commercial use is unknown, but it is reasonable to assume it involves thousands of products. Furthermore, there are numerous blends/mixtures, grades and concentrations sold in the marketplace.

Inorganic pigments can be made from minerals, metallic ores, metals and inorganic chemicals. Examples include titanium dioxide (white), iron oxides (umber) as well as other oxides of various colours. There are also other forms of pigments such as sulphates, carbonates, nitrates, and sulphides of chromium, cadmium, cobalt, zinc, lead, selenium, calcium, barium, as well as other metallic or non-metallic ions. Organic pigments are based on carbon-containing materials. Carbon black is an organic pigment, [214] although there are much more complex organic pigments. Organic dyes are derived from organic raw materials and are soluble in vehicles and application substrates.

Making complex dyes and organic pigments can involve multiple chemical synthesis reactions, which start from basic chemicals and are carried out in liquid media. Production

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[210] This NAICS code refers to the “Synthetic Dyes and Pigments” industry. While there are synthetic and manmade sources of raw materials and products, for the purposes of this report, a distinction is not made – one reason being that separate data on synthetic and natural products are not readily available.
[211] Merchak, Paul (2012) *Colored Organic Pigments*. Abstract. Based on definitions proposed by Color Pigments Manufacturers Association (CPMA)
Available at: http://www.astm.org/DIGITAL_LIBRARY/MNL/PAGES/MNL12201M.htm
[212] Zollinger, H. (2003). *Color Chemistry. Synthesis, Properties and Applications of Organic Dyes and Pigments*, 3rd ed. Weinheim: Wiley-VCH.
[213] Ibid
[214] Although sometimes considered an inorganic pigment.

typically involves relatively small facilities, using small vessels and liquids handling equipment. Making inorganic pigments typically involves grinding, particle sizing, drying, some inorganic chemical reactions in liquids, chemical purification and solids processing equipment.

Table 84: Manufacturing Aspects of Pigments and Dyes

Type of Product	Manufacturing Processes involved	Scale of Annual Production per Manufacturing Facility Annual Quantities	Number of Products Per Manufacturing Facility	Product Examples
Inorganic Pigments	Minerals processing, grinding, drying, high temperature calcination, inorganic chemistry, drying, solids separation and sizing.	Mostly high annual quantities per facility. Typically 5,000 to 300,000 tonnes per year.	One or a few per facility	Titanium dioxide, Iron oxide, Chromates, Mixed metal oxides.
Organic pigments and dyes	Complex organic synthesis (chemical reactions), liquid separation, liquids processing.	Mostly low annual quantities per facility. Typically 1 to 20,000 tonnes per year.	One to thousands	Litho red, diarlylide yellows, carbazole violet, alizarine maroon, methylene blue, indanthrone

Sources: Cheminfo Services files, Camford Information Services, Zollinger[215]

The value of domestic consumption of dyes and pigments in Canada was approximately $583 million in 2010. Total Canadian demand has been declining, with 2010 demand being about 40% below 2000 levels. A weakening manufacturing sector has been one of the factors contributing to the decline in the Canadian market.

[215] Zollinger, H. (2003). *Color Chemistry. Synthesis, Properties and Applications of Organic Dyes and Pigments*, 3rd ed. Weinheim: Wiley-VCH.

Table 85: Economic Statistics on the Dyes and Pigments Industry in Canada

($ millions)

Year	Shipments	Imports	Exports	Domestic Consumption	Net Trade	Establishments	Employment
2003	$557	$736	$374	$919	-$362	32	1,325
2004	$531	$743	$390	$884	-$353	32	1,228
2005	$530	$695	$431	$794	-$264	35	1,246
2006	$502	$637	$448	$691	-$189	32	1,162
2007	$465	$577	$445	$597	-$132	33	1,149
2008	$444	$569	$420	$593	-$149	34	1,144
2009	$391	$502	$373	$520	-$129	33	1,054
2010	$510	$537	$464	$583	-$73	33	910

Source: Industry Canada, http://www.ic.gc.ca/eic/site/chemicals-chimiques.nsf/eng/h_bt01181.html
Note: The above statistics do not include carbon black.

On a quantity basis, the Canadian market is dominated by inorganic pigments and more specifically, titanium dioxide. Iron oxides are a distant second. There is a host of other inorganic pigments used in Canada, including iron ferrites, sulphides, zinc oxide, chromates, and cadmium compounds. Organic pigments and dyes make up a minor portion of volumetric demand.[216,217]

Table 86: Canadian Market for Dyes and Pigments (2006)

(kilotonnes)

Product Segment	2006	% of Total
Dyes		
Acid Dyes	1	0.4%
Basic Dyes	3	1.1%
Direct Dyes	3	1.0%
Disperse Dyes	4	1.3%
Fiber Reactive Dyes	3	1.3%
Vat Dyes	1	0.3%
Fluorescent Brighteners	2	0.8%
Others	7	2.6%
Subtotal Dyes	**23**	**8.9%**
Organic Pigments	**17**	**6.4%**
Inorganic Pigments		
Titanium Dioxide	157	59.7%
Iron Oxides	30	11.4%
Others	36	13.7%
Subtotal Inorganic Pigments	**222**	**84.7%**
Total	**263**	**100.0%**

Source: Global Industry Analysts, Inc., *Pigments & Dyes – A Global Strategic Business Report*, May 2008.
More current data are not available, but the pattern of demand is not likely to have significantly changed.

[216] Freedonia Group, *Dyes and Organic Pigments to 2013*, June, 2009.
[217] Global Industry Analysts, Inc., *Pigments & Dyes – A Global Strategic Business Report*, May 2008.

Paints and coatings, printing inks, plastics, textiles, glass, ceramics and paper are the largest end-use applications for dyes and pigments. Canadian market data are not readily available, but these applications account for the majority of demand in North America.[218,219] There are numerous smaller applications, such as: leather, toners, cosmetics, toiletries, hair colouring; concrete, bricks, and fuels (e.g., gasoline).

There is a relatively small number of establishments in Canada that manufacture pigments and dyes, especially in comparison to the number of importers and users. Statistics Canada counted 34 manufacturing establishments in 2011, which were located only in Ontario, Quebec and British Columbia. No manufacturers are known to exist in Alberta.[220] The total number of dyes and pigments manufacturing establishments in Canada has remained between 32 and 34 over the last six years. In general, there is relatively low turnover in the industry. One reason for this is that the production of large volumes of inorganic pigments and carbon black requires facilities involving high capital cost to construct. This presents a barrier to entry for small potential producers. With respect to organic pigments and dyes production, there are barriers to entry presented by a requirement for strong technical capabilities in organic chemical synthesis. There are also market barriers, with suppliers offering a broad range of products being favoured to suppliers offering a limited colour product line. In addition, the overall total market for dye and pigment products is mature and has been declining in Canada. This trend may deter new entrants.

Kronos Canada and Dominion Colour Corporation are considered two of the largest primary producers in the Canadian synthetic dyes and pigments industry. Kronos Canada, which is Canada's only titanium dioxide producer, is the largest supplier in terms of quantity of primary product sold. Kronos Canada has two titanium dioxide plants (both located in Varennes, Quebec) with a total capacity of approximately 96,000 tonnes per year. The capacity of these plants is smaller than most of the competitive titanium dioxide facilities in the United States. Dominion Colour Corporation (DCC) produces both inorganic and organic pigments at its two plants in the Toronto area.

Other significant producers of inorganic pigments in Canada include Interstar Materials in Sherbrooke, Quebec (iron oxide pigments), G.H. Chemicals Inc. in St. Hyacinthe, Quebec (zinc oxide pigments), Zochem in Brampton, Ontario (zinc oxide), and Rockwood Specialties Inc. in Bromont, Quebec (iron oxide pigments).

Demand for dyes and pigments in Alberta is relatively low, possibly accounting for less than 5% of the Canadian total. Most of the imports enter Ontario while most of the rest enter Quebec. All other provinces/territories account for less than 10% of total imports. The pattern of provincial/territorial imports can be considered a first approximation of the regional pattern of demand for dyes and pigments in Canada. Ontario and Quebec are home

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[218] Freedonia Group, *Pigments to 2009: Inorganic, Organic and Specialty*, July, 2005.
[219] Freedonia Group, *Dyes and Organic Pigments to 2013*, June, 2009.
[220] Source: Statistics Canada, CANSIM, http://www5.statcan.gc.ca/cansim/a47.

to much of Canada's full manufacturing sector, and they make up a large portion of the Canadian production of paints and coatings, plastics processing, inks production, textiles manufacturing, and other major use-segments for dyes and pigments. Such products made in Ontario and Quebec are, of course, distributed across Canada (and exported), so that the final products containing imported dyes and pigments are somewhat better distributed across Canada.

Table 87: Canadian Imports of Synthetic Dyes and Pigments, by Province/Territory

(Province or Territory of Clearance) ($ millions)

Province or Territory	2007	2008	2009	2010	2011	% of 2011
Ontario	$449	$438	$394	$415	$450	77%
Quebec	$86	$88	$63	$71	$79	14%
British Columbia	$19	$18	$16	$17	$19	3%
Manitoba	$9	$10	$11	$15	$13	2%
Alberta	$7	$12	$9	$12	$12	2%
Saskatchewan	$5	$3	$4	$5	$7	1%
New Brunswick	$1	$2	$5	$4	$4	1%
Nova Scotia	$0.1	$0.1	$0.4	$0.0	$0.3	0.1%
Newfoundland and Labrador	$0.002	$0.001	$0.01	$0.001	$0.01	0.002%
Prince Edward Island	$0.0051		$0.0002			
Total	$577	$570	$502	$540	$584	100%

Source: Industry Canada (http://strategis.gc.ca/cis-sic/cis-sic.nsf/IDE/cis32513inte.html).

8. APPENDIX B: Market Profiles for Chemicals

8.1 Introduction

This section provide 34 brief profiles for chemicals. The profiles are not presented in any particular order. The information is intended to provide perspectives on the demand and production quantities, Alberta market context, and other relevant and readily available information. Brief analysis on activities involving development of biochemical processes or production are also provided where they were readily available.

8.2 Ethylene

Ethylene is a basic raw material used in Canada largely for the synthesis of so called derivatives. Alberta makes the following ethylene derivatives:

- polyethylene;
- ethylene oxide that is largely used for making ethylene glycol;
- ethylbenzene that is used to make styrene, which is used to make polystyrene; and
- alpha olefins that are largely used as comonomers in making polyethylene.

Most of the ethylene produced in Alberta is used internally or by affiliated companies (e.g., joint ventures). There are some merchant Canadian derivative producers that receive ethylene via pipeline. Very small quantities of ethylene are used for laboratory, welding and other applications, which receive ethylene in high pressure cylinders.

The total production and demand for ethylene in Alberta is about 4,000,000 tonnes per year. There are no imports into Alberta or the rest of Canada, and only negligible quantities of ethylene are exported from Canada. In Alberta, ethylene is made at two large complex integrated sites: Nova Joffre (3 plants) and Dow Fort Saskatchewan (1 plant). These companies also operate derivative or have derivative joint venture plants at these or other locations connected via pipeline. In Ontario, Nova Chemicals, which is now owned by International Petroleum Investment Company (IPIC), makes ethylene at its Corunna cracker and Imperial Oil Ltd. (IOL) has a smaller facility in Sarnia. Ethylene plants also make propylene, butadiene, isobutylene, methane and other co-products.

Ethylene is a commodity chemical that is a relatively low-priced. Its current North American value is about C$ 1,300 per tonne (59 ¢/lb). The corresponding value of total Canadian ethylene production is therefore $6-7 billion per year, with about 80% consumed in Alberta.

Ethylene is made in Alberta by stream cracking ethane, which has been extracted from natural gas. Other hydrocarbons (e.g., propane, butane) can be used but ethane yields a high amount of ethylene (i.e., ~80%) relative to all the co-products (e.g., propylene, propane, butadiene). There is a lack of market in Alberta for the co-products, which must be exported to distant North American customers. Ethylene plant economics favour ethane as the raw material. Limits on the ethane available from natural gas production in Alberta have hampered expansion of the ethylene and derivatives capacity in the province.

The key business success factors in the ethylene industry are:

- having access to low priced raw materials – largely ethane derived from natural gas;
- investing in large scale plants with good economies of scale to enable very low production costs; and
- having access to integrated derivative plants or secure merchant customers that can compete against global derivative producers.

Ethylene can be made from bioethanol. For example, Dow Chemical and Mitsui have announced plans to make bioethanol which would be converted to bioethylene. The bioethylene would be polymerized to polyethylene in large scale quantities. However, their joint-venture plans for a complex in Brazil that would be based on sugar cane have been postponed. There are bioresources available to make ethanol in Alberta, including wheat and cellulosic sources.

Additional ethylene availability should be welcomed in Alberta as derivative production could expand. One of the key challenges to "bioethylene" made via ethanol from wheat would be to produce it at a low cost and provide it at a price to derivative producers (customers) that would allow them to be competitive in global markets. Competing with ethane-based ethylene is expected to be a challenge. A potential advantage for derivative producers (say a polyethylene producer) in using bioethylene is that it would allow them to differentiate their product offering in the marketplace. There might be a price premium available for certain biopolyethylene grades derived from renewable sources in a sustainable manner. Some industry sources indicate that some consumers are willing to pay premiums for products derived from renewable sources.[221]

[221] ICIS Chemical Business (Feb. 28, 2011) *Dow Chemical Explores Methods for Producing its Key Feedstocks from Renewable Sources* (http://www.icis.com/Articles/2011/02/28/9438198/dow+studies+bio-based+propylene+routes.html

8.3 Ethylene Oxide and Ethylene Glycol

Ethylene oxide (EO) is made by oxidizing ethylene. Virtually of the ethylene oxide made in Canada is converted to mono-, di-, and tri ethylene glycol, mono ethylene glycol (EG) being the dominate product. A small amount of EO - possibly comprising 1% of total EO use in Canada, is used for ethoxylation reactions in the surfactant industry (see *Surfactants* section).

MEGlobal, which is a joint venture company owned 50/50 by Dow Chemical and Petrochemical Industries Company (PIC) of Kuwait (a wholly-owned subsidiary of Kuwait Petroleum Corporation) operates three EO/EG plants in Alberta – one in Fort Saskatchewan and two at the Prentiss site in Red Deer. Total capacity is estimated at 1,500 to 1,600 kilotonnes per year. Dow Chemical operates an ethylene plant in Fort Saskatchewan and has a joint venture with Nova Chemicals for a portion of the Joffre III ethylene plant. These plants would supply the EO/EG plants with ethylene.

About 95% of the EG produced in Canada is exported. About half of the exports are shipped to the United States, and most of the other half go to China. Mexico and Brazil have the other notable destinations for Canadian production. Canada imports relatively small quantities of EG from the United States. These imports are mostly used in Ontario and Quebec.

Table 88: Estimated Canadian Supply Demand for Ethylene Glycol

(kilotonnes)

	2010
Production	1,592
Total imports	8
Inventory change and adjustments	40
Total supply	**1,640**
Applications	
Coolant mixtures (antifreeze)	70
Solvents	10
Desiccants (oil and gas glycol dehydrators)	10
Other oil/gas uses	4
Explosives	2
Miscellaneous	1
Polyethylene terephthalate resin (PET)	0
Total domestic use	**97**
Exports	1,543
Total demand	**1,640**

Source: Cheminfo Services Inc. Includes mono, di, tri ethylene glycols.

Ethylene glycol is a commodity chemical used in a wide variety of applications, such as antifreeze / coolant formulations, a raw material for the polyester fibers, polyethylene terephthalate (PET) resin, additive in paints/coatings and other formulated chemical products, as a heat transfer fluid, and other industrial products. A portion of the glycol produced in Alberta is utilized locally by oil and gas producers operating field plants with dehydration units. Total oil and gas demand in Canada is estimated at 14 kilotonnes, and 70-80% of this would be used in Alberta.

The 2010 demand pattern for EG did not include PET resin. However in April 2011, Selenis Canada started up a PET resin plant in Montreal East, QC. Its PET resin capacity, which is about 115 kilotonnes per year, is to be expanded to 260 kilotonnes/year by 2014. This will add to Canada's consumption of ethylene glycol.

There are bioglycols offered in the market. For example, Dynalene Inc. from Pennsylvania offer bioglycols.[222] They are mixtures of glycols derived from vegetable oil. These are aimed at chemical formulation markets, such as paints and coatings, heat transfer fluids, etc.

S2G BioChem is considering southern Alberta sugarbeets as bio-glycol feedstock. Research is being conducted at the S2G pilot facility at the University of British Columbia to establish viability.[223]

8.4 Polyethylene

Polyethylene accounts for over 50% of the total volume polymers processed by the plastics industry in Canada.[224] It is generally a low priced polymer that can be easily processed using a number melting and forming technologies to make a great variety of plastic items. Total 2010 Canadian demand is estimated at close to 1,500 kilotonnes. Total Canadian capacity and production greatly exceed domestic consumption, so a large portion of production is exported to the United States, Asia and many other countries. There are various grades of polyethylene produced Canada, but there are also grades that need to be imported, which in part explains the magnitude of Canadian imports (52% of domestic consumption).

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[222] Dynalene. http://www.dynalene.com/v/vspfiles/templates/210/datasheets/Dynalene_BioGlycol_Technical_Data_Sheet.pdf

[223] Lethbridge Herald. (August 2013) *Sugar beet industry still has room for growth.* http://lethbridgeherald.com/2013/08/news/local-news/sugar-beet-industry-still-has-room-for-growth/

[224] Other polymers processed by the Canadian plastics industry include, but are not limited to: polyvinyl chloride (PVC), polystyrene (PS), polypropylene (PP), nylon, polycarbonate (PC), polyacetals, and acrylonitrile butadiene styrene (ABS). These polymers account for the great majority of total polymers processed in Canada.

The overall Canadian polyethylene market is mature, as it is in most other developed countries. Polyethylene has penetrated against substitute materials in many applications, such as glass bottles, metal pipes, paper packaging, paper bags, metal automobile parts, and metal containers.

Table 89: Estimated Canadian Polyethylene Supply/Demand
(kilotonnes)

	2010	% of Total Demand	% of Domestic Demand
Total capacity	**3,741**		
Production	3,368	81%	227%
Imports	767	19%	52%
Total supply	**4,135**	**100%**	**279%**
Demand			
Packaging films and bags	616	15%	41%
Injection molded items	241	6%	16%
Bottles, other blow molded items	219	5%	15%
Pipes and tubing	72	2%	5%
Wire & cable	75	2%	5%
Extrusion coatings, scrim	67	2%	5%
Rotational molded (large items)	30	1%	2%
All other	165	4%	11%
Canadian demand	**1,484**	**36%**	**100%**
Exports	2,654	64%	179%
Total demand	**4,139**	**100%**	**279%**

Source: Cheminfo Services Inc.

It is estimated that about half, or slightly more, of the polyethylene resin used in Canada is processed in Ontario. Ontario accounts for about 45% of all plastics processing establishments in Canada, but the province also includes some of the larger and older processors. (Establishment data are not available by type of polymer processed from Statistics Canada or Industry Canada.) There are about 200 plastics processors in Alberta, and it is likely that the majority process polyethylene. Some of these have been attracted by Alberta low cost polyethylene producers.

Table 90: Estimated Regional Demand for Polyethylene

Region	% of Domestic Demand
Ontario	50-60%
Quebec	20-30%
West	15-25%
Atlantic	1-5%

Source: Cheminfo Services Inc.

Table 91: Number of Establishments in Canadian Plastics Processing Industry

Province or Territory	Employers	Non-Employers/ Indeterminate	Total	% of Canada
Alberta	**150**	**55**	**205**	**8.4%**
British Columbia	189	79	268	11.0%
Manitoba	76	23	99	4.1%
New Brunswick	31	4	35	1.4%
Newfoundland and Labrador	7	4	11	0.5%
Northwest Territories	2	0	2	0.1%
Nova Scotia	25	8	33	1.4%
Nunavut	0	0	0	0.0%
Ontario	834	267	1,101	45.2%
Prince Edward Island	1	0	1	0.0%
Quebec	519	125	644	26.5%
Saskatchewan	23	10	33	1.4%
Yukon Territories	2	0	2	0.1%
CANADA	1,859	575	2,434	100%
Percent Distribution	76.4%	23.6%	100%	

Source: Statistics Canada, Canadian Business Patterns Database, December 2011.
Industry Canada. http://www.ic.gc.ca/eic/site/plastics-plastiques.nsf/eng/pl00291.html. NAICS code: 3262

Alberta is home to Canada's largest polyethylene production facilities. Nova Chemicals has a complex in Joffre, while Dow Chemical makes polyethylene at its Fort Saskatchewan facility. The other Canadian plants are Nova in Corunna, Ontario, and Imperial Oil Ltd in Sarnia, Ontario.

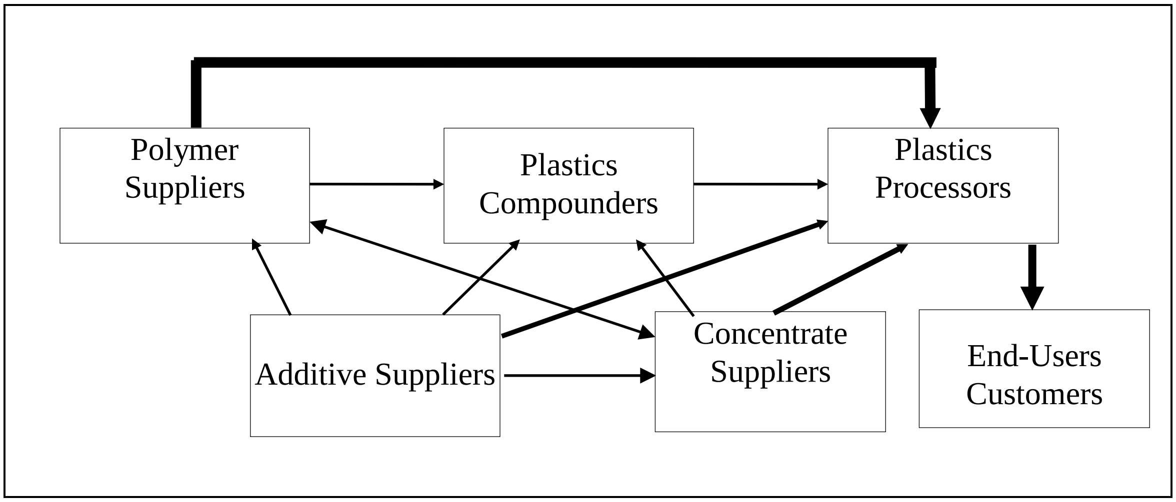
Table 92: Canada's Polyethylene Producers

Company	Location
Dow Chemical	Fort Saskatchewan, AB
Nova Chemical	Joffre, AB
Nova Chemical	Corunna, ON
Imperial Oil	Sarnia, ON

Source: Cheminfo Services Inc.

The polyethylene business system includes the primary polymer suppliers but there are other important entities. Additives are required to properly process polyethylene and to provide colour and product functionality. Additives include dyes and pigments, processing heat stabilizers, flame retardants, machine processing aids, fillers, UV inhibitors, surfactants, and other chemicals. These are added by the polymer suppliers to the raw polymer (from the polymerization reactors) or they can be added by concentrate suppliers or compounders. Some processors order concentrates rather than handle and blend a number of pigment and other additives in their facilities. Concentrates are then mixed with the polymer purchased from producers (or distributors).

Figure 8: Major Components in Polyethylene and Plastics Business System



Source: Cheminfo Services Inc.

There have been environmental pressures on the Canadian polyethylene industry. These include pressures to:

- reduce the mass flow of plastics in municipal solid waste (MSW) sent to landfills;
- increase plastic recycle rates;
- enhance biodegradability of products;
- reduce solvent VOC emissions from processing (e.g., printing on plastic films);
- reduce or eliminate use of hazardous or toxic plastic additives;
- reduce overall environmental footprint; and
- enhance sustainability performance.

As a result of these pressures, polyethylene has lost some market share to traditional and alternative materials (examples include paper sacks for yard wastes, bins for large garbage bags.)

8.5 Polystyrene

Polystyrene is thermoplastic polymer composed of the styrene monomer: a benzene ring with a C2 functional group from ethylene. Polystyrene (PS) is one of the most widely used polymers in the world with global demand estimated to be around several thousand kilotonnes per year. Some types of polystyrene may have a comonomer such as butadiene rubber in order to give the final product altered properties such as improved elasticity. Examples of these styrenic resins are styrene acrylonitrile (SAN), styrene butadiene rubber (SBR), and acrylonitrile butadiene styrene (ABS). As a resin, PS is a clear, hard, brittle polymer with diverse uses. PS is either made into rigid plastic items or expanded into a rigid, foam material. Applications as rigid plastic include CD and DVD cases, bottles, lids, trays, and disposable cutlery. Applications as foam products include thermal insulation material for homes, packaging sheet (e.g., meat trays), other sheet applications, beverage containers and food containers.

Polystyrene is derived from the polymerization of styrene monomer in a catalytic reaction. Styrene is produced from the catalytic reaction of benzene and ethylene to form ethyl-benzene following by a dehydrogenation reaction to yield styrene. Polystyrene has a variety of uses, including foam and resin applications. Canadian 2010 polystyrene demand is estimated at 130-160 kilotonnes per year. It is roughly estimated that demand in Alberta is 10% of the total.

Table 93: Estimates Canadian Demand for Polystyrene

End-use	**% of Canadian Use**
Packaging and other sheet items	15-20%
Injection molded cups, housewares	15-20%
Other injection molded items	20-25%
Packaging foam	10-15%
Extruded foams	10-15%
Expandable polystyrene (EPS) insulation	10-15%
EPS molded cups, and other shapes	5-10%
Total (kilotonnes)	130-160

Source: Cummings, J. (Editor). (2010). *C2+ Petrochemical Report*

Polystyrene resin is predominantly imported to Canada where it is then processed into final products. Polystyrene foam has low density and is often manufactured on-site rather than imported to reduce transportation costs. Major US producers of the resin in North America include BASF (Altamira, Mexico), Nova Chemicals Inc. (Monaca, PA and Painesville, OH), and Flint Hills Resources Inc. (Peru, IL and Fort Worth, TX). In terms of Canadian producers, Plasti-Fab manufactures EPS resin in Crossfield, Alberta with this production used exclusively for their own production of EPS foam insulation products (as well as other EPS products) at their six manufacturing locations in Canada. Plasti-Fab also sources EPS resin from other suppliers to supplement their own needs and for use in specialty products.[225] The other two resin manufacturers in Canada are NexKemia (formerly Huntsman Polymers) in Mansonville, QC and StyroChem in Montreal, QC. The table below lists the Canadian resin manufacturers. Their capacities range from 10 to 60 kilotonnes per year.[226]

Table 94: Polystyrene Resin Production Facilities in Canada

Facility Name	Location
NexKemia	Mansonville, QC
Plasti-fab	Crossfield, AB
StyroChem	Montreal, QC

Source: Cheminfo Services Inc.

As previously mentioned, Plastifab is the only Alberta-based PS resin manufacturer. However, it produces almost exclusively for its own production of expanded polystyrene (EPS) products. Three other facilities were identified in Alberta that manufacture PS products likely from imported resin. The following table lists the identified Alberta production facilities. Any new polystyrene resin producer might target these PS product manufacturers with the goal of providing them with a renewable raw material.

Table 95: Polystyrene Production Facilities in Alberta

Facility Name	Location	Capacity (kilotonne)
Plasti-fab	Crossfield, AB	Various polystyrene products
Emercor Ltd.	Calgary, AB	Structural Insulation panels
Beaver Plastics Ltd.	Edmonton, AB	Polystyrene foam items (insulation, construction, geotechnical, packaging)
Norseman Inc.	Edmonton, AB	Polystyrene foam items (insulation, construction, geotechnical, packaging)
Cas-Lin Industries	Crossfield, AB	Expanded Polystyrene (EPS) and Polyurethane (PUR) products for exterior wall, roof, and floor applications

Source: Companylistings.ca, Camford Information Services. (2001). *Polystyrene*. CPI Product Profiles.

[225] Plasti-Fab, (undated). *Expanded Polystyrene Product Solutions*, Company Brochure. Available at:. http://www.plastifab.com/technicallibrary/docs/plasti-fab_company_brochure.pdf

[226] Cheminfo Services Inc. (2012). *Use Profile Characterization for Certain Organic Flame Retardants Under the Chemicals Management Plan*

Polystyrene in all forms is predominantly traded with the United States while South Korea, Mexico, and China provide some minor imports. The following table provides a summary of the Canadian and Alberta trade in PS. At the national level, Canada has become a net exporter of expandable polystyrene since 2011. This may be due to the 2008 restart of the Mansonville, QC EPS plant by NexKemia, previously owned by Huntsman Polymers.[227] Another contributing factor to this change may be the increased output from StyroChem's Montreal facility as a result of the company's transition from production at its Fort Worth, TX facility to its facility in Canada.[228]

Table 96: Canadian and Alberta Trade in Polystyrene

	2009		2010		2011		2012	
Canada	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**
Imports	147,855	$206,325	126,259	$189,847	122,246	$199,919	121,177	$208,850
Exports	34,137	$56,413	85,842	$119,014	72,653	$106,293	60,468	$89,269
Alberta								
Imports	8,320	$11,027	2,237	$3,719	1,747	$3,132	1,547	$3,079
Exports	33	$14	275	$773	22	$16	60	$166

Source: Canadian International Merchandise Trade Database, HS: 390311: Polystyrene Expansible. HS 390319: Polystyrene, nes.

Production of strictly bio-based polystyrene is complicated due to the fact that the starting monomer, styrene, is derived from two petrochemical derivatives: benzene and ethylene. A fully bio-based polystyrene would require the biological production of styrene or ehtylbenzene; neither of which appear to be currently feasible. There are some routes to the biological production of ethylene via bio-ethanol such as the recent Dow-Mitsui joint venture to build a bioethanol plant in Brazil that will feed a bio-polyethylene facility.[229] The project is expected to begin operations in 2015. If it were possible to source all the ethylene used in the production of styrene, the resulting monomer would still be 74% of petrochemical origin since benzene makes up the bulk of the molecule. A viable, bio-based benzene process is required to significantly increase the renewable fraction of the monomer.

Benzene-based molecules are abundant in the lignin fraction of woody biomass and some biorefinery concepts have claimed that benzene might be a feasible product. A consortium of Syncom, the University of Groningen, and BioBTX B.V. released a statement in 2012

[227] NexKemia. (2010). *Site History.* Available at: http://www.nexkemia.com/about_us/site_history.aspx
[228] ICIS.com. (2011), *US Chemical Profile: Expandable Polystyrene.* Available at http://www.icis.com/Articles/2011/12/05/9513391/us+chemical+profile+expandable+polystyrene.html
[229] Biofuels Digest. (2011). *The Sugar Rush: Dow, Mitsui revive major renewables project in Brazil.* Available at: http://www.biofuelsdigest.com/bdigest/2011/07/20/the-sugar-rush-dow-mitsui-revive-major-renewables-project-in-brazil/

about the production of bio based benzene, toluene, and xylene from waste biomass.[230] At present, a bio-based replacement for styrene seems unlikely given that it relies on two unexplored pathways. There has been some interest recently in biological replacements for polystyrene that are not polymeric in nature. One such technology involves a freeze-dried mixture of clay and milk protein that can be molded into cups and provide similar insulation and performance to expandable polystyrene cups. The research was conducted at Case Western Reserve University in Cleveland, OH and has since spun off a company called Aeroclay Inc. to produce polystyrene replacement products.[231]

Another innovative bio-based replacement for polystyrene has been developed by Ecovative Design in Green Island, NY. This technology uses biomass waste such as seed husks as a substrate to grow mycelium, the vegetative portion of a fungus similar to a plant's roots. The mycelium grows on the substrate and forms a foam-like structure similar to expanded polystyrene packaging foam. Various molds are used to give the product its desired shape. Upon heating, the fungus is rendered inert and the product can be used for packaging material, building composites, and insulation. The company has been supported by the USEPA, the USDA and has recently announced a partnership with Sealed Air to expand production of their packaging material.[232] A Dutch polystyrene company, Synbra Technology bv, has licensed a PLA production technology developed by Sulzer Ltd. which will be used to produce PLA foam. This foam is being marketed as a bio-based replacement for expanded polystyrene foam packaging and uses CO_2 as a blowing agent. Synbra's plant will have a capacity of 5,000 tonnes per year and has been in full production since 2010.[233]

8.6 Hydrogen

Hydrogen gas is a diatomic molecule consisting of two hydrogen atoms (H_2) and owing to its high reactivity, it is rarely found in this state. H_2 is only present at trace levels in the atmosphere and it predominantly exists bound to oxygen in the form of water or bound to carbon and nitrogen in organic matter. Hydrogen is an important commodity and has applications in several major industries. The main global uses for hydrogen are in the petroleum industry (for removing sulphur from petroleum) and in the fertilizer industry for the production of ammonia. Typically large hydrogen plants are established near or integrated with oil refineries or fertilizer plants, with the majority of that hydrogen used on-site.[234] This is largely due to the high costs of hydrogen transportation.

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[230] Syncom. (2012). *Chemicals from biomass: syncom develops green chemistry*. Available at: http://www.syncom.nl/news/138-chemicals-from-biomass-syncom-develops-green-chemistry

[231] Discovery News. (2013). *Biodegradable Styrofoam Made of Milk, Clay*. Available at: http://news.discovery.com/earth/biodegradable-styrofoam-milk-clay.htm

[232] Ecovative. (2013). http://www.ecovativedesign.com/

[233] Synbra Technologies bv. *BioFoam.* Available at: http://www.biofoam.nl/index.php

[234] Sustainable Development Technologies Canada. (2006). *Renewable Fuel - Hydrogen*

Hydrogen is primarily produced by the steam reformation of methane (as would be contained in natural gas) in the presence of a nickel-based catalyst. In this process, high pressure natural gas (which consists largely of methane) is reacted with high temperature steam (700°C-1,000°C) over the catalyst to yield hydrogen and carbon monoxide (CO). This is an endothermic reaction that requires heat to be constantly supplied, often by burning a portion of the natural gas feed. In the reformer the CO is further reacted with steam in the gas shift reaction to yield more hydrogen and CO_2. The reaction equations are shown below.[235]

$$CH_4 + H_2O \rightarrow CO + 3H_2$$
$$\underline{CO + H_2O \rightarrow CO_2 + H_2}$$
$$CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$$

Hydrogen is separated from the CO_2 and H_2O in the gas phase using a process such as pressure-swing adsorption (PSA). PSA systems have an engineered absorbent material that selectively captures CO_2 and other undesired gases but does not adsorb hydrogen. When the gas stream is passed through the PSA unit, essentially pure hydrogen is produced. The steam reformation process can be applied to many hydrocarbon fuels such as coal, refinery process gas, or propane. Another important production method is the partial oxidation of methane or other hydrocarbons. In partial oxidation, a hydrocarbon such as methane is burned in an oxygen-deficient environment resulting in the production of CO and H_2 (called syngas) along with small amounts of H_2O and CO_2. [236]

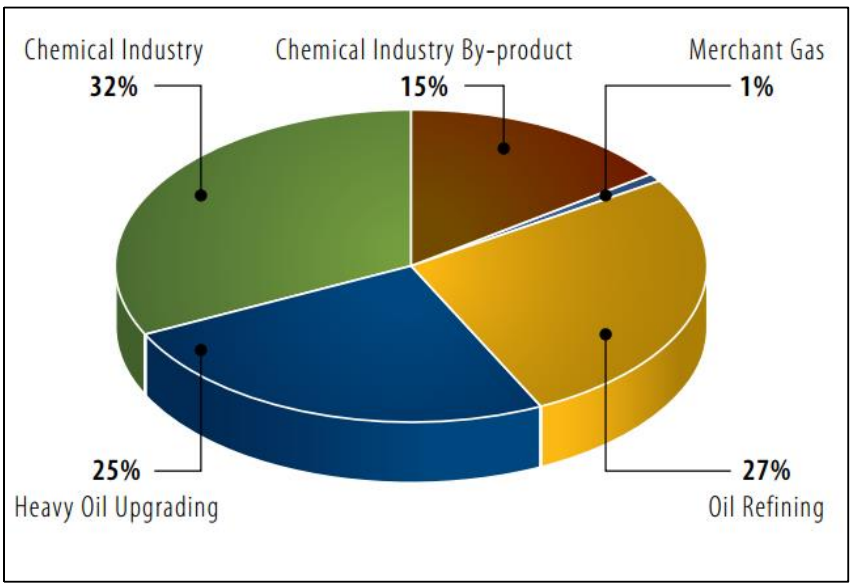
Other methods of hydrogen production include the electrolysis of water, and the potential thermal catalytic spitting of water into O_2 and H_2. There are some biological routes to hydrogen production but most are still in development. Biomass can be gasified in an oxygen-free environment to yield syngas, which is mostly carbon monoxide plus hydrogen ($CO + H_2$) from which a stream of pure hydrogen can be isolated. This is an area of active research among academia and a number of pilot facilities have been built. Nexterra is actively involved in biomass gasification and has built cogeneration systems for several sites in North America. Among their projects are gasification/cogeneration systems at Kruger Products Paper Mill (New Westminster, BC), Oak Ridge National Laboratory (Oak Ridge, TN), and the University of British Columbia (Vancouver, BC). The gasification facilities however are primarily designed to combust the syngas for heat and electricity rather than use it for hydrogen. The lack of widespread development is related to its inability to compete with the production costs of steam-methane reforming and the availability of a large biomass feed. Some types of bacteria or algae are capable of fermenting carbohydrate matter into CO_2 and H_2. Another route may be the enzymatic generation of hydrogen using an enzyme directly on the feedstock.[237] A recent paper by the American Institute of Chemical Engineers describes a process to produce hydrogen via the

[235] Department of Energy. (2012). *Alternative Fuels Data Center – Hydrogen*. Available Online at http://www.afdc.energy.gov/fuels/hydrogen.html
[236] Sustainable Development Technologies Canada. (2006). *Renewable Fuel - Hydrogen*
[237] Sustainable Development Technologies Canada. (2006). *Renewable Fuel - Hydrogen*

reformation of glycerol from the production of biodiesel; representing another biological route to H_2 production.[238]

Canada is the largest per capita producer of hydrogen in the world owing to its relatively small population and large fertilizer and petroleum industries. The oil and gas industry and fertilizer production industry both operate predominantly in the western provinces and these provinces represent the largest producers and users of hydrogen. Global production of hydrogen is 38 million tonnes/year (Mt/yr) with Canada representing 3.4 Mt/yr. Practically all hydrogen is generated via the reformation of natural gas or other fossil fuels and 90% of that demand is for heavy oil upgrading (oilsands), oil refining, ammonia production, and methanol production. The figure below shows the distribution of hydrogen production by segment in Canada. It can be reasonably assumed that all of Canada's heavy oil upgrading occurs in Western Canada and most of the Alberta demand is used at oilsands upgraders. The remainder of the hydrogen demand in Alberta is for oil refining (for hydrocrackers and hydrogenation), and in the production of ammonia.[239]

Figure 9: Uses for Canadian Hydrogen Production



Source: Sustainable Development Technologies Canada. (2006). *Renewable Fuel – Hydrogen*

[238] Iliuta, I., et al. (2013), *Hydrogen Production by Sorption-Enhanced Steam Glycerol Reforming: Sorption Kinetics and Reactor Simulation*. AIChE Journal.
[239] Sustainable Development Technologies Canada. (2006). *Renewable Fuel - Hydrogen*

Western Canada is the largest user of hydrogen in Canada and the bitumen upgrading operations likely make up the largest demand. The table below shows a breakdown of hydrogen generation capacity in Alberta circa 2004. Production at heavy oil upgrading and chemical manufacturing is generated and used on-site. Since 2005, crude oil and bitumen production from oilsands increased by 85%, from 974,000 barrels per day to 1,797,000 barrels per day in 2012[240], so hydrogen capacity and demand for sulphur removal is likely to have increased by a similar percentage.

Table 97: Hydrogen Capacity – Western Canada

(kilotonnes per year) (circa 2004)

Application	Capacity
Oil refining	198
Heavy oil upgrading	770
Chemical industry	913
Chemical industry by-product	463
Total	**2,344**

Source: Dalcor Consultants Ltd. (2004). *Canadian Hydrogen Futures*

There is little in the way of hydrogen trade since the large users generate and use it on site. Hydrogen generated as a process byproduct such as in the production of sodium chlorate production may sell hydrogen to other markets such as oil refineries, vegetable oil processing (hydrogenation) or to specialty gas distributors such as Praxair, Linde, and Air Liquide[241], who distribute the hydrogen in bulk or cylinder form. These industrial gas suppliers may also produce hydrogen for the merchant market.

Table 98: Oil and Gas Facilities with Hydrogen Capacity in Alberta

(circa 2004)

Facility Name	Location	H_2 Capacity (kilotonne)
	Oil Refineries	
Imperial Oil	Edmonton	17
Suncor	Edmonton	30
Shell	Scotford	43
	Oilsands and Upgraders	
Husky	Lloydminster	75
Albion Upgrader (Shell)	Scotford	225
Syncrude	Fort McMurray	150
Suncor	Fort McMurray	320

Source: Dalcor Consultants Ltd. (2004). *Canadian Hydrogen Futures.* (Capacities are likely to have changed since 2004.)

[240] Canadian Association of Petroleum Producers (CAPP) (June 2013) *Canadian Crude Oil Production Forecast 2013*
[241] Dalcor Consultants Ltd. (2004). *Canadian Hydrogen Futures*

The largest uses for hydrogen in the chemical production sector is in the production of ammonia via the Haber-Bosch process. In this process, nitrogen gas and hydrogen are reacted over a catalyst to form ammonia (NH_3). Urea is one of the most important forms of ammonia fertilizer and is produced by the reaction of ammonia with carbon dioxide. Another important use for hydrogen is in the production of methanol where natural gas is first converted to synthesis gas (H_2 + CO) and then reacted to form methanol (CH_3OH). The synthesis gas formation results in a surplus of hydrogen which must be sold off site. Large volumes of hydrogen are also produced at ethylene plants as a by-product and may be reused on site or sold off site. The table below lists the chemical facilities producing hydrogen in Alberta.[242]

Table 99: Chemical Facilities with Hydrogen Capacity in Alberta

(circa 2004)

Facility Name	**Location**	**H_2 Capacity (kilotonne)**
	Chemical Process Use	
Agrium (urea fertilizers)	Carseland, Fort Saskatchewan, Joffre, Redwater	252
Methanex (methanol)	Medicine Hat	150
Degussa (hydrogen peroxide)	Gibbons	3
Canadian Fertilizers (nitrogen based fertilizers)	Medicine Hat	168
Keyera (iso octane)	Edmonton	7
	Chemical Process By-Product	
Cancarb (carbon black)	Medicine Hat	26
ERCO (sodium chlorate)	Bruderheim, Grand Prairie,	8
Nexen (sodium chlorate)	Bruderheim	3
Dow LHC-1 (ethylene)	Fort Saskatchewan	140
Nova Chemicals (ethylene)	Joffre	240

Source: Dalcor Consultants Ltd. (2004). *Canadian Hydrogen Futures*. (Capacities are likely to have changed.)

Imported hydrogen is likely in the form of very high purity gas in cylinder trucks or mobile cylinders for use in areas where there are no nearby methane reformers (usually found near petroleum refineries or large chemical centres). Practically all hydrogen is imported from the USA. The overall trade balance indicates that Canada is a net exporter of hydrogen. The table below includes trade statistics for hydrogen.

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[242] Dalcor Consultants Ltd. (2004). *Canadian Hydrogen Futures*

Table 100: Canadian and Alberta Trade in Hydrogen

	2009		2010		2011		2012	
Canada	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**
Imports	2,673	$5,569	2,131	$3,499	3,029	$3,394	2,619	$3,405
Exports	13,391	$36,623	15,011	$41,054	16,124	$44,102	15,561	$42,559
Alberta								
Imports	269	$985	54	$229	218	$390	119	$363

Source: Canadian International Merchandise Trade Database, HS Code: 280410: Hydrogen

International trade in hydrogen is not an important source of hydrogen for Canada due to its abundant supply of natural gas and its oil/gas industry. The vast majority of hydrogen production and consumption occurs in integrated facilities and very little hydrogen is exported. As a result, many chemical manufacturers requiring smaller volumes of the gas will situate themselves near a large petrochemical of fertilizer facility from which they can purchase hydrogen. It is unlikely that biologically sourced hydrogen will be sold to large-volume users such as ammonia plants but there may be niche markets for small, isolated facilities requiring the gas. Such facilities would need to purchase hydrogen in compressed gas cylinders and pay a premium to obtain it. Bio-hydrogen from small gasification units or bio-reactors might be economically viable if they are able to compete with the price of hydrogen sold by specialty gas distributors (such as Linde, Praxair, Air Liquide). The majority of hydrogen demand in Alberta however, remain inaccessible to small scale hydrogen production due to the sheer size of the demand and hydrogen's high transportation costs.

8.7 Methanol

Methanol is also known as methyl alcohol or wood alcohol. Its chemical formula is CH_3OH and it is the simplest of all alcohols. It is a light, colourless, volatile liquid at room temperature. The applications methanol is used in and the estimated Canadian demand associated with those applications are shown in the table below.

Table 101: Estimated Canadian Demand for Methanol

Application	% of Total Canadian Demand
Formaldehyde (resins)	60-70%
Oil and Gas Field Chemical	10-15%
Chlorine Dioxide (Wood Pulp Bleaching)	10-15%
Windshield Washer	10-15%
Fuels (Biodiesel)	1-5%
Paints and Coatings, Adhesives, Sealants, Cleaning, other	<5%
Total (kilotonnes, 2010)	**600-700**

Source: Cheminfo Services estimates.

Methanol's main application is as a feedstock for the manufacture of other chemicals, including formaldehyde and chlorine dioxide. Approximately 62% of the Canadian demand for methanol is for the production of formaldehyde. Formaldehyde is used primarily in the production of formaldehyde resin. Three types of formaldehyde resin are produced in Canada: melamine formaldehyde (MF), phenol formaldehyde (PF), and urea formaldehyde (UF). The following Canadian facilities produce formaldehyde resins:

Table 102: Formaldehyde Resin Producers in Canada

Company	Resins Produced	Location of Plant
Arclin	MF, PF, UF	North Bay, Ontario
		Thunder Bay, Ontario
		Kamloops, British Columbia
		Sainte-Therese, Quebec
Momentive Performance Materials	UF, PF	Edmonton, Alberta
		Laval, Quebec
		North Bay, Ontario

Source: Industry Canada, Canadian Synthetic Resins Industry, http://www.ic.gc.ca/eic/site/plastics-plastiques.nsf/eng/pl01384.html

One of these facilities, owned by Momentive Performance Materials, is currently operating in Alberta. Formaldehyde resin is utilized for the production of oriented strand board (OSB), plywood, laminate flooring, fabrics, fiberglass and other applications. OSB manufacturing is currently experiencing a recovery in Canada, after the industry suffered through significant demand reductions during the recession. The Engineered Wood Association stated that there was a capacity to produce 12 billion square feet of OSB on a 3/8" basis at the market peak in 2006 and production was running at 95 per cent capacity. In 2012, production capacity was still at 9.47 billion square feet, but the industry was operating at a capacity of only 58 per cent. All of Canada's major OSB producers—Ainsworth, Tolko, Louisiana-Pacific, Georgia-Pacific, Norbord and Weyerhaeuser—all retracted operations to some extent, resulting in major curtailments or outright indefinite plant closures.[243] However, at this time, two mothballed OSB plants in Alberta are slated to be reopened. Ainsworth is preparing to restart their mill in High Level,[244] Alberta, and Tolko is restarting its mill in Slave Lake, Alberta.[245] This could potentially lead to an increase in demand of formaldehyde resins, and thus methanol over the short term. The

[243] Logging and Sawmill Journal, *Strands of Recovery Coming Together for OSB,* http://www.forestnet.com/LSJissues/june2012/strands.php

[244] The Working Forest Newspaper, *Ainsworth Preparing to Restart High Level AB OSB Mill,* http://www.workingforest.com/ainsworth-preparing-restart-high-level-ab-osb-mill/, January 17, 2013

[245] Tolko Website, *News Release – Tolko Announces Restart of Its Mill in Slave Lake, Alberta*, http://www.tolko.com/index.php/who-we-are/news/tolko-announces-restart-of-its-mill-in-slave-lake-alberta, February 12, 2013

following is a list of the current OSB facilities operating in Alberta (not including the two that are slated to reopen):

- Ainsworth Lumber Co. Ltd. - Grande Prairie;
- Footner Forest Ltd. – High Level;
- Tolko Industries – High Prairie;
- Weyerhaeuser – Edson.

Methanol has also found use in oil and gas field applications. Methanol can be used as a stabilizer in fracturing fluid, and as a corrosion and hydrate inhibitor in pipelines.[246] Although no exact figures were identified, Alberta oil and gas industry represents a sizable methanol market segment.

Two other applications of methanol are prevalent in Canada, namely the manufacture of chlorine dioxide, and windshield washer/de-icer fluids. Methanol is used as a reducing agent in the manufacture of chlorine dioxide, and chlorine dioxide is primarily utilized for the bleaching of wood pulp and the purification of municipal drinking water. Chlorine dioxide is almost always produced at the site where it is used, just prior to its utilization due to the fact that it is a very active and unstable chemical.[247] The following are the main kraft process pulp mills in Alberta:[248]

- Weyerhaeuser – Grande Prairie;
- Alpac Forest Products Inc. – Lac La Biche;
- Daishowa-Marubeni International Ltd. – Peace River; and
- West Fraser Mills Ltd. – Hinton.

Methanol is usually produced utilizing natural gas. The first step in the production process is to convert the natural gas into a synthesis gas stream consisting of CO, CO_2, H_2O and hydrogen. This is usually accomplished by the catalytic reforming of feed gas and steam. The second step is the catalytic synthesis of methanol from the synthesis gas.

There are currently two companies in Canada producing methanol, namely Methanex Corporation and Enerkem. Methanex is one of the largest methanol producers in the world, and in 2012 their global operations accounted for approximately 15% of world supply.[249]

[246] Cheminfo Services, Background Study on the Fluids/Muds and Chemicals Associated With Exploration and Production of Crude Oil, Natural Gas and Related Products, July 14, 2010
[247] Lenntech, *Optimization of a Kraft Pulp Mill Chlorine Dioxide Scrubber – With Q-PAC Repack Power Costs are Reduced by Over $80,000 per Year and Emissions are Non-Detectable,* http://www.lantecp.com/casestudy/cs35.pdf
[248] Government of Alberta, *Connecting With the Forest Industry,* http://srd.alberta.ca/LandsForests/ForestBusiness/BioproductsFromForestFibres/documents/ConnectingWithForestIndustry-Jun2010.pdf
[249] Methanex Annual Report, 2012, http://www.methanex.com/investor/documents/2013/Methanex_Annual_Report_2012.pdf

Their plant in Medicine Hat, Alberta, which was idled, was put back into production in 2011. It has a production capacity of 470,000 tonnes per year.[250]

Enerkem produces second generation biofuels (cellulosic ethanol) and methanol from their thermochemical process, using municipal solid waste (MSW) as their feedstock. Enerkem's process produces methanol, and then uses that methanol to produce cellulosic ethanol. Enerkem currently has one Canadian demonstration facility operational in Canada, located in Westbury, Quebec. This plant has a capacity of approximately 5 million litres of cellulosic ethanol per year. Additionally, Enerkem has two plants that are currently under construction, one in Edmonton, Alberta, and the other in Varennes, Quebec.[251]

The Edmonton Enerkem facility is slated to be completed in 2013, and will convert 100,000 tonnes of MSW into 38 million litres of biofuels per year.[252] Initially, however, the facility will produce only methanol, and will later utilize some of this methanol to produce ethanol. Enerkem has an offtake agreement with Methanex for their Edmonton facility, wherein Methanex will sell Enerkem's methanol production.[253]

Imports and exports of methanol in Alberta clearly show when the Alberta Methanex facility began production. Prior to 2011, when the Methanex facility was not operational, there were substantial imports of methanol (79,820 tonnes in 2010) and a negative trade balance. However, in 2011, as the Methanex facility began production, this trade balance shifted. In 2012, Alberta exported 136,370 tonnes more methanol than they imported.

Methanex has recently made an initial investment of US$5 million in Carbon Recycling International (CRI), a privately held company with headquarters in Reykjavik, Iceland. CRI operates the world's first plant to produce methanol from renewable sources. Located in Iceland, the plant utilizes the company's emissions-to- liquids (ETL) technology, which converts renewable energy and recycled CO_2 emissions into methanol.[254]

CRI markets its methanol in Europe under the Vulcanol trade name. The product is blended with gasoline and used for production of biodiesel. Vulcanol is certified by the international sustainability and carbon certification system as an ultralow carbon advanced renewable transport fuel with no biogenic footprint. Methanex and CRI intend to collaborate on large-scale projects based on the ETL technology, leveraging Methanex's operational experience

[250] Methanex Website, *Methanex in Canada*, http://www.methanex.com/ourcompany/locations_canada.html
[251] Enerkem Website, http://www.enerkem.com/en/home.html
[252] The City of Edmonton Website, http://www.edmonton.ca/for_residents/garbage_recycling/biofuels-facility.aspx
[253] Enerkem New Release, September 14, 2012, http://www.enerkem.com/assets/files/press_release/ENERKEM%20METHANEX%20OFFTAKE_newsrelease_sept2011_final_E.pdf
[254] Camford Chemical Report, *August 12, 2013.*

and global reach and CRI's unique expertise. The partners plan to concentrate their efforts on expanding the use of methanol blended fuels in Europe.[255]

Table 103: Canadian and Alberta Trade in Methanol

	2009		2010		2011		2012	
Canada	**(tonnes)**	**('$000)**	**(tonnes)**	**('$000)**	**(tonnes)**	**('$000)**	**(tonnes)**	**('$000)**
Imports	432,852	$128,451	470,634	$176,243	280,143	$144,406	185,183	$85,044
Exports	2,776	$873	5,503	$2,030	116,022	$38,039	168,130	$56,253
Alberta								
Imports	54,899	$14,611	71,820	$24,582	37,191	$14,287	21,948	$9,428
Exports	100	$32	65	$35	110,663	$35,808	158,318	$52,165

Source: Canadian International Merchandise Trade, HS 290511, Methanol, (methyl alcohol).

Production in Alberta has also had a significant effect on Canadian trade in methanol, as total Canadian imports fell from 470,634 tonnes in 2010 to 185,183 tonnes in 2012. Exports from Alberta also comprise the majority of Canadian methanol exports, accounting for 94% of total exports in 2012.

8.8 Ammonia

Ammonia is produced by reacting nitrogen and hydrogen in the presence of a catalyst at high temperature. Ammonia plants typically rely on reforming methane contained in natural gas for their hydrogen needs. Steam methane reforming (SMR) plants make hydrogen in sufficient quantities to support large scale ammonia production. Carbon dioxide is a co-product. Nitrogen is separated from oxygen present in air. Liquid cryogenic or pressure swing absorption air separation plants are typically employed to obtain the nitrogen. Oxygen is a co-product of air separation.

Methane Reforming for Hydrogen Production

$$CH_4 + 2H_2O \longrightarrow CO_2 + 4H_2$$

Ammonia Synthesis Reaction

$$N_2 + 3H_2 \longrightarrow 2NH_3$$

Total Canadian capacity for ammonia production is estimated to be between 5,500 and 6,000 kilotonnes. Production typically varies between 75% and 85% of capacity. The majority (i.e., about 65-70%) of Canada's ammonia capacity is located in Alberta. Ammonia can be used as fertilizer or used to make other fertilizers. Most facilities are integrated to urea production. Most of the urea is exported to U.S. and other fertilizer

[255] Ibid

markets. Some is used by urea formaldehyde resin producers sold to Panelboard producers. Agrium in Joffre, which relies on hydrogen from Nova ethylene operations, does not have access to carbon dioxide (from ammonia production) and is therefore not making urea. Other applications for ammonia include nitric acid, ammonium nitrate and other ammonium based fertilizers. An ammonia supply-demand balance is not readily available, one reason being the internal use for integration urea and other production.

Table 104: Location of Canada's Ammonia Producers and Their Products

(X denotes production capacity)

Company	Plant Location	Ammonia	Urea	Nitric Acid	Ammonium nitrate	Ammonium phosphate, sulphate
Agrium	**Redwater, AB**	**X**	**X**		**X**	**X**
Agrium	**Fort Sask. AB**	**X**	**X**	**X**		
Agrium	**Carseland, AB**	**X**	**X**			
Agrium	**Joffre, AB**	**X**				
Canadian Fertilizers	**Medicine Hat, AB**	**X**	**X**			
Saskferco	Belle Plaine, SK	X	X			
Koch	Brandon, MB	X	X	X	X	X
Terra Industries	Courtight, ON	X	X	X	X	

Camford Information Services, Product Profiles. Company websites.
Additional fertilizer products or mixtures may also be produced at the facilities shown.

Ammonia could be made from syngas (CO and hydrogen) derived from bioresources. A substantial amount of biomass would be required to approximate the scale of plants based on natural gas operating in Alberta.

8.9 Urea

Urea [$CO(NH_2)_2$], also known as carbamide or carbonyl diamide, is an organic chemical with the chemical formula $CO(NH_2)_2$. It is commonly produced as white crystalline powder or pellets and is a very important crop fertilizer alongside ammonia, ammonium nitrate, and ammonium phosphate. The great majority of urea is used in fertilizers (both solid and solution forms). A small portion is used in animal feed supplements. Urea is made by first reacting ammonia (NH_3) and carbon dioxide (CO_2) to form ammonium carbamate ($NH_2CO_2NH_4$). The carbamate is then dehydrated to yield 70 to 77 percent aqueous urea solution which may be dehydrated to form solid urea.[256]

[256] Cheminfo Services. (2008). *Socio-Economic Information, Compliance Options and Costs of Reducing Air Pollutant and Greenhouse Gas Emissions in the Canadian Fertilizer, Pesticide and Other Agricultural Chemicals Manufacturing Subsector*

The reactions involved are as follows:

$$2NH_3 + CO_2 \rightarrow NH_2CO_2NH_4$$

$$NH_2CO_2NH_4 \rightarrow NH_2CONH_2 + H_2O$$

The majority of domestic urea production lies in the western provinces and is dominated by Alberta due its large supply of natural gas: the main feedstock in the production of urea. Most large urea producers are integrated with onsite ammonia plants and natural gas reformers. The table below lists the existing Alberta urea manufacturers. Canadian capacity for urea has remained relatively constant with slow annual growth due the sector's maturity. Total domestic production is roughly 3,800 kilotonnes.[257]

Table 105: Urea Manufacturers in Alberta

Company	Plant Location
Agrium	Redwater, AB
	Fort Sask. AB
	Carseland, AB
Canadian Fertilizers	Medicine Hat, AB

Source: Camford Information Services, Product Profiles. Company websites

The vast majority of urea is used as an agricultural fertilizer since it has the highest nitrogen content of all solid nitrogen fertilizers. Urea is also used in the production of some polymers, namely urea-formaldehyde resins. Urea nitrate is an explosive produced from urea. Alberta represents nearly 60% of Canada's total urea exports and if Saskatchewan is considered, nearly all of Canada's urea exports are from the prairies. The following table outlines the Canadian and Alberta urea trade.[258]

Table 106: Canadian and Alberta Trade in Urea

	2009	2009	2010	2010	2011	2011	2012	2012
Canada	(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)
Imports	302,023	$133,127	569,403	$212,415	637,294	$312,464	903,478	$442,982
Exports	1,700,706	$657,826	1,733,667	$604,976	1,580,599	$729,467	1,428,368	$783,734
Alberta								
Imports	6,805	$3,133	6,303	$2,687	9,636	$4,702	39,915	$21,716
Exports	1,113,332	$456,652	1,203,501	$436,719	1,013,652	$483,214	855,709	$506,226

Source: Canadian International Merchandise Trade Database, HS 310210 Urea, whether or not in aqueous solution, in packages weighing more than 10 kg

[257] Ibid
[258] Ibid

As one of the most important chemical fertilizers in Canada and the world, there is some research activity in the production of bio-based urea. No research was identified on the direct synthesis of urea from biomass. Instead, research is focused on the renewable synthesis of urea's feedstock chemicals: CO_2, H_2 (for the production of ammonia) from the gasification of biomass. It may also be possible to produce biomethane from the anaerobic digestion of biomass to supplement natural gas in a reformer at urea plant.

BioNitrogen is an American company based in Florida that is developing small, modular urea plants with a capacity of 160 kilotonnes per year. The technology involves the gasification of waste biomass to produce syngas used in the production of urea. A demonstration plant is currently under construction in Hardee County, Florida.[259] Another US company, Agrebon, is based in Louisville, CO and offers a similar urea production process. Agrebon is in the financing stage for a plant co-located with Tharaldson Ethanol Inc. in North Dakota. Agrebon will use the biomass residue left over after the ethanol fermentation process as feedstock to their gasification unit. Much like BioNitrogen, the resulting syngas will be used to produce urea. Unlike BioNitrogen however, Agrebon's plants are small and modular with a daily output of 30 tonnes for a yearly output of approximately 10 kilotonnes.[260] No technologies were identified that produced biogas from biomass as a feed to a traditional natural gas-based ammonia/urea plant. In addition to the fact that Alberta already produces large quantities of urea, there is unlikely to be a significant market for bio-based urea in Alberta. Smaller farms may opt for a renewably sourced fertilizer if they offer organic or sustainable crop. urea may include natural replacements such as animal manure, chicken litter, or green manures (leguminous plants such as clover that fix nitrogen).

8.10 Carbon Black

Carbon black is a material produced by the incomplete combustion of heavy petroleum products such as fluid catalytic cracking tar, coal tar, ethylene cracking tar, and a small amount from vegetable oil. Carbon black is a form of amorphous carbon that has a high surface area to volume ratio.

Production of carbon black involves pyrolysis[261] or thermal cracking of hydrocarbon feedstocks. Cracking reactions, which separate the hydrogen from the carbon, occur between 1,200°C and 1,600°C. Most of the hydrocarbon raw materials come from petroleum refiners, although other hydrocarbon sources can be used such as coal tar oils or natural gas. Process yields are typically between 55% and 70%, although some plants may operate outside this

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[259] BioNitrogen. Available at: http://www.bionitrogen.com/technology-overview/
[260] Agrebon. (2012). Available at: http://www.agrebon.com/technology/
[261] Pyrolysis involves partial combustion of the hydrocarbon in a limited oxygen concentration environment.

range. Therefore, approximately 140,000 to 170,000 tonnes of raw material are required to make 100,000 tonnes of carbon black product.

There are three carbon black producers in Canada. Two of the plants are located in Ontario, and have over 80% of Canadian capacity. Both Ontario plants use oil streams as their raw material, and one plant (Columbian Chemicals) also uses coal tar oils from Rütgers Canada. The other plant, which is located in Alberta, uses natural gas as the raw material. Process yields are typically between 55% and 70%, although some plants may operate outside this range. Therefore, approximately 140,000 to 180,000 tonnes of raw material are required to make 100,000 tonnes of carbon black product.

Table 107: Capacity for Canadian Carbon Black Plants

(kilotonnes/year)

Company	Location	Capacity
Columbian Chemicals	Hamilton, ON	110
Cabot Canada	Sarnia, ON	100
Cancarb Inc.	Medicine Hat, AB	45
Total Canadian Capacity		255

Source: Cheminfo Services Inc.

Canada is a significant net exporter of carbon black and related materials. Most of this trade occurs with United States.

Table 108: Trade in Carbon Black and Related Materials

(kilotonnes)

	2009	2010	2011	2012
Imports	51	68	77	73
Exports	112	147	139	137

Source: Canadian International Merchandise Trade, HS 230800, Carbon, Carbon Blacks, and Other Forms of Carbon NES.

The Canadian market for carbon black is in the range of 150 kilotonnes per year. The most common use of carbon black is as a pigment and reinforcing phase in automobile tires. Carbon black also helps conduct heat away from the tread and belt area of the tire, reducing thermal damage and increasing tire life. The remaining 10% of use is for plastics, inks, coatings, and other applications. Carbon black particles are also employed in some radar absorbent materials and in photocopier and laser printer toner.

Table 109: Uses of Carbon Black

Use	Share
Tires and other rubbers goods	80-90%
Plastics	5-10%
Inks and Coatings	2-7%
Other	1-3%
Total	**100%**

Source: Industry sources

8.11 Carbon and Graphite Anodes

Carbon anodes are used in the aluminum and other metal producing industries. They are used in the electrolytic cells, which produce the metal (e.g., aluminium - Al^0) from metal oxides. The anodes act as electrical conductors through which passes the direct current that facilitates the dissolution of metal oxides (e.g., alumina - Al_2O_3). The aluminum industry consumes about 0.2 kilograms of carbon anode for each kilogram of aluminum produced. Industrial carbon anode is a baked composite usually made of calcined petroleum coke filler with a binder of coal-tar pitch coke. Similarly, the production of iron and steel from scrap metal often uses graphite anodes. In electric arc furnace steelmaking, the graphite electrodes conduct the electric current into the electric arc furnace where an arc is formed between the electrode tip and the scrap metal in the furnace charge. This produces the high temperatures necessary for melting the steel charge and for the metallurgical reactions taking place in the furnace.

Carbon Anodes

There are ten aluminum smelters in Canada. Nine of these -- representing 91% of smelting capacity -- are found in Quebec. The Kitimat facility in British Columbia is the only other aluminum smelter in Canada. Three companies -- Rio Tinto Alcan, Alcoa, and Alouette -- own all ten smelters. Rio Tinto Alcan owns about 50% of Canada’s aluminum smelting capacity, Alcoa about 35%, and Alouette about 15%.

The production of carbon anodes starts with green paste production. Green paste is produced from petroleum coke and coal tar pitch which acts as a binder. The coke is ground and mixed with pitch in heated mixers at a temperature between 100-150°C and pressed. This type of anode can then be used in a Söderberg cell. Prebaked anodes are also produced from the same green paste, but are baked in large furnaces at a temperature of about 1,100°C in the absence of air for about 14 days. The baking of anodes can be done at a plant at the same site where aluminum production takes place. However, there are also companies producing anodes and shipping them to their customers. In Canada, some companies bake anodes, and others import anodes.

There are two main types of aluminum smelting technologies, known as Söderberg and Prebake. The principal difference between them are the type of anodes used. Söderberg technology uses a continuous anode which is delivered to the cell in the form of a paste, and which bakes in the pot itself. Prebake technology uses multiple anodes in each cell. These anodes are pre-baked and then suspended in the cell.

The calcined petroleum coke that is used in the production of carbon anodes can be produced at the primary aluminum smelter or by off-site facilities. RioTinto Alcan operates a calcined coke plant in Strathcona, Alberta. At this location green petroleum coke, a waste product from the refining of crude oil, is heated to over 1,300°C in a rotary kiln, then cooled. The result of this process is calcined petroleum coke. RioTinto Alcan produces approximately 180,000 tonnes of calcined product annually and ships this product by rail to Alcan plants in British Columbia and Quebec, as well as Alcoa plants in Quebec, Washington State, and New York State.[262] RioTinto Alcan also operates coke calcining facilities at their aluminum smelters in Kitimat, British Columbia and Arvida, Quebec. All three plants have a combined calcining capacity of 490,000 tonnes/year.[263]

There are also merchant carbon anode producers that sell anodes to aluminum smelters. There are three known merchant carbon anode producers in the western Hemisphere, specifically (Alcoa in Lake Charles, Louisiana), Carbonorca (Venezuela) and Aluchemie (Rotterdam, Netherlands).[264]

Graphite Anodes

Meanwhile graphite electrodes are used in electric arc furnace steelmaking and in some base metal smelting operations. A graphite electrode is shaped in the form of a cylindrical rod with sockets at each end. New electrode sections are added as the graphite is consumed during use. The electrodes have similar uses in some base metal smelting operations.

[262] Alberta Industrial Heartland Association (July, 2012), *Alberta's Industrial Heartland Association – Industry and Organization Profiles*.
[263] Accessed at the website of Jacobs Consulting (http://www.petcokes.com/Pages/calciners.aspx).
[264] Mannweiler Consulting (June, 2010), *Sourcing Anodes as a Production Option – A Viable and Economic Alternative with Proven Success*.

Table 110: Canadian Electric Arc Furnace Steelmaking Facilities

Company	Location	Province	Steelmaking Capacity (million tonnes/year)
ArcelorMittal	Contrecoeur	QC	1.7
ArcelorMittal	Hamilton	ON	1.4
IPSCO Inc.	Regina	SK	1.1
Gerdau Ameristeel	Whitby	ON	1.0
ArcelorMittal	Contrecoeur	QC	0.7
Hamilton Specialty Bar	Hamilton	ON	0.4
Ivaco Rolling Mills	L'Orignal	ON	0.4
Gerdau Ameristeel	Selkirk	MB	0.4
Gerdau Ameristeel	Cambridge	ON	0.4
AltaSteel Ltd.	Edmonton	AB	0.4
Total			**7.7**

Source: Cheminfo Services Inc.

There are six known graphite electrode manufacturing facilities in North America. One is located in Canada, four in the U.S., and another company in Mexico. These facilities have a combined manufacturing capacity of 220 kilotonnes of electrodes per year.

Table 111: North American Graphite Electrode Plants

(kilotonnes/year)

Plant	Manufacturing Capacity
SGL Canada, Lachute, QC	30
SGL Carbon, Hickman, KY	60
SGL Carbon, Morgantown, NC	15
Showa Denko Carbon, Ridgeville, SC	45
Superior Graphite, Russelville, AR	10
Graftech, Monterray, Mexico	60
Total	**220**

Source: Cheminfo Services Inc. (March 19, 2010), *Technical and Socioeconomic Background Study on Coal Tars*.

The lone Canadian graphite electrode manufacturer is SGL Canada in Lachute, Quebec. The facility has the capacity to produce about 30 kt/yr of electrodes. The company sells the electrodes to electric arc furnace steel mills in Canada and the United States.

With respect to the development of bio-anodes, this research has been led by *the Commonwealth Scientific and Industrial Research Organisation* (CSIRO) in Australia. There has been a trend (in Australia) of declining quality of petroleum coke and the level of impurities is also increasing in petroleum-based carbon anodes. This has been particularly concerning to the aluminium industry because this reduces anode performance, contributes to corrosive gases in the exhaust stream, and contaminates the aluminium metal product. These supply issues, combined with an increased awareness and preparedness to reduce greenhouse gas emissions, has resulted in the aluminium industry considering the possibility of replacing fossil-based carbon anodes with low ash, renewable carbon-based biocoke[265] (i.e. use of wood char to produce carbon anodes).[266] Biomass is an attractive alternative because it is renewable and has low sulphur and ash content. Using biomass for anodes production would also make the process greenhouse gas neutral – carbon dioxide liberated in the production process is absorbed by the successive growing of trees.[267]

However the low density of wood char means additional processing is required to produce aluminium anodes. Researchers are blending charcoal with biopitch to make a coke-like material in an effort to overcome this issue. Characterising various charcoals and their properties is an important part of the project. Early research suggests anode production from softwoods and hardwoods will require different process methods because of their unique cellular structures.[268] Research by CSIRO has highlighted that viable anode grade petroleum coke requires a density of 800 kg/m^3. This is possible using a CSIRO patented technology of bio-coke making. This process requires high temperature pyrolysis of wood under mechanical compressive force. Wood can be sourced from either plantation or natural forests.[269] For biocoke to address the broad range of objectives, ideally each operation would develop and maintain its own plantations. This will help to close the carbon loop, recycle carbon dioxide and lead to improved environmental outcomes.[270]

CSIRO has also successfully trialled wood char for anode production for use in steel plants.[271]

[265] Haque, Nawshad & de Vries, Malisja. (2012), *Greenhouse Gas Emission Abatement of Bio-Coke from Wood for Application as Bioanode in Aluminum Process*.
[266] CSIRO (October 14, 2011), *Wood Char Shows Potential for Carbon Anode Production*.
[267] CSIRO (October 14, 2011), *Wood Char Shows Potential for Carbon Anode Production*.
[268] CSIRO (October 14, 2011), *Wood Char Shows Potential for Carbon Anode Production*.
[269] Haque, Nawshad & de Vries, Malisja. (2012), *Greenhouse Gas Emission Abatement of Bio-Coke from Wood for Application as Bioanode in Aluminum Process*.
[270] Process (February, 2007), *Bioanode Beginnings*.
[271] Process (February, 2007), *Bioanode Beginnings*.

8.12 Polyols

Polyols are alcohols with more than two reactive hydroxyl (-OH) groups per molecule. The total 2010 Canadian market for polyols is roughly estimated at 110 to 130 kilotonnes, valued at $300-400 million.[272] Polyols are used to make polyurethane foams and other products. About 90% of the demand in Canada is for polyether type polyols, while polyester polyols make up practically all of the remainder. There are various individual polyol chemicals (so trade data for such are not readily available.) There is no production of polyols in Canada. Dow Chemical shut down its Sarnia, ON plant several years ago. U.S. producers of polyols include: Dow Chemical, BASF Group, Huntsman Polyurethanes, Eastman Chemical and Lyondell Petrochemical. Their plant capacities which range from 50 to 500 kilotonnes per year, are based on using propylene and propylene oxide as the starting raw materials.

Polyols can make up between 20% and 70% of a polyurethane formulation. Diisocyanates, such as toluene diisocyanates (TDI) or methylene diphenyl isocyanates (MDI), along with various additives, foaming agents, etc. make up the remainder. The largest applications for polyurethanes are foams cut from slabstock for use in furniture, bedding, carpet underlay and other applications. Molded polyurethane shapes include auto seating, auto trims and other uses. There are also hard rigid and spray (e.g., coatings, insulation) polyurethane applications. Laminated board insulation uses polyester polyols and accounts for about 5-10% of total Canadian use.

Table 112: Estimated Polyols Consumption in Canada

(kilotonnes)

	2010
Slabstock (bedding, furniture, carpet underlay, etc.)	35-45
Molded foam products (auto seating, trims, etc.)	30-40
Rigid products, spray	20-30
Laminated board insulation	5-15
All other applications	5-15
Total	110-130

Source: Cheminfo Services Inc. based on historical industry input.

Nearly half of the Canadian polyol customers or polyurethane processing establishments are located in Ontario. However, it is estimated that Ontario accounts for nearly two thirds of total Canadian market demand for polyols. Ontario is home to large molded flexible

[272] This is total Canadian market value as estimated by industry sources. It includes value of imports, resell mark-ups and sales of domestic production.

polyurethane product manufacturers, a good portion of which are used in automotive applications. This would include production of automobile seats, headrests, padding, and other auto applications. Ontario is also home to large slabstock polyurethane foam producers, which serve nearby furniture, bedding and carpet underlay manufacturers. Demand for polyols in Alberta is estimated to be about 5-6% of the Canadian total. Alberta lacks auto applications for polyurethane foams.

Bio-based polyols made from vegetable oils (e.g., soy, corn oil) present alternatives to "petroleum-based" polyols. The main market interests in bio-based polyols are: their potential to offer a comparative or lower-priced alternative to petroleum–based polyols; and that they offer an environmentally attractive raw material source. Bio-based polyols have been undergoing development and some have been adopted by polyurethane users and processors, (e.g., companies such as: Ford, Woodbridge Foam, Lear Corporation; Johnson Controls). Bio-based polyols are typically not "drop-in" replacements to petroleum-based polyols. It can be challenging for polyurethane processors to standardize product quality with bio-based polyols. Reformulation of the products are required to accommodate bio-based polyols.

BASF and Dow Chemical are among the large polyol producers offering bio-based polyols. It is unknown if they are producing their own products. There are smaller companies developing products. For example, Rhino Linings and Bio-Based Insulation in the U.S. formed an alliance to develop a portfolio of renewable and sustainable bio-based polyols.[273]

8.13 Phenol

Phenol is a petrochemical usually made by first reacting benzene and propylene to from cumene. The cumene is then converted to phenol and acetone through oxidation and catalytic processes. There is no production of phenol or acetone in Canada. There are other routes to the making phenol, but cumene process is commercially preferred. Some U.S. producers of phenol are: INEOS, Dow Chemical, Sunoco, SABIC Innovative Plastics, Shell, and Dakota Gasification. Plant capacities range from about 20 to 600 kilotonnes per year. A portion of the capacity is allocated as raw material for internal production of other petrochemicals.

Phenol demand in Canada is largely for the production of phenol-formaldehyde (PF) resins, which are used as adhesives in the panelboard industry (e.g., plywood production). There may be some minor other uses that account for less than 5% of total Canadian demand. Canada lacks market applications for phenol, which on a global basis account for the majority of phenol use. These include production of bisphenol A (BPA), which accounts for approximately 45% of phenol demand. BPA is used for polycarbonate (PC) polymer

[273]Rhino Linings, http://www.rhinolinings.com/

(which is not made in Canada). Other markets for phenol that do not exist in Canada are caprolactam, aniline and adipic acid production.

Canada has been importing about 70,000 to 80,000 tonnes/year of phenol, virtually all of it from the United States. In 2012, Alberta demand was 48% of the Canadian total or about 36 kilotonnes worth $52 million.

Table 113: Canadian and Alberta Imports of Phenol

	2009		2010		2011		2012	
	(tonnes)	($ million)	(tonnes)	($ million)	(tonnes)	($ million)	(tonnes)	($ million)
Canada	70,451	$67	77,501	$96	73,812	$103	75,070	$110
Alberta	20,913	$21	30,070	$37	33,331	$47	35,666	$52

Source: Statistics Canada, Canadian International Merchandise Trade

Canadian major phenol users making phenol formaldehyde (PF) resins are shown in the table below.

Table 114: Major Canadian Producers of Phenol Formaldehyde Resins

Facility	Location	
Momentive Specialty Chemicals Canada Inc.	Edmonton	AB
Momentive Specialty Chemicals Canada Inc.	Lévis	QC
Tembec, ARC Resins.	Longueuil	QC
Arclin Canada Ltd.	Sainte Therese	QC
Arclin Canada Ltd.	Kamloops	BC
Arclin Canada Ltd.	North Bay	ON

Source: Cheminfo Services Inc. May not include all PF producers

Lignol Inc., a firm based in British Columbia, has been working to develop lignin-formaldehyde (LF) resins for use in panelboard application. Tolko Industries in British Columbia has been testing LF resins for plywood production. The first tests identified technical issues, and a second set of tests are planned. Tolko Industries has motivation in examining LP resins to reduce its purchase cost of adhesives. However, the resin must meet process and functional requirements, which require further development. While there may be environmental benefits to LF resins, Tolko indicates this would be a minor or non-factor for customers that are most interested in lower panelboard prices. Panelboard buyers do not want to pay any premium price for more a “greener” product.[274]

[274] Personal communication, Tolko Industries.

8.14 Ethanolamines

Ethanolamines are organic compounds that are flammable, corrosive, colorless, viscous liquids with an odor similar to that of ammonia. They can be used in a variety of applications due to their unique characteristics. Ethanolamines combine the properties of amines and alcohols in one molecule. They exhibit the unique capability of undergoing reactions common to both groups. As amines, they are mildly alkaline and react with acids to form salts or soaps. As alcohols they can be transformed to ethers and esters. Total Canadian demand for ethanolamines is about 24 kilotonnes for 2010.

Table 115: Estimated Canadian Demand for Ethanolamines
(kilotonnes)

Application	2010	% of Total
Oil and gas industry acid gas treatment	15	62%
Other uses	9	38%
Total	24	100%

Source: Cheminfo Services estimates

Ethanolamines are used for acid gas scrubbing to remove hydrogen sulphide and carbon dioxide from natural gas streams, petroleum refinery streams, flue gases, and chemical processing streams. The majority of this use is in Alberta's oil and gas industry. Other applications include use as reactants in the surfactants industry, concrete additives, and coatings. Uses for individual ethanolamines are identified below.

Monoethanolamine (MEA)
MEA forms an intermediate for cosmetics, surface-active agents, emulsifiers and plasticizing agents; is a gas-treating agent for refinery and natural gas streams; and is used in the manufacture of carbon dioxide and ammonia.

Diethanolamine (DEA)
As an intermediate, DEA is used in the manufacture of cosmetics, detergent and textile specialties, agrochemicals, petroleum demulsifiers; as a gas treating agent; in wax, polish and coating emulsifiers; in soluble oils; and as a corrosion inhibitor.

Triethanolamine (TEA)
TEA acts as an intermediate in surface-active agents for textile specialties, wax and polish, agrochemicals, petroleum demulsifiers, bathroom products, cement additives, cutting oils

and photographic film developers; a corrosion inhibitor; a dispersant for dyes, casein, shellac and rubber latex; and as a sequestering agent.[275]

N,N-Dimethylethanolamine (DMEOA)
DMEOA is used as a building block for the synthesis of cationic flocculants and ion exchange resins. Furthermore DMEOA is used as an intermediate + buffering agent in the synthesis of coatings.[276]

Methyl Diethanolamine (MDEA)
MDEA's popularity as a solvent for gas treating stems from several advantages it has over other alkanolamines, especially its ability to preferentially remove H_2S (and slip CO_2) from sour gas streams.

Ethyl Diethanolamine
No shipments of ethyl diethanolamine into Canada above one tonne were identified between 2009 and 2012. Additionally, no data on the domestic production of ethyl diethanolamine was found.

No ethanolamine manufacturers were identified in Canada, and minor quantities (383 tonnes) were exported from Canada in 2012 (likely by distributors that had imported in bulk).

Table 116: Canadian Imports of Ethanolamines

	2009	2009	2010	2010	2011	2011	2012	2012
	(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)
Monoethanolamine	11,675	$16,863	14,420	$18,663	15,664	$21,805	16,012	$21,996
Diethanolamine	3,074	$6,724	4,591	$6,890	4,260	$6,429	3,828	$6,185
Triethanolamine	4,523	$5,931	4,085	$5,105	5,767	$7,265	4,134	$5,845
N,N-Dimethyl Ethanolamine	126	$419	144	$445	117	$352	96	$285
Methyl Diethanolamine	1,363	$4,786	1,451	$5,069	2,271	$7,978	2,508	$7,086
Ethyl Diethanolamine	0.02	$0	0.13	$2	0	$0	0	$0
Total	20,762	$34,724	24,692	$36,172	28,079	$43,829	26,577	$41,397

Source: Statistics Canada, Canadian International Merchandise Trade.

Between 20 and 28 kt of ethanolamines have been imported into Canada each year between 2009 and 2012. Approximately 26.5 kt of ethanolamines were imported into Canada in 2012. Exports of ethanolamines have never increased above 500 tonnes, and have remained relatively steady between 380 tonnes and 480 tonnes each year between 2009 and 2012.

[275] Huntsman Corporation, *Ethanolamines*, http://www.huntsman.com/performance_products/a/Products/Amines/Ethanolamines.
[276] BASF Corporation, *N,N-Dimethylethanolamine S*, http://www.basf.com/group/corporate/en/brand/N_N_DIMETHYLETHANOLAMINE_S.

The majority of Canadian imports of ethanolamines is comprised of monoethanolamine (60%), triethanolamine (16%), and diethanolamine (14%).

Table 117: Distribution of Canadian Ethanolamine Imports

Ethanolamine	% of Total Canadian Ethanolamine Imports
Monoethanolamine	60%
Diethanolamine	14%
Triethanolamine	16%
N,N-Dimethyl Ethanolamine	0%
Methyl Diethanolamine	9%
Ethyl Diethanolamine	0%
Total	100%

Source: Statistics Canada, Canadian International Merchandise Trade.

Table 118: Alberta Imports of Ethanolamines

	2009	2009	2010	2010	2011	2011	2012	2012	Alberta's % of Total Canadian Imports
	(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)	
Monoethanolamine	6,842	$10,082	8,717	$11,693	9,645	$13,601	9,717	$13,785	61%
Diethanolamine	1,259	$2,985	1,255	$1,672	1,378	$1,872	1,205	$1,852	31%
Triethanolamine	1,498	$1,513	1,759	$1,719	3,311	$3,653	2,458	$3,110	59%
N,N-Dimethyl Ethanolamine	0	$0	5	$14	11	$34	11	$32	11%
Methyl Diethanolamine	1,090	$3,819	1,243	$4,349	2,012	$7,052	1,990	$5,667	79%
Ethyl Diethanolamine	0	$0	0	$0	0	$0	0	$0	0%
Total	10,689	$18,399	12,980	$19,447	16,357	$26,212	15,382	$24,445	58%

Source: Statistics Canada, Canadian International Merchandise Trade.

The Canadian importers database identified the following importer of ethanolamines into Canada:

- Dow Chemical Canada ULC – Calgary, Alberta;
- Momentive Specialty Chemicals Canada Inc. – Brampton, Ontario;
- Demilec Inc. – Boisbriand, Quebec;
- Huntsman Corporation – Texas;
- Nalco Canada – Burlington, Ontario; and
- Thames River Chemical – Burlington, Ontario.

Alberta imported between 10 and 15 kt of ethanolamines each year between 2009 and 2012. Alberta accounted for approximately 58% of total Canadian ethanolamine imports in 2012.

Table 119: Alberta Ethanolamine Imports, by Type of Ethanolamine

Ethanolamine	% of Total Alberta Ethanolamine Imports
Monoethanolamine	63%
Diethanolamine	8%
Triethanolamine	16%
N,N-Dimethyl Ethanolamine	0%
Methyl Diethanolamine	13%
Ethyl Diethanolamine	0%

Source: Statistics Canada, Canadian International Merchandise Trade.

The four ethanolamines most widely used in the oil and gas industry (monoethanolamine, diethanolamine, triethanolamine and methyl ethanolamine) are the four ethanolamines imported into Alberta in the highest volume. Methyl ethanolamine, while only accounting for 13% of Alberta's total ethanolamine imports, is still evidently important to Alberta's gas industry as 79% of Canadian methyl ethanolamine imports are sent to Alberta. A similar situation is evident for monoethanolamine and triethanolamine, as Alberta accounts for 61% and 59% of the total Canadian imports for those substances respectively.

Ethanolamines are produced commercially by reacting ethylene oxide with ammonia.[277] This reaction produces several of the ethanolamines at the same time, and the ratio of the products generated through this reaction can be controlled by changing the stoichiometry of the reactants.

Some methods of generating bio-based ethanolamines have been investigated, but there is no information that supports the existence of current commercial bio-ethanolamine production.[278/279] The bio-routes to ethanolamines involve using serine, which is another material that is currently commercially produced through non-bio routes, but can be produced without utilizing petrochemicals. As the technology is not currently commercially utilized, and may potentially be years away from commercially viable production, further research on bio-routes to ethanolamine production was not pursued.

[277] Huntsman Corporation, *Ethanolamines*, http://www.huntsman.com/performance_products/a/Products/Amines/Ethanolamines.
[278] Olga Kattan, *Membranes in the Biobased Economy – Electrodialysis of Amino Acids for the Production of Biochemicals*, 2013.
[279] Rontein et al., *Plants Synthesize Ethanolamine by Direct Decarboxylation of Serine Using a Pyridoxal Phosphate Enzyme*, 2001.

8.15 Morpholine

Morpholine (C_4H_8ONH) is also referred to as tetrahydro-1,4-oxazine and is a colourless, hygroscopic liquid with an amine-like odor. The major process for the production of morpholine is based on the reaction of diethylene glycol with ammonia at high temperatures and pressures, with or without a catalyst. Typically, diethylene glycol and ammonia are combined in the presence of hydrogen and a catalyst at a temperature between 150-400°C and a pressure between 3-4 MPa. The hydrogenation catalyst may be any one of a number of metals. Excess ammonia is stripped from the crude reaction mixture, and morpholine is obtained by fractional distillation.[280]

Globally, the end-use pattern for morpholine is roughly as follows: rubber chemicals, 40%; corrosion inhibitors, 30%; waxes and polishes, 5%; optical brighteners, 5%; and miscellaneous, 20%. In Canada, the main use for morpholine is estimated to be the formulation of corrosion inhibiting water treatment chemicals. In this application, the water treatment chemical is used at a rate of 2-10 ppm of morpholine to neutralize acid, usually carbonic acid. Total annual demand for morpholine in Canada is estimated at 400 tonnes, with 300 tonnes consumed in water treatment/corrosion inhibitor applications. Demand is distributed across the country. Total annual demand in Alberta is estimated at 40 tonnes, with most morpholine consumed in water treatment/corrosion inhibitor applications.

Table 120: Estimated Canadian and Alberta Morpholine Demand

(tonnes)

Application	2010 Canada	2010 Alberta
Water Treatment/Corrosion Inhibitors	200-300	30
Resin Manufacturing/Other	100-200	10
Total	354	40

Source: Cheminfo Services estimates; Import data from the Canadian International Merchandise Trade Database.

Morpholine is a versatile chemical with various small applications. For example, it is used as an intermediate in the production of delayed-action type rubber accelerators. Accelerators are added to rubber before fabrication to increase the rate of vulcanization. Since during fabrication there is a danger of prevulcanization, delayed-action accelerators are desirable.[281]

[280] IARC Monographs Volume 47 (1989), *Morpholine*.

[281] The description of end-use applications for morpholine (this paragraph and the next several) has been taken from the following publication: Huntsman (2005), *Morpholine*.

Other applications for morpholine and its derivatives include the following:

- Optical brighteners - morpholine is an important intermediate in the manufacture of optical brighteners employed by the soap and detergent industry in the compounding of detergents.
- Pharmaceutical chemicals – morpholine derivatives have been used in: ointments; analgesics and local anesthetics; respiratory and vasomotor stimulants, etc.
- Antioxidants for lubricating oils, lubricating oil stabilizers, multifunctional oil additives, fatty products, glyceridic oils, vitamin A, carotene and 2-chlorothiophene.
- Wax emulsifiers and surface active agents - when morpholine is reacted with fatty acids, it forms soaps possessing excellent emulsifying properties. One of the main advantages of morpholine-based emulsifiers is the similar boiling points of morpholine and water.

There are no domestic producers of morpholine in Canada. The small Canadian market is supplied by imports, primarily from the U.S. According to the Chemical Data Reporting website (www.epa.gov/cdr) of the U.S. EPA, the main producers of morpholine in the U.S. appear to be Huntsman Corporation and BASF Corporation. Three other companies reported morpholine manufacture or imports in the U.S., however these companies are expected to be importers or small producers. BASF has morpholine manufacturing capacities at its sites in Geismar, Louisiana and in Ludwigshafen, Germany.[282] Huntsman Corp. has morpholine manufacturing facilities located in Port Neches, Texas and Llanelli, Wales.[283] Huntsman and Saudi Arabia's Zamil Group have also announced plans to build a plant to produce morpholine (and diglycolamine agent) in Al-Jubail in Saudi Arabia.[284]

As there is no production of morpholine in Canada, it will be imported and distributed in Canada by BASF Corporation and Huntsman Corporation directly or by chemical distributors. According to the Canadian Importers Database, the three largest importers of morpholine in Canada in 2011 were Canada Colors and Chemicals, Univar Canada and Nexeo Solutions Canada. These three companies represented 70% of total Canadian imports of morpholine in 2011. All three of these companies are independent chemical distributors.

Research did not identify any activity with respect to the production of bio-morpholine. It has been suggested that morpholine cannot be produced from natural sources and has no organic ingredients as substitutes. When considering chemical means to condition steam lines in boiler systems, the additives to the steam lines must be volatile, so that they

[282] BASF Corporation (December 31, 2010), *BASF Raises Prices for Morpholine in Europe*.
[283] Huntsman Corporation, *Huntsman and Zamil Group Plan New Morpholine and Diglycolamine® Agent Joint Venture in Saudi Arabia*.
284 ICIS.com (April, 19, 2011), *Huntsman to Build Morpholine/Diglycolamine Plant in Saudi Arabia*.

purposely travel along with the steam. There are no known non-synthetic boiler additives that can serve this purpose.[285]

Outlined in the table below are imports of morpholine into Canada from 2009 to 2012. Imports have remained between 330-400 tonnes over this time-period. While Alberta import data is provided, these data do not represent the annual market for morpholine in Alberta. As the major importers of morpholine in Canada are chemical distributors, they will often import chemicals (e.g. morpholine) into one location in Canada and then distribute to accounts throughout Canada. As such, these chemical distributors could import into Ontario (with Ontario being the importing location of record) and then ship these chemicals to Alberta for consumption.

Table 121: Canadian and Alberta Trade in Morpholine

	2009		2010		2011		2012	
Canada	(tonnes)	($ million)	(tonnes)	($ million)	(tonnes)	($ million)	(tonnes)	($ million)
Imports	332.9	$1.3	354.4	$1.4	337.8	$1.7	400.0	$2.1
Alberta								
Imports	9.7	<$0.1	2.5	$0.1	0.2	$0.2	0	$0

Source: Canadian International Merchandise Trade Database – based on HS Codes: (i) 2934990020: Compounds of Morpholine and its Salts; and (ii) HS 2934999910: Morpholine.

8.16 Xanthates

The salts of the *O*-esters of carbonodithioic acids and the corresponding *O,S*-diesters are xanthates.[286] Other names for xanthates include xanthogenates, carbondithioates, dithiocarbonates and sodium or potassium salts of xanthanic (or dithiocarbonic) acids.[287] Four types of xanthates (ethyl, butyl, propyl and amyl) are produced in various combinations with sodium and potassium, which are stabilizers in the chemical formula.[288]

The commercially available xanthates are prepared from various primary or secondary alcohols. The alkyl group varies from C_2 to C_5 and the alkali metal may be sodium or

[285] NOSB TAP Materials Database Compiled by OMRI (February 15, 2001), *Morpholine.*
[286] Harris, Guy H. (2000), *Xanthates*, published in the Kirk-Othmer Encyclopedia of Chemical Technology.
[287] Canada Border Services Agency (November 2, 2007), *Statement of Reasons - Concerning a Determination Under Paragraph 76.03(7)(a) of the Special Import Measures Act Regarding Xanthates Originating in or Exported from The People's Republic Of China*.
[288] Canada Border Services Agency (November 2, 2007), *Statement of Reasons - Concerning a Determination Under Paragraph 76.03(7)(a) of the Special Import Measures Act Regarding Xanthates Originating in or Exported from The People's Republic Of China*.

potassium. Not all of the commercially available alcohols in the C_2–C_5 range are available as their xanthates, but most could be made if there were sufficient demand for them.[289]

Xanthates are prepared by reacting sodium or potassium hydroxide with an alcohol and carbon disulphide. The initial reaction is the formation of the alkoxide, which reacts with carbon disulphide to give the xanthate. In most commercial processes, the end product of the reaction is a wet mixture, which is then dried, normally in a vacuum dryer to allow the lowest temperature possible to be used. Since the decomposition of xanthate increases with temperature, the lower the temperature, the higher are the quality and yield.[290]

There is conflicting information on the global market for xanthates. Charles Tennant & Company (Canadian manufacturer) estimated the 2007 global demand for xanthates at approximately 100,000 tonnes. It was further estimated that 2007 production capacity for xanthates in China was between 115,000 and 145,000 tonnes per year. It was suggested that xanthate production in other countries, such as Mexico, India, South Africa, Australia and Canada, simply added to the global oversupply situation that prevailed at that time.[291] The estimate from Charles Tennant & Company is corroborated by a recent article which indicated that by far the most widely used reagent collector compound is the xanthate family and that xanthate remains the main chemical used in sulphide flotation with volumes of over 100,000 t/y used.[292] However another recent article published in China has estimated that China's demand for xanthate was around 166,000 tons in 2006, and increased to 241,000 tons in 2011. Xanthate production in China was estimated to be 186,000 tons in 2009 and increased to 221,000 tons in 2011.[293] Assuming the global market for xanthates is between 100,000-300,000 tonnes per year and that Canada represents 5% of this market (since there are a substantial amount of mines in Canada), then annual Canadian xanthate demand would be in the 5,000-15,000 tonne range. Assuming Alberta represents around 10% of this demand (although likely lower since other Provinces/Territories have many more mines than Alberta), Alberta xanthate consumption would be in the 500-1,500 tonne range.

Xanthates are chemical reagents used in the flotation of base and precious metals, which is the standard method for separating valuable minerals, such as gold, copper or zinc, from

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[289] Harris, Guy H. (2000), *Xanthates*, published in the Kirk-Othmer Encyclopedia of Chemical Technology.
[290] Canada Border Services Agency (November 2, 2007), *Statement of Reasons - Concerning a Determination Under Paragraph 76.03(7)(a) of the Special Import Measures Act Regarding Xanthates Originating in or Exported from The People's Republic Of China*.
[291] Canada Border Services Agency (November 2, 2007), *Statement of Reasons - Concerning a Determination Under Paragraph 76.03(7)(a) of the Special Import Measures Act Regarding Xanthates Originating in or Exported from The People's Republic Of China*.
[292] Moore, Paul. (June, 2011), *Mining Chemicals*, published in International Mining.
[293] Song, Jiang., et. al., (July 6, 2012), *China's Xanthate Sector Has Favorable Prospects*, published in China Chemical Reporter.

non-valuable minerals, such as limestone or quartz.[294] Xanthates are the principal metal sulphide collectors in this application.[295] To extract values, conditioned ores are mixed in a solution of water and xanthates and then agitated in flotation cells, which resemble large washing machines. Xanthates may be added in liquid or solid form. The xanthates cause the minerals to attach themselves to air bubbles and then float to the top of the flotation cell. As values reach the surface, the bubbles form a froth that overflows into a trough for collection. The residual may be re-used for additional recovery or removed for disposal. Most of the xanthates are consumed in the process. Several separate flotations are typically required for different ores. Since each ore is unique, there is no standard flotation procedure and no standard grade or type of xanthate used to extract specific values.[296]

The other major use of xanthates is the use of cellulose xanthates in the manufacture of rayon and cellophane.[297] Cellulose reacts with carbon disulphide in the presence of sodium hydroxide to produces sodium cellulose xanthate, which upon neutralization with sulphuric acid gives viscose rayon or cellophane paper.

The other uses of xanthates are very minor. Xanthates and derivatives have been recommended for the vulcanization of rubber, as herbicides, insecticides, fungicides, high pressure lubricant additives, and for analytical procedures. The use of xanthates as inhibitors of fertilizer nitrogen transformation in soil has been reported, as well as the use of certain metal xanthates as colour developers for image-recording materials.[298]

There is only one manufacturer of xanthates in Canada, specifically Charles Tennant & Company (Canada) Ltd. which manufactures xanthates through their manufacturing division, Prospec Chemicals Ltd., in Fort Saskatchewan, Alberta.[299] Prospec Chemicals manufactures xanthates and xanthogen formates for the mining industry worldwide. The facility manufactures 7,000 tonnes of xanthates annually as well as a growing number of specialty collectors. The strength of their xanthates is based on the alcohol chain attached to the xanthate molecule with ethyl (2-carbons) being the weakest and amyl (5-carbons) being the strongest. KAX 20, potassium ethyl xanthate, is very selective in nature while KAX 55, potassium N-Amyl xanthate, is a non-selective collector.[300]

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[294] Canada Border Services Agency (November 2, 2007), *Statement of Reasons - Concerning a Determination Under Paragraph 76.03(7)(a) of the Special Import Measures Act Regarding Xanthates Originating in or Exported from The People's Republic Of China*.
[295] Harris, Guy H. (2000), *Xanthates*, published in the Kirk-Othmer Encyclopedia of Chemical Technology.
[296] Canada Border Services Agency (November 2, 2007), *Statement of Reasons - Concerning a Determination Under Paragraph 76.03(7)(a) of the Special Import Measures Act Regarding Xanthates Originating in or Exported from The People's Republic Of China*.
[297] Harris, Guy H. (2000), *Xanthates*, published in the Kirk-Othmer Encyclopedia of Chemical Technology.
[298] Harris, Guy H. (2000), *Xanthates*, published in the Kirk-Othmer Encyclopedia of Chemical Technology.
[299] Canada Border Services Agency (November 2, 2007), *Statement of Reasons - Concerning a Determination Under Paragraph 76.03(7)(a) of the Special Import Measures Act Regarding Xanthates Originating in or Exported from The People's Republic Of China*.
[300] Accessed at the website of Charles Tennant & Company (http://ctc.ca/)

The Fort Saskatchewan location for Prospect Chemicals allows for the manufacturing plant to be in close proximity to a main raw material for the production of xanthates. The plant was completed in early 1984 and had a first year production capacity of 250 tonnes. The plant has continued to expand its capabilities and diversify production to include thionocarbamates, formates, dithiophosphates and specialty chemicals to compliment xanthate production.

Prospec Chemicals annual production capacity is as follows:[301]

- 8,000 tonnes of xanthates;
- 1,000 tonnes of dithiophosphates;
- 1,000 tonnes of thionocarbamates;
- 1,000 tonnes of formats; and
- 4,000 tonnes of specialty chemicals.

In 2008, Charles Tennant & Company (Canada) Ltd., started its new joint venture mining chemical manufacturing facility in China, with an initial production of 10,000 tonnes of xanthates. As of 2011, the plant capacity is as follows:[302]

- 20,000 tonnes of xanthates;
- 6,000 tonnes of dithiophosphates; and
- 4,000 tonnes of thionocarbamate and formats.

The specific xanthates produced by Prospec Chemicals in Fort Saskatchewan are: (i) potassium ethyl xanthate; (ii) potassium isobutyl xanthate; (iii) potassium isoamyl xanthate; (iv) potassium n-amyl xanthate; and (v) sodium isopropyl xanthate.[303]

As of 2000, there were only two manufacturers of xanthates in the US and Canada. Historically the two main producers of xanthates in the U.S. (i.e. American Cyanamid and Dow Chemical) closed their plants in the 1970s. American Cyanamid transferred its production to Canada, and since then has closed that plant. The estimated number of xanthate plants in the world in 2000 was 14–16.[304] Besides Prospec Chemicals Ltd., the other xanthates producer in North America may be SNF FloMin which reportedly produces a variety of xanthate solutions in Baytown, Texas. However, SNF FloMin also operates a large production facility in Qingdao, China and has grown to be the leading customized supplier of xanthates worldwide. China dominates in terms of global xanthate production with the two major producers in China being Qixia Tongda Flotation Reagent Co. Ltd. and Yantai Humon Chemical Auxiliary Co. LW.[305]

[301] Accessed at the website of Prospec Chemicals (www.prospecchemicals.com).
[302] Accessed at the website of Prospec Chemicals (www.prospecchemicals.com).
[303] Accessed at the website of Prospec Chemicals (www.prospecchemicals.com).
[304] Harris, Guy H. (2000), *Xanthates*, published in the Kirk-Othmer Encyclopedia of Chemical Technology.
[305] Song, Jiang., et. al., (July 6, 2012), *China's Xanthate Sector Has Favorable Prospects*, published in China Chemical Reporter.

Overall, it has been suggested that Chinese manufacturers have a combined production capacity that exceeds world demand, continue to increase xanthate production, and compete at low prices throughout the world.[306] This has affected the previously established suppliers, by causing them to withdraw from the manufacture and sale of some reagents. For example, both Cytec and Clariant have withdrawn from offering xanthates.[307]

Research did not identify any current activities with respect to producing bio-xanthates. The vast majority of global xanthate production occurs in China and likely there is little activity among manufacturers in that country to explore the potential of bio-xanthates. There are only 2 xanthate manufacturers in Canada and the U.S. and both of these companies now have Chinese manufacturing plants for xanthates as well (while maintaining production facilities in North America as well). It is likely the North American manufacturers have not explored the potential for bio-xanthates as well. The most likely bio-based option for producing xanthates would be to source the alcohol for the production process from some bio-source.

8.17 Acetic Acid

Acetic acid (CAS 64-19-7) is an organic compound with the chemical formula CH_3COOH. It is a colourless liquid that when undiluted is also called glacial acetic acid. Of all the major industrial organic chemicals, acetic acid has the most diverse production technology and uses the most varied feedstocks. Of these, however, methanol carbonylation has become the dominant acetic acid production technology, accounting for over 65% of global capacity. Other production processes are the oxidation of acetaldehyde (used by German producer Wacker) and the liquid-phase oxidation of n-butane or naphtha. Developments by companies including Japan's Showa Denko, Wacker and Saudi Arabia's SABIC are based on the oxidation of ethylene, ethane or methane.[308] The global market for acetic acid has been estimated to be 8-9 million tonnes per year.[309]

Acetic acid is largely used to manufacture vinyl acetate monomer, which accounts for one-third of acetic acid consumption. The largest use for vinyl acetate monomer is in the production of base resins for water-based paints, adhesives, paper coatings and textile finishes. The second largest use for acetic acid is purified terephthalic acid (PTA). PTA is the fastest growing market for acetic acid, with demand being driven by a boost in polyethylene terephthalate (PET) bottle resins and polyester resin.[310] Acetic anhydride and

[306] Canada Border Services Agency (November 2, 2007), *Statement of Reasons - Concerning a Determination Under Paragraph 76.03(7)(a) of the Special Import Measures Act Regarding Xanthates Originating in or Exported from The People's Republic Of China*.
[307] Moore, Paul. (June, 2011), *Mining Chemicals*, published in International Mining.
[308] ICIS.com (July 18, 2011), *U.S. Chemical Profile: Acetic Acid*.
[309] Green Chemicals Blog (October 16, 2012), *LanzaTech in CO_2-to-Acetic Acid*.
[310] ICIS.com (July 18, 2011), *U.S. Chemical Profile: Acetic Acid*.

solvents (ethyl acetate, butyl acetate) are the third- and fourth-largest users, respectively.[311] Acetic acid is also a raw material in the production of peracetic acid which is used as a bleaching agent in the pulp industry. In diluted form acetic acid, commonly known as vinegar, is used in the preserving of herring and pickles.[312] Global demand for acetic acid is forecast to grow 3-4% a year in the long term.[313]

As there is no Canadian manufacture of industrial acetic acid (see further discussion below), total Canadian demand can be determined by the available trade data. In 2012, net imports of acetic acid into Canada were 27,125 tonnes, while net imports into Alberta were 960 tonnes. Given that there is interprovincial trade in acetic acid in Canada, it is difficult to estimate actual annual demand in Alberta. However based on the available trade data, it is estimated that annual demand for acetic acid in Alberta would be in the 1,000-5,000 tonnes range. There is no production of vinyl acetate monomer and only one producer of purified terephthalic acid in Canada. In addition, there is no known production of acetic anhydride, ethyl acetate or butyl acetate in Canada. Therefore most of the main applications for acetic acid are not currently present in Canada.

Table 122: Canadian and Alberta Trade in Acetic Acid

	2009		2010		2011		2012	
Canada	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**
Imports	20,426	$17,726	27,651	$22,377	29,603	$22,077	32,461	$23,393
Exports	501	$385	3,134	$1,070	5,391	$1,790	5,336	$1,706
Alberta								
Imports	19	$43	270	$274	1,774	$1,157	961	$736
Exports	0.2	$0.1	3.7	$7.8	0.9	$2.8	1.3	$6.3

Source: Canadian International Merchandise Trade Database, HS Code 291521 – Acetic Acid.

The four largest importers of acetic acid in Canada in 2011 were the following: (i) CEPSA Chimie Montreal/CEPSA Quimica Montreal; (ii) LyondellBasell Acetyls; (iii) Macco Organics Inc.; and (iv) Univar Canada. These four companies represented 78% of the total value of acetic acid imported into Canada in 2011.[314] Macco Organics produces acetates in Valleyfield, Quebec, while CEPSA Chimie Montreal produces purified terephthalic acid in Montreal, Quebec. LyondellBassel does not have any production facilities in Canada and therefore their presence on the Canadian Importers Database may refer to some form of trans-shipment with the acetic acid eventually being sent to their U.S. facilities. Univar Canada is a major chemical distributor in Canada. Based on this information, three of the four major importers of acetic acid in Canada will not consume it in Alberta. Without

[311] ICIS.com (January 30, 2012), *European Chemical Profile: Acetic Acid*.
[312] Accessed at the website of SEKAB (www.sekab.com).
[313] ICIS.com (July 18, 2011), *U.S. Chemical Profile: Acetic Acid*.
[314] Accessed at the website of the Canadian Importers Database (www.ic.gc.ca/eic/site/cid-dic.nsf/eng/home).

contacting Univar Canada, it is not possible to determine where their customers for acetic acid are located.

There are currently no Canadian producers of acetic acid. Celanese Canada operated the lone acetic acid manufacturing plant in Canada, located in Edmonton, Alberta with an annual capacity of 80,000 tonnes. However this plant was closed in 2001, attributed to poor market conditions and the age of the plant.[315] Subsequently, Celanese Canada closed their vinyl acetate monomer plant (main end-use for acetic acid) in Edmonton in 2002.[316]

Table 123: U.S. and Western European Producers of Acetic Acid

Company	Location	Capacity (000 tonnes/year)
U.S.		
Celanese	Clear Lake, Texas	1,200
Eastman Chemical	Kingsport, Tennessee	255
DuPont	LaPorte, Texas	80
Millennium Petrochemicals	LaPorte, Texas	550
Eastman Chemical	Texas City, Texas	545
Total		**2,630**
Western Europe		
BP Chemicals	Hull, UK	520
Wacker Chemie	Burghausen, Germany	120
Lonza	Visp, Switzerland	50
SEKAB	Domsjo, Sweden	25
Sekisui Specialty Chemicals Europe	Tarragona, Spain	10
Total		**725**

Sources: ICIS.com (July 18, 2011), *U.S. Chemical Profile: Acetic Acid*.
ICIS.com (January 30, 2012), *European Chemical Profile: Acetic Acid*.

There are some significant activities globally with respect to the production of bio-acetic acid, as outlined in the summaries below.

Wacker Chemie

German chemical company Wacker Chemie has developed a fermentation-based acetic acid process and plans to license the technology. Wacker Chemie started its 500 tonnes/year bio-based acetic acid pilot plant in Burghausen, Germany in 2009. The plant

[315] European Chemical News (November 16, 2001), *Celanese Acetic Acid Closure*.
[316] ICIS.com (October 30, 2001), *Celanese to Close Edmonton, Canada VAM Plant in Q1-2002*.

uses straw as feedstock, but it can use other sugar-based biomass raw materials as well. The process called *ACEO* uses an enzymatic fermentation route, first producing ethanol (using yeast) and then acetic acid via a gas phase oxidation process.[317/318] The *ACEO* pilot plant can be expanded depending on economics. The process has been able to achieve more than 90% bio-acetic acid yield.[319]

Wacker Chemie has also been investigating two other bio-based acetic acid routes:[320] (i) fermentation to butanediol – the process ferments biomass feedstock using bacteria to butane 2,3-diol, which could then be dehydrated to produce methyl ethyl ketone (MEK) or directly produce acetic acid via gas phase oxidation. Acetic acid from MEK is also possible via gas phase oxidation; and (ii) homoacetate fermentation – ferments biomass feedstock to acetate/acetic acid using bacteria. These two routes are still very early in development.[321]

ZeaChem Inc.

ZeaChem Inc. (Lakewood, Colorado) has developed a cellulose-based biorefinery platform capable of producing advanced fuels and intermediate chemicals. In 2012 ZeaChem completed construction of the core facility for its integrated demonstration biorefinery in Boardman, Oregon. The core will produce intermediate chemicals acetic acid and ethyl acetate for use within paints, lacquers and solvents applications. ZeaChem will sell bio-based chemicals to commercial and industrial customers seeking renewable and cost-competitive alternatives to petroleum-sourced chemicals. ZeaChem plans to continue to build their biorefinery platform to produce a broad portfolio of sustainable and economical chemicals and fuels derived from cellulosic biomass.[322]

Acetic acid is a commercial product and is also ZeaChem's intermediate building block for the production of ethyl acetate and subsequently cellulosic ethanol.[323] ZeaChem utilizes a fermentation process using an acetogen, a naturally occurring organism, to produce acetic acid. Using the broth produced in those fermentation runs, the acetic acid is concentrated using a solvent extraction process. This process is extremely energy-efficient compared to the more common distillation process. The acetic acid concentration achieved is highly pure, known in the industry as glacial acetic acid. ZeaChem has indicated that their acetic acid is salable to various manufacturing industries for the production of film, bottles and fibers among other products. ZeaChem will also use the acetic acid in an esterification process to convert it into ethyl acetate, a high-value salable product and the chemical

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[317] ICIS.com (March 25, 2010), *Germany's Wacker to License Bio-Based Acetic Acid Process*.
[318] ICIS Green Chemicals (April 13, 2010), *Wacker Licenses Bio-Acetic Acid Process*.
[319] Ibid
[320] Ibid
[321] ICIS.com (March 25, 2010), *Germany's Wacker to License Bio-Based Acetic Acid Process*.
[322] SpecialChem (January 9, 2012), *ZeaChem to Start Bio-Based Acetic Acid & Ethyl Acetate Production in Oregon*.
[323] Green Car Congress (February 16, 2010), *ZeaChem Produces Bio-Based Acetic Acid at Commercial Purity Concentration*.

precursor of ZeaChem-produced cellulosic ethanol. ZeaChem intends to scale to a commercial biorefinery upon successful operations at its 250,000 gallon-per-year facility, which is proposed to be built in Boardman, Oregon.[324]

The demonstration biorefinery currently produces acetic acid and ethyl acetate using locally-grown hybrid poplar. ZeaChem plans to have a commercial 25 million gallon/year plant and were hoping to start construction in 2013 - as soon as the demonstration plant has proven its design and metrics. According to the company, the biorefinery will be flexible enough to produce 100% cellulosic ethanol if needed or varying volumes of ethanol, ethyl acetate or acetic acid, whichever product is in demand.[325]

LanzaTech

LanzaTech has established a carbon dioxide-based acetic acid partnership with Malaysian oil and gas company Petronas. The companies will work together to develop and commercialize acetic acid production using waste carbon dioxide (sourced from refinery off gases and natural gas wells) as feedstock. The collaboration is still at the beginning stage.[326]

LanzaTech's proprietary fermentation process converts carbon monoxide (CO) in industrial waste gases, reformed natural gas and gas derived from any biomass source, into low carbon fuels and chemicals. LanzaTech and Petronas will work together to extend this technology to include carbon dioxide containing gases from a variety of sources including refinery off gases and natural gas wells to produce acetic acid.[327]

Celanese

Celanese has been exploring a bio-catalytic route to making acetic acid, in collaboration with US-based Diversa.[328] This collaboration was announced over a decade ago and no updated information could be located on any progress that this partnership has achieved.

8.18 Isoprene

Isoprene (CAS 78-79-5) is an essential starting material for a variety of synthetic polymers, most notably synthetic rubbers. A major portion of the isoprene produced globally is converted into polyisoprene, which is used in products such as footwear, mechanical

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[324] Green Car Congress (February 16, 2010), *ZeaChem Produces Bio-Based Acetic Acid at Commercial Purity Concentration*.
[325] Green Chemicals Blog (October 16, 2012), *LanzaTech in CO_2-to-Acetic Acid*.
[326] Green Chemicals Blog (October 16, 2012), *LanzaTech in CO_2-to-Acetic Acid*.
[327] LanzaTech, *Petronas and LanzaTech to Recycle CO_2 into Sustainable Chemicals*.
[328] ICIS.com (July 18, 2011), *U.S. Chemical Profile: Acetic Acid*.

instruments, medical appliances, sporting goods, and most extensively in rubber tires.[329] Global annual demand for isoprene is in the 1 million tonne range.[330] In 2008, approximately 60% of isoprene was used for tires, 30% for adhesives and the remainder for medical or personal care products.[331]

There is isoprene production in Canada, believed to be limited to co-products that are manufactured by Nova Chemicals in Corunna, Ontario and/or Joffre, Alberta. No production estimates are available apart from Environment Canada indicating that production of isoprene in Canada in 2006 was greater than 10,000 tonnes. Imports were estimated to be between 1,000-10,000 tonnes, while greater than 10,000 tonnes of isoprene was exported in 2006.[332] There is only one synthetic rubber production facility operating in Canada, specifically Lanxess, located in Sarnia, Ontario. The Lanxess facility in Sarnia primarily produces butyl rubber and would be expected to be by far the largest consumer of isoprene in Canada. The butyl rubber produced by Lanxess in Sarnia is primarily used in tire production. Based on the 1 million tonne global annual market for isoprene, Canada is estimated to consume in the vicinity of 10,000 – 50,000 tonnes of isoprene annually. Given that Alberta has no synthetic rubber manufacturing facilities and limited adhesive manufacturers (i.e. under five identified adhesive manufacturers), it is expected that there will be extremely small quantities of isoprene consumed annually in Alberta. It should be noted that Alberta has one tire manufacturing plant (i.e. Goodyear in Medicine Hat), however it is expected that the facility does not consume isoprene directly but instead consumes it through the synthetic rubber it purchases.

The majority of automobile tires are made of natural rubber from latex-bearing trees.[333] Demand for natural rubber is rising at a time when supplies could be constrained in the future. More people in China and Latin America are buying automobiles, which is increasing demand for tires, a large end market for natural rubber. However, rubber plantations take several years to mature.[334] Petroleum-based isoprene can partially replace natural rubber, but it is constrained in its production capacity. As a result, increasing rubber supply is a major current challenge facing the tire and rubber industry.[335]

With rising natural rubber prices due to shortage of availability and increasing use of synthetic rubber which is hard to decompose, scientists are attempting to find alternative solutions for the tire industry.[336] Currently isoprene is produced almost exclusively from

[329] IHS (December, 2011), *Bio-Based Isoprene*.
[330] IHS (December, 2011), *Bio-Based Isoprene*.
[331] Biofuels Digest (May 4, 2010), *What is Isoprene and Why Should You Master It? A Look at Genencor and GlycosBio*.
[332] Environment Canada and Health Canada (November, 2008), *Screening Assessment for the Challenge – 1,3-Butadiene, 2-methyl- (Isoprene) – Chemical Abstracts Service Registry Number 78-79-5*.
[333] Michigan State University (May 15, 2012), *Isoprene Research Could Lead to Eco-Friendly Car Tires*.
[334] ICIS.com (November 8, 2011), *US Amyris to Target Natural Rubber Market for Isoprene*.
[335] ICIS Green Chemicals (June 25, 2012), *Ajinomoto Collaborates with Bridgestone on Bio-based Isoprene for Rubber Tires*.
[336] Commodity On-Line, *Bio-Isoprene to Emerge as New Alternative for Tyre Production*.

petroleum-derived feedstocks, which in itself has inherent risks due to price volatility and the supply/demand situation of oil. Additionally, the processing of oil tends to be both expensive and environmentally unfriendly. Therefore, there is significant interest in developing technology that will produce isoprene in a cost-effective, environmentally friendly way, utilizing renewable sources.[337]

New sources of isoprene are also becoming critical as the trend towards cracking lighter feedstocks with the advent of North American shale gas is limiting production of isoprene. Isoprene has traditionally been produced as a by-product of the thermal cracking of naphtha to produce ethylene or via C_4 refinery stream synthesis.[338] More specifically, with the advent of shale gas in North America, crackers in the region are shifting to lighter feedstocks, so new sources of isoprene have become necessary.[339]

Production of bio-isoprene from starches and food wastes can take away the oil price volatility.[340] Bio-isoprene can be used for the production of synthetic rubber, which in turn is an alternative for natural rubber and other elastomers. As a result, the development of bio-isoprene will help reduce the tire and rubber industry's dependence on oil-derived products. Aside from synthetic rubber for tire production, bio-isoprene can be used in a wide range of products such as specialty elastomers, surgical gloves, golf balls and adhesives.[341/342] As bio-isoprene monomer is produced from renewable raw materials, manufacturers in many industries will be able to count on a reliable, consistent supply that is not subject to fluctuating oil prices.[343]

There are a number of partnerships that have been established globally for research and development leading to the production of bio-isoprene. These partnerships are summarized below.

Ajinomoto and Bridgestone Corp.

Ajinomoto and Bridgestone Corp. are jointly developing bio-isoprene using biomass for feedstock. The firms have been jointly conducting research since June, 2011. Ajinomoto has already successfully manufactured bio-isoprene at a laboratory-scale using fermentation processes. Bridgestone has indicated that they have successfully polymerized

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[337] IHS (December, 2011), *Bio-Based Isoprene*.
[338] ICIS Green Chemicals (September 28, 2011), *Amyris and Michelin in Bio-Isoprene*.
[339] ICIS.com (November 18, 2011), *Amyris Moves Toward Bio-Isoprene Commercialization*.
[340] TheBioEnergySite.com (June, 2010), *BioIsoprene – A Renewable Product with Biofuel Potential*.
[341] Goodyear Company (March 6, 2012), *Bio-based Tires Edge Closer to Reality/Collaboration Between the Goodyear Tire & Rubber Company and DuPont Industrial Biosciences Results in Breakthrough Technology for Tires Made with Renewable Raw Materials.*
[342] Goodyear Company (March 6, 2012), *Bio-based Tires Edge Closer to Reality/Collaboration Between the Goodyear Tire & Rubber Company and DuPont Industrial Biosciences Results in Breakthrough Technology for Tires Made with Renewable Raw Materials.*
[343] Accessed at the website of DuPont Industrial Biosciences (http://biosciences.dupont.com/industries/biomaterials/).

polyisoprene synthetic rubber using Ajinomoto's bio-isoprene. Ajinomoto and Bridgestone will decide on the potential for commercialization in 2013.[344]

DuPont Industrial Biosciences and Goodyear

On September 16, 2008, Genencor announced its collaborative research agreement with The Goodyear Tire & Rubber Company for bio-isoprene production.[345] The objective of the partnership has been to produce a low-cost, biomass-based bio-isoprene that would provide a strategic raw material for synthetic polyisoprene, stabilize costs, decrease dependence on fossil oils and natural rubber sourcing, and improve the environmental footprint of the tire business.[346] In December 2009, Genencor and Goodyear showcased the world’s first concept demonstration tires made with bio-isoprene technology at the United Nations Climate Change Conference in Copenhagen. In May 2011, DuPont Industrial Biosciences acquired Danisco and its Genencor division.[347]

DuPont Industrial Biosciences, through its acquisition of Genencor, has been researching the production of bio-isoprene from renewable biomass such as corn stalks, sugar cane and waste from food. However, the C_5 platform that is established in the production of bio-isoprene means that it can be used in a number of biochemicals and biofuel products.[348] Bio-isoprene can be used not only in car tires, but also adhesives, surgical gloves and even golf balls.[349] Other reported markets include diapers, feminine hygiene products, surgical gloves and other rubber-based products, which use block copolymers such as styrene-isoprene-styrene. [350]

DuPont is developing pilot plants for the production of bio-isoprene and eventually will build up to a full manufacturing plant. The first manufacturing plant is expected to be built in the U.S. together with Goodyear. The company is also looking to develop the product in Brazil, where it can be close to a supply of natural feedstock.[351] Genencor had initially indicated in 2011 that the company was exploring a pilot bio-isoprene plant that could be constructed in 2012 in Iowa.[352]

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[344] ICIS Green Chemicals (June 25, 2012), *Ajinomoto Collaborates with Bridgestone on Bio-based Isoprene for Rubber Tires*.
[345] Goodyear Company (March 6, 2012), *Bio-based Tires Edge Closer to Reality/Collaboration Between the Goodyear Tire & Rubber Company and DuPont Industrial Biosciences Results in Breakthrough Technology for Tires Made with Renewable Raw Materials.*
[346] Biofuels Digest (May 4, 2010), *What is Isoprene and Why Should You Master It? A Look at Genencor and GlycosBio*.
[347] Goodyear Company (March 6, 2012), *Bio-based Tires Edge Closer to Reality/Collaboration Between the Goodyear Tire & Rubber Company and DuPont Industrial Biosciences Results in Breakthrough Technology for Tires Made with Renewable Raw Materials.*
[348] TheBioEnergySite.com (June, 2010), *BioIsoprene – A Renewable Product with Biofuel Potential*.
[349] TheBioEnergySite.com (June, 2010), *BioIsoprene – A Renewable Product with Biofuel Potential*.
[350] Biofuels Digest (May 4, 2010), *What is Isoprene and Why Should You Master It? A Look at Genencor and GlycosBio*.
[351] TheBioEnergySite.com (June, 2010), *BioIsoprene – A Renewable Product with Biofuel Potential*.
[352] ICIS Green Chemicals (September 28, 2011), *Amyris and Michelin in Bio-Isoprene*.

Goodyear stated in March, 2012 that the two companies have already demonstrated proof of the technology through the production of a prototype tire made with DuPont and Goodyear's bio-isoprene monomer. The two companies said they expect additional investments to establish pilot plant operations and manufacturing infrastructure.[353]

The bio-isoprene technology is based on e.coli which naturally produces some isoprene, however not enough and not nearly quickly enough – the metabolic pathways are too complex. Therefore the technology optimizes the process by which carbohydrates are stripped of oxygen, leading to a 3,3-dimethylallyl pyrophosphate. At this point, the enzyme isoprene synthase catalyzes the production of bio-isoprene. Because isoprene is a gas at low temperatures, it bubbles out of the fermentation chamber and is recoverable without the use of costly separation techniques.[354]

Amyris and Michelin

Michelin is working with U.S.-based Amyris for the development of bio-isoprene using Amyris' 15-carbon molecule "farnesene". Amyris expects to begin commercialization of bio-isoprene in 2015 (for various customers beyond Michelin), with Michelin reportedly committing off-take volumes on a ten-year basis.[355/356] The companies have indicated that they are working to develop the use of bio-isoprene for the production of renewable-based rubber tires and other rubber-based products such as adhesives, coatings and sealants.[357] Amyris and Michelin will both contribute funding and technical resources to develop bio-isoprene.[358] A production capacity for bio-isoprene has not been stated.[359]

Amyris' technology can employ a broad range of plant sugars as feedstock to produce bio-isoprene through fermentation. However, they will use Brazilian sugarcane for the first product to go into production. Amyris currently has access to roughly 15 million tons of sugarcane crush in Brazil, based on a renewable farnesene agreement signed with Brazilian ethanol, electric-energy and sugar producer ETH Bioenergia. Under this agreement, the companies formed a joint venture that provides access to up to 2 million tonnes/year of sugarcane crush capacity at one of ETH's greenfield mills in Brotas, Brazil. Amyris will use this sugar to make renewable farnesene, which will be marketed under the brand name *Biofene*. This quantity of sugarcane crush is estimated to be enough to produce well over 700 million liters of farnesene a year, which will meet their production needs for farnesene and even bio-isoprene, as necessary. The company has a goal of ultimately switching to

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[353] ICIS Green Chemicals (June 6, 2012), *Ajinomoto, Bridgestone in Bio-Isoprene*.
[354] Biofuels Digest (May 4, 2010), *What is Isoprene and Why Should You Master It? A Look at Genencor and GlycosBio*.
[355] ICIS Green Chemicals (June 6, 2012), *Ajinomoto, Bridgestone in Bio-Isoprene*.
[356] ICIS Green Chemicals (September 28, 2011), *Amyris and Michelin in Bio-Isoprene*.
[357] ICIS Green Chemicals (September 28, 2011), *Amyris and Michelin in Bio-Isoprene*.
[358] ICIS Green Chemicals (June 25, 2012), *Ajinomoto Collaborates with Bridgestone on Bio-based Isoprene for Rubber Tires*.
[359] ICIS.com (November 18, 2011), *Amyris Moves Toward Bio-Isoprene Commercialization*.

cellulosic sugars as a raw material to achieve a better environmental footprint.[360] In December 2012, Amyris successfully began production of *Biofene*, at its Brotas facility. Product shipments from the Brotas plant began in late January, 2013.[361]

Amyris is also working with Japan chemical firm Kuraray to develop high-performance polymers by replacing petroleum-based butadiene and isoprene feedstock with Amyris' farnesene molecule.[362]

Glycos Biotechnologies

Glycos Biotechnologies has established an agreement with Malaysian biotech hub Bio-XCell for the establishment of an industrial biochemical plant and biotechnology R&D facility in Johor, Malaysia. Glycos Biotechnologies plans to focus on producing bio-isoprene at this facility in order to support Malaysia's rubber industry.[363] Malaysia was chosen as the location since it is the world's hub for rubber-based products (including 60% of surgical glove production) which can be made from bio-isoprene.[364] Glycos Biotechnologies commercial facility is being developed in several phases with a production rate capacity of up to 30,000 tonnes per year being reached by 2014 with a subsequent scale-up to 90,000 tonnes.[365] Apart from bio-isoprene the facility will also produce crude glycerol-based ethanol and acetone.[366] Investment in the facility is estimated at around $15-$20 million.[367] Glycos Biotechnologies is currently operating a 150,000 liters/year pilot facility outside Houston, Texas which started operation in November 2009. [368]

The technology (Bio-SIM™) developed by Glycos uses e.coli to convert glycerine or low-grade free fatty acids into acetone, technical-grade ethanol and bio-isoprene. The technology provides high-yields of bio-isoprene from low-cost feedstocks such as crude glycerol that are available globally and are sustainable on a large scale.[369] While the technology/microorganism can use sugars and cellulosics, the company's initial feedstock strategy is to use glycerine, waste fats/oils, free fatty acid distillates and other oleochemical processing by-products because of their economic advantage over sugars/starch/cellulosic

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[360] ICIS.com (November 18, 2011), *Amyris Moves Toward Bio-Isoprene Commercialization*.
[361] Amryis (March 21, 2013), *Amyris Welcomes Proposed Change of Control in its Sugarcane Supplier in Brazil*.
[362] ICIS Green Chemicals (June 6, 2012), *Ajinomoto, Bridgestone in Bio-Isoprene*.
[363] InnovativeIndustry.net. (December 12, 2010), *From Glycerine to Green Chemicals Part 1*.
[364] Biofuels Digest (May 4, 2010), *What is Isoprene and Why Should You Master It? A Look at Genencor and GlycosBio*.
[365] Glycos Biotechnologies (December 11, 2011), *Glycos Biotechnologies Selects Toyo Engineering & Construction Sdn Bhd to Construct the Company's Asian Biochemical Facility*.
[366] InnovativeIndustry.net. (December 12, 2010), *From Glycerine to Green Chemicals Part 1*.
[367] ICIS Green Chemicals (July 13, 2010), *Interview: Glycos Biotechnologies*.
[368] ICIS Green Chemicals (July 13, 2010), *Interview: Glycos Biotechnologies*.
[369] Accessed at the website of Glycos Biotechnologies (http://www.glycosbio.com/products-overview/isoprene/).

feedstock. The company can choose what type of high value chemicals to produce depending on domestic market needs.[370]

The company's long-term strategy is to form joint venture partnerships with oleochemical/biodiesel producers where they can benefit from additional revenue in making biochemicals by adding on Glycos' technology to their existing infrastructure. There are also plans to partner with end market players especially in the development of glycerine-based isoprene for use in latex. [371]

Aemetis

In June 2011, AE Biofuels (now called Aemetis) acquired Maryland-based industrial biotech company Zymetis, which led to the change of the company's direction. Aemetis now owns Zymetis' proprietary aerobic marine organisms, (Saccharophagus degradans 2-40 trademarked *Z-microbe*) that will enable the company to produce bio-isoprene, glycerine, and in the pipeline – adipic acid and butanediols.[372]

The Z-Microbe is a patented organism that converts a variety of renewable feedstocks such as sugar, starch and cellulose directly into renewable chemicals and fuels. The Z-Microbe technology utilizes consolidated bio-processing technology to convert multiple feedstocks into chemicals and fuels in one, low-cost process. The Aemetis Z-Microbe is a novel aerobic, marine bacterium with degradative abilities on a broad-spectrum of feedstocks.[373]

8.19 1,4-butanediol

1,4-butanediol (BDO) is a di-alcohol with two terminal hydroxyl (OH) groups, giving it a variety of useful chemical properties. It is one of the four isomers of butanediol. The two hydroxyl groups are useful in creating chains for polymer chemistry and the main uses for the chemical are for the production of polymers. 1,4-butanediol is used to make pharmaceutical and recreational drugs, and is therefore regulated under federal law in many jurisdictions including the United States. The table below describes the major global end-uses for BDO.[374] However, the demand in Canada is assumed to be low, with practically no demand in Alberta. Most of the global use for BDO lies in the production of polymers and synthetic fibers; neither of which are currently manufactured in Alberta or the rest of Canada. There may be minor Canadian uses for polyurethane, solvents and pharmaceuticals.

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[370] ICIS Green Chemicals (July 13, 2010), *Interview: Glycos Biotechnologies*.
[371] ICIS Green Chemicals (July 13, 2010), *Interview: Glycos Biotechnologies*.
[372] ICIS Green Chemicals (November 21, 2011), *AE Biofuels Enters Renewable Chems*.
[373] Accessed at the website of Aemetis (www.aemetis.com/technology).
[374] ICIS.com (2011). US Chemical Profile: Butanediol. Available at:
http://www.icis.com/Articles/2011/09/26/9494852/us+chemical+profile+butanediol.html

Table 124: Global End-use Pattern for 1,4-Butanediol

End-use	% of Global Use
Tetrahydrofuran	51%
gamma-Butyrolactone	20%
Polybutylene terephthalate resins	20%
Polyurethanes	5%
Other (solvent, resin raw material, chemical/pharmaceutical production)	4%

Source: Kirschner, M. (2009). *Chemical Profile: 1,4-Butanediol.* ICIS.com

The largest industrial use for 1,4-butanediol is in the production of tetrahydrofuran (THF) which is used to make polytetramethylene ether glycol (PTMEG). PTMEG is used to make spandex fibers, polyesters, and urethanes. Other important chemicals made from 1,4-butandiol include polybutylene terephthalate and gamma-butyrolactone, which is used in electronics, pharmaceuticals and other polymers. Given that the largest industrial use of BDO is for the production of synthetic fibers, Canadian use is relatively low and production is likely nonexistent. The large producers of BDO such as BASF are often integrated with the production of derivative products such as synthetic fibers or polymer resins. As a results, new plants in Canada or Alberta will likely require a partnership with a large user or BDO interested in offering a renewable product line in addition to an established product line. The table below lists the important producers of BDO in the US and would be likely partners for a bio-based BDO facility in Alberta.[375]

Table 125: Capacity of U.S. Producers of 1,4-Butandiol

(kilotonnes/year)

Company	Location	Capacity
BASF	Geismar, Louisiana	300
Invista	LaPorte, Texas	245
InternationalSpecialty Products	Lima, Ohio	145
LyondellBasell	Channelview, Texas	120
Total		810

Source: ICIS.com (2011). US Chemical Profile: Butanediol.

1,4-butanediol was originally produced via the Reppe acetylene process where acetylene is reacted with two equivalents of formaldehyde to yield 1,4-butynediol. This intermediate is then hydrogenated to 1,4-butanediol. Mitsubishi Chemicals pioneered the first non-

[375] Ibid.

acetylene route using butadiene. LyonedellBasell makes BDO using propylene oxide and other producers use the Davy process with maleic anhydride as the starting material. Recently, bio-based 1,4-butanediol production methods have gained attention with companies such as Genomatica (US), Novamont (Italy), and BioAmber (US) reporting that full scale production should be expected in 2013. Genomatica uses genetically engineered *E. coli* bacteria to metabolize sugars into 1,4-butanediol and announced in February 2013 that they would begin commercial production.[376] The Myryant Corporation (Quincy, MA) has partnered with Davy Process Technology to investigate the potential to replace maleic anhydride with bio-succinic acid produced from biomass for the production of BDO.[377]

BioAmber - through its Bluewater Biochemicals subsidiary - is currently building a manufacturing facility in Sarnia to produce bio-based succinic acid from corn. The $80 million plant will be located on part of the existing LANXESS industrial park site and is expected to be complete in 2014. Using corn as raw material, it will have an initial capacity of 17,000 tonnes per year, later producing 35,000 tonnes/year of biosuccinic acid, some of which will be converted to produce 23,000 tonnes/year 1,4-butanediol (BDO). The company uses a licensed DuPont hydrogenation catalyst to make 1,4-butanediol from bio succinic acid produced at its facility in France and has been doing so since 2010. [378] The provincial and federal governments are providing the company with $35 million in grants and loans to locate in Sarnia. Support was secured from the Ontario Ministry for Economic Development and Trade, Sustainable Development Technology Canada and the Canadian Sustainable Chemistry Alliance. Sarnia was chosen for its unique access to chemical infrastructure, skilled labor, educational facilities, competitive transportation costs and its proximity to some of Canada's richest agricultural land.[379, 380] Using the Sarnia facility as an example, Edmonton may be a viable candidate for a BDO plant given its similar situation as a major chemical manufacturing hub and proximity to agricultural land. Any BDO produced in Alberta will likely need to be exported to the US or Asia in order to access the market for BDO derivatives.

The main global producers of 1,4-butanediol include BASF (Germany), Dairen Chemicals (Taiwan), LyondellBasell Chemicals (The Netherlands), Shanxi Sanwei Group (China), International Specialty Products (US), Invista (US), and Mitsubishi Chemicals (Japan).[381]

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376 Genomatica. (2013). *BASF Licenses Genomatica's BDO Process.* Available at : http://www.genomatica.com/news/press-releases/basf-licenses-genomaticas-bdo-process/

377 Myriant Corporaation. (2011). *Myriant Technologies and Davy Process Technology Join Forces to Integrate the Myriant Bio-based Succinic Acid and Davy Butanediol Technologies to Offer a Renewable and Bio-based Butanediol Product*. Available at: http://www.myriant.com/media/press-releases/myriant-technologies-and-davy-process-technology-join-forces.cfm

378 BioAmber. Bio-Based 1,4-Butanediol. Available at: http://bio-amber.com/products/en/products/bdo_1_4_butanediol

379 Camford Chemical Report, Volume 43 Number 35 September 5, 2011

380 Tyler Kula, The Observer (October 2011) New bioindustrial plant announced for Sarnia. Available at: http://www.theobserver.ca/ArticleDisplay.aspx?e=3277325&archive=true. Accessed: January 18, 2012

381 ICIS.com (2011). US Chemical Profile: Butanediol. Available at: http://www.icis.com/Articles/2011/09/26/9494852/us+chemical+profile+butanediol.html

8.20 Epichlorohydrin (ECH)

Epichlorohydrin is an organochlorine compound consisting of three carbon atoms with an epoxide group. The chemical is sometimes called chloromethyl oxirane and exhibits a pungent garlic-like odour. Its unique functional groups make it highly reactive and it is used in the production of polymers, epoxy glues, and epoxy resins. [382]

The major uses for ECH are in epoxy resins which are important polymers used for adhesives and coatings. According to Dow Chemical Ltd., the world's largest producer of ECH[383], these applications account for roughly 83% of global consumption. Epoxy resins find applications in coatings for materials requiring a durable, chemically resistant outer layer. The resins also have good insulation properties and are used in the electronics industry for the production of circuit boards. Some fiberglass and carbon-fibre composite material use epoxy resins as the matrix thus having applications in sporting equipment, aerospace, and vehicle manufacturing. Thin coatings of the resin are also used to protect storage tanks, pipelines, and food/beverage cans from corrosion and abrasion. Historically, glycerol was produced from propylene via an epichlorohydrin intermediate but the recent surge in biodiesel production (where glycerol is produced in large quantities) has rendered this process route obsolete. Other applications for ECH include polyamide-epichlorohydrin resins (used to improve the strength of wet paper), water treatment chemicals, surfactants, and elastomers.[384][385]

ECH is produced in a two-step process from allyl chloride, derived from propylene. In the first step, allyl chloride is reacted with hypochlorous acid to give a mixture of two dichloro alcohol isomers. The mixture is then reacted with sodium hydroxide to form the epoxide ECH. [386]

There is some interest in processes to convert glycerol (considered a waste by-product of biodiesel manufacturing) into ECH. The Dow Chemical Company has patented a method where glycerol is dichlorinated using hydrogen chloride in the presence of a carboxylic acid catalyst followed by treatment with a base to form ECH. The feed material for this

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[382] ICIS. (2003). *Product Profile: Epichlorohydrin*. Available at: http://www.icis.com/Articles/2003/10/20/527103/product+profile+epichlorohydrin.html
[383] Dow Chemical Company. (2013). *Product Safety Assessment (PSA): Epichlorohydrin*. Available at: http://www.dow.com/productsafety/finder/epi.htm
[384] Ibid.
[385] Solvay Chemicals. (2002). *Applications of Epichlorohydrin.* Available at: http://www.solvaychemicals.com/Chemicals%20Literature%20Documents/Allylic_products/APP-2200-0000-W-EN_WW_.pdf
[386] Dow Chemical Company. (2013). *Product Safety Assessment (PSA): Epichlorohydrin*. Available at: http://www.dow.com/productsafety/finder/epi.htm

process may be less expensive than propylene (which is used in the traditional process) and represents a bio-based production route for ECH.[387]

Epichlorohydrin is not manufactured in Canada but is rather imported for use in polymers and epoxy resin. There are no facilities currently producing epoxy resins in Canada and the last facility to do so was Valspar in Toronto. Since the dominant end-use for ECH is in the production of epoxy resins, any new capacity in Canada would be restricted to exporting its product to the US or globally. Further complicating the ECH market is the fact that the leading ECH producers are also forward integrated to the production of epoxy resins. ECH produced in Alberta would rely on being cost-competitive with these established, industrial ECH facilities. Dow Chemical is also in the process of researching a bio-based route to ECH via biodiesel-derived glycerol.

The global production capacity for ECH was estimated by Dow Chemicals as 903,000 tonnes/year via the allyl chloride process described above.[388] The table below shows the major global producers of ECH indicating that Dow Chemical is the global leader in production.[389]

Table 126: Capacity of Major Global ECH Producers

(kilotonnes/year)

Company	Location	Capacity
Dow Chemical	Freeport, Texas, USA	380
Dow Chemical	Stade, Germany	105
Momentive	Norco, Louisiana, USA	100
Nan Ya	Mailiao, Taiwan	80
Momentive	Pernis, Netherlands	80
Solvay	Rheinberg, Germany	52
Asahi Glass	Kashima, Japan	50

Source: ICIS Chemical Business. *Product Profile: Epichlorohydrin*

Since Canada has no domestic production of ECH, it is solely an importer of the chemical with roughly 90% of imports originating from the US in 2012. The table below shows Canada's import statistics for the past four years. The import data indicates that the demand in Canada is low and likely restricted to low-volume, specialty applications.

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[387] Santacesaria, E. (2010). *New Process for Producing Epichlorohydrin via Glycerol Chlorination. Industrial & Engineering Chemistry Research*

[388] Dow Chemical Company. (2012). *Product Safety Assessment. DOW Epichlorohydrin*

[389] Environment Canada. (2008). *Screening Assessment for the Challenge, Oxirane, (chloromethyl)- (Epichlorohydrin)*

Table 127: Canadian and Alberta Trade in Epichlorohydrin

	2009		2010		2011		2012	
Canada	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**
Imports	4	$20	7	$31	37	$187	46	$231
Alberta								
Imports	0	$0	0	$0	0	$0	2	$12

Source: Canadian International Merchandise Trade, HS 291030: 1-Chloro-2,3-epoxypropane (epichlorohydrin)

8.21 Polylactic Acid

Polylactic acid (PLA) is a thermoplastic polyester derived from lactic acid: a fermentation product of sugars and starches. The plastic produced is a clear, stiff polymer with properties similar to polystyrene. It can be processed with conventional plastic processing technologies and formed into films, fibres, or molded parts. PLA has applications in plastic bottles, food packaging, films and bags, textiles, molded plastic cases and parts, and foam packing/insulation.[390] PLA films act as good oxygen barriers and may be suitable for food packaging applications. Temperatures above 60°C cause the polymer to lose structural integrity although new forms of the polymer are reported to have increased heat tolerance.[391] An attractive property of PLA is its ability to decompose to water and carbon dioxide when disposed of in a composting facility. Conventional small-scale municipal composting will not decompose polylactic acid. PLA has been used in some niche applications requiring biocompatibility such as in medical implants for bone and tissue surgery.

The main applications for lactic acid are as a food additive for pH buffering, flavouring, and bacterial inhibitor. It is produced on an industrial scale by the fermentation of starch or sugar by certain bacterial strains of the genus *Lactobacilli*. PLA can be produced from lactic acid via two pathways. The first involves the direct condensation polymerization of lactic acid with the production of one mole of water per mole of lactic acid reacted. The reaction is performed under vacuum or in azeotropic distillation in order to favour the formation of higher molecular weight polymers. The second, more common pathway, is the ring-opening polymerization of lactide: the cyclic di-ester of lactic acid.[392] The second method is employed by Natureworks LLC at their Blair, Nebraska plant for the production

[390] Garlotta, D. (2001). *A Literature Review of Poly(Lactic Acid).* Journal of Polymers and the Environment.
[391] Food Production Daily. (2012*). PLA bioplastics production could hit 1m tonnes by 2020 – nova-Institut*. Available at: http://www.foodproductiondaily.com/Packaging/PLA-bioplastics-production-could-hit-1m-tonnes-by-2020-nova-Institut
[392] Garlotta, D. (2001). *A Literature Review of Poly(Lactic Acid).* Journal of Polymers and the Environment.

of PLA. Lactic acid has two optical isomers L- and D- and the resulting PLA can take on a variety of properties by adjusting the proportions of each isomer in the polymer. Pure L-lactic acid is a crystalline, hard plastic, while D-L-lactic acid mixtures form pliable plastics. Global production of PLA is estimated at around 180,000 tonnes with 70% of that demand used for food packaging.[393]

There is no known PLA production in Canada although Canada does have a large production of corn: one of the main raw materials used to make PLA. The largest US producer of PLA is NatureWorks LLC based in Blair, Nebraska who sells the polymer under the trade name Ingeo.[394] The facility includes the world's largest lactic acid plant which feeds a PLA polymer plant with a 140,000 tonnes capacity. Other global producers of PLA include PURAC Biomaterials (Netherlands), and Pyramid Bioplastics Guben GmBH (Germany). PURAC has partnered with Sulzer (a Swiss engineering firm) and Synbra (a Dutch polystyrene producer) to produce a PLA foam (BioFoam) which it is marketing as a renewable replacement for polystyrene foam.[395,396]

Canada imports only modest quantities of PLA and little to none is imported into Alberta. The table below illustrates Canada's trade in PLA. Although there is no current demand for PLA in Alberta, the polymer could conceivably compete with polyethylene as a feedstock for the production of films and other plastic products. PLA is processed using conventional extrusion, molding, or film blowing technologies which means that a processor could conceivable expand their operations to include a PLA line. It is not a drop in substitute, however, and requires a tailored production process. Polylactic acid is unlikely to be cost competitive with polyethylene but it may be an attractive option for producers seeking to offer a small renewable product line at a premium cost. Unfortunately, there are few plastic processors in Alberta that may benefit from such a product line. Any plastic processor willing to produce PLA articles or films would need customers willing to pay the premium price. Since many of the plastic articles produced in Alberta are expected to be disposables (such as bags, packaging films, packing material), a higher cost product is unlikely to be attractive to these customers. An alternative angle for Alberta may lie in the production of PLA plastic resin to be sold outside of the province to large plastic processors in the US, China, or the rest of Canada. PLA can be produced from sugars and starches which are essentially the same feedstocks for producing bio-ethanol. The wheat harvested in Alberta could be a potential PLA feedstock.

[393] Food Production Daily. (2012*). PLA bioplastics production could hit 1m tonnes by 2020 – nova-Institut*. Available at: http://www.foodproductiondaily.com/Packaging/PLA-bioplastics-production-could-hit-1m-tonnes-by-2020-nova-Institut

[394] NatureWorks LLC. (2013). *The Ingeo Journey*. http://www.natureworksllc.com/The-Ingeo-Journey

[395] Synbra Technologies bv. *BioFoam.* Available at: http://www.biofoam.nl/index.php

[396] De Guzman, D., (2012). *NatureWorks expands PLA capacity.* Green Chemicals Blog. Available at: http://greenchemicalsblog.com/2012/09/06/natureworks-expands-pla-capacity/

Table 128: Canadian and Alberta Trade in Polylactic Acid

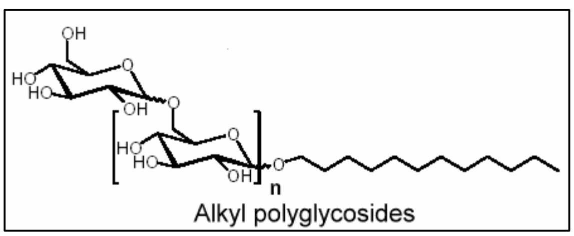
	2009		2010		2011		2012	
Canada	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**
Imports	1,511	$4,561	2,547	$7,626	1,726	$5,694	1,819	$5,722
Exports	80	$63	13	$54	49	$66	21	$30
Alberta								
Imports	0	$0	0	$0	0	$0	0	$2

Source: Canadian International Merchandise Trade Database, HS: 390770: Poly(lactic acid).

8.22 Alkyl Polyglucosides

Alkyl polyglucosides (APG) are a group of surfactants derived from fatty alcohols and starches or sugars. APG was initially conceived as surfactants for personal care washes and shampoos but have recently found applications in facial cleansing lotions, oral care products, wipes, laundry detergents, hard surface cleaners and industrial/institutional cleaning applications. These chemicals are an emerging group of non-ionic surfactants that have good emulsifying, foaming, and wetting properties. Chemically, APGs consists of glucose rings (the monomer of cellulose and many polysaccharides) bonded to and alkyl chain (straight, saturated hydrocarbon chain) as illustrated in the figure below. The substance is fully biodegradable and made from entirely renewable materials.[397] The sugar groups form the hydrophilic end of the molecule (water-attracting) while the alkyl groups forms the hydrophobic (water-repelling) end of the molecule. APGs are formed by the reaction of fatty alcohols with monosaccharides or polysaccharides in the presence of an acid catalyst (often sulfuric acid) at high temperatures.[398]

Figure 10: Chemical Structure of Alkyl Polyglycosides



Source: Cyberlipid.org. Available at: http://www.cyberlipid.org/glycolip/glyl0062.htm

[397] De Guzman, D. (2011). *Sugar-based surfactant development gains ground, riding on the success of growing demand for APG.* Green Chemicals Blog. Available at: http://www.icis.com/Articles/2011/05/09/9457923/development+and+demand+for+sugar-based+surfactants+are+on+the.html

[398] U.S. Patent 3598865, "Polyglycosides and process of preparing mono and Polyglycosides" of August 10, 1971, Atlas Chemical Industries.

There are a variety of related substances derived from natural oils and sugars that have similar properties to APG such as the *Suga* brand of bio surfactants made by the US company Colonial Chemicals. Lamberti, an Italian chemical company, is marketing a similar chemical: alkyl polyglucoside ethers. APGs belongs to a group of natural surfactants that have enjoyed recent market growth in niche as well as large market applications such as mass personal care, detergents, and home care cleaning. Very little data is available on country-specific demand for APG or even global demand. The global specialty surfactants market has been estimated at $600 million (US) of which naturally derived surfactants represent about 10%. APG is the leading natural surfactant category but no production volumes were readily available. The leading manufacturer of APG is currently Cognis, based in Germany and recently acquired by BASF. Other APG suppliers include Clariant, SEPPIC (France), Croda (UK), and LG Household & Health Care (South Korea).[399]

Alkyl polyglucosides are commonly found in home cleaners labelled as "green" products such as the Green Works' product line made by Clorox. These home cleaners are derived from plant-based feedstock and the majority contain APGs as a surfactant. These products are widely available in the Canadian marketplace and could conceivably be extended to industrial or commercial cleaning products.[400]

The market demand for APG in Canada and Alberta is unknown but expected to be low. APG belongs in a class of specialty surfactants for personal and home care which are not expected to be manufactured in Alberta. One Canadian company, Polyrheo Inc. (Montreal), was identified as a supplier of APGs but it is unclear whether they merely distribute APGs.[401] Fatty alcohols and polysaccharides could conceivably be produced in Alberta for the production of APG however the demand is not expected to be high. Producers of APG are marketing their surfactants and formulations thereof as cleaners for industrial uses as well as personal uses. Some potential customers for an APG-based surfactant product might be laundry/dish detergent producers, and industrial/commercial cleaning products. Customer demand for renewable products will need to be high to justify the higher costs compared to conventional surfactants.

[399] De Guzman, D. (2011). *Sugar-based surfactant development gains ground, riding on the success of growing demand for APG.* Green Chemicals Blog. Available at: http://www.icis.com/Articles/2011/05/09/9457923/development+and+demand+for+sugar-based+surfactants+are+on+the.html

[400] GreenWorks. (2011). Available at: http://www.greenworkscleaners.com/products/ingredients/

[401] Polyrheo Inc. (2011). *Alkyl Poly Glucoside (APG).* http://www.polyrheo.com/?product=alkyl-poly-glucoside-apg

8.23 Acrylic Acid and Acrylate Polymers

Acrylate polymers form a diverse group of chemicals based on the core structure of acrylic acid. Acrylic acid can be reacted to form a wide range of acrylic monomers such as methacylates and ethyl acrylates. Due to their applications in water treatment and surfactants, this section will focus on polyacrylic acid and polyacrylamides. Acrylic acid is not produced in Canada.

Polyacrylic acid is a low molecular weight polymer that is soluble in water. These polymers may be composed entirely of acrylic acid monomers or some proportion of acrylic acid and other co-monomers. Acrylic acid is produced by the catalytic oxidation of propylene as either a liquid solution or as concentrated glacial acrylic acid. These polymers are used as dispersants, absorbent polymers, anti-scalants, and detergents. Polyacrylic acid is produced from acrylic acid with or without an additional co-monomer in the presence of an initiator such as hydrogen peroxide and persulphate salts. The superabsorbent properties of polyacrylic acids and related polymers make them useful in water absorbing applications such as diapers and meat packaging. The largest global use of polyacrylic acid is in the detergent market (39%). The table below illustrates the remaining global demand for the polymer.

Table 129: Global Demand Pattern for Polyacrylic acid

Industry	**% Global Demand**
Detergents	39%
Water Treatment	20%
Clay and calcium carbonate	15%
Other (inks and paints, coatings, etc.)	26%

Source: Burridge E; (2005). *Product Profile: Polyacrylic Acids*, European Chemical News.

Polyacrylamide (PAM) is a water soluble polymer comprised of acrylamide monomers. Its ability to absorb and hold water allows it to form a gel when exposed to water. This property is exploited in its largest industrial application: as a flocculant, coagulant, and filtration aid. The table below lists the main global uses for PAM. It is formed by the solution or dispersion polymerization of acrylamide. The solution polymerization route produces dry polymer beads which must be ground into a powder in order to be used in water. Despite their names, acrylamides are not produced from acrylic acid and are instead produced mainly via the metal-catalyzed reaction of acrylonitrile. Acrylonitrile is produced via the Sohio process of catalytic ammoxidation of propylene.

Table 130: Global Demand Pattern for Acrylamides

Industry	% Global Demand
Water treatment	37%
Petroleum	27%
Pulp and paper	18%
Other (food, agriculture irrigation, etc.)	18%

Source: Burridge E; (2005). *Product Profile: Polyacrylic Acids*, European Chemical News.

Table 131: Canadian Polyacrylamide Producers

(kilotonnes/year)

Company	Location	Business
SNF Floerger	Trois-Rivieres, QC	Water treatment chemicals, flocculants
Nalco Canada	Burlington, ON	Water treatment chemicals, flocculants
Rohm and Haas Canada LP	Toronto, ON	Acrylic polymer emulsions

Source: Camford Information Services Inc. (1998). *CPI Product Profiles: Polyacrylamides*

There are substantial imports of acrylic polymers in Canada and Alberta but due to the wide range of polymers and polymer mixtures, it is difficult to narrowly define the market. The majority of PAM importers were oil and gas companies who likely use PAM as part of their drilling fluids. One important application is in enhanced oil recovery where PAM added to water produces a thick, highly viscous fluid that is injected into oil reservoirs to improve recovery. Oil and gas chemicals may also use PAM in their water treatment process as a flocculant to improve suspended solids removal. Municipalities may use PAM for their wastewater treatment and water purification processes. The tables below show the Canadian trade in acrylic polymers (including polyacrylamide) as well as the major importers in Alberta. The trade data includes polyacrylamides and polyacrylic acid. Canada is a large net importer of acrylic polymers with Alberta imports approaching 50 kilotonnes in recent years. Polyacrylic acid use in Alberta is expected to be similar to polyacrylamide since the majority of importers are oil/gas or related companies.

Table 132: Canadian and Alberta Trade in Acrylic Polymers

	2009		2010		2011		2012	
Canada	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**
Imports	131,614	$349,205	223,932	$481,131	182,300	$521,167	180,738	$506,904
Exports	70,112	$142,636	82,354	$170,816	79,429	$194,541	75,721	$185,452
Alberta								
Imports	22,240	$53,570	84,787	$106,162	47,323	$127,498	48,904	$135,605
Exports	105	$253	126	$255	49	$272	570	$1,309

Source: Canadian International Merchandise Trade Database, HS: 390690: Acrylic polymers, nes, in primary forms.

Table 133: Major Alberta Importers of Acrylic Polymers

Company	City	Province	Business Area
Baker Hughes Canada Company	Calgary	Alberta	Oil drilling services
Canadian Natural Resources Limited	Calgary	Alberta	Oil and gas
Cenovus Energy Inc.	Calgary	Alberta	Oil and gas
Husky Oil Operations Limited	Calgary	Alberta	Oil and gas
Hychem Canada Inc	Calgary	Alberta	Oil/gas, water treatment chemical supplier
Suncor Energy Oil Sands Limited Partnership	Calgary	Alberta	Oil and gas
Univar Canada Ltd.	Edmonton	Alberta	Chemical Distributor

Source: Industry Canada, Canadian Importers Database. HS 390690: Acrylic polymers, nes, in primary forms.

Since Alberta produces large quantities of propylene, it might be considered a reasonable choice for the production of acrylates and acrylic monomers (acrylic acid, acrylamide). However, there are no know acrylate producers in Alberta despite the abundance of propylene. There has been some recent development in bio-based routes to acrylic acid such as the Dow Chemical Company partnership with OPX biotechnologies. The OPX Biotechnologies process uses genetically engineered strains of E. coli to convert sugars into 3-hydroxyproionic acid, which can then be converted to acrylic acid.[402] 3-hydroxyproionic acid may also be used to create biodegradable polyesters directly.[403] Cargill and its partner Novozymes are also in the process of researching a similar technology.[404] Mitsui Chemicals has recently signed an agreement with Kemira OYJ (a Finish water chemistry company) for their polyacrylamide manufacturing technology. Mitsui uses a proprietary biocatalyst to produce the polymer instead of the conventional copper-based catalyst.[405]

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402 Bullis, K. (2010). *Better Bugs to Make Plastics.* MIT Technology Review. Available at: http://www.technologyreview.com/news/420852/better-bugs-to-make-plastics/#comments

403 University of Minnesota. (2010). *Biodegradable Polyester Produced From Non-toxic, Renewable Monomer*. Available at: http://www.license.umn.edu/Products/Biodegradable-Polyester-Produced-From-Non-toxic--Renewable-Monomer__Z05135.aspx

404 De Guzman, D. (2012). *OPXBio Update.* ICIS Green Chemicals. Available at: http://www.icis.com/blogs/green-chemicals/2012/01/first-2012-post-opxbio-update/

405 Saidak, T. (2013). *Mitsui Chemicals signs acrylamide bio-process technology license agreement with Kemira.* BioFuels Digest. Available at: http://www.biofuelsdigest.com/bdigest/2013/01/24/mitsui-chemicals-signs-acrylamide-bio-process-technology-license-agreement-with-kemira/

8.24 Acetone

Acetone is a flammable, oxygenated solvent at room temperature and pressure. It is a strong solvent with high volatility but is exempt from restrictions on volatile organic compounds (VOC) since it does not contribute to the formation of ground-level ozone.

The main uses for acetone are for chemical synthesis and industrial solvents. One third of the global demand for acetone is for solvents or degreasers. One quarter of global demand lies in the production of acetate cyanohydrin, which is a precursor to methyl methacrylate (MMA) and MMA polymers. The production of bisphenol-A (BPA) is another important use for acetone. The remaining demand is for the production of other solvents and chemicals such as methyl isobutyl ketone (MIBK), methyl isobutyl carbinol (MIBC), isophorone, cellulose acetate fiber, plastics, pharmaceuticals, printing inks, paints and varnishes. It is commonly found in household nail polish removers.[406]

Globally, roughly 90% of acetone is produced via the cumene process. Cumene or isopropylbenzene is made from fossil-fuel derived benzene and propylene. In this reaction, phenol is co-produced with acetone with 0.62 tonnes of acetone produced per tonne of phenol. The reaction involves the liquid phase oxidation of cumene to cumene hydroperoxide, which is cleaved to phenol and acetone in the presence of sulfuric acid.[407] There is no known production of acetone (or phenol, which is heavily imported into Canada) in Canada (although this will be confirmed, as some acetone may be generated as a co-product of some chemical processes). Benzene is produced in petroleum refineries. At its chemical operations in Fort Saskatchewan Alberta, Shell Canada reacts benzene with purchased ethylene to make ethylbenzene that it dehydrogenates to make styrene and hydrogen, which are sold. The styrene is used for making polystyrene and for other applications.

A biological route to the production of acetone was developed in England during the First World War from the fermentation of starch and sugars by some members of the bacteria genus *Clostridium*. This process yields a dilute mixture of acetone, butanol, and ethanol in about a 3:6:1 ratio, respectively. The co-products are separated via distillation.[408] This process was abandoned due to the adoption of the cumene process but it may present an opportunity for the renewable production of acetone from wheat or other available biomass sources in Alberta.

The total imports of acetone to Canada in 2012 were 12,000 tonnes, at an average value of approximately $1,400 per metric tonne, or about $17 million in total value. Close to 97%

[406] IHS Chemical, (2011). *Acetone*, Chemical Economics Handbook.
[407] Burridge E; (2010). *Product Profile: Acetone*, European Chemical News.
[408] Ullmann's Encyclopedia of Industrial Chemistry. (2003). *Acetone.* Wiley-VCH Verlag GmbH & Co, 6th ed.Vol 1.

of imports originated from the United States.[409] There were small amounts of acetone exports from Canada (51 tonnes) but since no Canadian acetone manufacturers were identified, this is likely due to reselling of bulk imported acetone by Canadian chemical distributors shipping to customers in the United States. Alberta imported 362 tonnes of acetone in 2012 and according to the Canadian Importers Database, the two major importers to the province were Shell Chemicals (likely for use as a solvent) and Univar Canada Ltd. (a chemical distributor).[410, 411] Main uses in Alberta are likely for industrial solvents for oilfield chemicals, and other formulated chemical products.

Table 134: Canadian and Alberta Trade in Acetone

	2009		2010		2011		2012	
Canada	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**
Imports	10,367	$12,668	10,591	$13,763	11,739	$17,614	12,132	$17,195
Exports	83	$85	68	$84	257	$225	51	$107
Alberta								
Imports	9	$30	173	$169	274	$400	362	$418
Exports	0	$0	0	$0	0	$0	3	$2

Source: Canadian International Merchandise Trade Database, HS: 291411: Acetone.

Although imports to Alberta are relatively small, there is the potential for displacement of those imports with a domestically produced acetone from biomass. Replacement of other solvents such as methyl ethyl ketone (MEK) by bio-acetone may also be a possibility since both solvents are typically used in a similar way. The imports of MEK to Alberta in 2012 were 276 tonnes.[412] Making bio-based acetone, along with butanol, and ethanol could form part of a value-added biosolvents product line focused on displacing a variety of conventional (fossil-fuel derived) solvents (not just acetone and butanol) imported into Alberta as well as other provinces.

8.25 Naphthas

Naphthas are a broad family of hydrocarbon liquids that contain mostly aliphatic molecules and are distilled predominantly from crude oil. Most naphthas are consumed internally within crude oil refineries and are ultimately made into gasoline or other refined products. Naphthas are also used in large quantities as feedstocks for petrochemical plants where they are thermally cracked for ethylene and other primary chemicals production. Naphtha solvents are upgraded products distilled from light and heavy naphtha refinery streams.

[409] Canadian International Merchandise Trade Database, Statistics Canada
[410] Canadian International Merchandise Trade Database, Statistics Canada
[411] Canadian Importers Database, Industry Canada.
[412] Canadian International Merchandise Trade Database, Statistics Canada

Production of naphtha solvents consumes only a small portion of the total naphtha quantity. The following profile discusses naphtha solvents exclusively.

Naphtha solvents are classified according to their boiling point ranges and the concentration of aromatic compounds. Isoparaffinic solvents are defined as naphtha solvents. The lightest naphtha solvents are fast-evaporating liquids containing 7 and 8-carbon molecules having a boiling point range between 70 C and 93 C (160 F and 200°F). The heaviest naphtha solvent can have a boiling point as high as 260 C (500°F) and be almost as viscous as a light oil. The most common solvent in the naphtha group, with approximately half of the overall volume, is commonly referred to as "mineral spirits", a solvent fractionated from a heavy naphtha hydrocarbon stream, and having a boiling point range of 154 C to 200 C (310 to 390°F).

Canadian demand is estimated at 100 to 120 kilotonnes for 2010.

Table 135: Estimated Canadian Demand for Naphthas

Application	% of Canadian Demand
Packaged Products (Household, Commercial, Industrial)	20-25%
Paints and Coatings	15-20%
Cleaning, Degreasing	20-30%
Printing	5-10%
Asphalt Cutbacks	5-10%
Other Applications	10-20%
Total (kilotonnes, 2010)	100-120

Source: Cheminfo Services estimates.

Packaged household, commercial and industrial products containing naphthas include degreasing products, various sprays, general purpose cleaners, automobile products, BBQ lighter fluid and many other items. Products are often sold in 1 L, 4 L, and 20 L sizes. There are 4-5 domestic packaging companies that supply branded and private-label products. Recochem is one of the largest Canadian packagers of such products.

Naphthas are also used in paints and coatings. Naphtha solvents can be used in primers, top-coatings, and maintenance products, such as road marking paints. However, water-based paints have taken market share from solvent-based products.

Naphtha solvents are used for cleaning. Most of this material is standard mineral spirits. The use is distributed widely across many sectors in Canada. Suppliers sell through small distributors in drums to industrial metal-working shops, auto repair shops, metal working shops, coating shops, farms and many other customers. A portion of the solvents used in cleaning applications is recycled.

Although most asphalt cutback uses water emulsions, naphtha solvents are used in some cutback formulations, and other asphalt products such as foundation sealers and roofing cements. There is limited use of naphthas in adhesives and none identified for adhesive tape manufacture. Some of the largest accounts for naphthas are formulators of roofing and asphalt cements. Some light naphtha solvents are used for formulating contact cement.

There is some naphtha solvents used in the formulation of oil and gas field chemicals. Naphthas can be used as a carrier for chemicals such as demulsifiers, corrosion inhibitors, and other products. Some of the solvents used in oil and gas chemicals become mixed with the oil or gas product and are re-processed at refineries.

There are three oil refineries in Canada that have units producing naphtha solvents. The Imperial Oil and Shell solvent plants are both located in Sarnia, ON and produce a full product slate. The Imperial Oil plant has a higher capacity than Shell's unit. The Suncor refinery in Edmonton, AB, only produces a single mineral spirit product, which is sold in the prairie market.

Bio-naphtha is being produced. The Finnish company Neste Oil launched the production and sales of bio-naphtha as a co-product of its NExBTL renewable diesel refining process at its sites in Finland, the Netherlands and Singapore in 2012. Feedstocks to produce bio-naphtha currently fall into three categories: natural oils, biomass, and bio-methane for naphtha production via gas-to liquids (GTL) technologies. Current developers of technologies by feedstock type are listed below.[413]

Natural oils:

- NExBTL – Neste's process produces renewable diesel, renewable jet fuel, bio-propane and bio-naphtha;
- Total – Total has patented a process to produce bio-naphtha from plant oils, they also produce renewable diesel, renewable jet fuel, and bio-propane;
- EERC/Tesoro – The Energy & Environmental Research Center (EERC) at the University of North Dakota is collaborating with Tesoro to produce bio-naphtha using renewable plant oils;
- Syntroleum – Syntroleum has developed a process that uses natural plant oils and animal fats to produce renewable diesel, renewable jet fuel, bio-propane and bio-naphtha.

Three companies were identified that produce bio-naphtha from biomass, namely Solena, Rentech and UPM. All three use gasification to produce syngas, which is catalytically converted into a number of products, including bio-naphtha. Two companies (Shell and Sasol) have processes that utilize methane as a feedstock, and using catalysis to produce a number of hydrocarbon products, including naphtha. Neither of these companies have

[413] Nexant, *Bio-Naphtha: Missing Link to the "Green" Chemicals Value Chain,* 2013.

expressed an interest in using bio-methane as feedstock instead of methane, but their processes could be easily adapted to allow for this.[414]

8.26 Toluene

Toluene ($C_6H_5CH_3$) is an aromatic hydrocarbon solvent consisting of a 6-carbon ring structure and one attached methyl group. Globally, toluene is mainly (i.e., ~80%) used as an intermediate in the production of fuels and chemicals. The other 20% of global use is largely as a solvent in coatings, adhesives, inks and as a processing aid ("extraction solvent") in the production of pharmaceutical and other chemical products. Overall, toluene solvent is used in hundreds of products and by a large number of manufacturing facilities. However, the largest demands in Canada are: in petroleum refineries, where it is used to make transportation fuels, and as a chemical reactant. Solvent applications for toluene, which are relatively minor include paints and coatings, printing, tape manufacturing, and for oil/gas field chemicals.

Total Canadian demand is estimated at 150 to 200 kilotonnes per year. Relatively large quantities of toluene are dealkylated to make benzene that is used as a raw material for Petresa Canada's linear alkylbenzene (LAB) plant in Montreal, Quebec.[415]

Table 136: Canadian Demand for Toluene

Application	% of Canadian Demand
Petroleum refinery and chemicals	80-90%
Paints and Coatings	5-10%
Printing	1-5%
Oil/Gas Field Chemicals	1-5%
Cleaning and degreasing	1-5%
Adhesives and Sealants	1-5%
Tapes	1-5%
Miscellaneous	1-5%
Total (kilotonnes, 2010)	150-200

Source: Cheminfo Services estimates

Canadian petroleum refineries and chemicals plants that make toluene include: Shell Canada in Sarnia, ON: Imperial Oil in Sarnia, ON; and Suncor Energy in Sarnia, Ontario and Montreal, QC. These producers also operate other aromatic units.

[414] Nexant, *Bio-Naphtha: Missing Link to the "Green" Chemicals Value Chain,* 2013.
[415] This was not confirmed in time for this report.

Table 137: Canadian and Alberta Trade in Toluene

	2009		2010		2011		2012	
Canada	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**
Imports	9,544	$17,559	57,150	$48,724	64,456	$69,750	72,901	$91,008
Exports	22,636	$14,929	12,623	$9,686	7,671	$8,355	11,871	$13,770
Alberta								
Imports	2,486	$2,219	841	$808	5,342	$6,694	3,317	$4,637
Exports	4,367	$1,874	47	$13	242	$319	73	$70

Source: Canadian International Merchandise Trade, HS 290511, Methanol, (methyl alcohol).

There was a substantial increase in toluene imports in 2010 from a much lower level in 2009. It is assumed this increased quantity of imported toluene is destined for benzene production for Petresa Canada's LAB facility.[416] Alberta represents a relatively small proportion of Canadian toluene imports.

8.27 Xylenes

Xylenes are aromatic hydrocarbons consisting of a benzene ring with two methyl groups. There are three isomers, namely: ortho-xylene, meta-xylene, and para-xylene. These xylenes can be separated for use as chemical feedstocks, or left as mixtures and sold in lower price applications such as solvents.

Ortho-xylene is oxidized to make phthalic anhydride, which is used to make phthalate plasticizers among other things. Meta-xylene is oxidized to make isophthalic acid, which is used in unsaturated polyester resins. However, para-xylene has by far the largest market of the three isomers. Para-xylene is predominantly used for the making of purified terephthalic acid (PTA). PTA is used to make polymers such as polyethylene terephthalate (PET) and polybutylene terephthalate (PBT). PET is one of the largest volume polymers in the world.[417]

Limited plastics production occurs in Alberta, and no imports or exports of p-xylenes were recorded for Alberta between 2009 and 2012 (see xylene trade data below). Similarly, there were limited imports of o-xylenes into Alberta, indicating that these chemicals are not widely used within Alberta. However, mixed xylenes are used in solvent applications, and can be found in paints and coatings, industrial adhesives and cleansers, and degreasing agents.

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[416] Calls placed to industry to confirm this assumption were not returned in time for preparation of this report.
[417] Nexant Chemical Systems Website, http://www.chemsystems.com/about/cs/news/items/PERP%200910_8_Xylenes.cfm

Xylenes are primarily generated via refinery catalytic reformers, olefins plants, coal tar processing, and toluene disproportionation units. Additional processing of these streams is required to separate the mixed xylenes, and to separate the isomers.

There are six chemicals plants featuring aromatics units in Canada. These units typically produce benzene, toluene and xylenes, as well as heavy aromatics. No data was available on how much xylene they produce. The facilities are shown in the table below.

Table 138: Canadian Aromatics Units

Facility Owner	Location
Shell Canada	Scotford, Alberta
Imperial Oil	Sarnia, Ontario
Nova Chemicals	Corunna, Ontario
Shell Canada	Sarnia, Ontario
Suncor Energy Products	Sarnia, Ontario
Suncor Energy	Montreal, Quebec

Source: Oil &Gas Journal, Dec 2009

Xylol, as defined by the *Canadian International Merchandise Trade Database*, is not manufactured in the same manner as the other xylene isomers/mixture described above. Instead, xylol is specifically defined as a product of the distillation of coal tar. Some of the other direct products of the distillation of coal tar include pitch, creosote oil, dead oil, benzol, toluol, naphthalene, anthracene and other products.

One coal tar refining facility was identified in Canada, namely Rutgers International (VTF Canada) in Hamilton, Ontario. Rutgers International utilises feedstock from nearby integrated iron and steel making facilities (the main producers of coal tar), and then refines the coal tar. The refining process takes the raw wet coal tar and moves it through a dehydrator, which removes any remaining flushing liquor that was used to quench the coal tar at the steel mill. The dry coal tar is then heated in a vacuum distillation tower.

8.27.1 Xylenes Uses and Trade Data

The following subsections provide trade data as well as some analysis on the individual xylene isomers, mixed xylenes, and xylol. The trade data was sourced from Statistics Canada's *Canadian International Merchandise Trade Database*.

8.27.1.1 Mixed Xylenes

Approximately 10% of world production of xylenes is estimated to consist of xylene mixtures.[418] These mixtures are used as a solvent in a number of products where good solvent capacity and relatively fast evaporation are required, such as paints, glue, car care products, sealing agents, and degreasing agents.

Table 139: Canadian and Alberta Trade in Mixed Xylenes

	2009		2010		2011		2012	
Canada	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**
Imports	65,701	$114,807	42,217	$49,947	184,583	$221,355	123,469	$154,430
Exports	21,376	$12,379	5,606	$4,295	2,515	$3,242	1,425	$1,913
Alberta								
Imports	2,037	$1,890	1,055	$1,123	7,231	$9,367	7,695	$114,807
Exports	6,311	$3,350	0	$0	413	$533	51	$12,379

Source: Canadian International Merchandise Trade, HS 290244, Mixed Xylenes.

Alberta exports of mixed xylenes dropped from 6,311 tonnes in 2009 to 0 in 2010. Since then, in 2011 and 2012, Alberta exports of mixed xylenes have not reached more than 500 tonnes, and were only 51 tonnes in 2012. While Alberta exported just over three times the amount of mixed xylenes than they imported in 2009, the trend has since reversed significantly as exports have nearly halted and imports have climbed to over 7,000 tonnes per year.

Alberta exports of mixed xylenes made up nearly one third of total Canadian mixed xylene exports in 2009. When Alberta exports ceased completely in 2010, however, total Canadian exports of mixed xylenes decreased over 40%, indicating that this downturn in mixed xylenes exports may not have been isolated to Alberta. Much like the Alberta mixed xylene exports, total Canadian exports of mixed xylenes have not recovered post 2010, and imports of mixed xylenes have increased from 65,701 tonnes in 2009 to 154,430 tonnes in 2012.

8.27.1.2 o-Xylenes

Ortho-xylene is generally used for phthalic anhydride (PAN) production. The major use for PAN is in plasticizers for polyvinyl chloride strongly tied to the housing market and unsaturated polyester resins used in manufacture of reinforced laminates for the

[418] Swedish Chemicals Agency, *Information on Substances – Xylene,* http://apps.kemi.se/flodessok/floden/kemamne_eng/xylen_eng.htm

construction and automobile industries as well as in alkyd resins used in solvent based paints.

Table 140: Canadian and Alberta Trade in o-Xylenes

	2009		2010		2011		2012	
Canada	(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)
Imports	73	$466	120	$363	169	$431	131	$444
Exports	21,436	$15,924	21,436	$19,258	18,083	$24,476	14,141	$21,068
Net	21,305	$15,480	21,267	$18,827	17,963	$24,113	14,068	$20,602
Alberta								
Imports	18	$84	4	$17	4	$20	12	$46

Source: Canadian International Merchandise Trade, HS 290241, o-Xylene.

No exports of o-xylenes from Alberta were recorded between 2009 and 2012, and imports of o-xylenes did not exceed 20 tonnes between 2009 and 2012. Overall, Alberta involvement in o-xylenes has been extremely limited between 2009 and 2012. Canadian imports of o-xylene reached their peak in 2011 at 169 tonnes, and between 2009 and 2012 were never been equivalent to more than 1% of exports. Given that there were no recorded exports of o-xylenes from Alberta from this period, it is likely that there are a number of other facilities in Canada capable of producing xylenes.

8.27.1.3 m-Xylenes

No Canadian exports of m-xylene were recorded between 2009 and 2012. Only 10 kilograms of m-xylene was imported into Alberta between 2009 and 2012 (ten kilograms were imported in 2012).

Table 141: Imports of m-Xylenes into Canada

(tonnes, $'000)

2009		2010		2011		2012	
(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)
47,132	$36,433	115,654	$105,435	4	$13	5	$38

Source: Canadian International Merchandise Trade, HS 290242, m-Xylene.

Imports of m-xylene into Canada have fallen since 2009, declining from 47 tonnes to approximately 5 tonnes in 2012.

8.27.1.4 p-Xylenes

No trade was recorded for p-xylenes in Alberta between 2009 and 2012. Canadian trade for p-xylenes was also minor, although exports of p-xylenes have been increasing. This increase, however, has not been steady, as all exports of p-xylenes from Canada ceased completely in 2010, before continuing in 2011.

Table 142: Canadian Trade in p-Xylenes
(tonnes, $'000)

	2009		2010		2011		2012	
Canada	('000 litres)	($000)	('000 litres)	($000)	('000 litres)	($000)	('000 litres)	($000)
Imports	151	$87	26	$15	35	$20	89	$52
Exports	7,877	$6,413	0	$0	4,829	$7,915	14,768	$21,157
Net	6,324	$7,825	-35	$-20	4,803	$7,900	14,617	$21,070

Source: Canadian International Merchandise Trade, HS 290243, p-Xylene.

8.27.1.5 Xylol (from coal tar distillation)

No exports of xylol from Alberta were recorded between 2009 and 2012. Imports of xylol into Alberta have fluctuated largely between 4,311 litres and 9,446 litres, although imports fell to only 341 litres in 2010.

Table 143: Canadian Trade in Xylol

	2009		2010		2011		2012	
Canada	('000 litres)	($000)	('000 litres)	($000)	('000 litres)	($000)	('000 litres)	($000)
Imports	4,467	$2,814	431	$1,242	9,667	$7,525	13,654	$10,826
Exports	2,929	$2,130	1,828	$1,537	3,857	$3,907	4,687	$3,574
Net	-1,538	$-684	1,397	$295	-5,810	$-3,618	-8,967	$-7,252
Alberta								
Imports	4,311	$2,473	341	$934	9,446	$7,040	6,771	$4,363

Source: Canadian International Merchandise Trade, HS 270730, Xylol.

Imports of xylol into Alberta made up the majority of total Canadian xylol imports between 2009 and 2011, and still represented approximately nearly 50% of total Canadian xylol imports in 2012. More xylol was imported into Canada then exported from Canada each year except for 2010, which saw a significant drop in xylol imports. Aside from 2010, xylol imports have increased each year, from 4,467 tonnes in 2009, to 13,654 tonnes in 2012.

8.28 Ethanol

The total Canadian capacity for ethanol is now between 1.5 to 2.0 billion litres per year. Over 90% of ethanol production is used as a gasoline additive. Greenfield's Chatham and Greenfield's Tiverton ethanol production facilities have the capability to also make industrial grade ethanol. This grade is used in a variety of applications such as pharmaceuticals, hand sanitizers, chemical formulations (e.g., paints, adhesives), cleaners and cosmetics. In many of these applications, the ethanol needs to be free of odoriferous and other substances that are contained in fuel grade ethanol. As a result, components of ethanol that can contribute to objectionable odours such as some aldehydes and fusel oils[419] need to be removed to make industrial grades. This is carried out using additional distillation steps. The demand for industrial grade ethanol in Canada is roughly estimated to be 20 to 40 kilotonnes per year. It is mostly sold to chemical product formulators in Ontario and Quebec. Alberta demand may be on the order of 1 to 4 kilotonnes per year.

Table 144: Canadian Ethanol Plants

Company	City	Prov
Greenfield Ethanol	Johnstown	ON
Greenfield Ethanol	Varennes	QC
Greenfield Ethanol*	Tiverton	ON
Greenfield Ethanol*	Chatham	ON
IGPC Ethanol Inc.	Aylmer	ON
Permolex International, L.P.	Red Deer	AB
Pound-Maker Agventures Ltd.	Lanigan	SK
Suncor St. Clair Ethanol Plant	Sarnia	ON
Terra Grain Fuels Inc.	Belle Plaine	SK
NorAmera Bioenergy Corp.	Weyburn	SK
North West Bio-Energy Ltd.	Unity	SK
Amaizeingly Green Products LP	Collingwood	ON
Husky Energy	Lloydminster	SK
Husky Energy	Minnedosa	MB
Iogen Corporation	Ottawa	ON

Source: Cheminfo Services Inc. * Producers known to be capable of making industrial grade ethanol for solvent and other applications.

[419] The term fusel oil comes from an old German word "*fuseln*", which means "to bungle" and was applied to bad spirit as in distilled alcohol and also bad tobacco.
Source: Monash Scientific, Available at: http://www.monashscientific.com.au/FuselOils.htm.

8.29 Heavy Aromatics

Heavy aromatic solvents are a group of three commodity grade solvents characterized by specific boiling ranges, flash points[420], and an aromatics content close to 100%. Flash points range from 38 C to 93 C (100 F to 200 F) Products are sometimes distinguished by their flash points in degrees Fahrenheit. They are part of the aromatics group of hydrocarbon solvents, having in common a 6-carbon “aromatic-ring” structure that gives the solvents a distinct odour. Heavy aromatic solvents are made at petroleum refining companies and petrochemical plants, which North American suppliers such as ExxonMobil, Shell, Chevron and Citgo.

Total Canadian demand for aromatic solvents is estimated to be between 30 and 40 kilotonnes for the year 2010.

Table 145: Canadian Demand for Heavy Aromatics

Application	% of Total Canadian Demand
Paints and Coatings	20-30%
Oil and Gas Field Chemical	20-30%
Pesticides	20-30%
Metalworking applications	5-10%
Wood Treatment	5-10%
Miscellaneous	1-5%
Total Canadian demand (kilotonnes, 2010)	30-40

Source: Cheminfo Services estimates, based industry input.

Heavy aromatic are used in coatings formulations as a solvent, as well as diluents and cleaning solvents. One of the larger uses in the coatings market has been the metal coil coatings segment. Heavy aromatics can constitute a portion of the solvent mix used for coil coating resin formulations. No coil coating facilities were identified in Alberta. Two large coil coaters in Ontario are: Baycoat in Hamilton; and Metal Koting in Toronto. Coil coating facilities typically operate controls to reduce VOC emissions and odour releases to air.

Other heavy aromatic uses for coatings are more for manufacturing/industrial applications (not consumer paints). Examples would be automotive coatings, where heavy aromatics have been used in low levels in primer, base coat and clear coat formulations. All of the automotive manufacturing in Canada occurs in Ontario, although vehicle refinishing and heavy mobile equipment refinishing is spread out across Canada.

[420] Flash point is the lowest temperature at which the vapours from the solvent will first ignite from a spark in an enclosed cup test. A higher flash point temperature indicates that the solvent is less volatile and requires higher temperatures to ignite.

The oil and gas industry is one of the larger markets for heavy aromatics. Heavy aromatics have been in some demulsifiers, corrosion inhibitors, drilling muds, paraffin control agents and other applications. The majority of the Canadian oil and gas industry is centered in Alberta.

Heavy aromatics have been used in other applications, including agricultural pesticides. The market is seasonal with the most of the volume shipped between January and June each year. The majority of Canadian pesticide manufacturing facilities are in Ontario (11 of 25), and only 2 are located in Alberta[421], indicating a fairly limited Alberta market for heavy aromatics used in pesticide manufacture.

8.30 Methyl Ethyl Ketone

Methyl ethyl ketone or MEK, is an organic compound with the formula $CH_3C(O)CH_2CH_3$, and is also sometimes referred to as butanone. MEK is manufactured in high volumes for use in paints, glues, and other finishes because it rapidly evaporates and will dissolve many substances. There is no known production in Canada. Total Canadian imports and demand for MEK were 6 kilotonnes in 2010.

Table 146: Estimated Canadian Demand for MEK

(kilotonnes)

Application	% of Total Canadian Demand
Paints and Coatings	40-50%
Printing	40-50%
General Purpose Cleaning	5-10%
Adhesives and Sealants	1-5%
Miscellaneous	1-5%
Total (kilotonnes)	6.1

Source: Cheminfo Services estimates.

Nearly half of Canadian demand for MEK is in the coatings industry. MEK is used in some industrial coatings formulations, where the strong solvency is required for many of the durable and long chain polymers involved. Architectural paints are now rarely formulated with ketones. MEK is also used in automotive paints and applied at assembly plants in Ontario. MEK is used in some printing ink formulations, particularly in rotogravure or flexographic inks used for polymeric substrates. Wallpaper printing uses MEK/aromatic solvent mixtures, and vinyl printing for automotive upholstery, furniture and pool liners use MEK as a solvent because of its effectiveness on plasticized polyvinyl chloride (PVC).

[421] Industry Canada, *Canadian Industry Statistics,* NAICS 32523

MEK has found some use as a cleaning solvent due to its strong solvency, use in some polymer adhesives, and other applications.

The main commercial route to MEK is the dehydrogenation of butanol. Some companies employ sulphuric acid hydration of n-butene to make the butanol. No data on bio-based MEK was identified, however there is activity and information about regarding how MEK can be substituted with a variety of other bio-based solvents for certain applications. Some of the more common bio-based solvents used for cleaning purposes include ethyl lactate, d-limonene, and vegetable oil based solvents.

Canadian imports of MEK ranged from approximately 5,000 tonnes to just over 6,000 tonnes between 2009 and 2012. Exports were very limited, as no more than 55 tonnes of MEK were exported in any year between 2009 and 2012. Exports are likely sales from Canadian distributors of imported product. Imports of MEK into Alberta were under 300 tonnes between 2009 and 2012.

Table 147: Canadian and Alberta Trade in MEK

	2009		2010		2011		2012	
Canada	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**
Imports	5,273	$9,529	6,115	$11,197	6,056	$14,058	5,099	$11,280
Exports	7	$63	55	$116	45	$191	54	$141
Alberta								
Imports	173	$282	177	$309	14	$69	276	$709

Source: Canadian International Merchandise Trade, HS 291412, butanone, (methyl ethyl ketone).

8.31 Methyl Isobutyl Ketone (MIBK)

Methyl isobutyl ketone (MIBK) is a colourless liquid, a ketone and a solvent with the formula $(CH_3)_2CHCH_2C(O)CH_3$. MIBK is used primarily in the paints and coatings market, with some use in printing. Additionally, MIBK can also be used in metal extraction processes, as a solvent for pharmaceuticals and adhesives, and as a chemical intermediate. There is no known producers of MIBK in Canada, so total domestic demand is equal to imports in the 0.8 to 2 kilotonnes/year range.

Table 148: Canadian Demand for Methyl Isobutyl Ketone (MIBK)

Application	% of Total Canadian Demand
Paints and Coatings	70-80%
Printing	10-15%
Other Consumer and Commercial	10-15%
Other uses	1-5%
Total (kilotonnes, 2010)	0.9

Source: Cheminfo Services estimates.

The majority of Canadian demand for MIBK exists in the paints and coatings sector, and most of that demand is for automotive coatings specifically. All automotive production in Canada occurs in Ontario, and therefore any potential use of MIBK for automotive coatings in Alberta would be for refinishing purposes, although auto refinishes are not formulated in Alberta. No trade data for MIBK was identified for Alberta.

Table 149: Canadian Imports of Methyl Isobutyl Ketone (MIBK)

	2009		2010		2011		2012	
Canada	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**
Imports	864	$1,630	878	$1,775	933	$1,959	1,375	$2,573

Source: Canadian International Merchandise Trade, HS 290511, 291413 4-Methylpentan-2-one(methyl isobutyl ketone).

There are two main methods of producing MIBK. One is through acetone condensation, which gives diacetone alcohol that dehydrates to give mesityl oxide, which is then hydrogenated to MIBK. MIBK is also produced from isopropanol, with diisobutyl ketone (DIBK) and acetone as co-products. Some limited information on bio-based MIBK was found, however the sources were limited and the current widespread commercial use of bio-based MIBK could not be confirmed.[422/423] There are, however, several bio-based solvents that might be used to replace MIBK in certain applications, such as ethyl lactate, d-limonene, and possibly soy based solvents.

[422] Transparency Market Research, *Methyl Isobutyl Ketone (MIBK) Market - Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2012 – 2018*.
[423] University of Minnesota, *Methyl Isobutyl Ketone from Glucose Using a Biobased Chemical Process.*

8.32 Ethers, Esters and Acetates

This group includes glycol ethers, glycol ether esters, and ethyl, propyl, butyl and other acetates, all of which are water-soluble solvents. These are used in a variety of applications, including paints and coatings, printing, degreasing, film laminations, and general purpose cleaning. This profile covers only ethers, esters and acetates used as solvents, and chemicals such as vinyl acetate (that is a polymer precursor) are not discussed.

Table 150: Estimated Canadian Demand for Ethers, Esters and Acetates
(kilotonnes)

Application	% of Total Canadian Demand
Paints and Coatings	30-40%
Printing	20-30%
Other Consumer and Commercial	15-20%
Film Laminations	10-15%
Cleaning, Other uses	1-5%
Total Canadian (kilotonnes, 2010)	15-30

Source: Cheminfo Services estimates.

Esters (predominantly butyl acetate) and glycol ether esters are common solvents in industrial paints and coatings and automotive coatings. Glycol ethers can be used as a cosolvent in waterborne paints. About 50 to 60% of the Canadian demand for these products within the paints and coatings industry is for automotive coatings, including automotive re-finishes. Demand for these products for architectural paints accounts for approximately 20-30% of demand. Other uses include electronics, flatwood products, and auto-parts.

Demand for ethers, esters and acetates within the printing sector is concentrated in flexographic printing inks and diluents (e.g., for printing on plastic films), as is the case for most solvents used in this application. Lithographic printing also uses fountain solutions containing small amounts of glycol ethers and acetates to dampen the plates. Glycol ethers and glycol ether esters are also utilized for degreasing and aqueous cleaning formulations. There is also some limited use of ethers, esters and acetates for general purpose cleaning.

The following import and export tables show trade data for several ethers and acetates for all of Canada and for Alberta. Due to limitations in available trade data, this information will not cover all ethers, esters and acetates in Canada, and does not include information on the domestic production of any of these chemicals. However, the data does provide some perspective regarding the relative importance of these chemicals.

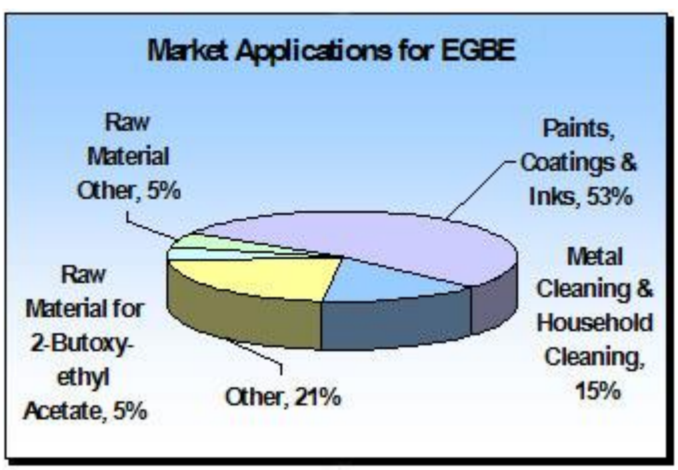
Table 151: Canadian Ether Imports

	2009		2010		2011		2012	
	(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)
Diethyl Ether	1,099	$2,527	1,537	$3,232	822	$1,538	1,021	$1,695
Acyclic Ethers and Derivatives	1,195	$6,631	8,396	$31,305	459	$4,119	760	$5,290
Aromatic Ethers and Derivatives	277	$2,118	401	$2,320	304	$1,933	246	$2,182
Monobutyl Ethers of Ethylene Glycol	4,251	$7,716	4,722	$8,803	4,409	$9,074	4,970	$9,235
Other Monoalkylethers of Ethylene Glycol or of Diethylene Glycol	1,720	$3,906	1,582	$3,688	1,468	$3,528	1,018	$3,436
Total	8,541	22,898	16,638	49,347	7,463	20,192	8,016	21,839

Source: Statistics Canada, Canadian International Merchandise Trade.

Canadian imports of ethers totalled approximately 8 kt in 2012, with only two ethers being imported at volumes surpassing one kilotonne: diethyl ether (1 kt); and monobutyl ethers of ethylene glycol (4.9 kt). Imports of monobutyl ethers of ethylene glycol (EGBE) comprise approximately 62% of total ether imports into Canada, and is the single most widely produced glycol ether.[424] EGBE is widely used as a solvent in various applications, such as in surface coatings, spray lacquer, quick-dry lacquers, enamels, varnishes, varnish removers, latex paint, metal cleaners, and in commercially available cleaning products. The following figure shows the approximate distribution of market demand for EGBE in different applications.

Figure 11: Market Applications For EGBE



Source: Dow Chemicals, *Product Safety Assessment – Ethylene Glycol Monobutyl Ether*.

[424] Dow Chemicals, *Product Safety Assessment – Ethylene Glycol Monobutyl Ether*.

EGBE is not known to be produced in Canada. EGBE can be produced by reacting ethylene oxide and normal butanol (n-butanol) using a catalyst. If the ratio of ethylene oxide to n-butanol is greater than one, di- and tri-ethylene glycol monoethers are produced along with the EGBE. Four companies imported the majority of EGBE into Canada in 2012 (80% of total EGBE imports), these companies are:[425]

- Dow Chemical Canada;
- Eastman Chemical Canada;
- Equistar Chemical, LP; and
- Univar Canada Ltd.

One ether was exported from Canada at volumes of over one kt in 2012, namely acyclic ethers and derivatives (2.8kt). Acyclic ethers and derivatives accounted for approximately 99% of total ether exports from Canada in 2012.

Table 152: Alberta Ether Imports

	2009		2010		2011		2012	
	(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)
Diethyl Ether	3	$31	0	$0	0	$3	0	$0
Acyclic Ethers and Derivatives	25	$169	3	$18	4	$17	26	$238
Aromatic Ethers and Derivatives	60	$419	1	$23	2	$14	10	$230
Monobutyl Ethers of Ethylene Glycol	654	$1,159	768	$1,319	890	$1,824	1,303	$2,430
Other Monoalkylethers of Ethylene Glycol or of Diethylene Glycol	77	$161	35	$87	4	$15	7	$43
Total	820	1,940	806	1,448	900	1,873	1,346	2,940

Source: Statistics Canada, Canadian International Merchandise Trade.

EGBE constitutes 97% of Alberta ether imports, and no other ether was imported in quantities of more than 26 tonnes in 2012 (1,303 tonnes of EGBE was imported into Alberta in 2012). This indicates that Alberta demand for EGBE is much higher than for any of the other ethers. Alberta demand for EGBE was also relatively high in comparison to some of the other Canadian provinces, as Alberta accounted for approximately 26% of total Canadian EGBE imports. No information on bio-routes to the production of EGBE was identified.

[425] Industry Canada, *Canadian Importers Database.*

Table 153: Canadian Acetate Imports

	2009		2010		2011		2012	
	(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)
Ethyl Acetate	6,689	$9,906	7,698	$10,552	7,669	$11,454	7,577	$11,839
N-butyl Acetate	7,090	$8,462	6,341	$9,203	8,091	$13,308	7,661	$10,548
Dinoseb Acetate	15	$70	7	$73	8	$78	2	$19
Sodium Diacetate	372	565	374	566	388	587	608	919
Total	14,167	19,003	14,420	20,395	16,155	25,427	15,847	23,326

Source: Statistics Canada, Canadian International Merchandise Trade.

Two acetates represented nearly all of the imports of acetates into Canada:

- ethyl acetate – 48% of total acetate imports; and
- n-butyl acetate – 48% of total acetate imports.

As there is little acetate production in Canada, these import figures indicate that the above two substances comprise the majority of Canadian demand for acetates. The only manufacturer of acetates identified in Canada was Macco Organiques Inc., operating out of Valleyfield Quebec. The only product Macco distributes out of those acetates discussed above is sodium diacetate.

Table 154: Alberta Acetate Imports

	2009		2010		2011		2012	
	(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)
Ethyl Acetate	28	$66	19	$53	65	$191	77	$150
N-butyl Acetate	20	$30	10	$17	895	$1,514	72	$110
Dinoseb Acetate	0	$0	0	$0	0	$0	0	$0
Sodium Diacetate	0	0	0	0	0	0	0.31	0
Total	48	96	29	70	961	1,705	150	261

Source: Statistics Canada, Canadian International Merchandise Trade.

Only 150 tonnes of acetates were imported into Alberta in 2012. The two acetates that made up the majority of Canadian imports also made up the majority of Alberta imports. Ethyl acetate and n-butyl acetate were imported into Alberta in similar ratios to their imports into Canada – about 50:50. However, Alberta demand for acetates is relatively low being less than 1% of total Canadian acetate imports.

8.33 Hydrogen Peroxide

Hydrogen peroxide is a commodity chemical that is a clear, water soluble liquid with the chemical formula H_2O_2. It is the simplest peroxide and like other peroxides, it is a strong oxidizer. It is used in the brightening of mechanical pulps, which accounts for roughly 50% of global demand and over 90% of Canadian demand. Other applications in Canada include textile bleaching (1%), water treatment (3%), and chemical synthesis (2%).[426] Hydrogen peroxide is commercially produced by the anthraquinone process. Anthraquinone, a polyaromatic organic compound acts as a catalyst to combine H_2 and O_2 into H_2O_2. Degussa is the only major producer in Alberta.[427]

Table 155: Major Hydrogen Peroxide Producers in Canada
(kilotonnes)

Company	Location	Capacity
Degussa	Gibbons, AB	90
Arkema	Becancour, QC	73
FMC of Canada	Prince George, BC	48
Kemira	Maitland, ON	41

Source: ICIS.com (2004). *Product Profile: Hydrogen Peroxide*, Camford Information Services, *Product Profiles: Hydrogen Peroxide*

The major users of hydrogen peroxide in Alberta are the mechanical pulp mills. Kraft mills may also use some H_2O_2 as part of their bleaching process.[428] Other uses in Alberta are low.

Table 156: Major Mechanical Pulp Mills in Alberta

Company	Location
ANC Timber Ltd.	Whitecourt
Millar Western Forest Products Ltd	Whitecourt
Slave Lake Pulp Corporation	Slave Lake

Source: Government of Alberta. (2010). *Connecting with the Forest Industry.*

The following table documents Canadian trade in hydrogen peroxide. It shows that Canada and Alberta are both net exporters.

[426] Camford Information Services (2000). *Product Profiles: Hydrogen Peroxide*
[427] Ibid
[428] Camford Information Services (2000). *Product Profiles: Hydrogen Peroxide*

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Table 157: Canadian and Alberta Trade in Hydrogen Peroxide

	2009		2010		2011		2012	
Canada	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**	**(tonnes)**	**($000)**
Imports	29,980	21,540	47,429	31,998	53,667	30,873	48,575	26,040
Exports	79,627	36,075	87,298	37,400	103,191	45,875	88,496	40,120
Alberta								
Imports	760	446	220	171	116	79	328	222
Exports	9,479	6,266	23,678	14,568	37,966	23,173	29,549	17,875

Source: Canadian International Merchandise Trade Database, HS 284700: Hydrogen Peroxide

Bio-based routes to hydrogen peroxide are not common but since the feedstock to the traditional process are H_2 and O_2, it is conceivable that renewable source of hydrogen could be used. A conventional hydrogen peroxide producer might incorporate a gasification system to produce hydrogen from biomass to create a small, renewable hydrogen peroxide product line. It is unclear whether there is consumer interest in renewable hydrogen peroxide. Hydrogen from the electrolysis of water supplied by renewable energy may also be a potential route although no research was readily discovered on either methods.

8.34 Sulphuric Acid

Sulphuric acid is a clear, water soluble, highly corrosive mineral acid with the formula H_2SO_4. It is one of the most widely used chemicals globally and a common industrial acid.

Canadian production of sulphuric acid has been relatively flat at about 4.3 million tonnes since 1995. The table below illustrates the capacity of sulphuric acid plants in Canada. Acid from metal smelters is typically produced by the wet sulphuric acid process where SO_2 (g) from the smelter is catalytically oxidized to SO_3 (g) followed by hydration to H_2SO_4. This type of acid production is typical in Ontario and Quebec where the majority of Canadian sulphide mineral smelting occurs. A second source of sulphur for the production of sulphuric acid is from the desulphurization of petroleum and natural gas in Western Canada. Typically, natural gas producers, refineries, and bitumen upgraders will produce elemental sulphur that is sold to dedicated sulphuric acid plants. These facilities burn sulphur to produce SO_2, which is then fed into the contact process where it first oxidized to SO_3 (g). The SO_3 is dissolved to form oleum ($H_2S_2O_7$ (l)) and is reacted with water to form sulphuric acid. Total Canadian sulphuric acid consumption in 2005 was estimated to be approximately 2,400 kilotonnes with 1,500 kilotonnes consumed by captive producers (largely the fertilizer industry in Western Canada). Merchant consumption accounted for the remaining 900 kilotonnes.[429]

[429] Cheminfo Services, (2007). *North American Sulphuric Acid Market Analysis*.

Table 158: Estimated Capacity of Canadian Sulphuric Acid Producers

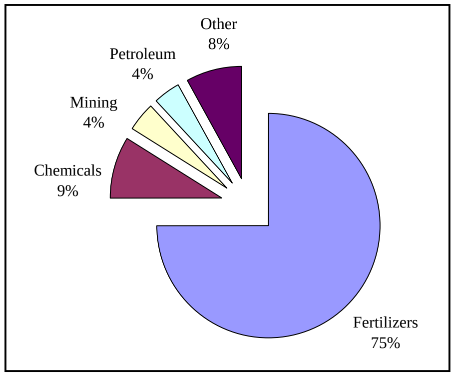
(kilotonnes)

Company	Location	Capacity	% of Total
Sulphur Burner Acid			
Agrium	Redwater, AB	900	17%
Agrium	Ft Saskatchewan, AB	233	4%
Border Chemical	Transcona, MB	150	3%
Marsulex	Ft Saskatchewan, AB	150	3%
Cameco	Key Lake, SK	72	1%
Cameco	Rabbit Lake, SK	72	1%
Smelter Acid			
CVRD Inco Limited	Coppercliff, ON	1536	29%
Falconbridge	Rouyn-Noranda, PQ	460	9%
Canadian Electrolytic Zinc	Valleyfield, PQ	440	8%
Cominco	Trail, BC	430	8%
Falconbridge	Sudbury, ON	300	6%
Brunswick Mining & Smelting	Belledune, NB	180	3%
Gaspe Copper Mines	Murdochville, PQ	160	3%
Others		208	4%
Total		5,291	100%

Source: Camford Information Services, *Sulphuric Acid Profile*. Only some capacities are up to date for 2012.

As illustrated in the table below, fertilizer companies consume approximately three quarters of the sulphuric acid production in North America. Production of chemicals, mining operations, pulp and paper, and petroleum refining comprise the majority of the remaining demand. Demand in these sectors tends to be more concentrated with fewer facilities than the "Other" application areas, which is a fragmented set of diverse users in many sectors of the economy, for example including iron and steel and pulp and paper production. In Canada, the distribution of uses is largely skewed as pulp and paper and chemicals account for significant uses. Fertilizers are another important use.

Figure 12: North American Sulphuric Acid Uses



Source: Chemical Market Reporter (November-December 2005), *Chemical Profile for Sulphuric Acid - Smelter*.

Table 159: Estimated Regional Canadian Merchant Consumption of Sulphuric Acid, 2005

(kilotonnes)

Segment	Western Canada and Prairies	Ontario	Quebec and Eastern Canada	Total
Pulp and Paper	297	86	121	504
Inorganic Chemicals	31	155	124	310
Mining	20	10	10	40
Organic Chemicals	2	12	10	24
Petroleum Alkylation	12	6	6	24
Iron and Steel	0	24	0	24
Other	7	10	7	24
Fertilizers	0	0	0	0
Total	370	302	278	950

Source: Cheminfo Services estimates based from various Canadian and U.S. sources.

One of the uses for merchant sulphuric acid in Western Canada is kraft pulp mills. Small quantities may also be used in mechanical pulp mills as well as paper mills. Sulphuric acid at kraft mills is used mostly as a reactant in chlorine dioxide generators. Chlorine dioxide is a kraft pulp bleaching agent that has virtually replaced elemental chlorine bleaching in

North America. It is almost always made on-site, and usually requiring some sulphuric acid for its production.

Sulphuric acid is used in mining of copper, uranium, and other metals. In Canada, an estimated 150 kilotonnes of sulphuric acid is used for mining, with about 110 kilotonnes of this amount used for uranium mining in Saskatchewan. The remainder is used in mining of other metals as well as non-metal mines (excluding smelting).[430]

Fertilizer production accounts for the highest demand in North America and in Alberta, which has a large fertilizer industry. The great majority of the sulphuric acid use for fertilizers is supplied by on-site sulphur burning acid plants. Sulphuric acid is use in the "wet method" for the production of phosphoric acid. Phosphoric acid is mainly used in the production of phosphate fertilizers, such as ammonium phosphates. The overall reaction is as follows:

$$Ca_5F(PO_4)_3 + 5\ H_2SO_4 + 10\ H_2O \rightarrow 5\ CaSO_4{\bullet}2\ H_2O + HF + 3\ H_3PO_4\ \text{(acid)}$$

Sulphuric acid is also used as in the production of various chemicals such as automobile batteries, sugar bleaching, cellulose fibres, steel manufacturing, and the regeneration of ion exchange resins. Water treatment operations and other chemical processes may use sulphuric acid to regulate pH.[431]

The table below describes the current trade in sulphuric acid and indicates that Canada is a large exporter of the chemical due to its high domestic sulphur production. Alberta does not export significant quantities of sulphuric acid compared to the national figures due in large part to the captive sulphuric acid market for fertilizer production.

Table 160: Canadian and Alberta Trade in Sulphuric Acid

	2009	2009	2010	2010	2011	2011	2012	2012
Canada	(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)
Imports	104,718	$15,130	80,164	$13,268	111,213	$21,324	74,674	$14,243
Exports	862,053	$151,183	1,194,934	$88,100	1,843,323	$168,186	2,024,626	$169,445
Alberta								
Imports	4,645	$481	38	$55	37	$54	19	$36
Exports	0	$0	279	$26	583	$472	1,084	$284

Source: Canadian International Merchandise Trade Database, HS 280700 Sulphuric acid; Oleum

430 Cheminfo Services, (2007). *North American Sulphuric Acid Market Analysis*.
431 Ibid.

Research revealed a small number of processes for developing “renewable” sulphur. A US patent published in 2004 describes a method to produce sulphuric acid by contacting a sulphur material (sulphide ore or elemental sulphur) with a type of acidophilic bacteria.[432] This method is not technically a bio-based method since it does not use biomass as the feedstock material. It is more aptly considered a process to produce biologically-derived sulphuric acid. The company Carbon Recycling International (Iceland) released a statement in May 2013 about a proposed facility to produce methanol and sulphuric acid from the stack emissions at Hellisheidi power plant in Iceland. The company already produces methanol from the CO_2 emissions at other Icelandic power plants. The SO_2 generated by the combustion of coal or biomass will presumably be used to produce sulphuric acid. Unless the CO_2 from the power plant comes from biomass, the produced sulphur cannot be said to be of bio-based origins.[433]

8.35 Diluent for Bitumen Pipeline Transport

Diluent is a thinning agent made up of a mixture of organic compounds containing the lighter hydrocarbons. Diluent is added to bitumen produced at oilsands facilities and in situ oil facilities in order to allow the bitumen to flow through pipelines. In general, approximately one barrel of diluent is required for every three barrels of bitumen to ensure optimal movement.[434] The lighter hydrocarbons utilized in diluents will consist of hydrocarbons with a carbon chain length of five to nine carbon atoms (C-5’s to C-9s).[435]

Different diluent formulations may be utilized, however, diluent used in Alberta’s oil and gas industry generally does not need to be pure or conform to a narrow range of performance parameters.[436] However, the diluent needs to be within a certain fairly broad API gravity range and have a relatively low sulphur content. Therefore, a bio-alternative could potentially be used in order to replace some diluent content.

It is reasonable to assume that oilsands mining facilities that are integrated with upgraders will have little or no immediate financial or significant environmental interest to replace any internally-produced diluents with bio-diluent (though they do purchase some diluent). In-situ bitumen facilities that do not produce their own diluent and must purchase diluent in order to ship their product, may have some interest. The price of the biodiluent would need to be competitive. There would also need to be no technical or customer issues (e.g., associated with bitumen transportation and refining, or other issues).

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[432] Cassels, J. (2004). *Materials and method for the biological production of sulphuric acid*. US Patent 20040086450 A1

[433] Carbon Recycling International. (2012). Available at: http://www.carbonrecycling.is/

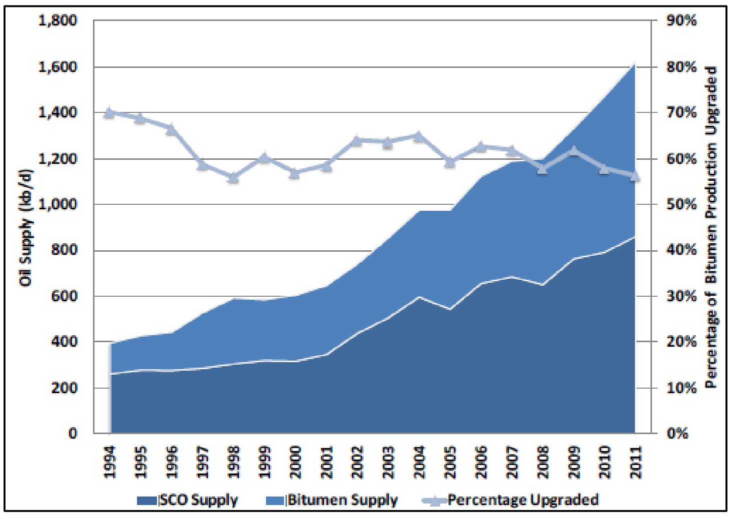
[434] Financial Post, *Diluent Shortages Could Make for Sticky Situation for Alberta Bitumen,* May 2013.

[435] Cheminfo Services based on industry sources.

[436] Cheminfo Services based on industry sources.

There are approximately 16 in-situ bitumen facilities in Alberta. These facilities are not integrated with upgraders, and therefore purchase diluent in order to ship their bitumen via pipeline to upgraders, refiners, or other customers purchasing bitumen. These facilities are currently expanding at faster rates than integrated oilsands facilities. This may present an opportunity for diluent producers in the coming years. The following figure shows the bitumen supply, the synthetic crude oil (SCO) supply, and the percentage of bitumen produced in Alberta that has been upgraded within Alberta in 1994-2011.

Figure 13: Alberta Bitumen Supply



Source: Strategy West Inc., Canada's Oil Sands – A World Scale Hydrocarbon Resource

The figure shows that the percentage of Alberta bitumen upgraded within Alberta has been declining as bitumen production has outstripped Alberta upgrader capacity. Increasing quantities of bitumen are therefore being shipped to out-of-province upgraders. As the requirement to ship bitumen produced by in-situ operations via pipeline increases, so will the demand for diluent.

This situation was apparent as early as 2006, when the National Energy Board published a report stating that diluent demand will outstrip domestic diluent production and that diluent prices were rising and would likely continue to rise.[437] Increasing quantities of light oils to be used as diluents are already being shipped from the United States to Alberta.[438] This could potentially represent an opportunity for diluent producers (and therefore producers of bio-products that could be used as/in diluent formulations) if this trend continues.

However, this situation could change. Enbridge has recently announced they are considering constructing a new diluent pipeline in addition to pursuing an expansion of

[437] National Energy Board, *Canada's Oil Sands – Opportunities and Challenges to 2015: An Update*, 2006.
[438] Financial Post, *Diluent Shortages Could Make for Sticky Situation for Alberta Bitumen*, May 2013.

their Southern Lights pipeline (which is already bringing diluent from the Chicago area to Edmonton).[439/440] Additionally, future rail expansion in Alberta could lessen the requirement for diluent (as bitumen shipped by rail does not require diluent), and some bitumen producers are already shipping their bitumen by rail as opposed to by pipeline.[441]

Diluent prices fluctuate depending upon the differential between the market price for light oils such as naphtha and the market price of heavy oils. The constantly evolving situation regarding regional pricing for light oils that can be used as diluents and/or diluent products is complex and requires further analysis for better understanding.

A bio alternative to the light oils used as diluents (specifically bio-naphtha) is available, although it is unknown if this is suitable for use in diluent. The Finnish company Neste Oil launched the production and sales of bio-naphtha as a co-product of its NExBTL renewable diesel refining process at its sites in Finland, the Netherlands and Singapore in 2012. Feedstocks to produce bio-naphtha currently fall into three categories: natural oils, biomass, and bio-methane for naphtha production via gas-to liquids (GTL) technologies. Current developers of technologies by feedstock type are listed below.[442]

- NExBTL – Neste's process produces renewable diesel, renewable jet fuel, bio-propane and bio-naphtha;
- Total – Total has patented a process to produce bio-naphtha from plant oils, they also produce renewable diesel, renewable jet fuel, and bio-propane;
- EERC/Tesoro – The Energy & Environmental Research Center (EERC) at the University of North Dakota is collaborating with Tesoro to produce bio-naphtha using renewable plant oils;
- Syntroleum – Syntroleum has developed a process that uses natural plant oils and animal fats to produce renewable diesel, renewable jet fuel, bio-propane and bio-naphtha.

Several companies producing bio-naphtha from biomass, include: Solena, Rentech and UPM. These companies use gasification to produce syngas, which is then catalytically converted into a number of products, including bio-naphtha. Two companies (Shell and Sasol) have processes that utilize methane as a feedstock, which is then catalytically converted to a number of hydrocarbon products, including naphtha.[443] No information was identified on the current prices of the bio-naphtha produced by these businesses. Therefore, no comparison of bio-naphtha prices to normal diluent prices is available. However, given experience with other bio-products, bio-naphtha is expected to be more expensive than conventional naphtha, which presents a barrier for customer adoption.

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[439] The Record, *Enbridge Plans new Diluent Pipeline in Northern Alberta with $1B Price Tag*, October 2013.
[440] Times Colonist, *Enbridge Plans New Diluent Pipeline in Northern Alberta With $1B Price Tag,* October 2013.
[441] Oil and Gas Investment Bulletin, *Shipping Crude Oil by Rail: A Victim of its Own Success?*, April 2013.
[442] Nexant, *Bio-Naphtha: Missing Link to the "Green" Chemicals Value Chain,* 2013.
[443] Nexant, *Bio-Naphtha: Missing Link to the "Green" Chemicals Value Chain,* 2013.

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9. APPENDIX C: Decision Matrix

Table 161: Attractiveness of Potential Biochemicals Opportunities for Further Research

	Regional Market in or Near Alberta	Maturity of Bio-based Production Process	Import Displacement Potential for Alberta	Niche Market Potentials	Total Score	Rank
Guar gum						
Carboxymethylcellulose						
Phenol						
Ethanolamines						
Hydrogen						
Surfactants						
Oilfield chemicals						
Lubricants						
Alpha-olefins						
Acrylic acid and acrylate polymers						
Soaps and cleaners						
Ammonia						
Methanol						
Adhesives and sealants						
Xanthates						
Isopropanol						
Heavy aromatics						
Toiletries and cosmetics						
Pesticides						
Ethylene						
Urea						
Hexane						
Paints and coatings						
Polylactic acid						
Alkyl polyalkyloglucosides						
Acetone						
Ethanol						
Polystyrene, competitive materials						
Glycerol carbonate						
Acetic acid						
Explosives						
Polyols						
Ethers, esters and acetates						
Polyethylene						
Morpholine						
1,4 butanediol						
Naphthas						
Hydrogen peroxide						
Ethylene oxide and ethylene glycol						
Carbon black						
Sulphuric acid						
Pigments and dyes						
Isoprene						
Epichlorohydrin						
Carbon and graphite anodes						
Toluene						
Xylenes						
Methyl ethyl ketone						
Methyl isobutyl ketone						