Canada's Chemical Industry: Evolving with the Times

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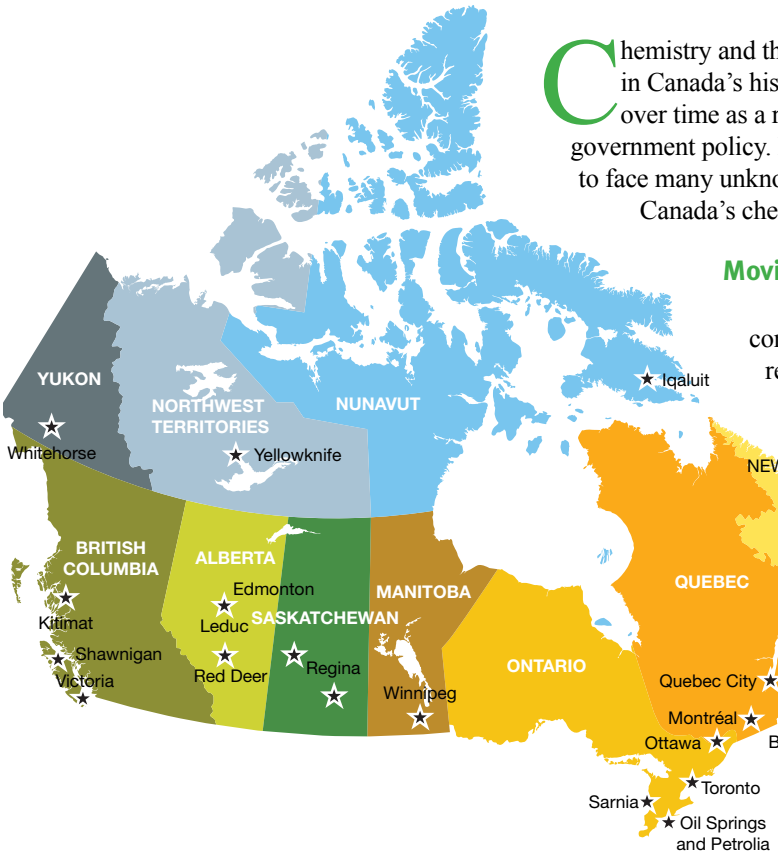
Canada's chemical industry began in eastern Canada in the Montréal area, then moved to Sarnia in central Canada. More recently, it traveled further west, and is now dominated by the oil sector in Alberta.

Chemistry and the chemical industry have played an important role in Canada's history and economy *(1)*. The industry has transformed over time as a result of natural resources, societal needs, and government policy. Looking forward, the chemical industry will have to face many unknowns, such as the evolution of the bioeconomy. Still, Canada's chemical engineers have good reason to be optimistic.



▲ **Figure 1.** Canada exported $35 billion of chemical products in 2017. Its chemical industry focuses mainly on crude petroleum and natural gas processing, as well as the refining of coal and ores. Prominent centers of the chemical industry include Sarnia, parts of Ontario, and various cities in Alberta, including Leduc and Red Deer.

Moving from Canada's east to west

The early days in Montréal. Early Canadian communities, along with the industrial infrastructure required to produce commercial and consumer goods, were established during the 19th century in Montréal along the St. Lawrence River. Further north, Shawinigan was the ideal location for the production of electrochemicals. Hydroelectric power was cheap, its feedstock was readily available, and the customer base in Québec and Northern Ontario drove demand. Numerous and varied products — from explosives to industrial cleaning products and personal care items to pharmaceuticals — were manufactured in and around Montréal.

Canada's "Chemical Valley." The Canadian oil sector was born in 1858, when a Sarnia-area farmer digging for water discovered oil with high sulfur content. The sulfur content made oil recovery more

difficult, so exploitation was delayed until a sulfur extraction process was developed. In 1859, oil with a low sulfur content was discovered in Pennsylvania, and the U.S. oil boom began.

Soon, refineries were built to make products for heating and lighting, and oil residues were used in road construction. The cities of Oil Springs and Petrolia, Ontario, were founded after the discovery of oil. One of the companies founded at the time was Fairbank Oil Co., which continues to operate as the oldest oil producer in Canada.

Imperial Oil, Ltd., (IOL) was established in Sarnia, on the banks of the St. Clair River and the Great Lakes in February 1899. In 1947, oil was discovered by Imperial Oil in Alberta, and a pipeline was built in 1953 to transport oil from Alberta to Sarnia, catalyzing expansion of the industry. Refineries and chemical plants were continuously built from the late 1940s until the 1970s, and Sarnia became known as the heart of Canada's Chemical Valley.

During World War II, a shortage of natural rubber necessitated completion of an integrated synthetic rubber plant *(2)*, located south of the IOL refinery.

A consortium of IOL, Dow Chemical, and a group of U.S.-based rubber companies developed the project and chose the site because of its secure location, access to water (for process and cooling), coal (for electricity generation), and hydrocarbons (for butadiene and styrene manufacturing) *(3)*. At the end of the war, these companies remained and expanded their production.

The rubber complex became the Polymer Co., a federally owned enterprise known as a Crown corporation. At the time, with tariffs on chemicals and strict government regulations, companies such as DuPont, Canadian Industries Ltd. (CIL, part of ICI UK), and others established Canadian companies with significant (30%) local ownership, despite the small Canadian market.

The Canada-United States Free Trade Agreement in 1988 phased out trade restrictions on both sides, which opened the Canadian industry to competition from across North America and worldwide. Canada's petrochemical industry continued to prosper during this era. Fewer, mostly Canadian-owned, companies remain in Ontario and serve the international markets.

In Québec, Gulf, Texaco, BP, and Imperial Oil closed or sold their Montréal refineries in the 1980s; more recently, Shell closed its facilities as well. Today, only the Suncor refinery in Montréal and Valero's Jean Gaulin refinery outside Québec City remain in the province. Accordingly, the chemical industry restructured significantly over this period.

Today, Sarnia refers to itself as Canada's Hybrid Chemistry Cluster, a large collection of co-located chemical and petrochemical companies and industrial facilities. Sarnia increasingly includes new companies based on renewable feedstocks, as well as those based on improved hydrocarbon processing technology. Local high-sulfur crude oil is still processed by IOL at its Sarnia refinery.

The city's infrastructure is intact, despite the closure of some facilities, and brownfield sites are being redeveloped. Recently, U.S. shale-based feedstocks have entered Sarnia refineries, affecting oil and gas pricing, which in turn has affected downstream markets. For example, Nova Chemicals' petrochemical complex in Sarnia has modernized to process natural gas rather than crude oils, as it considers expansion.

Oil and gas in western Canada. In February 1947, Imperial Oil struck oil in Leduc, Alberta, establishing the oil economy in Alberta and western Canada. Today, Canada is estimated to have the third-largest oil reserves in the world, with 97% of Canadian reserves located in the western Canadian oil sands *(4)*.

Alberta's thriving petrochemical industry developed quickly from the 1970s through the 1990s. The growth was based on what has been called the Alberta advantage — conventional feedstock available at a lower cost than on the U.S. Gulf Coast. Dow Chemical, Shell, NOVA Chemicals, and others have invested over $6 billion in petrochemical plants in Alberta because of this price advantage.

The province's thriving petrochemical sector is based primarily on feedstocks derived from natural gas, with an increasing portion being derived from bitumen and heavy oil upgrading. Alberta alone boasts 168 billion barrels of bitumen that are economically recoverable with today's technology, while total oil sand reserves in place are estimated at 2 trillion barrels *(5)*. Petrochemical industry expansions that will utilize shale oil and gas are also underway.

However, the recent drop in oil prices has slowed development of the oil and gas sector in Alberta. At the same time, it has reduced raw material costs for the chemical industry.

Alberta oil and synthetic crudes typically sell at a discount below other North American crudes. For example, the price of Western Canadian Select (WCS, a key benchmark oil used in oil trading markets and the colloquial "price of oil" in Canada) historically runs about 15–20% lower than that of West Texas Intermediate (WTI, the main benchmark oil in the U.S.).

This price disparity has recently been exacerbated by oil transportation issues related to an oversupply of Alberta crudes, which has saturated available pipeline and rail capacity. This has caused WCS to drop to more than a 40% discount below WTI *(6)*.

This transportation capacity limit and related price discount problems are the subject of ongoing political conver-

sations in Canada — particularly regarding the construction (or prevention) of new pipelines from Alberta, either to the U.S. or to Canada's west coast.

Canada's chemical industry today

Table 1, Table 2, and Figure 2 summarize the chemical (including related industries) sector in Canada from 1970 to 2016. Table 1 relates data for the general chemical industry, while Table 2 specifies data for industrial chemicals production. Over this period, the chemical industry has transformed from a national management structure to a global business management structure.

Many sectors of the industry have matured, leading to lower margins, pressure to reduce operating costs, and increases in investment-driven productivity. Basic chemical businesses were the first to experience this change, followed by specialty businesses, and now pharmaceuticals.

Responsible Care — a Canadian initiative

Responsible Care is a code of practice for the chemical industry, based on the principle of "doing the right thing and being seen to do the right thing" *(7)*. It was developed by the Canadian Chemical Producers' Association (CCPA), now the Chemistry Industry Association of Canada (CIAC). The initiative was adopted by the U.S. chemical industry in 1988, and today has been adopted by over 60 countries, led and coordinated by the International Council of Chemical Associations (ICCA).

Responsible Care has inspired major improvements in the global chemicals industry. The achievements of various country associations, such as the CIAC and the American Chemistry Council (ACC), are available on the ICCA website *(8)*. Responsible Care has been recognized by the United Nations (UN) and by the Strategic Approach to International Chemicals Management (SAICM), which is a joint activity of the UN and the World Health Organisation (WHO).

Table 1. Canada's general chemical industry by the numbers, from 1970 to 2016*

Category	1970 *(4)*	1984 *(4)*	2016 *(17)*
Shipments	$2.6 billion	$17.2 billion	$53.1 billion
Number of Employees	79,000	88,000	86,700

*All monetary values are in Canadian dollars (CAD)

Table 2. Canada's industrial chemicals industry by the numbers, from 1970 to 2016*

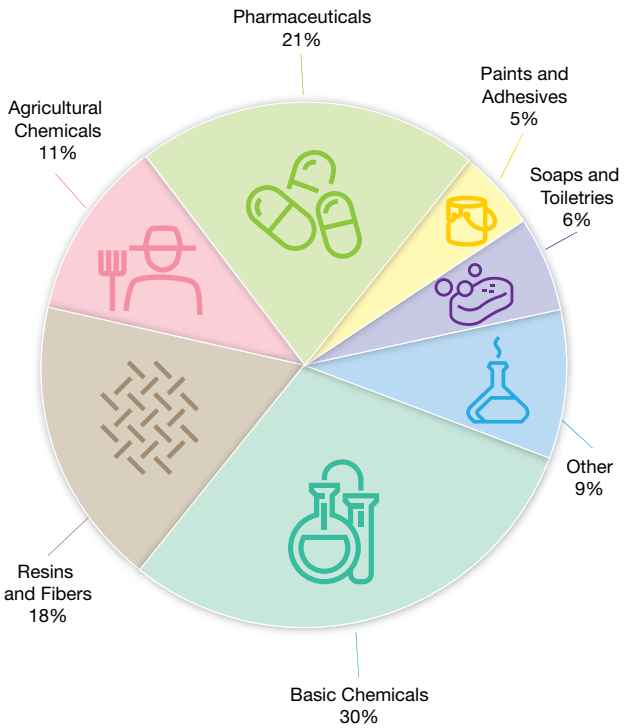
Category	1970 *(4)*	1984 *(4)*	2016 *(17)*
Shipments	$1 billion	$8.4 billion	$53.1 billion
Exports	$2.5 million (23%)	$3.3 billion (39%)	$18.7 billion (73%)
Exports to U.S.	$1.1 million (10%)	$2.1 billion (25%)	$15.6 billion (60%)
Captial Expenditure	$300 million	$596 million	$2.4 billion
Average Employee Income	$9.1 billion	$36.2 billion	$81.5 billion
Number of Employees	28,400	28,500	17,500

*All monetary values are in Canadian dollars (CAD)

Canada's next feedstock for the chemical industry

Investments in the chemical industry tend to occur alongside the presence of low-cost feedstocks. Often, processes with low-cost feedstocks also have high operational costs, which are typically related to the cost of energy to run such processes. As noted previously, in Canada, changes in low-cost feedstocks have moved the chemical industry from Montréal via Sarnia to Red Deer, Alberta.

Today, the availability of low-cost shale oil and gas in the U.S., enabled by advances in hydraulic fracturing technology, presents a challenge to the low-cost feedstock market in Canada. Going forward, from where will the nation source its competitive feedstocks?



▲ **Figure 2.** Distribution of the Canadian chemical industry's products, based on shipments. (Source: Ref. 17).

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Fossil-based feedstocks

Conventional oil and gas. Conventional oil and gas production has long been an important driver for the Canadian chemical industry — and it will continue to be, but possibly to a lesser extent over time. Conventional oil reserve production is steadily decreasing (Figure 3).

The current refining capacity in Canada is insufficient to meet the country's demand. The eastern half of Canada imports a large amount of its refined products from the U.S. Gulf Coast, complementing oil transported by pipeline from Alberta.

Liquefied natural gas. As hydraulic fracturing has become more prevalent, natural gas producers in Canada have suffered in recent years. However, selling liquefied natural gas (LNG) to China may change this situation, as China shifts away from coal to natural gas. Royal Dutch Shell is considering an LNG megaproject in the town of Kitimat, British Columbia (BC), that will include a 670-km pipeline linking the town with BC's gas fields.

Bitumen-based oil and gas. As a potential feedstock for the Canadian chemical industry, oil sands crude, also called bitumen, is essentially unlimited over the short term. Bitumen sells at a substantially lower price than conventional crudes, partly due to its heavy structure, but also because of its remoteness from major markets.

Bitumen is primarily located in the Fort McMurray region of northern Alberta, over 400 km north of Edmonton. This places the material almost 4,000 km from primary markets in the U.S. Gulf Coast, and almost 2,000 km through the Rocky Mountains to deep-water ports in western British Columbia.

Getting Alberta's bitumen to market poses substantial transportation challenges. Various pipeline approaches have been proposed, and they could change the structure of Canada's chemical industry. One approach would carry diluted bitumen east and west from Alberta to Canadian ocean ports on the Pacific and Atlantic Oceans, thus providing access to broader international markets. Another would transport product to the U.S. Gulf Coast.

But these pipeline proposals do not address adding value to bitumen by using it to make refined fuels and chemicals. If implemented, this could have a major impact on Canada's industry. It has been estimated that Canada misses out on a potential value of more than $US 60 billion each year by continuing to export unprocessed bitumen. Canada must expand its bitumen refining capacity to provide fuel and chemical feedstock, but it is still unknown whether it can do so cost-competitively.

Natural gas liquids. Alberta's surplus of low-cost natural gas liquids (NGLs) during the 1990s catalyzed large investments in petrochemical production. Recently, investments in Alberta and Sarnia have been based on feedstock imported from fracking operations in the U.S.

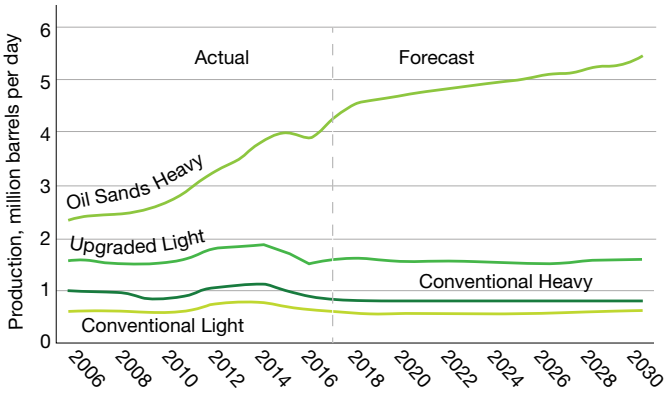
Some companies have invested largely in their Canadian sites that are close to the border, by way of existing pipelines. These groups have optimized existing infrastructure to keep investment costs as low as possible. However, most new investments are being made in the U.S., close to the fracking operations.

Fracking-based oil and gas. Largely because of the availability of low-cost feedstock, the U.S. has the capacity to become oil- and gas-independent, and access to low-cost feedstock has spurred billions of dollars of investment in the U.S. Some of this investment has spilled over into Canada, but at a much lower level than the activity in the U.S. for a variety of reasons, including political decisions being made at the provincial level.

Currently, fracking takes place in Canada's western provinces, and has for over 30 years. More than 175,000 wells have been drilled nationwide *(9)*. The provinces and territories of Québec, New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Laborador, and the Yukon have delayed or banned fracking, either by law or by policy, despite the fact that it has transformed the chemical industry in the U.S.

The reasons cited for opposition to the practice include concerns related to water consumption, seismic activity, various environmental impacts, and the use of fossil fuels in general. In most of these areas, the bans have had little impact on fracking, as there existed little to no activity to begin with. For example, Ontario and the Northwest Territories have not instituted fracking bans, citing a complete lack of fracking applications *(10)*.

The next frontier for growth in fracking-derived petrochemicals may be Ontario, which has the petrochemical complexes and expertise necessary to serve as a foundation for future growth *(11)*.



▲ **Figure 3.** Production of conventional oil vs. bitumen-based oil in western Canada. (Source: Ref. 17).

Despite attempts to ban fracking in the province in 2015, Ontario still technically permits deep shale drilling *(9)*. However, the existing regulatory framework for fracking is essentially untested, as there is currently no shale gas/oil recovery activity within the province, nor have any applications been filed to do so *(12)*.

Previous administrations have indicated that shale gas development could be permitted given sufficient regulations to protect the environment and the public *(12)*. The Responsible Care approach, which builds trust by publicly doing "the right thing," could help satisfy this *(9)*.

Even if Ontario is unable to supply its own shale gas for this purpose, petrochemical industry growth is still plausible — there is sufficient access to shale gas from the U.S. Midwest via excellent transportation infrastructure *(11)*.

Renewable feedstocks and the emerging bio-based economy

In December 2016, Canada's first ministers released the Pan-Canadian Framework on Clean Growth and Climate Change *(13)*. Clean technology and greenhouse gas (GHG) emission reductions are core elements of the plan, which calls for government programs to address these issues and seeks to foster innovation in creating new jobs, new technologies, and new export opportunities.

Several programs have been announced since this time in support of Clean Tech and in support of important economic transformations, including the bio-economy.

Biomass is a large and competitive source of renewable carbon in Canada, and unlike renewables such as solar and wind, it can be used to produce biofuels, biochemicals, and biomaterials. The bio-based economy has the potential to create jobs should innovative value chains be supported by business and innovation ecosystems.

The emerging bio-economy can eventually be expected to merge with the global chemical industry as it increasingly transitions toward the adaptation of biomass resources for consumer needs, industry demand, and climate-change solutions *(14)*.

Canadian forestry companies are exploring strategies to diversify their revenue and manufacture a variety of bioproducts from wood *(15)*. For example, the West Fraser mill in Hinton, Alberta, has recently implemented a process to precipitate softwood lignin, and it seeks to substitute modified lignin for the phenol formaldehyde (PF) resins it currently uses.

West Fraser, Domtar, and other forestry companies are also exploring the development of lignin-based polymers. The Domtar mill in Windsor, Québec, has implemented the CelluForce process to make nanocrystalline cellulose, and multinational companies such as Schlumberger and Suzano have invested in the innovation.

The Cascades mill in Cabano, Québec, has installed a hot water extraction process, and uses water instead of pulping chemicals. It plans to market extracted hemicellulose-based products.

This transformation toward the bioeconomy is expected to continue, and even accelerate as policy is developed in support of the circular economy. The forest industry and chemical industry can be expected to work together to build novel value chains to address critical issues such as single-use plastics.

Depending on factors such as the creation of successful partnerships between chemical and forest industry companies, and supply chain synergies between chemicals and biochemicals, this could significantly reshape Canada's chemical industry over the next few decades.

How might this take place in the near term? As one example, a cluster is being developed in Sarnia based on the concept of fostering partnerships — *i.e.*, synergies that develop among industry, colleges, universities, and local governments — to support the hybrid chemistry cluster that will complement and build on existing petrochemical value chains.

In partnership with Western Univ., the chemical valley community has formed the Bioindustrial Innovation Canada/Sustainable Chemistry Alliance as the basis for a successful cluster. Two industrial parks in Sarnia, managed by ARLANXEO and TransAlta, are focused on attracting sustainable businesses and offering existing infrastructure to support new investors with the goal of reducing capital costs, as well as developing a skilled workforce.

As a result, Sarnia is on its way to becoming a hybrid cluster for bio-based chemicals and green energy, with Suncor Ethanol, Enbridge Solar, Biox, and others. Innovative companies such as Origin Biomaterials and Woodland Biofuels have established themselves in Sarnia.

Comet Biorefining has announced plans for a biomass-based sugar mill by 2019, in partnership with the farm co-op Cellulosic Sugar Producers Coop (CSPC). CSPC will handle the front-end harvest and delivery, and the sugars will feed production of bio-based chemicals such as succinic acid, levulinic acid, aspartic acid, and others. Moreover, the sustainable mill is expected to inspire the creation of biomass clusters across Canada.

The path forward: Reasons to be optimistic

Canada's chemical industry has evolved continuously since European settlers arrived, and it continues to change aggressively in the face of volatile and unpredictable oil prices, globalization, global competition, and numerous other factors.

Canada's chemical and plastics sectors are currently supported by secure access to low-cost raw materials and

existing infrastructure. According to recent government estimates *(16)*, chemical and plastics production are among the world's largest manufacturing industries.

In recent years, the Canadian petroleum industry has been seriously impacted by low crude oil prices, resulting in calls for economic diversification in the trade. Many are uncertain about building oil pipelines, and about having access to them to export Canada's oil to global markets. The current federal government appears to be serious about mitigating the effects of climate change by reducing GHG emissions.

Investment in clean technologies and an emphasis on the bio-economy will likely continue in the coming years, with increased emphasis on renewable cellulosic feedstocks from agriculture and forestry for green chemistry and biomaterials.

Some critical questions still need to be addressed by government and industry in Canada, such as:

• Canada's economy has historically been more dependent on natural resource extraction than on value-added manufacturing, so much so that Canadians describe themselves in a tongue-and-cheek way using the biblical phrase "hewers of wood and drawers of water." Can Canada get out of this mindset?

• What can Canada do to help develop its downstream chemicals sector?

• Will governments at all levels be willing to implement long-term strategies to accomplish this goal?

• Canada has significant opportunities to contribute to the emerging bio-economy. Can Canada establish interest for investment in Canadian companies, as well as catalyze a leading position centered on its substantial biomass resources?

• Can Canada attract large multinational chemical companies, so-called anchor companies that can catalyze the bioeconomy and establish commercial-scale operations?

• How can Canada attract investment in startups and grow these to midsized companies?

How these issues will reshape the Canadian economy and its chemical sector is difficult to predict. But the Canadian chemical industry is certainly beginning a new era of major change, to be driven by process innovation.

In Canada, chemicals are among the top three sectors of the manufacturing industry in revenue, value added, and exports. The Canadian chemical industry has a high proportion of university graduates in its workforce, reflecting the high-skill, high-wage nature of the industry.

The industry has an exciting future to look forward to, and will work to adapt to the changing world and remain a leader building on Canada's fundamental competitive advantages.

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