Catalyzing Change:

Why Canada Needs a Roadmap to Net-zero Chemistry

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Catalyzing Change: Why Canada Needs a Roadmap to Net-zero Chemistry

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Executive Summary

Canada's chemical sector produces thousands of products that we use every day, from cosmetics to food packaging, generating annual revenues of $68.5 billion and more than 90,000 direct jobs.[1,2] Chemical and fertilizer production is, however, also responsible for 23 megatonnes of direct emissions and an estimated additional 14 megatonnes of supply chain emissions.[3,4]

Despite the economic importance of the sector and the high level of emissions it produces, the need to transition our chemical industry has been largely overlooked.

A net-zero chemical industry presents an enormous opportunity for Canada. We will need high-value, low-emissions chemicals in a net-zero world—from the plastics in our EVs, to the resins protecting our solar panels against the weather, and the refrigerants in our heat pumps.

Other jurisdictions have made large investments in net-zero chemicals, including pilots with electric crackers and low-carbon ammonia facilities. In the race to a net-zero chemicals future, Canada is starting from a deficit and risks falling further behind if we don't take action now.

Getting this transition right and seizing the economic opportunity requires forward thinking, **and that's why the chemical sector—in cooperation with federal and provincial governments—must develop a roadmap to net zero.**

In this report, Clean Energy Canada outlines the key opportunities, technologies, and barriers that such a roadmap should address across five action areas. Industry and government can use this blueprint to help develop a complete and detailed roadmap with clear commitments coming from both sides.

Government and industry must work collaboratively to future-proof Canada's chemical sector by moving toward high-value, net-zero-aligned products, and by building a net-zero roadmap that includes:

1. Increasing circularity, including through regulation and incentives for recycling
2. Transitioning to renewable feedstocks and helping ensure their availability
3. Moving away from higher-emitting energy sources through electrification and fuel-switching
4. Developing a credible plan for the effective use of carbon capture and storage
5. Continued investing in energy efficiency gains

Introduction

Canada's chemical sector is an invisible giant, with annual revenues of $68.5 billion and the third largest GDP contribution of the manufacturing industries.[1,2] Over 90,000 people in Canada are employed in chemical manufacturing, most of whom live in Ontario, Quebec, and Alberta.[5]

However, when it comes to industrial policy and the need to transition to net zero by 2050, the chemical sector has not received the same level of public attention as sectors such as steel or cement. It is a complex sector, with many different products and emission reduction pathways, but given that the chemical and fertilizer industry is directly responsible for 23 megatonnes of greenhouse gas emissions per year—almost equal to emissions from the iron, steel, and cement sectors combined—a plan for a net-zero chemical industry in Canada is long overdue.[3]

Many chemical products are made from oil and gas products. But unlike gasoline for cars, these products will not be completely phased out in a net-zero economy. In fact, a large number of chemicals are going to be critical in the energy transition: from solar photovoltaics to light materials in electric vehicles, and from battery chemistries to the refrigerants used in heat pumps.

This report outlines the net-zero chemical opportunity for Canada: where chemicals will be used in a net-zero economy and how emissions can be reduced through electrification, circularity, a switch in feedstocks, and new technologies. Bringing together theoretical possibilities with practical realities, this report was informed by a review of academic research combined with industry stakeholder interviews.

The report covers the chemical manufacturing sector, which includes ammonia and urea production for fertilizers, but does not include mining activities for phosphate or potash fertilizers. For consistency, this report will therefore refer to the "chemical sector" (including ammonia and urea production), rather than the "chemicals and fertilizers" sector.

Note on Methodology

In preparation of this report, Clean Energy Canada held interviews with ten chemical companies in Canada representing chemical plants across six provinces, including some of Canada's largest producers. Most of these companies produce petrochemicals such as polyethylene, styrene monomers, or polypropylene. We did not interview any companies in the fertilizer subsector.

We would like to thank the Chemistry Industry Association of Canada (CIAC) for providing their assistance in setting up these interviews. We are grateful for the insights provided by these stakeholders as they have informed the observations and recommendations in this report. However, participation in this process is not necessarily an endorsement of every statement or recommendation. Interview participants are listed in the Annex.

The Opportunity: Chemicals in a Net-Zero Future

The chemical industry—and especially the petrochemical industry—has historically used raw materials similar to the oil and gas industry, and petrochemicals are often produced by the same companies that produce oil and gas for consumption as fuels. However, where many of the fossil fuel industry's products such as gasoline for cars or natural gas for home heating will need to be phased out in a net-zero economy, the same is not true for many chemical products.

In fact, many products and technologies that are essential to the energy transition rely on chemicals. A Deloitte analysis found that the **chemical sector supports over 75% of all emissions reduction technologies needed to meet net-zero goals by 2050**,* such as battery materials for EVs, refrigerants for heat pumps, and solvents for semiconductors (see Breakout 1 for more examples).[7] The analysis also showed that investment in these sectors has risen rapidly in the United States, especially after the adoption of the Inflation Reduction Act.[7] In Canada, recent investments in clean energy and clean manufacturing will spur similar demand for products that could be served by a chemical industry aligned with a net-zero future.

Canada, as an advanced economy with sizable chemical production, has the opportunity to be a frontrunner in innovation and emissions reductions and to become an exporter of low-emissions chemicals that support the global energy transition. The country is already a net exporter of chemicals, with $42 billion worth of chemical exports in 2022.[8] Most (90%) of the current exports go to the United States, which has been making bold moves to implement its own climate agenda.[9] The European Union (EU) presents another important market, making up $1.5 billion of Canada's chemical exports. With the EU's new Carbon Border Adjustment Mechanism applying carbon tariffs to a range of industrial products including fertilizers and hydrogen, low-emissions products will become increasingly competitive in that market.[10]

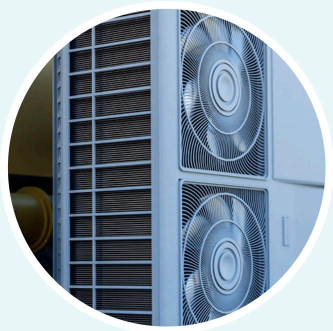
But Canada is not yet seizing its net-zero chemical opportunity. Some chemical companies have made large investments in moving their production toward net zero, such as Dow's $8.9 billion low-emissions ethylene cracker and derivatives site in Fort Saskatchewan, Alberta.[11] However, most of the investments in low-emissions chemicals and fertilizers have taken place in other countries. Nutrien, for example, is headquartered in Saskatoon, but is evaluating its facility in Geismar, Louisiana for opening the world's largest clean ammonia production facility.[12]

* Net-zero technologies identified based on the IEA's 2021 Roadmap to Net-Zero.[6]

BREAKOUT 1 Examples of the importance of chemistry for net zero technologies

Electric vehicles: The batteries in EVs add substantial weight. For both safety and efficiency, this weight increase will have to be compensated for by using lighter material in the car's other components. The uptake of EVs will therefore drive demand for plastics. Already, the American Chemistry Council estimates that the amount of plastics per vehicle has increased 16% from 2012 to 2021, to an average of 411 pounds.[13] An industry-led market study estimated that the electric vehicle plastics market would grow from US$3.7 billion in 2022 to $12.6 billion in 2027.[14] EV producers have started thinking about how to make their supply chains net-zero. Volkswagen, for example, has a net-zero target that includes its supply chains, while General Motors used over 39 million pounds of recycled plastic in its vehicles in 2023 and has set targets to increase this amount, and EV producer Rivian has a target of 40% recycled and bio-based content in the polymers used in their vehicles by 2030.[15,16,17]

Batteries: The large-scale electrification that will be necessary for the energy transition will require a rapid increase in the uptake of battery technologies, as well as the recycling of batteries to limit environmental damage from mining. Rechargeable lithium-ion batteries rely on cathode active materials—chemicals composed of metal oxides. In March 2022, both BASF and General Motors announced plans to open plants producing cathode active materials (CAM) in Bécancour, Quebec, and in 2023, Ford made a similar investment.[18–20] Honda's recent $15 billion investment in Ontario will also include CAM production.[21]



Refrigerants: Fridges and air conditioning units rely on refrigerants to transfer heat and keep us cool. The same technology is used by electric heat pumps, which will be increasingly adopted to decarbonize home heating. Refrigerants used in the past were phased out under the Montreal Protocol because of their damaging effects to the ozone layer. However, the new generation of refrigerants has a high global warming potential when leaked into the atmosphere. Countries therefore agreed in 2016 to also phase these out.[22] As heating and cooling technologies using refrigerants are more widely adopted, the chemistry of refrigerants will be an active and important field of research and development to ensure these chemicals do not have unintended effects.

Weather-protection on solar PV panels: Epoxy resins, which are currently made out of oil derivatives including Bisphenol A (BPA), are commonly used for coating and insulation, and to protect solar panels against the weather.[23] With an increased uptake of solar PV, a sustainable alternative that can ensure longevity of the panels will be needed. Several bio-based alternatives are in development, including chemicals based on vegetable oil or sugars.[24,25]

Nitrogen fertilizers for food production: With the global population expected to grow rapidly over the next few decades, so will the demand for food. It is expected that this will in turn create a significant increase in the demand for nitrogen fertilizers, even as their application becomes more targeted and efficient to prevent overuse.[26]

The Challenge: Reducing Emissions

Emissions profile

The chemical and fertilizer sector in Canada is directly responsible for an annual total of 23 megatonnes of greenhouse gas emissions. 65% of reported emissions come from Alberta-based facilities and 20% from Ontario-based facilities.[3,27]

The petrochemical manufacturing subsector is responsible for the largest share of reported emissions (39%), with fertilizer chemicals at 38% as a close second.[27]

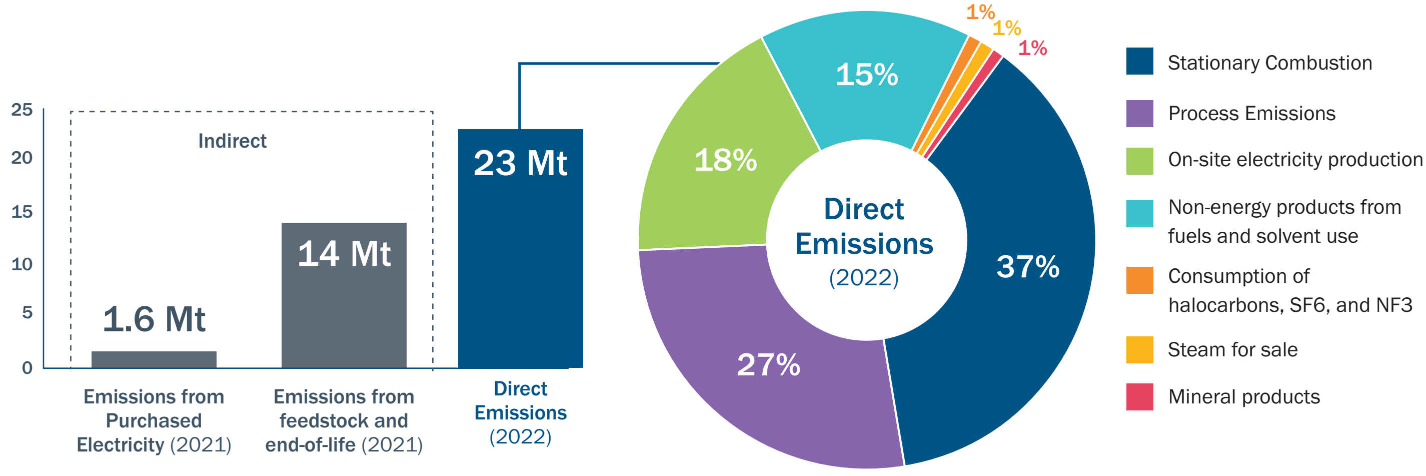
There are over 3,300 chemical manufacturers operating in Canada, but emissions from the sector are largely concentrated in a small number of facilities and companies.[28] The five highest emitting facilities together make up more than half (52%) of the sector's total.[27] Six of the ten largest emitters are in Alberta.[27]

The 23 megatonnes of direct emissions are mainly caused by the combustion of fossil fuels, process emissions, and onsite electricity production.

However, the sector is also responsible for indirect emissions, both from the production of feedstocks used in the industry (upstream) and the end-of-life incineration or disposal of products. The Canadian Climate Institute estimates that these indirect emissions made up an additional 14 megatonnes in 2021.[4]

To build a net-zero world by 2050, the global chemical sector's emissions must peak in the next few years and decline by about 15% by 2030, even as a growing population and the energy transition spur further demand for high-value chemicals.[29]

Figure 1: Direct and indirect emissions from the Canadian chemical sector (2021/2022)[3,4]



Note: since direct and indirect emissions in this figure are based on separate data sources and years, they cannot be directly compared or summed.

State of play in the Canadian chemical sector

In drafting this report, Clean Energy Canada held expert interviews with ten companies that have chemical production facilities in Canada. These companies represent operations across six different provinces, with the majority of facilities located in Sarnia, Ontario, or in industrial clusters in Alberta. Most of the companies we spoke to produce petrochemicals made using fossil fuels, often including natural gas, or components of natural gas or oil (including benzene, ethane, and propane).

The most commonly produced chemical products in Canada (by tonnes of production) are ethylene, polyethylene, ammonia, and urea—all produced on the basis of fossil fuels.[30] Together, these make up about two-thirds of the mass of chemicals produced.

BREAKOUT 2 Examples of chemicals produced in Canada and some of their uses

On the basis of fossil fuels

Ethylene and polyethylene	Plastic used for packaging and grocery bags, but also larger multi-use items such as kayaks, water tanks, and in construction.
Styrene monomers	Plastic used in food and drink containers, packaging, building insulation, and electronics.
Polypropylene	Plastic used in car parts such as door panels, bottles, jars, hot beverage cups, food packaging, fibers, fabrics, and medical applications.
Ethylbenzene	Solvent found in synthetic rubber, fuels, paints, and inks.
Methanol	Base chemical or shipping fuel.
Carbon black	Reinforcing rubber for tires.
Ammonia	Fertilizer, industrial refrigerant, cleaning products.

On the basis of other feedstocks

Sodium chlorate	Used in pulp and paper industry, but also in mining and pyrotechnics.
Sodium hydroxide	Soaps, detergents, water treatment, pulp and paper production.
Chlorine	Water treatment.

Most of the companies interviewed have corporate net-zero 2050 targets. These targets usually cover emissions directly from production and from purchased electricity (Scope 1 and 2), but not the upstream emissions from feedstock production or downstream emissions from the use of the product (Scope 3).

Many of the companies interviewed also have 2030 Scope 1 and 2 emissions reduction targets, although some of these targets are intensity-based, meaning companies commit to reducing their emissions per unit of production rather than their overall emissions. Dow has a net-zero target for 2050 that includes Scope 3 as well as an absolute emissions reduction target for 2030, and Shell recently updated its global corporate 2030 absolute reduction target to include emissions from sold products (part of Scope 3).[31]

When it comes to implementing these commitments, most of the companies we interviewed are in early stages. Many have taken measures to improve energy efficiency, such as through waste heat recovery. In fact, many have a long-standing commitment to improving operational and energy use efficiencies, driven primarily by the resulting cost savings. A few companies have invested in carbon capture and storage (CCS) projects, or are considering their options for fuel switching to hydrogen or electricity. However, when it comes to the next big steps of technology and feedstock switching, companies largely indicated that they are still evaluating their options and waiting for technology to develop further and come down in cost.

Drivers for change

There are several factors driving companies to adopt emissions reductions targets and measures:

Regulatory pressure: Interviewees said "it cannot be understated how important [regulations] can be in spurring change", and that regulatory drivers are "the true engine" for change. Regulation could take the form of direct product regulations, but also more indirect climate policies such as emissions pricing or investment tax credits, which can change the cost calculation for companies when making investment decisions.

Internal sustainability leadership: Interviewees indicated that motivation to be a market leader in sustainability can also be a driver for change. Some companies responded that they were proud to be an early mover or market leader, or that their management had a personal commitment to sustainability.

Rising customer/stakeholder pressure and market opportunities for lower-emissions products: Several companies indicated having received direct requests from customers for low-emissions products or products with increased recycled content. However, they also indicated that customers are not always able to pay the increased price for these products, and in some cases the feedstock was not available at the scale needed.

Cross-cutting barriers

Interviews also identified several cross-cutting barriers to further emission reductions in the sector.* Most of these barriers can be grouped into the following categories:

Regulatory uncertainty: Companies emphasized that, given the scale of the necessary transformations and investments, regulatory certainty is key. One company said that a lack of clarity on policies that were still under development at the time of the interview (including investment tax credits) made investment decisions more difficult. Several companies also mentioned long-term certainty on carbon pricing is needed to make investments bankable. Uncertainty existed in relation to existing programs and policies, potential changes in government, and interaction between federal and provincial policies.

Cost: The adoption of new technologies to reduce emissions in the chemical industry often requires large upfront investments. Understanding the economics and justifying the capital for these investments was seen as one of the largest hurdles. Moreover, chemical companies compete in global markets—both on the price of their product as well as for capital investment. With rising interest rates there is also a shorter payback tolerance, making large investments more difficult to justify. The cost of energy when switching fuels (e.g. from natural gas to electricity or hydrogen) can also be prohibitive in some jurisdictions.

Technology availability: The chemical sector in Canada comprises many different products and processes. While solutions to reduce emissions exist for many of these, interviewees noted that some technologies are still in early stages of development and are not yet available at commercial scale, or at a competitive price. Specifically, companies mentioned that further development was needed for the following technologies or processes: carbon capture, chemical recycling, the use of biomass as a feedstock, electric furnaces, methane pyrolysis for hydrogen, and the burning of hydrogen as a fuel.

* Note that these reflect barriers at the time of the interviews, which were mostly held in January and February 2024.

Structural/practical barriers: Chemical facilities generally have long lifetimes spanning decades. Retrofitting assets is costly, but shutting down existing infrastructure is also difficult to justify financially. Many chemical plants run constantly, only pausing once every few years to implement necessary maintenance (which comes with a cost of lost production). These turnaround cycles differ per plant, from two to five years and as long as ten years. If this maintenance window is missed for emissions reduction upgrades, it can be years before there is another opportunity to implement the project. Funding and assistance programs are not always attuned to that reality, and several companies cited examples of being ineligible for funding as a consequence or not having enough time to engineer and execute a project within maintenance and funding windows.

Geography: Barriers to emissions reductions are not universal across the country. While carbon capture and storage may become a viable option for the industry in Alberta, in Ontario there is currently no regulatory framework (although this is under consultation), and its future potential will likely be limited by a lack of suitable geology. Some companies in Sarnia also cited a lack of plot space available within close proximity to emissions sources as a constraint. Facilities in Alberta and Saskatchewan that wish to reduce emissions through electrification, on the other hand, are constrained by a relatively carbon intensive electricity supply. Other geographic concerns include province-specific regulations (such as specific concerns about the emissions-pricing system in Ontario), the availability of a skilled workforce, and regional challenges with the availability of feedstocks, (including usable plastic waste for recycling in less populated areas).

Action Areas to Include in a Roadmap to Net Zero

Achieving a net-zero chemical sector in Canada will be challenging, but presents an enormous economic opportunity. Pivoting toward the products that will be in demand in a net-zero world will require forward thinking, planning, and investment from governments and industry. At the same time, this transition will not be possible without federal and provincial governments providing regulatory certainty, setting ambitious targets and policy, and supporting the development of new technologies.

To jumpstart this transition and ensure policies and investments build on a realistic pathway to net-zero, **the chemical industry, in conjunction with government, should develop a Roadmap to Net-Zero Chemicals.**

The Canadian concrete sector has undergone a similar effort in collaboration with the federal government.[32] In the U.S., the Department of Energy has produced a Pathways to Commercial Liftoff report for the chemical and refining sectors, mapping a pathway to net-zero.[33] These could be examples for the Canadian chemical sector to follow. To ensure industry is working with governments at all levels, this roadmap should be developed with the federal government in collaboration with key provinces. However, given the geographically specific nature of chemical production in Canada, both Alberta and Ontario have opportunities to show leadership through their own provincial industrial strategy and planning.

A successful roadmap requires buy-in and commitments from both government and industry stakeholders. It needs to set out the specific role of different technological solutions and policy levers in the transition, while having the flexibility to adapt to changes in technology maturity, availability, and efficacy. It also needs to include commitments from both industry and governments on actions to be taken in the short- and long-term. A successful roadmap must therefore be developed by the sector itself, in collaboration with government. The sections below aim to provide a blueprint, identifying the key action areas that a roadmap should address.

This paper is intended to lay the groundwork for a net-zero roadmap by providing a framework of key action areas and early priority actions toward a net-zero chemical sector in Canada, producing high-value chemicals that underpin a net-zero future:

Cross-cutting goal	**Transition to the use of Canadian chemicals in high-value supply chains that underpin a net-zero future**			
1	**2**	**3**	**4**	**5**
Increasing circularity	Transitioning to renewable feedstocks	Electrification and fuel switching	Carbon capture and storage	Improving energy efficiency

Table 1: Overview of action areas to be included in a Roadmap to Net-Zero

1 | Increasing circularity

Barriers /challenges

- Insufficient collection and sorting of waste
- Technology development

Early priority actions for governments

- Coordinate to ensure consistent collection, sorting, and recycling practices;
- Ensure recyclability is taken into account before products are put on the market; and
- Set future targets for minimum recycled content in products.

Early priority actions for industry

- Identify where circularity can play a role in current and future production processes;
- Design products that are recyclable at their end of life; and
- Invest in research and pilot projects using chemical recycling.

2 | Transitioning to renewable feedstocks

Barriers /challenges

- Availability of alternative feedstocks
- Cost of alternative feedstocks
- Energy or land use requirements

Early priority actions for governments

- Fund research and development for alternative, sustainable feedstocks that do not compete with food production;
- Work with other ambitious jurisdictions to facilitate knowledge sharing and research collaboration for developing alternative feedstock supply chains; and
- Develop a strategic plan for the use of biomass across different sectors in the energy transition to ensure limited supply is allocated to the best use cases through the use of tax credits or other mechanisms that incentivise producing biomass for specific industries.

Early priority actions for industry

- Fund research and development for alternative, sustainable feedstocks; and
- Identify future sustainable feedstock alternatives for their products.

3 | Electrification/fuel switching

Barriers / challenges

- Narrow windows to implement upgrades
- Regulatory certainty
- Cost
- High energy requirements and higher carbon intensity of electricity supply in some provinces
- Technology development
- Available infrastructure

Early priority actions for governments

- Co-fund projects demonstrating early adoption of emissions reduction technologies beyond carbon capture, such as industrial heat pumps and electric crackers;
- Align funding programs with the practical realities of the chemical sector such as turnaround times, for example by designing funding programs that have a continuous intake process;
- Provide carbon pricing certainty through maintaining the industrial carbon price and providing a framework for carbon contracts for difference; and
- Develop energy strategies that ensure abundant, clean, predictable, and affordable electricity to facilitate electrification.

Early priority actions for industry

- Bring together a consortium to launch an electric cracking pilot facility in Canada, building on research in Europe;
- Invest in pilot projects adopting emission reduction technologies, including behind-the-meter renewables, electricity storage, and the electrification of process heat; and
- Map out realistic pathways to a net-zero future for each of their product categories.

4 | Carbon capture and storage

Barriers / challenges

- Regional availability
- Cost
- High energy requirement
- Narrow windows to implement upgrades

Early priority actions for governments

- Align funding programs with the practical realities of the chemical sector such as turnaround times;
- Provide carbon pricing certainty through maintaining the industrial carbon price and providing a framework for carbon contracts for difference; and
- Provide assistance for promising carbon capture projects in the chemical sector while maintaining a technology-neutral approach to emissions reductions that fairly evaluates and supports the most promising technologies and pathways.

Early priority actions for industry

- Evaluate emissions reductions technologies and pathways with a technology-neutral approach that facilitates the piloting and commercialization of the most effective and financially sustainable solutions; and
- Invest in pilot and commercial projects for emissions reductions and collect data on cost, energy usage, and effective capture rates, and share best practices.

5 | Energy efficiency gains

Barriers / challenges

- Limited gains left to be made

Early priority actions for governments

- Align funding programs with the practical realities of the chemical sector such as turnaround times.

Early priority actions for industry

- Continue to invest in energy efficiency gains and research and development budgets to explore innovations for future deep efficiency savings.

Cross-Cutting Goal:

Transition the Canadian Chemicals Sector to Underpin High-Value Supply Chains That Deliver a Net-Zero Future

A pathway to net zero for Canadian chemistry will mean a transition of the sector, both in its production methods and in what it produces. The energy transition provides an opportunity for Canadian producers to pivot toward high-value end products that underpin a net-zero future.

Historically, the chemicals sector has often been involved in supply chains for disposable products—single-use plastics are a well-known example. In 2022 the Organisation for Economic Co-operation and Development (OECD) found that nearly two-thirds of plastic waste came from plastics with lifetimes of under five years.[34] Every year, Canadians throw away more than three million tonnes of plastic.[35] The OECD estimated that in 2019 the end-of-life greenhouse gas emissions caused by plastic disposal around the world amounted to 193 megatonnes of CO_2e annually (close to the total emissions of a country like Colombia).[36] Globally, plastic production is expected to double by 2050 and more than triple by 2100 without intervention.[37]

To address direct emissions from the chemical sector as well as the estimated 14 megatonnes of annual emissions caused by the end-of-life disposal of products and by the use of feedstocks, the sector should optimize the use of its products and resources.[4] Only addressing inputs (e.g. switching feedstocks to biomass or hydrogen) while still producing the same amount of chemicals would lead to an unrealistically large strain on renewable electricity supply or land use.[38,39] If the current amount of plastic produced for Canadian consumption was created using biomass from crops, for example, it would require a land area equivalent to a third of Nova Scotia.[40,*]

A realistic and profitable pathway to net zero therefore requires rethinking supply chains. The same chemical products that are currently used to produce disposable yogurt containers can also be used to produce doors for EVs. A pivot toward high-value supply chains for longer-lasting products that underpin a net-zero future is an important part of the chemical sector's road to net zero. It will reduce emissions from end-of-life disposal, feedstock use, and production. At the same time, higher-value supply chains can provide opportunities for investments in emissions reductions, as buyers may be explicitly interested in purchasing low-emissions products.

The opportunity to reduce emissions by addressing overuse and waste of chemicals has been recognized by other subsectors, too. Nitrogen fertilizers, for example, are often overapplied, with one study estimating that more than 50% of fertilizer is wasted and another study estimating that a combination of harvest losses, food waste, and overapplication together cause 40% of nitrogen in fertilizers to be lost.[41, 38]

* Canadian plastic consumption data based on 2019 data from Statistics Canada. Nova Scotia is 55,284 km^2.

Fertilizer Canada has estimated that emissions from fertilizer application could be significantly reduced through a "Right Source, Right Rate, Right Time, Right Place" (4R) best management approach, applying fertilizers more efficiently.[42] The Canadian concrete sector, too, included the need to use concrete more efficiently in its Roadmap to Net-zero.[32]

The federal government has already advanced efforts to achieve a shift away from disposable end products, including through its Single Use Plastics Prohibition, which went into effect in June 2023, prohibiting the manufacture, import, and sale of certain categories of single-use plastic such as checkout bags, ring carriers, straws, and stirring sticks.[43,*] More policy action is needed to reduce disposable production, including at provincial and international levels. In 2022, the United Nations Environmental Assembly adopted a resolution committing to end plastic pollution.[44] International negotiations in Ottawa in April 2024 resulted in the Ottawa Roadmap, promising a global agreement before the end of 2024.[45]

Governments have an important role to play in this transition. They should implement policies aimed at reducing lower-value and disposable end products. At the same time, they should facilitate a shift toward high-value, net-zero-aligned chemical products by developing incentives and considering how to market low-carbon Canadian chemicals for domestic and export markets.

The chemical industry also has a role in this shift to future-proof the industry by seeking opportunities to orient production toward high-value, net-zero-aligned supply chains.

* In November 2023, the Federal Court of Canada found the prohibition to be too broad and unconstitutional under the Canadian Environmental Protection Act. The federal government's appeal of the case is ongoing and the prohibition remains in place under a stay order.

1 Increasing circularity

Background

Chemical supply chains, especially plastics, currently use a lot of fossil feedstocks and turn these into products that are disposed of at the end of their life. This adds new carbon into the carbon cycle and contributes to global warming.

The emissions caused by a chemical product after it has been sold to another sector or end consumer are not accounted for in the Canadian chemical sector's total emissions of 23 megatonnes per year. However, most chemical products cause significant emissions at the end of their lifetime. These could be refrigerants that leak from cooling systems, urea applied to agricultural land emitting CO_2, or plastic waste that is burned or landfilled. An analysis of the chemical sector in Germany estimated that end-of-life emissions could account for more than 50% of the chemical sector's emissions.[46]

According to estimates from the OECD and the Canadian federal government, only 6 to 9% of plastic waste in Canada was recycled, while 4% was incinerated, and 82 to 86% landfilled. The remainder of Canadian plastic waste (1 to 7%) was "mismanaged," meaning it ended up in nature or waterways.[47,35,48]

Potential net-zero solutions

Circularity (reusing the carbon atoms that are already in material cycles, or more commonly known as recycling) can significantly reduce the need for fossil feedstocks or scarce alternatives like biomass. Customer demand for recycled content has also been on the rise, according to companies interviewed by Clean Energy Canada. Academic analyses show that an effective recycling rate of 70-75%, combined with more costly or scarce feedstock technologies like biomass or using captured carbon would enable net-zero emissions plastics.[38,49,50]

Existing recycling facilities mainly use mechanical recycling—reusing materials without changing the chemical structure—for example by turning plastic waste into plastic pellets for new production.

Barriers to circularity

Mechanical recycling, especially of plastics, has not been very successful to date. There are two main hurdles to mechanical plastics recycling.[53] Firstly, collection and sortation systems are insufficient in many places and not standardized, resulting in a shortage of usable feedstock. Interviewees indicated this could especially pose a challenge in areas with significant plastic production, but relatively lower population density (and therefore less usable consumer waste), such as in Alberta. They also pointed to a lack of capacity and consistency in recycling practices across municipalities as a barrier to feedstock supply. Secondly, plastic waste often consists of a mix of different polymers and additives such as plasticizers and colourings, making it difficult to turn collected plastic waste into usable pellets. Better collection systems, as well as regulation to design plastics to be recyclable could alleviate these problems.

Additionally, current recycling techniques often do not achieve a "closed loop"—delivering a product of equal quality as the original. Instead, higher-value plastics are still often "downcycled" into lower-value or non-recyclable plastics, such as when polyethylene terephthalate bottles are turned into fibers for clothing.[53,54] Even when plastics are recycled, the process can degrade the quality such that a product can only be recycled once or twice before ultimately being discarded.

BREAKOUT 3 Chemical recycling

For products and materials where mechanical recycling is not possible, industry has suggested that chemical recycling may provide a pathway for circularity. Chemical recycling is an umbrella term for technologies that change the chemical composition of waste to make it reusable, for example through gasification, pyrolysis, or depolymerisation. However, some experts have raised concerns about the broad use of the term "chemical recycling," arguing that there needs to be transparency about what new product is being produced through the recycling process to prevent plastic incineration from falling under this banner.[51]

Chemical recycling is still in early stages of development, but several interviewed companies indicated that they were conducting research into this pathway. Cabot, a company producing carbon black in Sarnia, Ontario, has started projects in other parts of the world to chemically recycle used tires, reclaiming carbon and tire pyrolysis oil to be used in carbon black production.[52] Chemical recycling is more energy intensive, making mechanical recycling preferable where possible.[46]

Short-term steps

In April 2024, the federal government announced a Federal Plastics Registry, which will require companies that put plastics into the Canadian market to report the quantity of those plastics and where different quantities end up at the end of their lifetime (whether it be collected, diverted, or disposed).[55]

Federal or provincial governments should:

- Coordinate to ensure consistent collection, sorting, and recycling practices;
- Ensure recyclability is taken into account before products are put on the market; and
- Set future targets for minimum recycled content in products.

Chemical producers should:

- Identify where circularity can play a role in their current and future production processes;
- Design products that are recyclable at their end of life; and
- Invest in research and pilot projects using chemical recycling.

2 Transitioning to renewable feedstocks

Background

While many chemical companies operating in Canada are committed to efficiency improvements in the short-term and exploring larger technology shifts to eliminate production emissions in the medium- to long-term, one aspect of the transition seems to go largely unnoticed: the feedstock.

The majority of chemical production in Canada uses fossil feedstocks such as crude oil derivatives like naphtha or natural gas liquids. Although fossil feedstocks are not combusted for heat, significant greenhouse gases are emitted in feedstock production, chemical production, and when chemicals are disposed of at their end of life.

The production of fossil fuel feedstocks for chemicals causes significant upstream emissions. In the production of natural gas and natural gas liquids, significant amounts of methane (a greenhouse gas more potent than CO_2) leak into the atmosphere.[59]

Inorganic feedstocks (not containing carbon) for other chemicals may have a smaller emissions impact, but can still cause other challenges. Chemicals such as sodium chlorate, hydrochloric acid, and chlorine, for example, are based on salts. Around half of these salts are sourced in Canada, while the rest need to be imported. Interviewees from this subsector indicated that the largest source of emissions for these feedstocks is made up by the shipment of raw materials.

BREAKOUT 4 How fossil fuels are turned into the most common chemicals

Ethylene is produced through steam cracking of fossil fuel feedstocks, which in Canada are mainly ethane and propane. Most of the ethylene is then turned into polyethylene through polymerization, forming the basis for most consumer plastics—but ethylene is also turned into other chemicals used in the production of paints or cosmetics, for example. In the production of these and other petrochemicals such as polystyrene and propylene, the carbon atoms from the natural gas or petroleum are stored in the chemical product. When the product is burned or disintegrates in a landfill or the environment, these carbon atoms can enter the atmosphere in the form of CO_2 or methane.[56]

Ammonia, another one of Canada's most commonly produced chemicals, is made out of hydrogen derived from natural gas, resulting in significant process emissions.[57] Canada currently produces around 8,200 tonnes of hydrogen per day almost exclusively from natural gas, emitting nine kilograms of CO_2 per kilogram of hydrogen produced.[57] Most of this hydrogen is used for the production of ammonia, which is then commonly combined with liquid carbon dioxide to produce urea. When urea is used as a fertilizer in agriculture, the carbon stored in the urea molecules is released into the air.[58]

Potential net-zero solutions: hydrogen

Instead of the current "grey" hydrogen production process, "blue", or "green", or even "turquoise" hydrogen can be used to produce "blue" or "green" ammonia (see Breakout 5).

The federal government has adopted a Clean Hydrogen Investment Tax Credit (ITC) which provides refundable tax credits for property acquired for clean hydrogen and ammonia production.[67] The tax credit is between 15 and 40% depending on the level of emissions per tonne of hydrogen produced.

Hydrogen has also been suggested as a feedstock for some organic chemicals. Since these chemicals contain carbon atoms, the hydrogen would need to be combined with a source of carbon. Captured carbon could theoretically provide a carbon-neutral source, as long as the carbon is captured directly from the air rather than from an industrial process.*

Although a theoretical possibility, there is very little practical experience with using hydrogen as a feedstock for organic chemicals. Some experience exists in methanol production (a precursor to many other chemicals) where CO_2 is already recycled and sometimes additional CO_2 is injected into the process to balance an excess of hydrogen in the converter.[68] Currently, there are two active plants in China using carbon captured from industrial emissions and hydrogen recovered from coke oven gas to produce methanol.[69] One of the companies interviewed by Clean Energy Canada said that manufacturing pathways are viable, but it's unsure if it could be produced at a price customers are able to pay.

* If carbon used is from the combustion of fossil fuels or industrial process emissions, it is not a carbon-neutral feedstock,as new carbon is ultimately released into the atmosphere.

BREAKOUT 5 Different shades of low-carbon hydrogen

Green hydrogen is produced through the electrolysis of water with renewable electricity, where water molecules are broken into hydrogen and oxygen. Several projects have been launched to produce green ammonia in Canada, including two projects in Point Tupper, Nova Scotia, four wind energy-based projects in Newfoundland, as well as projects in Quebec and British Columbia.[63,64,65,66]

Blue hydrogen uses the same technology as current hydrogen production (reforming natural gas through steam), but the CO_2 emitted in the process is captured. With capture rates of over 90%, this could theoretically reduce emissions to 2-3 kg CO_2/kg H_2.[57] In practice, the two existing projects producing blue hydrogen in Alberta have not yet reached those carbon capture rates. Shell's Quest facility captured 77% of the CO_2 in the syngas in 2022 (an estimated 43% of the facility's total emissions), while Nutrien's fertilizer facility with CCS captured an estimated 29% of the facility's emissions.[60,61] Blue hydrogen still requires the production of natural gas, which is associated with significant upstream emissions. Other technologies like **methane pyrolysis** are still in development but are viewed by some in the sector as promising solutions, with two companies in British Columbia promising to deliver "turquoise hydrogen" produced with this technology.[62] Methane pyrolysis still uses natural gas, but produces solid carbon rather than CO_2 as a byproduct. One interviewee pointed out that methane pyrolysis could be a particularly suitable solution in Ontario where carbon capture is less feasible than in other regions.

The federal hydrogen investment tax credit uses the carbon intensity of hydrogen production as a metric, rather than distinguishing between different production methods.

Barriers to clean hydrogen (and captured carbon) as a feedstock

Recent studies conducting life cycle analyses found that the production of ammonia through the "blue" pathway could reduce emissions by 43 to 70%, whereas green ammonia production could reduce emissions by 90 to 100%.[*,70,71] However, green hydrogen is currently twice as expensive as blue hydrogen, and both alternatives are more expensive than the fully emitting variant.[72] Interviewed companies widely agreed that cost was the biggest barrier for using low-carbon hydrogen, especially green hydrogen, as a feedstock. Costs are expected to come down as green hydrogen production becomes more widespread. Bloomberg's models of hydrogen cost see green hydrogen becoming cheaper than blue hydrogen in Canada by 2030, but there may still be regional disparities.[72]

In addition to cost, using a combination of hydrogen and captured carbon for organic chemicals[**] may not prove viable in terms of both technology and energy use. Just as burning hydrocarbons (such as fossil fuels) releases a lot of energy, putting these molecules back together requires a lot of (clean) energy. Studies have found that producing plastics from captured CO_2 and green hydrogen would drastically increase electricity needs, with one study estimating that it would require 40 to 70 times more electricity than current production.[39,38,73] For global primary chemical production, this pathway would require 32 PWh of electricity in 2050—more than current global energy consumption for all purposes.[38]

Potential net-zero solutions: biomass

Biomass could serve as another alternative feedstock for carbon-based chemicals. Since the carbon in biomass has been absorbed from the atmosphere through photosynthesis, biomass-based chemicals can be carbon-neutral over their lifetime. Some studies even suggest that biomass-based plastics could function as a carbon sink, so long as they are not burned and don't disintegrate.[37]

There are numerous pathways for creating organic chemicals from biomass. Polyethylene, for example, has been successfully produced through the dehydration of ethanol made out of sugarcane or maize.[74] Many bio-based chemical pathways rely on producing methanol (a precursor to many chemicals) through gasification or anaerobic digestion of biomass. Some studies suggest this could also be applicable to ammonia production.[75]

Since methane, ethane, and propane are among the most common feedstocks for petrochemicals (such as ethylene for polyethylene plastics), the use of renewable natural gas (RNG) or renewable propane—for example produced with post-consumer waste or captured from landfills—could also be used to meet a share of feedstock needs.

Barriers to using biomass as a feedstock

Given the heterogeneity of products within the chemical industry, different biobased pathways will have to be developed to fit product specifications. Producers indicate that biobased feedstock may present a net-zero pathway for some of their products, but that more research is needed to see where this pathway can bring about real emissions reductions. For carbon black, for example, biomass currently has a much lower conversion rate than fossil feedstock, meaning that overall emissions could turn out higher when switching feedstocks.

Companies interviewed by Clean Energy Canada widely agree that the lack of availability of alternative feedstocks poses a real challenge. Several interviewees said their companies were considering switching feedstocks in the longer term, but that finding "adequate and affordable" feedstocks was a concern, especially with other industries competing for this emissions reduction pathway. Interviewees also mentioned possible ethical concerns about land use. Where waste biomass is not an option, the land area required to grow biomass poses a problem and risks competing with food crops. One analysis estimated that the production of net-zero chemicals with biomass would require around 3,000 m^2 of land per tonne of plastic produced.[38] That means the current amount of plastic produced for Canadian consumption would require a land area equivalent to a third of Nova Scotia.[40]

A circular bioeconomy combining recycling with biomass feedstock could reduce emissions while limiting the land used to grow biomass.[37] Moreover, the use of waste biomass could provide a feedstock that does not compete with food production, such as municipal solid waste or manure.[76] In the use of waste biomass, it is important to take a lifecycle approach when calculating emissions reductions.

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* Depending on assumptions, including whether the emissions from producing solar panels/windmills for renewable electricity are taken into account.

** Organic chemicals are chemicals which contain bonds between carbon and hydrogen atoms. They are currently mainly produced on the basis of fossil fuel feedstocks.

Short-term steps

Transitioning to renewable feedstocks is a complicated but crucial part of the road to net-zero chemicals. As such, it will require a comprehensive policy framework and collaboration between government and industry.

In the European Union, several member states recently issued a joint statement stressing that "an overarching European policy framework is required to realise the shift from fossil to sustainable carbon feedstocks, in order to secure long-term competitiveness of the European chemical industry in a climate-neutral and circular economy."[77] The statement also outlines policy measures that the European Commission should take, including technology neutral incentives to substitute virgin fossil carbon by recycled materials, sustainable biomass and captured CO_2, product regulation, support for innovation, and a sustainable carbon availability strategy.

As Canada seeks to stay competitive in a global market moving to net-zero, it should follow suit in outlining strategic actions to support the transition to renewable feedstocks.

Federal and provincial governments should:

- Fund research and development for alternative, sustainable feedstocks that do not compete with food production;
- Work with other ambitious jurisdictions to facilitate knowledge sharing and research collaboration for developing alternative feedstock supply chains; and
- Develop a strategic plan for the use of biomass across different sectors in the energy transition to ensure limited supply is allocated to the best use cases through the use of tax credits or other mechanisms that incentivise producing biomass for specific industries.

Chemical producers should:

- Fund research and development for alternative feedstocks; and
- Identify future sustainable feedstock alternatives for their products.

3 Electrification and fuel switching

Background

Stationary combustion of fuels for the production of heat is responsible for over a third of direct emissions in the Canadian chemical industry, and interviewed companies consistently pointed to heat and steam production from natural gas as one of their largest sources of emissions and energy usage.[3]

Many chemical manufacturing processes require high temperatures, with some processes taking place between 400 and 1000 degrees Celsius. However, these temperatures are still not as high as those required in the steel or cement industries.[78]

Potential net-zero solutions

The use of fossil fuels such as natural gas for energy is relatively inefficient. In the world's total energy system, almost two-thirds of all primary energy is wasted in energy production, transportation, and use.[79] Electrification is often a more efficient use of energy.

In the chemical sector, direct electrification with renewables could provide an efficient, zero-emissions alternative for heat and steam production. Several different technologies for electrical heating at high temperatures have already reached maturity, including electric boilers, induction furnaces, and electric arc furnaces.[78] Direct electrification is especially efficient in processes that require lower heat (up to 500 degrees celsius).[46] Heat pumps, for example, can currently reach temperatures up to 180 degrees Celsius with very high efficiency, whereas electric boilers combined with electric superheaters can produce steam at up to 500 degrees Celsius. An analysis in Europe found that direct electrification with a low-emissions grid could cut more than half of the emissions from the chemical industry.[78]

The federal government has made available an investment tax credit of up to 30% which can be used for acquiring clean technology property, including renewable electricity generation and storage equipment, solar or geothermal heating, or heat pumps.[80]

For higher temperature heat, the combustion of clean hydrogen may also provide a desired outcome. Interviewed companies had differing opinions on the potential to use hydrogen as a combustion fuel, with some seeing it as a realistic pathway or good transition fuel, while others emphasized that direct electrification would be more efficient and less costly. These viewpoints are also influenced by regional variations in the cost of different energy sources and the needs of distinct subsectors.

Many chemical companies produce hydrogen as a byproduct, including petrochemical companies cracking hydrocarbons and companies producing chemicals through the electrolysis of salts. Often, this hydrogen is already recycled as a fuel, but sometimes it is sold or even vented. Facilities that recycle their hydrogen as fuel already have the infrastructure and technical capacity to combust hydrogen, making a potential fuel switch more feasible.

Barriers to electrification and fuel-switching

There is no progress as of yet in the electrification of heat production in Canadian chemicals. Among interviewed companies, one indicated they had looked at an electric boiler to produce supplementary steam, but none had implemented any of these technologies.

Hesitance about the commercial readiness of electric technologies played a role in the lack of uptake. Additionally, interviewees mentioned the high upfront costs of these large-scale retrofits was prohibitive. Retrofitting an existing chemical plant or building a new low-emissions plant comes at a high upfront capital cost, which is not always easy to justify for companies competing in global markets.

In addition to capital costs, companies raised concerns about the cost of energy—in particular the cost of hydrogen as a fuel. For electrification to be a viable option, electricity and grid infrastructure also need to be reliable and affordable (see Breakout 7).

Making investments also often requires longer-term policy certainty. If companies know that they will have to reduce their emissions to meet regulatory requirements, they know investments in electrification or fuel switching will pay off in the long term. Similarly, some companies mentioned a lack of certainty around carbon pricing (especially beyond 2030) made it more difficult to make a business case for investing in emissions reductions.

Finally, there are the practical realities of implementing large upgrades. Many chemical plants run constantly, only pausing once every few years to implement necessary maintenance. These turnaround cycles differ per plant, from two to five years, to as long as ten years, and maintenance periods are planned well in advance. If this maintenance window is missed for emission reductions upgrades, it can be years before there is another opportunity. Funding and assistance programs are not always attuned to that reality and several companies cited examples of being ineligible for funding as a consequence.

BREAKOUT 6 Electric cracking

Much of the petrochemical industry relies on cracking, where large hydrocarbons are converted into smaller hydrocarbon molecules. This production method is used, for example, for ethylene, propylene, benzene, and other precursors to plastics. Ethylene (and other olefins) can be produced from naphtha or from natural gas liquids like ethane. Cracking from ethane is most common in the Canadian petrochemical industry, as it is a cheaper feedstock and widely available in Canada.[81]

Steam crackers function at very high temperatures, up to around 850 degrees Celsius, usually burning propane or natural gas.[82] Electrifying the cracking process would eliminate the direct use of natural gas in the chemical industry's most energy-intensive process.[83] Additionally, researchers argue that switching to electric crackers would significantly increase the efficiency, with fossil fuel-powered naphtha crackers currently using only 30% of the energy from fuel combustion for the cracking reaction.[84] In current processes, a lot of the heat is recovered and used to power steam turbines, which could also be replaced by electromotors. In addition to building new fully electric crackers, existing crackers could likely be retrofitted with electric heat.

Still, cracking hydrocarbons produces a range of byproducts, including methane and hydrogen. In conventional crackers, these byproducts are used as combustion fuel, resulting in additional CO_2 and water vapor. Electric crackers, which do not use combustion, will have to be complemented by a separate use for these byproducts, for example by separating them out and putting them on the fuel market.

The first electric cracker pilots are now being built in Europe. In 2021, Dow and Shell signed a cooperation agreement to research electric cracking in the Netherlands.[85] In Germany, BASF, SABIC and Linde broke ground on an electric cracker in August 2022, promising emissions reductions of 95% or more.[86] INEOS Olefins secured funding in February 2023 to build an electric ethylene cracker in Belgium.[87]

While most of these companies also operate in Canada, there are no (publicly announced) electric cracker pilots or research projects in Canada yet, presenting an underutilized opportunity to translate global learning to Canada.

BREAKOUT 7 The need for reliable clean electricity

A switch from fossil fuels to renewable electricity will require the build-out of reliable and affordable clean electricity. A single electric cracker can require several hundred megawatts of electricity. Since most chemical plants run continuously, they cannot rely solely on intermittent renewables (like solar or wind), and so the electrification of the chemical industry will require a well-balanced generation mix complemented by storage solutions. In the future, demand response may also be part of the solution, as early modelling studies show that dynamic operations (ramping production up and down) may enable large emissions reductions without overbuilding renewable energy resources.[88]

Around half of the interviewed companies currently produce (part of) their own electricity through cogeneration. Some of them had concerns that purchasing electricity from the grid or producing it through on-site renewables could drive up costs. Some companies also indicated being committed to long-term contracts to sell part of their cogeneration to the grid. As jurisdictions move to net zero, the treatment of existing cogeneration facilities under electricity policy should be transparent and predictable.

Clean Energy Canada's modelling shows that electricity from wind and solar with storage are competitive in both Ontario and Alberta.[89] However, careful planning and oversight is required for a successful energy transition.[90] In this planning, provincial governments should take the electrification needs of the chemical sector into account, particularly the need for a reliable, continuous supply.

Some companies have taken small initial steps at their plants in Canada to move toward renewables. Imperial installed a 20 MW battery energy storage system at its Sarnia petrochemical plant, the largest behind-the-meter energy storage in North America at the time.[91] The battery system allows the company to take clean electricity from the grid overnight and store it to use during daytime peak hours.[92] Shell installed a 5 MW solar farm at its Scotford plant in Alberta.[93] Currently, it produces only 3% of the plant's electricity needs (and electricity still makes up a small share of its total energy needs), but expansion is underway.[94,95] However, companies are hesitant to make large investments in electrification and renewables without certainty about regulation or cost developments.

Short-term steps

Provincial and federal governments should:

- Co-fund projects demonstrating early adoption of emissions reduction technologies beyond carbon capture, such as industrial heat pumps and electric crackers;
- Align funding programs with the practical realities of the chemical sector such as turnaround times, for example by designing funding programs that have a continuous intake process;
- Provide carbon pricing certainty through maintaining the industrial carbon price and providing a framework for carbon contracts for difference; and
- Develop energy strategies that ensure abundant, clean, predictable, and affordable electricity to facilitate electrification.

Chemical producers should:

- Bring together a consortium to launch an electric cracking pilot facility in Canada, building on research in Europe;
- Invest in pilot projects adopting emission reduction technologies, including behind-the-meter renewables and electricity storage, and the electrification of process heat; and
- Map out realistic pathways to a net-zero future for each of their product categories.

4 Carbon capture and storage (CCS)

Background

CCS is a popular solution among both industry and government. The federal government has adopted an investment tax credit for CCUS (carbon capture, utilization, and storage) and the province of Alberta has launched several initiatives to support CCS, including the Alberta Carbon Capture Incentive Program (estimated at $3.2 to $5.3 billion over the next decade[96]), as well as a $131 million grant program for CCS and industrial energy efficiency, and the Carbon Capture Kickstart program as part of Emissions Reductions Alberta.[97] One interviewee even referred to the "tunnel vision" certain Canadian governments seemed to have, with funding almost exclusively dedicated to this technology.

Potential emission reduction solutions

Carbon capture and storage can provide a solution where other options for emissions reduction are not readily available, for example for capturing waste gasses from chemical cracking processes, or other process emissions from chemical reactions.

Among interviewed chemical companies, CCS was the most common answer when asked what technological developments would enable them to create truly net-zero products. While some companies interviewed by Clean Energy Canada indicated that a lot more research and technology development would be necessary, others considered CCS ready for implementation and have started projects. Shell's Polaris project in Scotford, for example, is designed to capture post-combustion emissions from the Scotford Refinery's hydrogen plant as well as a CO_2 waste stream from the facility's mono-ethylene glycol plant.[98] The project recently reached Final Investment Decision and the company indicates it has the potential to reduce Scope 1 emissions by up to 22%.[99]

Using pure oxygen (oxyfuel) for fuel combustion could create a more pure stream of CO_2 which is easier to capture while also eliminating NO_x emissions. A life cycle analysis of ethylene plants found that a combination of oxyfuel and carbon capture could reduce overall emissions from ethylene plants by up to 24%.[100]

In November 2023, Dow announced the construction of a low-emissions integrated ethylene cracker and derivatives site in Fort Saskatchewan, Alberta, which will receive $8.9 billion in capital investment (including $1.8 billion from the Alberta Petrochemicals Incentive Program [APIP] and $400 million from federal investment tax credits).[11] The site is expected to almost eliminate emissions from operations. It will still crack fossil ethane, but will only burn hydrogen as fuel in the steam cracker. The cracking of ethane into ethylene produces an offgas that contains both hydrogen and methane as byproducts. The hydrogen component will be separated out of the stream and recycled back to the furnaces as a fuel. The remaining methane will be separated and converted into hydrogen (using an autothermal reforming process [ATR]) with CO_2 emissions captured in the process. The plant is expected to begin operating in 2027, with construction beginning in 2024.

Barriers to CCS

While many producers see great potential for CCS, presently there is not a lot of experience with this technology in the chemical sector (aside from the Shell Quest CCS project). Carbon capture projects in other sectors have also delivered mixed results. The Boundary Dam project in Saskatchewan, for example, had promised to capture up to 90% of carbon from power production, but analysts found that its long-term capture rate was only 57%.[101]

Of course, other technologies to reduce emissions in the chemical sector, such as industrial heat pumps or electric crackers, also require further technological development and demonstrations. However, there is a risk in seeing carbon capture as a silver bullet or safe bet, rather than one among a suite of potential options.

Crucially, carbon capture requires a very large amount of energy, especially in chemical production where there are multiple point sources of emissions or there is a low concentration of CO_2 in flue gasses, such as when a facility burns a mixture of natural gas and hydrogen.

Because of its complexity and high energy usage, CCS is also a very expensive option.[102] According to the Intergovernmental Panel on Climate Change's latest report, it is one of the most expensive emission reduction technologies.[103]

The federal government has adopted an investment tax credit for CCUS property, which offers up to 50% of the cost of capture equipment for process emissions and 37.5% of the cost of carbon transport and storage equipment. The ITC is expected to cost close to $6 billion over six years.[104] Notably, the ITC has provisions that require repayment of the tax credit if the carbon is not permanently sequestered.

Infrastructure for carbon transport and storage does not currently exist in Ontario, limiting the technology as an option for chemical facilities in Sarnia. This also means facilities in Ontario are missing out on federal financial support provided as part of the CCUS ITC. In Alberta, on the other hand, the Alberta Carbon Trunk Line, the development of CCS hubs, and an existing regulatory framework for carbon sequestration make CCS a more attractive option for chemical companies.

Short-term steps

Provincial and federal governments should:

- Align funding programs with the practical realities of the chemical sector such as turnaround times;
- Provide carbon pricing certainty through maintaining the industrial carbon price and providing a framework for carbon contracts for difference; and
- Provide assistance for promising carbon capture projects in the chemical sector, while maintaining a technology-neutral approach to emissions reductions that fairly evaluates and supports the most promising technologies and pathways.

Chemical producers should:

- Evaluate emissions reductions technologies and pathways with a technology-neutral approach that facilitates the piloting and commercialization of the most effective and financially sustainable solutions. This would ensure CCS plays a role that is technologically and financially viable over the longer term; and
- Invest in pilot and commercial projects for emissions reductions, and collect data on cost, energy usage, and effective capture rates, and share best practices.

5 Improving energy efficiency

Potential emission reduction solutions

In the shorter term, emissions from fuel combustion and heat production can be reduced by increasing the efficiency of production processes. Examples include recovering waste heat, consolidating distillation, or cracking at lower temperatures. Interviewed companies almost all indicated that they had been working on identifying or implementing energy efficiency improvements. NOVA Chemicals, for example, is developing its Low Emissions Ethylene Process (LEEP) technology and investigating cracking at lower temperatures.[105]

Barriers to improving efficiency

As reduced energy use can also bring down the cost of production, many companies have historically recognized the benefits from increased efficiency. In fact, some companies indicated this meant that many of the energy efficiency gains have already been realized and the potential for further improvement was limited.

Efficiency improvement projects may also be limited by turnaround times, leaving only specific windows every few years to implement upgrades to existing plants.

Short-term steps

Provincial and federal governments should:

- Align funding programs for energy efficiency gains with the practical realities of the chemical sector such as turnaround times.

Chemical producers should:

- Continue to invest in energy efficiency gains.

Conclusion

Canada's chemistry sector has the opportunity to become a high-value part of a net-zero economy. The technologies and infrastructure we will rely on for the production of clean energy, for transport, and even for heating and cooling our homes, are dependent on chemistry. Producing these vital building blocks with low emissions will give Canadian companies a competitive edge.

That is good news for the sector and the 90,000 people who work in it, as well as for some of the regions at the heart of the energy transition, such as Alberta's Industrial Heartland and Sarnia, Ontario.

However, while other jurisdictions like the EU and U.S. have started investing, Canada risks missing the boat. If we want to catch up and keep one of our core industrial sectors competitive in a net-zero world, we need to start with a plan. Adopting a common roadmap will provide policy certainty and give the chemistry industry confidence to invest in necessary upgrades.

With the early actions outlined in this report, both industry and governments of different levels can start taking the first steps:

Government and industry can work collaboratively to future-proof Canada's chemistry sector by moving toward high-value, net-zero-aligned products and building a net-zero roadmap that includes:

Cross-cutting goal | **Transition to the use of Canadian chemicals in high-value supply chains that underpin a net-zero future**

1 Increasing circularity, including through regulation and incentives for recycling

2 Transitioning to renewable feedstocks and helping ensure their availability

3 Moving away from higher-emitting energy sources through electrification and fuel-switching

4 Developing a credible plan for the effective use of carbon capture and storage

5 Continued investing in energy efficiency gains

Annex: Interviews

We would like to thank the Chemistry Industry Association of Canada for providing their assistance in setting up most of our interviews.

We are grateful for the insights provided by these stakeholders as they have informed the observations and recommendations in this report. However, participation in this process is not necessarily an endorsement of all statements and recommendations.

The following companies and experts participated in an interview:

- Dean Pearson, Facility General Manager, and Magaidh Crossland, Environmental Specialist—Cabot Canada
- James Brown, Climate and Energy Policy Leader—Dow Canada
- Ed Bechberger, CEO, and Emily Fattore, Vice President Human Resources and Sustainability—ERCO worldwide
- Nicolas Beck, Head of Market Intelligence, and Stephen Appleton, Canadian Company Manager—Fortescue
- Robert Janzen, Senior Technical Lead, Downstream, Climate Integration Team—Imperial
- Nathan La Rocque, Energy Manager, North America—INEOS Styrolution
- Jennifer Li, Sustainability Program Specialist, and Veronique Fournier, Sustainability Program Specialist—Inter Pipeline
- Renato Monteiro, Vice President Low-Carbon Methanol Supply; Jody Magill, Manager, Global Communications, Manufacturing; and Brad Apking, Plant Manager—Methanex
- Shane Lamden, Environment Manager, and Kevin Wilke, Climate Solutions Leader—NOVA Chemicals
- Jana Masters, Policy Adviser, and Tracy Smith, Corporate Relations Lead for Government and Policy—Shell Canada
- Robert de Boer, Senior Scientist Specialist, Energy and Materials Transition—TNO (Netherlands Organisation for Applied Scientific Research, part of electric cracker research consortium e-MissiOn MOOI)

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