

INDUSTRY

Chemicals and Plastics



10.5 CHEMICALS AND PLASTICS

Function	Basic materials of industrial society. Used across all sectors. Chemicals: Especially for fabrics, solvents, fertilizers, pesticides, paints, cleaning compounds, and pharmaceuticals. Plastics: Especially for packaging, construction, and automotive manufacturing.
GHG emissions	Chemicals: 3.5% of national emissions, 23.8 Mt CO₂e in 2024[452]¹. Plastics: Less than 0.2% of national emissions, 1.1 Mt CO₂e in 2023[453,454].
Options for decarbonization	Fuel switching, electrification, carbon capture, utilization and storage, energy efficiency upgrades, alternative or recycled feedstocks, demand reduction measures, material efficiency, circularity, and improved recycling and waste management.
Stage of transition	Early Emergence
Nature of the problem today	Reliance on fossil carbon for feedstocks and energy, high and increasing demand for chemicals and plastics, low recycling rates and circularity, and mismanaged disposal.
Other systemic issues	Adverse health and environmental effects, persistent and bioaccumulating chemicals, plastic and microplastic pollution[455–457].
Strategic opportunities and concerns	Opportunities: Canada could be a first mover as many technologies are still in pilot and demonstration phase. Buildout of new value chains handling secondary plastics (i.e. recycled plastics) sustainably. Concerns: Increased dependence on alternative or bio-based feedstocks could have land-use and biodiversity impacts; chemical recycling processes energy-intensive or generate hazardous byproducts; risk that improved recycling and recovery could reinforce overconsumption of non-essential plastics rather than absolute demand reduction, increasing production of emissions-intensive primary plastics (i.e. virgin plastics).
Priorities for action	Invest in research, development, and deployment of carbon capture, utilization, and storage; alternative feedstocks; and electrified equipment. Improve regulations and funding for end-of-product-life management systems including demand reduction, reuse, and recycling.
Longer-term issues	Controlling leakage of chemicals (plastics, refrigerants, and fertilizers) into the environment and associated issues. End-of-product-life emissions (could be up to 50% of sector emissions)[458,459]. Availability of feedstocks and clean energy. Carbon supply in a decarbonized energy system.
Indicators of progress	Percentage of site energy as clean electricity or low-carbon fuels, percentage of captured emissions, decreasing carbon intensity of chemicals and plastics, percentage of alternative and recycled feedstock used, improved circular economy indicators, percentage of plastic diverted from landfill, number and success of extended producer responsibility programs.

¹ All noted references can be found in the full Playbook document.

10.5.1 Current Status

Chemicals are used across the economy, and it is estimated that 96% of manufactured products rely on chemicals to some extent[460]. It is possible to divide chemicals produced in Canada into four broad categories[454,461–463]:

- **Industrial chemicals:** Basic chemicals and synthetic resins, rubbers, and fibres used to make plastics, fabrics, and solvents. Greenhouse gas reporting program (GHGRP) facility emissions: 13.40 Mt in 2024.²
- **Agricultural chemicals:** Fertilizers and pesticides. GHGRP facility emissions: 5.75 Mt in 2024.³
- **Chemical products:** Paints, coatings, adhesives, soaps, cleaning compounds, toiletries, printing ink, and other miscellaneous chemical products. GHGRP facility emissions: 0.12 Mt in 2024.⁴
- **Pharmaceuticals:** Medicines and associated compounds. GHGRP facility emissions: 0.07 Mt in 2024.⁵

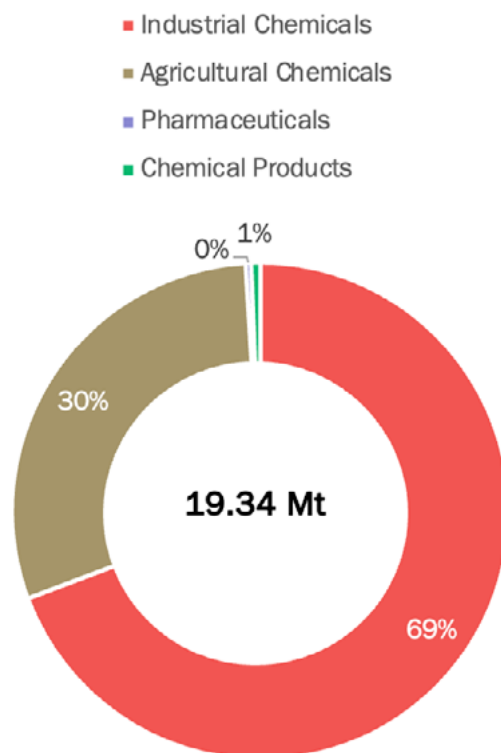


Figure 34. Chemical sector GHGRP facility emissions, Canada 2024[463]



² NAICS codes 3251 and 3252

³ NAICS code 3253

⁴ NAICS codes 3255, 3256, and 3259

⁵ NAICS code 3254

Plastics, produced from chemicals, are widely used due to their low cost, moldability, and versatility across applications such as packaging, automotive components, electronics, textiles, and construction materials.⁶ Most plastics are discarded despite some being durable; in 2021, about 0.7 tonnes were thrown away for every tonne produced in Canada, creating major challenges for waste management and circularity[464].

Most chemical products are derived from oil and gas feedstocks and are therefore referred to as petrochemicals. Seven primary chemicals make up more than 60% of the chemical sector's energy consumption[465]. *Ammonia* and *methanol*, two primary chemicals, are made using natural gas[466]. Five other primary chemicals—*ethylene*, *propylene*, *benzene*, *toluene*, and *mixed xylenes*—are derived principally from natural gas liquids and light crude oil distillates. These seven primary chemicals can be consumed or processed further into thousands of other chemical and plastic products[459]. The olefins—ethylene and propylene—are produced predominantly by high-temperature “steam cracking” of ethane and propane. The aromatics—benzene, toluene, and mixed xylenes—are typically obtained from the catalytic reforming of naphtha.

In Canada, two-thirds of the chemicals produced, by mass, were ammonia (anhydrous 4.5 Mt and nitrate 1.1 Mt), polyethylene (3.6 Mt), and urea (3.5 Mt[458,467]. Plastic resin production (including polyethylene and polypropylene) represents a significant share of chemical manufacturing, with sales estimated at \$11.3 billion CAD in 2024⁷[468].

Chemicals are produced by approximately 3,650 manufacturers in Canada. Chemical and plastic production is mainly located in Ontario (45%), Alberta (25%), and Quebec (16%), leveraging local fossil fuel resources and manufacturing capacity. In 2024, the sector employed 94,500 people, generated approximately \$77 billion in revenues, and exported \$55.6 billion⁸ in products, with 77% going to the United States[462]. In the same year, the sector's GDP was \$32.2 billion⁹[437].

Global chemical manufacturing is expected to triple by 2050 compared to 2010, with chemicals playing an important role in emission reduction technologies.

10.5.2 Nature of the Problem

The chemical and plastics sector relies on high-temperature production processes that use fossil-based fuels and feedstocks, making it emissions-intensive and fundamentally fossil-dependent, with decarbonization further constrained by long-life capital-intensive assets that drive lengthy intervals between major investments.

In 2024, the chemical industry emitted 23.8 Mt of CO₂e, representing 3.5% of Canada's annual emissions[452]. Most emissions originate from energy use within facilities (mainly fuel combustion and on-site electricity generation), while the rest come from industrial processes and the use of non-energy fuels and solvents (see Figure 35). An additional 14 Mt of CO₂e are linked to chemical feedstock production and end-of-life management, and 1.6 Mt of CO₂e is attributed to electricity purchase[458].

6 NAICS code 3261

7 2024 Canadian dollars

8 2024 Canadian dollars

9 Chained (2012) Canadian dollars

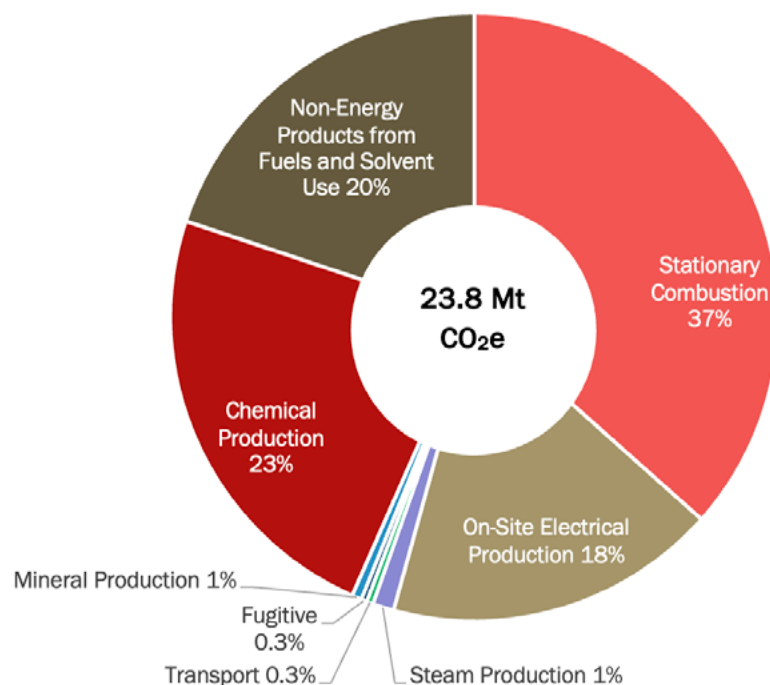


Figure 35. Chemical and fertilizer sector emissions by source, Canada 2024[452]

Plastics and rubber product manufacturing contributed 1.1 Mt CO₂e (less than 0.2% of national emissions) in 2023, because these facilities only transform plastic resins and rubber materials into final or intermediate goods[452,454,469]. Plastic production is carbon-intensive primarily due to upstream oil and gas extraction and high-temperature cracking processes to produce building-block chemicals such as ethylene and propylene[470,471]. End-of-life treatments including landfilling, recycling, and incineration also generate additional GHG emissions.

Decarbonizing the chemical and plastics sector is particularly challenging because it depends on fossil fuels not only for energy but also for material feedstocks, making it inseparable from the broader energy system. The sector must address emissions from energy use, processing, and waste management of embodied carbon while continuing the supply of essential chemicals and accommodating significant expected growth by 2050[459,460].

A major barrier to decarbonization is that chemical facilities are already highly optimized, leaving little room for further reductions without adopting new low-carbon production technologies, which remain immature and costly. The heterogeneity of products makes the standardization and widespread application of new solutions to existing facilities difficult. Geography also constrains solutions through limitations on accessible low-carbon electricity, carbon storage sites, and alternative feedstocks.

Chemical production involves substantial investments in equipment and infrastructure, and major changes (for example, switching processing technologies or feedstocks) are best timed with cycles of facility renewal every few decades[472]. Funding can often miss these major reinvestment cycles[458]. Additionally, the lack of carbon price certainty and/or low carbon prices disincentivizes investments in cleaner infrastructure[458].

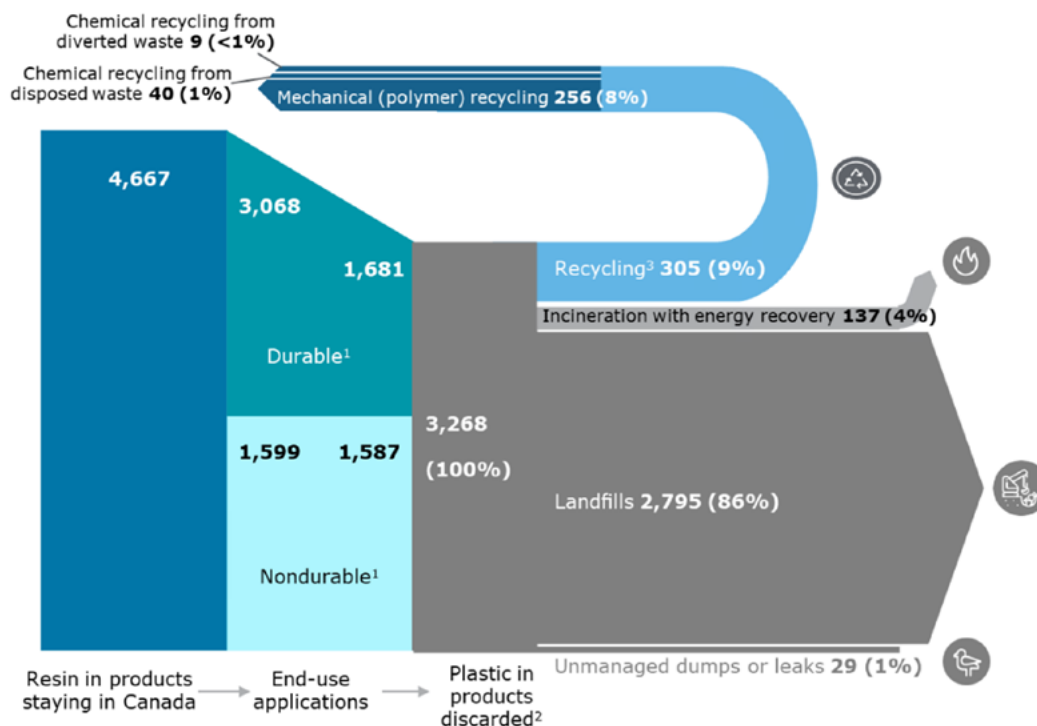


Figure 36. Recycling and disposal of plastics and resins in Canada, 2016 (thousand tonnes per year)[474]

Demand-side policies typically only focus on the effects of chemical or plastic pollution, targeting recycling or waste management. There is a lack of a broader strategy to address designing products for durability and reuse, or with less plastic and chemical usage altogether (e.g., downgauging, lightweighting), in order to reduce demand for emissions-intensive virgin materials[472].

Plastic recycling in Canada generally lacks standardization and efficacy[458]. In 2021, it was estimated that only 7% of discarded plastic was recycled, and 2% was incinerated with energy recovery[473]. In 2016, landfilling the remaining plastic resulted in an estimated \$7.8 billion¹⁰ opportunity loss for Canada[474]. Additionally, the economics of plastic recycling are dependent on oil and gas pricing: when oil and gas are inexpensive, primary plastic outcompetes recycled plastic on price[474].

The intertwined nature of oil and gas production and the chemical sector adds a layer of complexity. As demand for transport fuels and fossil-based electricity generation declines while demand for plastics and other synthetic materials continues to rise, analyses indicate that petrochemical feedstocks could shift from being a secondary product of oil and gas refining to a primary output. This evolution could further tighten the integration between the two sectors, creating carbon lock-ins that slow the transition away from fossil-fuel-based energy systems, while also risking stranded oil and gas assets if future policies place significant downward pressure on fossil-based chemical production[472,475–477]. Decarbonization pathways for chemicals and plastics must therefore be considered alongside broader oil and gas transition pathways to support a coordinated shift across both sectors.

¹⁰ 2016 Canadian dollars

Economic factors add further challenges. Chemicals are traded globally as commodities, and Canadian producers compete with jurisdictions with lower costs and less stringent environmental controls. With most Canadian chemical products exported to the United States, trade and environmental uncertainties pose additional risks to the sector's decarbonization efforts.

10.5.3 Net-Zero Pathways

Today, oil and natural gas provide both the energy (heat) and the building blocks (hydrogen and carbon) required for chemical and plastic production, making the sector doubly reliant on fossil inputs. In a net-zero chemical and plastics industry:

- **Heat** could be generated from net-zero electricity, oil and gas with CCS, sustainable biomass, or low-carbon hydrogen.
- Low-carbon **hydrogen** could be sourced from natural gas reforming with CCS, methane pyrolysis, or from water electrolysis with net-zero electricity.
- **Carbon** could come from oil and gas with CCS, recycled materials, sustainable biomass, or captured carbon dioxide.

These measures could be combined in different ways depending on lifecycle assessments, desired outputs, available resources, and the cost and maturity of various technologies. Initially, CCS will be important as fossil fuels will continue to provide the bulk of feedstocks even if energy is decarbonized. Later, alternative feedstocks, such as biomass and captured carbon, will become more prominent. If fossil carbon is incorporated into products (carbon is an element in all the base chemicals except ammonia), end-of-product-life emissions will require offset technologies such as direct air

capture (DAC). Plentiful, reliable, and affordable clean electricity is critical for the chemical industry to advance towards net zero. Circular economy strategies (e.g. recycling and reuse), though primarily aimed at reducing pollution and improving resource use, also reduce demand for energy and primary feedstocks, lowering lifecycle emissions and the burden of sourcing clean energy and sustainable biomass[478].

The four basic elements for decarbonization are therefore:

- 1. Carbon Capture and Storage (CCS)/ Carbon Capture and Utilization (CCU):** CCS can be applied to manage the feedstock, energy, and process emissions directly involved in chemical and plastic production[476]. Direct air capture (DAC), which requires more research and low-cost renewable electricity to become economical, or other carbon removal strategies could help offset remaining emissions[460]. Ultimately, captured carbon could be reused to make new chemical products[479]. CCS cannot be the only solution due to large electrical requirements, decentralized chemical facility emissions, limited geological carbon storage capacity, and associated high costs. Complementary solutions are also required[458].
- 2. Electrification and Fuel Switching:** Many chemical processes occur between 400 and 1,000°C, so heat and steam production from natural gas is today a large emission source. Electrified steam crackers, which address onsite energy emissions and can greatly improve efficiency, are progressing toward commercial-scale deployment, with the world's first demonstration plant now operating in Europe. However, capital costs for commercial-scale electric crackers may be prohibitively high in the

near-term and operating costs may also be uneconomic, especially where electricity is expensive[480]. For lower temperature heat (under 500°C), electric boilers, induction furnaces, electric arc furnaces, heat batteries, electric heat pumps, and mechanical vapour recompression can all replace fossil fuel-based heating equipment[458]. For larger equipment like crackers where the costs to electrify can be prohibitive, switching to lower-carbon fuels in the interim is a solution. For instance, equipment that currently runs on natural gas could be transitioned to renewable natural gas or hydrogen[461].

3. **Low-Carbon Feedstocks:** Chemical production could be converted to non-fossil feedstocks. Low-carbon hydrogen (produced by water electrolysis with non-emitting electricity, methane pyrolysis, or from natural gas reforming with CCS) can be used to make ammonia or combined with captured CO₂ to produce methanol—but cost and/or clean electricity availability are significant challenges[461]. Renewable biomass can also serve as a feedstock for both chemicals and plastics, but there are limitations with availability, sustainability, and technical complexity. Emerging biomass-based processes for chemicals and bioplastics often involve costly, multi-step transformations and require further research to become viable[470,479].

Recycled plastics and other secondary materials are another important feedstock option to reduce lifecycle and feedstock emissions and capture otherwise wasted economic value[481]. Mechanical recycling, which occurs today in Canada, can displace demand for primary resins but often produces lower-quality outputs due to impurities.

Chemical recycling, while subject to energy, cost, and maturity limitations, can produce “like-new” resins, using depolymerization or dissolution, or feedstocks of syngas or synthetic oil, using thermal conversion technologies such as pyrolysis or gasification. Another benefit of chemical recycling is its ability to process a wider range of plastic waste streams than mechanical recycling, particularly those that are mixed, contaminated, or otherwise difficult to recycle mechanically. These technologies represent potential pathways for scaling recycled inputs in high-value applications[474,476,482–484]. Recycling has two roles in this framework: reducing waste at end-of-life and supplying lower-carbon feedstocks back into the system.

4. **Demand Reduction and End-of-Life Management:** Measures such as better fertilizer application practices, changed cropping systems, reduction of food waste, and improved plastic end-of-life management can reduce demand or increase circular use of chemicals and plastics and correspondingly reduce sector lifecycle emissions[460,470,485]. These measures are intended to reduce avoidable and inefficient use while continuing to meet demand for essential chemical and plastic products. Designing plastic products to be more durable, reusable, or recyclable reduces demand for primary chemical inputs by keeping products in the economy longer[486]. Any material substitutions should be guided by lifecycle assessments that consider land-use changes and transport emissions[487]. Policies like extended producer responsibility (EPR) and better labelling can support more consistent sorting and collection, which are foundational to effective recycling and reuse.

When plastics cannot be recycled mechanically or chemically, end-of-life options include composting, incineration with energy recovery, and landfilling. However, compostable and biodegradable plastics often face barriers due to inconsistent facility capabilities and a lack of standardized certification. Incineration, while a potential route for unrecyclable plastics, raises concerns around GHG emissions, air pollution, and public acceptance.

A small portion of essential plastics and chemicals that cannot be recycled due to contamination concerns (e.g. medical waste such as syringes, gloves, and masks) will continue to end up in landfills, requiring mitigation through carbon offsetting or capture strategies[474].

10.5.4 Priorities for Action

1. Electrification and Clean Energy Supply (Short-Term)

Canada currently has no projects to electrify chemical facilities, so funding should prioritize demonstration projects for heat batteries, industrial heat pumps, and electric crackers. Financing should be put in place to help with electrifying other large equipment like boilers and furnaces. A regional deployment strategy may be considered, with trial electrification projects prioritized at chemical facilities in provinces that already have reliable low-carbon grid electricity, such as Quebec. Investments in on-site clean energy production and electrical storage should be supported for companies in provinces like Alberta, where grid electricity is heavily reliant on fossil fuels. Securing clean energy is especially important as carbon capture technologies are currently energy-intensive and necessary to decarbonize the chemical sector.

2. Carbon Capture and Pricing Certainty (Short- to Medium-Term)

CCS projects are best initiated in provinces that have proven geological storage, existing pipeline infrastructure, and established regulatory frameworks, providing early proof points and commercial success stories before expanding into more challenging regions. Investment in the research, development, and implementation of carbon capture technologies and strategies will also help bring costs down over time[461]. In the meantime, carbon contracts for difference could help to establish carbon price certainty and help investors with decisions on carbon capture implementation. Carbon border adjustments and support mechanisms will also help net-zero chemicals gain a foothold in the market.

3. Circularity (Short-Term with Ongoing Benefits)

The circularity of chemical products must be improved to reduce demand for virgin materials and minimize waste management emissions. Systems to manage end-use products can be improved by implementing programs such as mandatory extended producer responsibility (EPR) across the country so progress is trackable. Companies should be encouraged to design chemical products for recycling or reuse and reduce the use of all chemical products where possible. For industries such as agriculture, best management practices for chemical application can reduce demand.

4. Waste and Recycling Systems (Medium-Term)

Canada should invest in infrastructure for the collection, sorting, and reprocessing of chemical and plastic products, supported by clear national labelling standards and public awareness campaigns. These systems should be optimized for energy efficiency, and research into innovative recycling methods should be advanced to reduce the energy and GHG footprint of mechanical and chemical recycling[474]. A national plastics registry that collects high-quality standardized data on material flows from manufacture to end-of-life would improve transparency and guide evidence-based policy[488]. Single-use plastics bans, informed by local context and lifecycle GHG assessments for reusable or substitute alternatives, can reduce plastic pollution and lower end-of-life emissions[487,489]. Where single-use plastics cannot be avoided, recycled, or chemically converted, strategies such as landfilling paired with gas capture and carbon offsets may need support to manage residual emissions. Improving circularity and recycling systems requires coordinated, consistent approaches from municipal, provincial, and federal governments. This enables reduced investment risks and stable national markets for secondary materials.

5. Alternative Feedstocks (Long-Term)

Over the longer term, Canada will need to scale chemical production pathways that rely on non-fossil feedstocks. Whether using recycled materials, captured carbon, or biomass feedstocks, these feedstocks should not compete with food production and must be evaluated for availability, sustainability, and technological readiness.

6. Funding and Support (Cross-Cutting Enabler)

Funding programs should be designed with rolling intake to accommodate the operation and maintenance schedules of existing facilities. Additionally, technologies supported in funding programs should be evaluated without bias and guided by lifecycle assessments and techno-socio-economic benefits, as the industry is very diverse and the best solution for decarbonization will differ from project to project.



Criteria Status

-
- Fails to meet criteria
-
- Meets in some respect
-
- Not promising
-
- Potentially meets criteria
-
- Meets criteria

10.5.5 Chemicals and Plastics Pathways Table

Fails to meet criteria Meets in some respect Potentially meets criteria Meets criteria			Economic		Technical			Social			
PATHWAY ELEMENTS	ROLE IN NET-ZERO SYSTEM	SIGNAL TO DECISION-MAKERS	ALIGNMENT WITH CARBON NEUTRALITY	ECONOMIC VIABILITY	ECONOMIC DEVELOPMENT OPPORTUNITY	MATURITY	OPERATIONAL FIT	INFRA-STRUCTURE AND SUPPLY CHAIN SUITABILITY	SOCIAL ACCEPTABILITY	RELEVANCE TO STAKEHOLDERS	RELATED BENEFITS AND COSTS
 Process Energy											
Low-Carbon Hydrogen (heat)	Decarbonization Pathway Applicable for heat applications where electric options are not viable and clean hydrogen is available.	Enable Support demonstration where economics are positive. Build out hydrogen generation and supply infrastructure.	 Reduces carbon intensity, but only net-zero with CCS or certified low-carbon supply.	 Hydrogen costs falling near hubs. Retrofits cheaper than full electrification when capital-constrained.	 Supports gas utility transition strategies. Strengthens hydrogen supply chain.	 Burner and control modifications are feasible at scale for hydrogen. Full-scale hydrogen plant under development.	 Minimal layout changes and short outages. Useful for peaking or reliability where electric power is constrained.	 Requires verified H ₂ supply and sometimes new storage. Trucking or pipelines depend on regional ecosystems. On-site fuel generation or hubs reduce infrastructure burden.	 Mixed views: sustainability of feedstocks and hydrogen safety are concerns and acceptance improves with transparency.	 Relevant to utilities and operators for near-term decarbonization planning. Canadian deployment occurring today.	 Concerns with methane leakage from blue hydrogen production.
Electrified Steam Crackers	Potential Decarbonization Pathway Applicable to high-temperature furnace heat as grids expand and decarbonize.	Incubate Support research and demonstration in Canada. Build out grid infrastructure.	 Electrified heaters eliminate combustion emissions from core furnace combustion. Depends on grid carbon intensity.	 Business case hinges on abundant, reliable, low-cost clean power. Early projects require co-funding.	 First-mover advantage in low-CO ₂ resins, advanced controls, high-skill electrical/automation jobs at resin hubs.	 Demo/early commercial globally.	 Major furnace revamps during multi-year turnarounds. Extensive control upgrade and operator training. Modification of tail gas used in process.	 Requires major grid infrastructure upgrades and reliable electricity.	 Generally acceptable. Local concerns focus on grid buildouts. Air and noise benefits help.	 Strategic for polyethylene/polypropylene producers in ON/AB/QC resin corridors.	 Eliminates furnace NO _x . Finer temperature control improves yields. Scaling electrical grid may have land-use concerns.
Electric Arc Furnaces (EAFs)	Niche Pathway Relevant for electro-thermal sub-processes meeting some high-temperature heat needs.	Enable Support demonstrations with positive economics. Build out grid infrastructure.	 Delivers zero-emission process heat when powered by clean electricity. Depends on grid carbon intensity.	 Economics depend on duty cycle, electricity price, and retrofit scope. Usually secondary to e-boilers/ e-crackers in chemical plants.	 Limited domestic opportunity beyond specialized OEMs/contractors. Part of broader industrial electrification.	 Mature in metals. Limited chemical deployments.	 Works where electro-thermal heating can be substituted without product impacts. Best aligned with batch or discrete operations.	 Requires high-capacity electrical feeds and transformers. Supply chain available via metals sector vendors.	 Positive with fewer combustion emissions onsite.	 Relevant to select intermediates or allied operations at multi-industry complexes. Not a sector-wide lever.	 Eliminates onsite flue gas, reducing NO _x and particulates. Precise temperature control can improve yields.

PATHWAY ELEMENTS	ROLE IN NET-ZERO SYSTEM	SIGNAL TO DECISION-MAKERS	ALIGNMENT WITH CARBON NEUTRALITY	Economic		Technical			Social		
				ECONOMIC VIABILITY	ECONOMIC DEVELOPMENT OPPORTUNITY	MATURITY	OPERATIONAL FIT	INFRA-STRUCTURE AND SUPPLY CHAIN SUITABILITY	SOCIAL ACCEPTABILITY	RELEVANCE TO STAKEHOLDERS	RELATED BENEFITS AND COSTS
Electric Boilers, Industrial Heat Pumps, Heat Batteries, Mechanical Vapour Recompression (MVR)	Niche Pathway Relevant to preheating, steam & hot-water loops at ammonia, resins, and solvents plants, excludes cracker furnaces that burn byproduct fuel.	Enable Support demonstration with dedicated funding, then deploy where cost effective along with grid buildout.	 Delivers zero-emission steam, hot water, and low-temperature heat with decarbonized electricity. Abatement is smaller where site steam comes from cogeneration with CCS.	 Capex moderate. Operational costs tied to electricity. Attractive where power purchase agreements, load management, or on-site generation exist.	 Drives demand for Canadian equipment/services and grid buildout.	 Technologies are commercial globally. Canada lacks deployments.	 Needs spare waste heat and a nearby higher-temperature use for it. Adds little where site heat is already well integrated. Install during turnarounds; requires high-voltage training.	 Needs interconnection capacity and stable, clean electricity. On-site renewables and storage can hedge availability and price risk for continuous chemical loads.	 Generally positive. Seen as clean industry investment.	 Top action for utilities, operators, and provinces seeking rapid Scope-1 reductions and electrification of heat and steam services.	 Lower NOx/PM, improved operator safety, better temperature control, and efficiency. Frees gas for higher-value chemical synthesis.
Renewable Natural Gas (RNG)	Niche Pathway Works as an option where sustainable feedstocks exist and can meet supply. Feedstock scarcity limits scale.	Enable Support demonstration where RNG supply is secure	 Only net zero if RNG fully displaces fossil natural gas. Requires low-carbon feedstocks. Methane leakage remains a concern.	 RNG scarce and premium-priced. Retrofits cheaper than full electrification when capital-constrained.	 Supports gas utility transition strategies. Strengthens RNG supply chain.	 RNG is mature with limited deployment.	 Drop-in fuel. Useful for peaking or reliability where electric power is constrained.	 May be difficult for suppliers to connect to existing infrastructure, limiting supply. Competition for biomass.	 Broadly accepted and seen as waste valorization.	 Relevant to utilities and operators for near-term decarbonization planning. Canadian deployment occurring today.	 Concerns with methane leakage from RNG transport and combustion.
On-site Clean Electrical Generation	Priority Enabling Pathway Required to meet the electrification demands of the chemicals and plastic sector.	Deploy Build out on-site clean electricity generation as existing assets reach end-of-life.	 Reduces burden on the electrical grid and ensures electricity used is generated from non-emitting sources.	 Many methods of on-site generation are at cost parity or can provide operational savings depending on scale.	 Generates more jobs on-site at chemical and plastic facilities.	 Many technologies for clean on-site generation are commercial today and have been implemented in other Canadian sectors.	 Training of staff to maintain and operate the new processes. Depending on the technology, layout or available space may be a concern.	 Reduces burden on electrical infrastructure. Most technologies have established supply chains.	 Positive as grid power demand is lowered and more local jobs may be generated.	 Power demand is expected to be very high, so on-site power generation will be essential. Current focus may be more on direct emission sources.	 Reduced burden on electrical grid.

			ALIGNMENT WITH CARBON NEUTRALITY	Economic		Technical			Social		
PATHWAY ELEMENTS	ROLE IN NET-ZERO SYSTEM	SIGNAL TO DECISION- MAKERS		ECONOMIC VIABILITY	ECONOMIC DEVELOPMENT OPPORTUNITY	MATURITY	OPERATIONAL FIT	INFRA- STRUCTURE AND SUPPLY CHAIN SUITABILITY	SOCIAL ACCEPTABILITY	RELEVANCE TO STAKEHOLDERS	RELATED BENEFITS AND COSTS
 Primary Feedstock Substitution											
Low-Carbon Hydrogen (feedstock)	Decarbonization Pathway Has relevance to ammonia and methanol production.	Enable Support demonstration where economics are positive. Build out hydrogen generation and supply infrastructure.	 Directly decarbonizes Canada’s large ammonia/ methanol production by replacing emissions-intensive hydrogen. Only net-zero with certified low-carbon supply.	 Hydrogen cost tied to electricity and/or capture performance and CO ₂ storage availability. Early offtake contracts help.	 Opens manufacturing, logistics, and export opportunities anchored in industrial hubs. Net-zero fertilizer production.	 Technologies commercial. Regional scaling and integration with CO ₂ handling still developing.	 Strongest fit where hydrogen can be produced on-site. Minimal product reformulation required.	 Requires low-carbon hydrogen infrastructure. Benefits from colocation with chemical production and proximity to CCS hubs for blue pathways.	 Mixed views: sustainability of feedstocks and hydrogen safety are concerns, and acceptance improves with transparency.	 Aligns with provincial strategies and export ambitions for low-carbon ammonia and methanol.	 Concerns with methane leakage from blue hydrogen production.
Biomass	Potential Decarbonization Pathway Applicable to some chemical production processes where sustainable feedstocks are available and production pathways are mature.	Incubate Support research and development of production pathways.	 Renewable carbon source for chemicals/ plastics. Life-cycle benefits depend on sourcing, land use, and competition with other sectors.	 Costs high due to preprocessing, conversion complexity, and logistics. Potentially viable where residues/ biogenic CO ₂ are accessible.	 Can create niche economic clusters and rural jobs.	 Emerging. Several routes remain pre-scale in Canada requiring further R&D/demos.	 Best where stable biomass supply exists. Requires new processes and technologies but can integrate with up- or downstream technologies.	 Requires certified supply chains, preprocessing facilities, and consistent specs. Obtaining sufficient volumes close to demand is challenging.	 Public support higher when feedstocks are non-food, local, and transparently certified. Caution around land-use impacts.	 Relevant to specialty chemicals, bioplastics, and regions with forestry/ agricultural residues.	 Repurposes waste biomass. Possible land use concerns.

			ALIGNMENT WITH CARBON NEUTRALITY	Economic		Technical			Social		
PATHWAY ELEMENTS	ROLE IN NET-ZERO SYSTEM	SIGNAL TO DECISION-MAKERS		ECONOMIC VIABILITY	ECONOMIC DEVELOPMENT OPPORTUNITY	MATURITY	OPERATIONAL FIT	INFRA-STRUCTURE AND SUPPLY CHAIN SUITABILITY	SOCIAL ACCEPTABILITY	RELEVANCE TO STAKEHOLDERS	RELATED BENEFITS AND COSTS
 Carbon Capture											
Carbon Capture and Storage (CCS)	Niche Pathway Essential for large, steady point sources. Cannot stand alone due to energy needs, dispersion, and cost.	Enable Support pilots and demonstrations. Build out CO ₂ transport and storage network.	 Captures process and combustion CO ₂ at chemical clusters. Decentralized emissions have lower capture efficacy. Net zero requires negative emissions.	 High capital and operational costs. Viability improves with price certainty (e.g., contracts for difference) and shared hubs lowering transport/storage costs.	 Growth in engineering, construction, and storage services. Fosters CO ₂ network buildout leveraged by other sectors.	 Components mature. Site-level integration and optimization continue.	 Best on concentrated, steady streams. Requires additional electrical and space for capture units and compression. Substantial increase in operational complexity	 Needs CO ₂ pipelines and storage. Hub models and permitting capacity are decisive constraints. Some regions, like Alberta, are further ahead.	 Support improves with monitoring, reporting, verification standards, and Indigenous partnerships.	 Prioritized in AB/ON/QC clusters to maintain production and jobs while cutting emissions.	 Reduction in air pollution emissions from gas combustion. Some concerns about CO ₂ leakage.
Demand Reduction in Use of Chemicals and Plastics	Priority Enabling Pathway Avoids tonnes of primary feedstock production by addressing systemic inefficiencies across other sectors.	Deploy Incentivize demand reduction of carbon-intensive products and sustainable product substitution.	 Directly reduces upstream production, transport, and disposal emissions.	 Variable by sector and product but can provide cost savings through improved practices or products. Some costs associated with program design and monitoring.	 Opportunities for producers of alternative products.	 Many practices are well established or demonstrated systems within Canada.	 May require some logistical changes for reuse of goods.	 New sustainable product offerings need to be developed for some sectors.	 Reducing waste resonates with public. Behaviour change barriers exist for durable product models and food habits. Acceptability varies by product.	 Some practices are accepted today. Varies by sector.	 Varies by sector.
Product Design	Priority Enabling Pathway Avoids tonnes of primary material and improves recyclability, durability, and reusability.	Enable Build policy to incentivize or mandate design of products for reuse, recycling, and repair. Support product R&D.	 Design for circularity reduces lifecycle emissions, enables closed-loop material use, and lowers primary production.	 Often positive over product lifetime (reduced material/production costs, extended use). Upfront R&D and redesign costs can be high.	 Stimulates innovation, eco-design industries, and repair, remanufacturing, and recycling markets. Creates skilled design and service jobs.	 Eco-design principles established. Application uneven across sectors (packaging and electronics ahead, others lagging).	 Requires changes to design workflows, new material specifications, and skilled labour for redesign and repair.	 Requires buildout of recycling, reuse, and repair supply chains and infrastructure. Improve product labelling and standards. Practical in sectors with established EPR and circular economy standards.	 Public support for durability, reparability, and reuse. May be resistance with redesign costs and adapting reusable formats.	 Some interest among manufacturers, brand owners, retailers, policymakers, and recyclers. Directly linked to extended producer responsibility frameworks.	 Can reduce waste, lower resource extraction, improve product longevity, and foster repair/reuse cultures.

			ALIGNMENT WITH CARBON NEUTRALITY	Economic		Technical			Social		
PATHWAY ELEMENTS	ROLE IN NET-ZERO SYSTEM	SIGNAL TO DECISION- MAKERS		ECONOMIC VIABILITY	ECONOMIC DEVELOPMENT OPPORTUNITY	MATURITY	OPERATIONAL FIT	INFRA- STRUCTURE AND SUPPLY CHAIN SUITABILITY	SOCIAL ACCEPTABILITY	RELEVANCE TO STAKEHOLDERS	RELATED BENEFITS AND COSTS
 Recycling and Systems											
Mechanical Recycling	<i>Priority</i> Enabling Pathway Cuts primary resin demand and creates lower-carbon feedstock. Cannot meet demand alone and only works with high-quality plastics.	Deploy Continue to build out collecting and sorting infrastructure. Mandate or incentivize producer buyback.	 Avoids up- and downstream emissions by substituting primary feedstock. Some emissions could be associated with energy use in recycling.	 Current cost-competitiveness is heavily tied to oil and gas pricing, demand, and collection.	 Generates local jobs in waste-handling facilities. Can encourage smart and sustainable product design.	 Mature technology.	 Functions similarly to traditional waste collection. May require additional logistics planning or training. Only works with high-quality plastics.	 Collecting and sorting high-quality plastics can be complicated. Market impacted by primary product prices if not mandated or incentivized. Not all locations have recycling infrastructure.	 Generally well accepted and implemented in many Canadian regions. Positive association with reduced landfilling.	 Secondary plastics can have impurities, making them less desirable. Relevant where mandates, EPR systems, company sustainability targets, or zero plastic waste strategies exist.	 Reduced burden on landfills and primary resource extraction and associated land use and water- and air-quality impacts.
Chemical Recycling: Thermal Plastic Conversion (Pyrolysis and Gasification)	Enabling Pathway Cuts primary feedstock demand by creating synthetic oil and gas but cannot meet demand alone.	Incubate Support pilots and demonstration. Improve existing collecting and sorting infrastructure.	 Reduces unmanaged disposal emissions and avoids upstream emissions but can add direct or energy-related emissions. Net-zero alignment may require carbon capture.	 Capital-intensive. Economics depend on tipping fees, heat, power, or product revenues, and stringent pollution controls.	 Generates local jobs where facilities are built. Development beyond a waste management solution depends on the buy-in for products (syngas, synthetic-oil, or carbon black).	 Pyrolysis and gasification have been demonstrated or are used in Canada today with coal or wood feedstocks.	 Typically requires buildout of a new facility with extensive permitting. Fits with current waste collection and management operations.	 Requires buildout of new supply chains for products.	 Health and air-quality concerns are moderate for gasification and pyrolysis as the process is contained.	 Relevant mainly to municipalities managing non-recyclable fractions. As supply chain expands, interest in products (synthetic gas, synthetic oil, and carbon black) may grow in relevance.	 Sanitation and land use improved from reduced landfilling and high recovery of hard-to-recycle plastics. Some air quality concerns.
Chemical Recycling: Depoly- merization and Dissolution	<i>Potential</i> Enabling Pathway Cuts primary resin demand by creating lower-carbon feedstocks, but functions only with certain plastics. Cannot meet demand alone.	Incubate Support research and development. Improve existing collecting and sorting infrastructure.	 Avoids up- and downstream emissions by substituting primary feedstock. Can be energy intensive and requires decarbonized electricity.	 High energy-related costs for depolymerization. High capital costs. Economics dependent on oil and gas pricing. Requires green premiums.	 Improves the quality of products offered in the secondary market. Minimal product degradation. Generates local jobs.	 Pre-commercialization.	 Some methods are selective for the type of plastic or are incompatible with impurities. Requires new facilities or additions to existing facilities.	 Collecting and sorting high-quality plastics can be complicated. Market impacted by primary product prices if not mandated or incentivized. Not all locations have recycling infrastructure.	 Public recycling practices already well accepted. Skepticism about the efficacy of chemical recycling.	 Relevant where mandates, EPR systems, company sustainability targets, or zero plastic waste strategies exist.	 Avoids downgrading of plastics, keeping them in the economy longer and reducing landfill burden. Waste products may be harmful.

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Recycling Standards, Product Labelling, and Improved Extended Producer Responsibility (EPR)	<i>Priority Enabling Pathway</i> Critical for secondary plastic and chemicals market and primary feedstock demand reduction.	Deploy Implement improved plastic tracking and product labelling. Deploy standardized EPR systems.	Raises diversion and recycled content, decreasing primary resin production and associated upstream emissions.	Can provide cost savings through material recovery. Costs are shared between producers and governments.	Recovers economic value that might otherwise be landfilled. Encourages designing for recycling.	Approaches tested, mature, and proven.	Fits with existing recycling logistics and facilities.	Requires establishing consistent and clear product labels as well as tracking plastics as they move through supply chains.	Strong public support. Visible benefits reinforce participation.	Central to industry/ government roadmaps. Complements production decarbonization.	Litter/leakage reduction. Supports procurement of low-carbon materials.
Residual Emissions and Waste											
Incineration with Energy Recovery	<i>Niche Pathway</i> Last-resort option for managing waste. Limited role in a circular, low-carbon system.	Monitor Support where no other options exist.	Reduces unmanaged disposal emissions but can add direct or energy-related emissions. Applies to most or all plastics. Alignment typically requires capture or offsets.	Capital-intensive. Economics depend on tipping fees, heat, power, or product revenues, and stringent pollution controls.	Generates local jobs where facilities are built.	Mature technology used in Canada today.	Typically requires buildout of a new facility with extensive permitting. Fits with current waste collection and management operations.	Requires district energy or power interconnections. Strict emissions monitoring. Ash handling and disposal logistics.	Incineration is contested locally due to concern over health risks.	Relevant mainly to municipalities managing non-recyclable fractions.	Reduced landfilling and provision of district heat/power. Air- and water-quality concerns.
Plastic Composting	<i>Potential Niche Pathway</i> Option for specialized plastics. Limited role in a circular, low-carbon system.	Enable Develop labelling regulations and consumer guidance. Support R&D of low-temperature compostable plastics.	Applicable for very specifically manufactured plastics. Some GHGs associated with composting.	Composting facility capital and operating costs can be higher due to heat requirements. Requires more expensive compostable plastic inputs.	Generates local jobs where facilities are built. No development beyond a waste management solution.	Some bioplastics are produced and composted in Canada today, but many are mismanaged.	Some composting facilities do not get hot enough to degrade bioplastics, requiring new facilities or retrofit.	Upstream supply chain issues with manufacturing compostable plastics and then downstream with sorting these for compost.	Same level of acceptability to traditional composting. Requires education programs on labelling and composting correctly.	Requires specialized products with sufficient labeling. Typically only relevant with single-use consumer-facing products (utensils, plastic bags, etc.). Variable government interest.	Nutrients and carbon are recycled as fertilizer for agriculture. Air- and water-quality impacts are low.

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Direct Air Capture (DAC)	Potential Niche Pathway Negative emissions backstop for unavoidable process/end-of-life emissions.	Incubate Support R&D and pilots.	 Offsets the remaining embodied carbon emissions in products. Requires decarbonized electricity.	 Currently high cost/kWh. Niche this decade pending technological improvements and clean-power availability.	 Engineering, construction, and storage services growth. Fosters CO ₂ network buildout leveraged by other sectors.	 Emerging deployments. Integration experience growing via pilots tied to CCS hubs.	 Adds energy load and siting complexity. Procurement via long-term contracts.	 Needs CO ₂ offtake/storage and low-cost clean electricity.	 Neutral-to- cautious due to perceived costs. Support improves when framed as small residual share.	 Limited near-term role. Strategic hedge for firms/ governments targeting full net-zero balance sheets.	 Potential issues with land use and carbon leakage.