Commission on Carbon Competitiveness

Assessment of Carbon Competitiveness in Canada's Heavy Industrial Sectors

October 2024

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The **Commission on Carbon Competitiveness** (C3) is made up of leading Canadian and US experts in economics, climate policy, and trade law. C3 aims to help Canadian industry remain globally competitive as the world decarbonizes, reduce greenhouse gas emissions, attract new investment, and develop long-term competitive advantages in emerging low-carbon industries.

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Executive Summary

For Canada, effective climate policy must be about more than decarbonization; it must also be about positioning Canada to thrive in a world that is transitioning to a net-zero economy. Climate policy must, therefore, be crafted as part of a broader economic strategy that seeks to advance Canada's carbon competitiveness – a challenge that we see as comprising multiple interconnected objectives: decarbonize Canadian industry, avoid carbon leakage (i.e., Canadian industry losing market share due to higher carbon costs than their international competitors), attract low-carbon investment across the economy, and foster the growth of green sectors with high growth potential.

Getting policy right is particularly important in Canada's heavy industrial sectors. These sectors produce commodities—ranging from fertilizer to building materials—that are essential to quality of life. They are also important sources of jobs and economic growth. However, the status quo is not a viable option for these sectors, which together account for almost 40% of Canada's greenhouse gas (GHG) emissions. Transitioning to low-carbon production is critical to their future competitiveness; they all trade heavily in global markets that are increasingly accounting for the carbon footprint of imported products.

In this first of a series of papers by Canada's Commission on Carbon Competitiveness, we focus on two dimensions of this broad challenge: how to decarbonize Canada's heavy industries without giving rise to substantial risk of carbon leakage. We focus on nine industrial sectors that are both high emitting and challenged in passing on costs from climate policy to their customers because the prices of their goods are determined on international markets. Our focus is the short term—specifically, we investigate whether these industries could lose market share this decade, given Canada's announced climate policies to 2030.

We start our analysis by evaluating which sectors of the Canadian economy are most emissions-intensive and trade-exposed, identifying nine such sectors: conventional oil and gas extraction, oil sands extraction, petroleum refining, cement and concrete, iron and steel, basic chemicals, agricultural chemicals, pulp and paper, and aluminum. These sectors constituted more than a third of our exports and GHG emissions and almost 10% of Canada's GDP in 2022.

We assess the vulnerability of each of these sectors to carbon leakage out to 2030. This is a complex question, so we examine it from multiple angles, aiming to determine whether the balance of evidence suggests that there is a significant risk of losing market share to international competitors who face lower climate policy costs. The tests we conduct include

- determining the change in GDP growth for each sector that would be induced by climate policy in line with Canada's 2030 target. Any sector that has been experiencing less annual average GDP growth than the economy as a whole would be considered vulnerable to carbon leakage.
- modelling financial impact to these firms (using a Monte Carlo analysis) to understand how a variety of factors—including future emissions intensity, ability to pass on costs to consumers, and strength of climate policy—could impact sales and profitability in these sectors. Any sector that has an impact of more than 10% of revenue or 5% of profits is classified as at potential risk of losing market share.
- using an energy-economy model from Navius Research to evaluate the emissions reductions by 2030 forecasted in each sector based on all legislated or announced climate policy as of the end of 2022. Those sectors that are reducing emissions by less than 1% per year before 2030 may ultimately be subject to stricter climate policy and were thus classified as at potential risk of losing market share.
- conducting a number of other analyses, such as examining the historical economic performance of these sectors, identifying whether jurisdictions that compete with these sectors have carbon pricing regimes, and considering whether their unique characteristics would make any sector more or less prone to competitiveness risks.

Table ES1 provides a summary of our results. It is colour-coded, with green indicating a relatively low risk of carbon leakage through 2030, yellow indicating a moderate risk, and red indicating a high risk. We find that four of the nine sectors—conventional oil and gas, oilsands, petroleum refineries, and aluminum—show a relatively lower risk of lost market share, while four other sectors —steel, pulp and paper, basic chemicals, and agricultural chemicals—are at substantial risk of leakage this decade. Our final sector, cement and concrete, is somewhere in between.

These findings strongly suggest that Canada's industrial climate policies will need to be tailored to meet the needs of the individual sectors involved; their fundamental differences mean that each faces very different competitiveness risks and opportunities along the road to decarbonization.

It's important to point out that our analysis made several assumptions that may have increased the chances of finding risks. For example, we assumed that the rest of the world does not increase their climate ambition; given the uncertainty inherent in that assumption, we felt it was best to take this conservative approach. In the same vein, where we calculate the cost of carbon that firms face, we include costs for emissions embedded in goods that firms purchase, though firms do not directly pay for those emissions under Canada's existing carbon pricing regime. When looking at impacts on profits and sales, we also model the impacts of all announced policies, assuming that they will all become law. The upside of these conservative assumptions is that we can have more confidence in our findings where we identified sectors that were not at high risk of leakage.

Table ES1. Summary of sectoral results

Oil and gas extraction	The economic impacts of climate policy to 2030 are modest. Operating margin for non-conventional oil extraction (oilsands) falls by 3% to 47.5% with stricter climate policy, and annual GDP growth is still predicted to be over 5%. Furthermore, the risk of lost market share to foreign producers this decade is limited by patterns of trade.
Petroleum refineries	While modelled results show that impacts from stricter climate policies may be significant, these figures overstate the impacts of Canadian industrial climate policies: First, they include the impacts of other policies/trends, such as electric vehicle support, that reduce demand for gasoline. Second, they assume refiners can't pass through cost increases to customers, and so they do not reflect the reality of the market.
Alumina and aluminum production and processing	Strong economic performance is predicted to 2030 with stricter climate policy; operating margins fall only modestly (from 14.7% to 14.1%), and growth rates remain robust. Patterns of trade and the readiness of decarbonization technologies help to limit competitiveness impacts.
Cement and concrete product manufacturing	Aggregate growth rates for this sector are robust, at 4.2% annually to 2030, under a scenario of stricter climate policy. However, with low profit margins and high compliance costs, there's a medium to high level of operational risk for facilities. Furthermore, the sector's emissions are projected to increase slightly between now and 2030, rather than decline, which may create pressure to implement even stricter climate policy in this sector. Cement products have low value relative to weight, which limits their tradeability and, hence, their vulnerability to international competitiveness impacts to some extent.
Basic chemical manufacturing	There is anemic growth (<1% annually) to 2030 under a scenario of stricter climate policy. Furthermore, announced climate policies do not result in sufficient emissions reductions (only 0.4% per year), and this sector may, therefore, be subject to increased demands under future climate policy.
Pesticide, fertilizer, and other agricultural chemical manufacturing	There is negligible growth to 2030 under a scenario of stricter climate policy. As is the case with basic chemicals, announced climate policies do not result in sufficient emissions reductions (only 0.4% per year), and this sector may, therefore, be subject to increased demands under future climate policy. Patterns of trade may exacerbate competitiveness risk; the sector's imports and exports are mainly with jurisdictions that do not have any form of carbon pricing.
Iron and steel mills and ferro-alloy manufacturing	Recent economic performance compared to other manufacturing sectors has been sub-par. Looking ahead, there is a significant operational risk for facilities in this sector under announced climate policies, with profit tests showing high risk immediately. On the other hand, the potential costs of decarbonization have been softened by federal funding to convert two of Canada's largest steel mills to cleaner production.
Pulp and paper manufacturing	Projected growth rates under stricter climate policy are low, at just 1% per year. Furthermore, a high level of operational risk is identified using profit tests.

What are the policy implications? They start with our finding that industrial carbon pricing (along with announced companion policies) does not provide a sufficient incentive to reduce emissions in line with Canada's 2030 target, let alone net zero by 2050. If Canada is to meet its targets and do its part to keep global warming within safe levels, and Canadian industry is to decarbonize in line with the expectations of global markets and investors, Canadian climate policies must be strengthened.

When considering how best to do that, pricing-based mechanisms such as the existing large-emitter trading systems (LETS) should remain at the forefront, for reasons of both efficiency and fiscal prudence. These are the most cost-effective tools available, and Canada can little afford to abandon a policy approach that has the potential to yield more bang for its buck than any other.

However, our analysis also shows that not all the sectors we examined are equally able to bear increased climate policy costs without engendering (or worsening) competitiveness problems. As Canada strengthens its climate policies it should prioritize complementary policies for those sectors that face the highest competitiveness risks. Options to complement industrial carbon pricing include continuing to provide substantial output-based allocations under LETS, implementing a border carbon adjustment, or pursuing product-based emissions-intensity standards. The question then is how industrial carbon pricing can be best combined with such policies, considering their relative strengths and weaknesses.

In our subsequent paper, we will dive deeper into these complementary policies, examining the role they could and should play in Canada's climate policy mix for heavy industrial sectors, and grounding our recommendations in a thorough analysis of the competitive circumstances the different sectors face.

What Is the Commission on Carbon Competitiveness?

The Commission on Carbon Competitiveness is a group of 11 experts from different backgrounds, convening with the aim of supporting the transformation of Canada's emissions-intensive trade-exposed sectors into globally competitive low-carbon leaders for the benefit of all Canadians. To that end, the Commission will identify and promote policies that will enable Canada's industrial sectors to play their full part in national decarbonization efforts while also contributing to Canada's prosperity.

The Commission is generously supported by the Trottier Family Foundation, with additional support from the Chisholm Thomson Family Foundation.

TWO

Introduction

The Challenge of Industrial Decarbonization

As Canada transitions to net-zero over the coming decades, heavy industries have an important role to play. Canada's industrial sectors are important sources of economic growth and jobs. They produce commodities such as fuel, fertilizer, and building materials that are essential to quality of life. However, the status quo is not a viable option for these sectors, which together account for almost 40% of Canada's greenhouse gas (GHG) emissions. Transitioning to low-carbon production is critical to their future competitiveness; they all trade heavily in global markets that are increasingly accounting for the carbon footprint of imported products.

Canadian industrial facilities face important technological and financial challenges on the road to low-carbon production. Every week brings news of promising new innovations in industries such as low-carbon steel-making, aluminum, cement, and in low-carbon inputs like renewable energy and green hydrogen. But many of those new technologies are more costly than conventional technology—at least for now—and will be even more costly if they are expected to replace existing assets that are not yet at the end of their productive life. Moreover, Canadian facilities compete globally for the capital necessary to make these low-carbon investments.

Canada's industrial sectors are not only emissions intensive but are also heavily trade exposed. For those sectors, Canadian producers don't set prices, but rather, they take prices that are set in global markets. If producers in those emissions-intensive trade-exposed (EITE) sectors incur cost increases as they decarbonize, they will struggle to pass those increases along to customers. If they try to do so, they may simply lose market share to producers in jurisdictions that don't face similar carbon costs. This is what's known as carbon leakage.

Losing market share in that way boils down to the simple political reality that not all countries have similarly strong climate policies, nor will they for many years. The threat of that sort of loss of competitiveness poses an environmental challenge, as displaced emissions still contribute to climate change. It is also an economic problem. If Canadian industries move or lose market share, that translates into lost jobs, lower GDP, and less government revenue, often with impacts concentrated in specific locations.

Canada's Federal industrial carbon pricing system, also known as the Output-Based Pricing System (OBPS, see Box 1), is at the foundation of Canada's approach to climate policy. Pricing-based systems such as the OBPS are among the most cost-effective policy tools available, and they include policy design features that can help minimize leakage risks. In this paper, we examine the extent to which Canada's climate policies—including but not limited to industrial carbon pricing—will achieve what they are intended to achieve, i.e., needed emissions reductions in heavy industry while avoiding leakage risk.

Box 1. Canada's Output-Based Pricing System

Canada's OBPS, along with fossil fuel charges, is a pillar of the carbon pricing regime established under the Greenhouse Gas Pollution Pricing Act (GGPPA). It applies to Canada's large final emitters, covering 38 industrial activities in 11 sectors, including

- oil and gas production
- chemicals
- mineral processing
- iron, steel, and metal tubs
- mining and ore processing
- nitrogen fertilizers

Covered facilities in these sectors are those that have emitted 50 ktCO,e or more per year and are located in provinces or territories that do not have equivalent regimes in place ("backstop jurisdictions"). As of August 2024, this includes only 4 of the 13 provinces and territories, the others having implemented their own "equivalent" versions of OBPS or cap-and-trade.

The OBPS requires covered facilities to compensate for any emissions above a limit determined by the facility's output multiplied by a standard that is equal to some percentage (less than 100%) of the sector's average emissions intensity. For example, the standard for styrene is 0.925 tonnes of COe per tonne of styrene, so a facility producing 100,000 tonnes of styrene would have a limit of 92,500 tonnes of CO,e. For most sectors, the standard is set at 80% of the sectoral average emissions intensity, but for a few sectors at high risk of leakage or a high proportion of industrial process emissions, it is set at up to 95%.

The granting of those 80%-90% credits toward compliance is called output-based allocation (OBA), and is designed to reduce the risk of losing market share. To incentivize emission reductions, OBA standards are slated to be reduced by 2% per year starting in 2023.

Those facilities that emit less than their limit receive tradable surplus credits. Compensation for emissions above the standard can be in cash, purchased surplus credits, or offsets. Cash payments are at the prevailing carbon price under the GGPPA, currently slated to rise to $170/tonne by 2030.

The carbon costs that producers face can be expressed in either of two ways. They face a **marginal cost** equal to the prevailing carbon price for every additional tonne of emissions they create. They face this price even if they are emitting less than their limit, since it means one less tonne of credits they can sell. They also face an **average cost**, equal to the total amount they need to pay divided by total emissions. Since OBA means that many of their emissions are free, average cost will be much less than marginal cost. So if the price of carbon is $65/tonne (*marginal cost*), and a firm gets output-based allowances for 85% of sector average emissions intensity, if it produces at the sectoral average emissions intensity, its **average** cost of carbon will be $65*15% = $9.75.

What Do We Mean By Carbon Competitiveness?

Competitiveness is a broad concept. The suite of factors that has traditionally determined competitiveness in Canadian and international markets includes foreign trade and investment policies, fiscal policies, regulations, natural resource endowments, technology developments, and many more factors. Canada's steel and aluminum industries, for example, are struggling with long-standing global overcapacity driven by production subsidies in China and other countries.

In the current era, there are a suite of major new influences on competitiveness. As nations look to secure supply chains, enhance resilience in the face of growing climate impacts, and navigate an energy transition that aims to balance affordability, security, and greenhouse gas (GHG) emission reductions, a new competitive landscape is emerging. This period of dynamic change is re-shaping supply chains, trading relationships, and geopolitics as efforts to decarbonize existing industries and foster emerging low-carbon industries ushers in a new era of economic competition.

As a result, over the balance of this decade and beyond, carbon competitiveness is emerging as an increasingly influential factor shaping economic competitiveness. It is introducing new opportunities and challenges alike.

We see carbon competitiveness as the achievement of multiple interconnected objectives: decarbonize Canadian industry, avoid carbon leakage (i.e., Canadian industry losing market share due to higher carbon costs than their international competitors), attract low-carbon investment across the economy, and foster the growth of green sectors with high growth potential.

A concern for carbon competitiveness does not mean we aim to preserve the competitiveness of all existing sectors or firms. Healthy economies naturally change over time in a process of creative destruction, and climate policies are influencing that dynamic in new ways. Trying to preserve the status quo in the face of changing circumstances is not a winning economic strategy.

However, concern for competitiveness does mean dealing with loss of competitiveness when it must come by, among other things, supporting affected workers and communities and by investing in sectors that will become the drivers of prosperity in the future.

Thinking about Canada's carbon competitiveness, it's helpful to consider its implications for the short-term needs and long-term prospects of different types of sectors. To this end, and building on the Canadian Climate Institute's categorization of sectors in their Sink or Swim report (CCI, 2021), we have identified three distinct types of carbon competitiveness sectors for consideration— demand-stable sectors, demand-vulnerable sectors, and high-growth potential sectors.

Demand-stable sectors include those industries that are large emitters and which face relatively stable or moderately growing demand for their products into the future (e.g., steel, cement, aluminum). They will need to transform how they produce goods if Canada is to meet its climate targets, if they are to remain competitive in global markets that increasingly care about embedded carbon in goods, and if they want to attract investment. For these sectors, the main challenge is the cost of decarbonizing, as they face significant capital investments and/or higher operating costs to address their GHG emissions. From a policy perspective, the focus should be on helping this sector preserve competitiveness through this transition, ensuring they respond to climate policies by making transformative investments in low-carbon technologies without losing market share to competitors that face less ambitious climate policies.

Demand-vulnerable sectors include those large emitters whose primary products will face structural decline in demand in the mid- (after 2035) to long-term (by mid-century) in the face of a global transition toward net-zero, and consequently must prepare in the near-term to manage through headwinds and potentially reorient themselves to capture new opportunities (e.g., oil producers processing bitumen for non-combustion uses such as carbon fibre). For these sectors, the main challenge is demand decline.

High-growth potential sectors include those sectors whose markets will potentially see strong growth in a low-carbon future, including both clean energy and mineral resources (e.g. critical minerals, low-carbon hydrogen) and climate and clean tech (hard and soft). For these sectors the main challenges are access to capital for early stage innovation and scaling to commercialization, and the need to ensure near-term markets for their products in spite of higher costs to achieve low-carbon production.

The focus of this paper is on the first two sector-types described above. In the Commission's subsequent papers, we will tackle the types of policies that will foster competitiveness in new, high-growth potential industries.

Overview of This Report

In Section 2 of this report, we apply standard tests to Canada's industrial sectors to identify those that are most emissions intensive and trade exposed. The result is a list of nine sectors on which the rest of the report will focus.

In Section 3, we look at two contextual factors that influence the ability of Canadian industrial firms to either absorb or pass on the costs of climate policy. The first of these is historical performance in the focus sectors. We calculate historical growth rates relative to the economy as a whole and profit margins relative to all Canadian manufacturing on the assumption that relatively high growth rates and high profit margins indicate competitive breathing space for sectors in the face of climate policies and improved ability to absorb climate policy costs. We also assess the extent to which international trade in these nine sectors is covered by some form of carbon pricing. Other things being equal, if a large share of trade is with jurisdictions that have or will soon have carbon pricing in place, this implies an increased ability to pass on the carbon price to buyers and a reduced risk of losing market share.

In Section 4, we model the impacts of Canadian climate policy on the nine focus sectors going out to 2030 under two scenarios: policies currently in law and a scenario that includes announced policies in addition to those already legislated. We first ask whether Canada's current and announced climate policies are sufficient to reduce emissions in those sectors, in line with our announced national target of 40% reductions by 2030 over 2005 levels. Sectors that are badly off trajectory may require stronger future climate policies.

We then look for changes in GDP levels expected under the two different scenarios for future climate policy. Lost output here could indicate lost market share in global and domestic markets. Finally, we look at the financial impact under the Announced Policies scenario, asking whether Canadian climate policy impacts operational viability in the nine sectors—i.e., does it risk shutting down installations? We estimate compliance costs, tax effects, and costs passed through to producers via purchased inputs and electricity and then use sales and profit tests that are consistent with vulnerability tests used in Alberta's Technology Innovation and Emissions Reduction (TIER) program.

In Section 5, we summarize the results for each sector and interpret them in light of each sector's unique characteristics, aiming to understand ultimately how vulnerable each is to leakage risk in the face of Canada's climate policies.

In Section 6, we briefly describe the policy implications of the foregoing leakage risk analysis. We argue that industrial carbon pricing, in the form of Large Emitter Trading Systems (LETS), must remain at the foundation of Canada's approach to decarbonization. These pricing-based policies are the most cost-effective policy option available. Their continuance helps to provide needed certainty to the marketplace. Complementary policies are needed, however, specifically to address leakage risks. These policies include the existing system of Output-Based Allocations under LETS, as well as several new-to-Canada policies including border carbon adjustments and emissions-intensity standards.

Section 7 of the report concludes with thoughts about what the results of this report mean for our coming research, including our next report, which will assess the various tools at Canada's disposal in decarbonizing its heavy industrial sectors in ways that maintain or enhance their competitiveness through the low-carbon transition.

THREE

Which Heavy Industrial Sectors Are Potentially Most Vulnerable to Competitiveness Risk?

This section uses historical emissions and economic data and applies established indicators of competitiveness risk to identify the heavy industrial sectors that are the most emissions intensive and trade exposed. We identify nine sectors that meet our criteria and are therefore potentially facing a risk of carbon leakage as Canada reduces emissions to 2030 and net-zero beyond.

The emissions-intensive trade-exposed metrics provide a good starting point to evaluate the vulnerability of sectors to losing market share to competitors that face lower carbon costs. However, while the EITE assessment provides a good tool to compare the relative risks between sectors, it provides only a limited view of the possible impacts of that risk. Crucial factors affecting competitiveness risk are missing from the calculations, including trends in prices or market demand, regulatory costs, and the impact of policies in other jurisdictions. The competitiveness risks facing these nine sectors are therefore assessed in more detail in subsequent sections of the paper.

Specific EITE threshold tests are widely used in Canada and abroad to identify sectors at risk of carbon leakage. Such sectors are typically eligible for preferential treatment in carbon pricing systems, meaning that only a portion of their emissions is subject to pricing for compliance requirements. Applying a compliance obligation to only a fraction of emissions through the granting of free emissions in LETS (i.e. cap-and-trade and output-based pricing systems (OBPS))[1] reduces the financial hit to the balance sheets of companies in these sectors by lowering the average cost of their carbon price (see Box 1). This preferential treatment is intended to maintain the viability of the firm by reducing impacts on firm market share and profitability, particularly for trade-exposed sectors where regulated firms are competing with less regulated foreign producers.

1 See for example Sawyer & Stiebert (2017).

The EITE Tests Applied

To apply the EITE tests, emissions data is matched with historical output or value-added data to get emissions intensity and then paired with the trade intensity of the sector and judged against a threshold. The criteria for determining EITE designation vary significantly between jurisdictions depending on local preferences. In some applications of the test, for example, in the case of the federal OBPS, a carbon price forecast is applied to make the indicator more accurate, while in other cases, as in Ontario, a carbon price is not assumed.

The application of these tests in Canada tends to be opaque, with the data and analysis not made public. Instead, the designated EITE sectors are published as a schedule in a regulation or a policy document. Often, other criteria are used to make the designation, and the application of these criteria is even less well understood by industry and the public.

Application of our EITE test involves four steps:

1. **Identify sectors potentially at risk.** We used Schedule 1 of Canada's OBPS (Environment and Climate Change Canada, 2022) to determine the scope of economic sectors and subsectors to assess. We identified and assessed a total of 42 economic sectors (see Appendix 1).

2. **Select EITE tests**. In this analysis, we apply and compare the EITE tests used in the federal OBPS and in Ontario (Government of Ontario, 2019). These two sets of tests include the criteria used in the initial screen of economic sectors to determine their EITE status in many different jurisdictions, including Alberta's TIER program (Government of Alberta, 2020). The calculations of emissions intensity and trade exposure include the following:

	Emissions intensity	Trade exposure
Federal OBPS	$\frac{\text{Direct carbon cost}}{\text{Gross value added}^{2}}$	$\frac{\text{Exports + imports}}{\text{Domestic sales + imports}}$
Ontario	$\frac{\text{Direct emissions}}{\text{Gross value added}}$	

With the emissions intensity and trade exposure calculated, the results are compared against threshold values that categorize the sector's degree of risk. The federal OBPS thresholds are focused on identifying sectors with high and very high risk, while Ontario sorts the sectors into three groups: low, medium, and high risk. Note that the trade exposure metric is essentially a trade intensity indicator, where the total trade of the sector is compared against the domestic market (or domestic sales plus imports). The higher the trade intensity, the more trade exposed is the sector.

[2] GVA is like gross domestic product, which is the dollar value of all goods and services minus input costs, but GVA adds the cost impact of subsidies and taxes on production.

3. **Assemble 2021 economic and emissions data.** Statistics Canada economic data for 2021 provides a uniform and consistent data set for all the economic sectors, including data on sector output, gross value added (GVA), exports, and imports (Statistics Canada, 2023b). The 2021 emission data for the 42 sectors is taken from the Canadian Carbon Intensity Database (Canadian Climate Institute, n.d.). To be conservative in our assessment and account for potential carbon costs on all emissions, we calculate emissions intensity using both the Ontario and the federal OBPS tests, including Scope 1 (direct) emissions, Scope 2 (indirect) emissions, and upstream Scope 3 (supply chain) emissions for all sectors.[3] By including Scope 2 and 3 (upstream) emissions, our approach adds a more complete set of carbon pricing costs typically not applied in these tests, which compensates somewhat for not including other policy costs, such as the Clean Fuel Regulations. That said, we do not include revenue recycling or subsidy programs, which in most jurisdictions substantially reduce the carbon exposure of large emitters.

4. **Apply the test.** We applied six federal OBPS tests and one Ontario test. The Ontario test, as mentioned above, does not require including a carbon price in the calculation of emissions intensity, and as such, the test is applied to data for 2021 only.

   For the federal OBPS tests, an average carbon cost is required to calculate the emissions intensity. Our application of the federal OBPS test assumes the carbon price climbing as per the federal price schedule, with our results reported for 2023, 2026, and 2030. We estimated the average carbon cost for emitters as follows:

   - The federal carbon price schedule dictates a price of $65[4] per tonne in 2023, rising to $170 per tonne (nominal value) or $148 (real prices in 2021) by 2030.
   - We used analysis by the Canadian Climate Institute on provincial and federal industrial pricing systems to estimate the quantity of emissions required for compliance, which is effectively the level of the OBPS benchmark. The analysis assumes that 15% of the covered Scope 1 and 2 emissions in each sector are subject to a compliance obligation starting in 2023 (Sawyer et al., 2021). This share increases by 2% per year from 2023 to 2030 to reflect the case of the federal OBPS, while the rate is 1% for officially highly at-risk sectors including natural gas production, petrochemicals, and cement.
   - For Scope 1 and 2 emissions, the estimated average carbon cost per tonne is $9.75 in 2023. At a 2% tightening rate and following the federal carbon price schedule rising to $170 per tonne in 2030, the cost is $22 in 2026 and $43 in 2030 while at 1% the average costs are $19 in 2026 and $33 in 2030 (all in real prices 2021). These costs will vary widely by sector with higher costs in more emissions-intensive sectors.[5]

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[3] Scope 1 emissions are those under the direct control of the facility, such as emissions from burning fuel for industrial heat. Scope 2 emissions are embedded in purchased electricity (and steam and heat). Scope 3 are all other emissions, but here we include only those embedded in input goods from up the supply chain.

[4] All figures CAD.

[5] To be clear, the increase in average costs estimated here comes not only from the tightening of the benchmark, but also from the increase in the carbon price in line with the legislated schedule.

- Upstream Scope 3 carbon costs are passed on in production inputs, adding costs to the emissions intensity equation based on the structure of the sector's supply chain, as reported by Statistics Canada (2023b). In practice, this means that upstream Scope 3 carbon costs are added to the equation for each sector as a unique blend of input costs from OBPS sectors, which have a lower average cost than the headline carbon price, and sectors that face the fuel charge but not OBPS treatment.

Table 1 shows the summary results for each test across all 42 sectors. For each test, the number of sectors that exceed the EITE threshold or pass the test is reported as well as each sector's share of GVA for all EITE 42 sectors and for the national economy. Appendix 1 includes detailed results for all 42 sectors. Summary observations include:

- The Ontario metrics that do not include a carbon price score a much higher level of exposure than the federal OBPS metrics in the early years (2023 and 2026). When the carbon price is included in the calculations (i.e., the federal OBPS metrics), the combination of the ratcheting benchmarks and the rising carbon price results in rising levels of potential exposure closer to 2030.
- Using the trade metrics alone presumes a much higher level of exposure than the combined emissions-intensity and trade-exposed metrics. It also fundamentally ignores the carbon price being applied to the sector, as well as the relative emission intensity of the sector. Using the trade intensity alone is, therefore, not a good indicator for establishing EITE criteria.

Table 1. Summary results for the federal OBPS and Ontario EITE test

	Federal OBPS (opt-in tests)[6]										Ontario	
	EI>3% & TE>20%			EI>15% & TE>10%			EI>30% & TE>0%			TE >80%	EI ≥1,000 & TE ≥10%	Is TE >30%
	2023	2026	2030	2023	2026	2030	2023	2026	2030	2021	2021	
# Sectors (of 42)	4	11	16	1	1	2	0	1	1	23	15	37
% total EITE GVA*	4%	33%	66%	0%	0%	1%	0%	0%	0%	76%	65%	97%
% total national GVA**	0.7%	5%	11%	0.05%	0.05%	0.2%	0%	0.05%	0.05%	12%	10%	16%

Sources: Statistics Canada (2023b) and (Canadian Climate Institute, n.d.)

* Relative to all GVA for all 42 EITE sectors.

** Relative to total national GVA for the entire country.

Notes: EI is emissions intensity. TE is trade exposure.

6 These OBPS opt-in tests are slightly different from the published OBPS regulations (here), but are consistent, producing the same results.

Highly Exposed Economic Sectors and Their Economic Importance

One of the objectives of conducting the EITE exercise above was to identify high-priority sectors that are both economically important but also likely facing a high competitiveness risk. The identified sectors will then be the focus of the rest of this paper. We chose to use the federal OBPS emissions intensity 3%/trade exposure 20% threshold tests (Table 2) as our starting point for selection. We then further filtered by setting a threshold that a sector had to have an emissions intensity score in the top third of all sectors in any of the three periods (2023, 2026, or 2030) to weed out those sectors with relatively low emissions intensity. The result was a set of nine sectors of interest:[7]

conventional oil and gas (except oil sands)	basic chemical manufacturing	iron and steel mills and ferro-alloy manufacturing
non-conventional oil extraction (oil sands)	pesticide, fertilizer, and other agricultural chemical manufacturing	petroleum refineries
alumina and aluminum production and processing	cement and concrete product manufacturing	pulp and paper manufacturing

These nine sectors, at least based on the EITE tests above, have a very high potential competitiveness risk and may, therefore, also be at greatest need for creative policy solutions.

The nine sectors are important to Canada's economy. In total, they made up 8.5% of GDP and 1% of direct employment (167,000 employed) in 2022. The national employment figures mask the fact that some of these industries, notably oil and gas, are currently very important employers in particular regions as well as important sources of indirect employment. Unsurprisingly, given their nature as trade exposed, these EITE sectors punch above their weight in trade, accounting for over 35% of Canada's goods exports.

As discussed earlier in the paper, these sectors are also large emitters of GHGs, accounting for about a third of Canada's total emissions. Their importance to Canada lies in both their economic contribution and the necessity of reducing their emissions to help Canada reach its GHG emission reduction targets.

In a decarbonizing global economy, we expect some of these sectors to grow in relative economic importance, while others will decline, driven mainly by global market trends but also domestic policy impacts. To maintain a strong trade balance and avoid regional unemployment, contraction in sectors that face declining demand must be offset by growth in other sectors.

7 The 16 sectors identified as EITE by 2030 under this criterion in Table 1 correspond to 14 of the nine sectors on which we will focus. That is, our nine sectors feature 14 of those sectors with some aggregation. Two other sectors (diamond mining and potash production) were screened out by our additional emissions intensity filter.

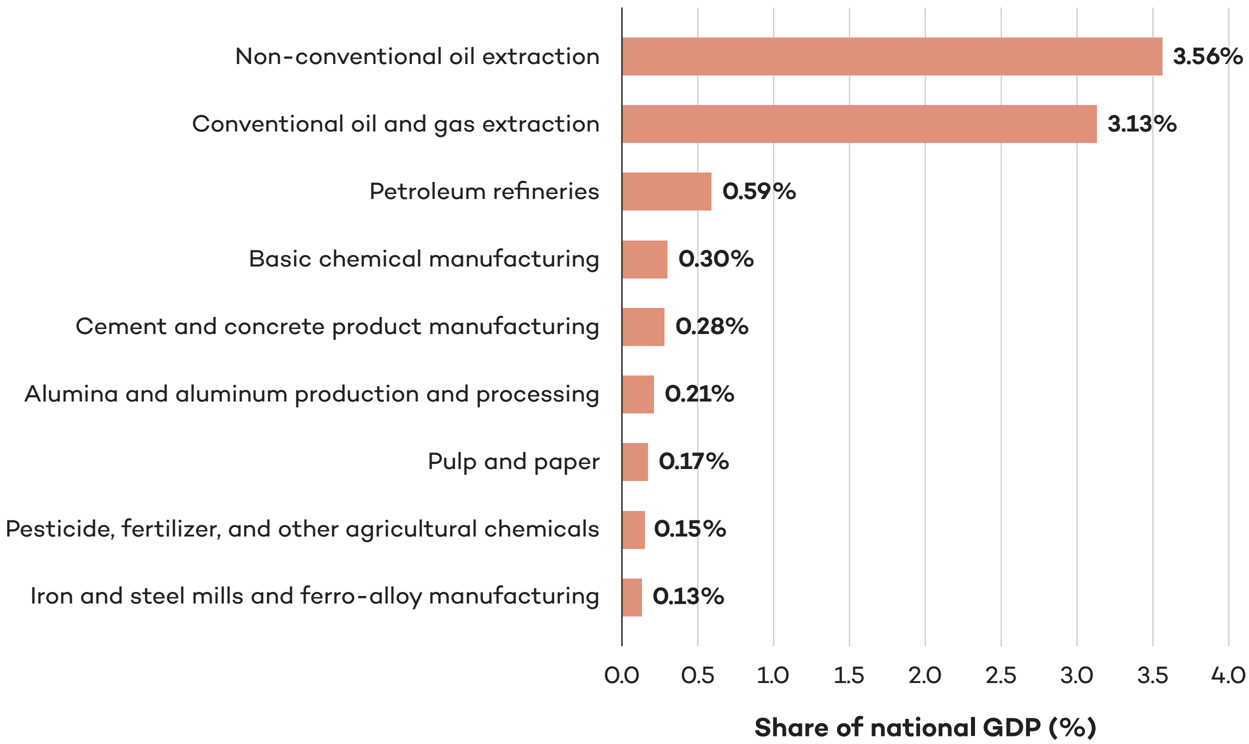
Table 2. Highly exposed and economically important sectors

	Federal OBPS (opt-in tests of high exposure)										Ontario	
	EI>3% & TE>20%			EI>15% & TE>10%			EI>30% & TE>0%			TE >80%	EI ≥1,000 & TE ≥10%	Is TE >30%
	2023	2026	2030	2023	2026	2030	2023	2026	2030	2021	2021	
Oil and gas extraction (except oil sands)	-	Yes	Yes	-	-	-	-	-	-	-	High	Yes
Oil sands extraction	-	-	Yes	-	-	-	-	-	-	Yes	High	Yes
Petroleum refineries	-	Yes	Yes	-	-	-	-	-	-	-	High	Yes
Basic chemical manufacturing	-	Yes	Yes	-	-	-	-	-	-	-	High	Yes
Pesticide, fertilizer, and other agricultural chemicals	Yes	Yes	Yes	-	-	-	-	-	-	Yes	High	Yes
Cement and concrete products	-	-	-	-	Yes	Yes	-	-	-	Yes	High	-
Iron and steel mills and ferro-alloy	Yes	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes	-	High	Yes
Alumina and aluminum production	Yes	Yes	Yes	-	-	-	-	-	-	Yes	High	Yes
Pulp, paper, and paperboard mills	Yes	Yes	Yes	-	-	-	-	-	-	-	High	Yes

Note: EI is emissions intensive. TE is trade-exposed.

Source: Authors' own calculations using data as in Table 1

Figure 1. Highly exposed and economically important sectors



Source: Statistics Canada (2023c)

FOUR

Context: Historical and present sectoral characteristics

This section considers several contextual factors that influence the ability of a given sector to either absorb or pass on the costs of climate policy.

First, we use historical economic data to assess the comparative economic health of the nine high-EITE sectors. We assess important historical patterns in primary indicators for these sectors in comparison to the overall economic trajectory. Exceeding the macroeconomic performance relative to the overall trend indicates some ability to absorb additional carbon costs.

Next, we relate the imports and exports of the nine priority sectors to global markets that have implemented or are in the process of implementing carbon pricing. We use detailed trade data by country and U.S. state and identify the share of trade for each sector that goes to or comes from markets that have some form of carbon pricing program operating or in advanced stages of development. A higher share of trade with carbon pricing jurisdictions indicates some ability to pass on additional carbon costs to buyers.

Finally, we explore, for each sector, what the pathway to decarbonization looks like, taking into account their major sources of GHG emissions and the state of the various new technologies in the pipeline to reduce them.

Macroeconomic Trends: Historical economic performance as an indicator of vulnerability

The ability of a sector to increase revenue while reducing expenses and increasing its operating margin may give an indication of its ability to absorb increased carbon costs. That said, competitiveness impacts will be highly variable; for example, some sectors can pass on some or all carbon costs and do not have to absorb them, while others may not be able to pass on costs due to trading in global commodity markets.

In this section, we look at two headline indicators of a sector's ability to earn, namely value added (GDP) and operating margin (revenue minus expenses). We conclude that each of these high-EITE sectors outperformed the total economy and other manufacturing sectors[8] on these key economic health indicators, especially in terms of revenue growth and operating margin. They also grew at faster rates than the total economy.

[8] For total manufacturing, we use the North American Industry Classification System (NAICS) codes 31 – 33.

A 5-year time slice is used to capture longer-term trends in operating margin (2016 to 2021) while GDP data is available for 2016 to 2022 (6 years). The COVID-19 slowdown is addressed somewhat by comparing each sector's performance against the performance of all manufacturing, including heavy industry, over several years.

Two measures are developed for the indicators. First, for GDP, revenue, and expenses, the compounded annual growth rate (CGAR%) for 2016 to 2021 is estimated, and the average operating margin (or profit before taxes and accounting adjustments) for the period is calculated. Second, the sector's performance is benchmarked as an index: for GDP against the total economy to capture broad-based trends and for revenue, expenses, and operating margin against the manufacturing sector to capture the performance of industry alone. A score above 1 indicates that the sector is outperforming the benchmark. For example, if national GDP grew at 2%, and the sector grew at 3%, a score of 1.5 would indicate the sector outperformed the total economy.

Results are provided for each indicator in Table 3. High-level observations include:

GDP Shows High Value Creation Relative to the Total Economy, Except in Iron and Steel and Pulp and Paper.
This indicator points to strong macroeconomic performance across all identified high-risk sectors except iron and steel and Pulp and Paper. Oil and gas extraction and cement showed growth rates that were three times higher than the total economy. Both chemicals manufacturing sectors marginally outperformed the broader economy. The iron and steel sector underperformed at about 70% of the growth rate, while the pulp and paper sector experienced negative growth.

Revenue Growth Was Strong Relative to the Average for All Manufacturing Sectors.
Revenue growth in all the sectors was higher than for all manufacturing. Revenue growth in iron and steel manufacturing was almost seven times higher than the rate for all manufacturing. This is a 5-year average and, therefore, smooths over some of the COVID-19 economic bump that we observe in the historical data.

Expenses Rose Much Faster Than the Average for the Manufacturing Sector. For all sectors except conventional oil and gas extraction and cement, the growth in expenses is much higher than that of all manufacturing. Iron and steel and petroleum refineries experienced large increases in costs, primarily related to oil price increases. Taken on their own—i.e., without considering growth in revenue—these findings would indicate that the high-EITE sectors are vulnerable.

For All Sectors Except Iron and Steel, Operating Margins Were High. Oil and gas extraction experienced profit levels that were 3.5 to five times higher than that for all manufacturing. The operating margin of iron and steel is less than 50% of the national average and well below the other high-EITE sectors. This result shows a strong ability to earn for most of the sectors characterized as high EITE.

Table 3. Historical macroeconomic performance and ability to earn of high-risk sectors

	GDP*		Revenue**		Expenses**		Operating margin**	
	CAGR%	Total economy=1*	CAGR%	All industry=1*	CAGR%	All industry=1*	Average profit (%)	All industry=1*
Benchmark	**1.9%**	**1**	**1.5%**	**1**	**1.2%**	**1**	**10%**	**1**
Oil and gas (except oil sands)	4.7%	2.52	2.2%	1.47	0.6%	0.50	36%	3.64
Oil sands extraction	6.5%	3.48	4.3%	2.87	1.9%	1.66	49%	4.96
Petroleum refineries	2.3%	1.24	5.9%	3.88	5.3%	4.56	16%	1.64
Basic chemical manufacturing	2.2%	1.19	3.6%	2.37	3.0%	2.53	22%	2.19
Pesticide, fertilizer, and other agricultural chemicals	2.6%	1.37	2.9%	1.90	2.3%	2.00	22%	2.20
Cement and concrete products	6.2%	3.32	3.0%	1.95	1.1%	0.97	13%	1.33
Iron and steel mills and ferro-alloy	1.2%	0.67	10.2%	6.71	8.4%	7.17	4%	0.44
Alumina and aluminum production	4.0%	2.16	4.6%	3.02	3.9%	3.33	15%	1.49
Pulp and paper	-5.1%	-2.73	1.6%	1.04	3.0%	2.55	13%	1.36

* A score above 1 indicates the sector is outperforming the benchmark.

Sources: *Statistics Canada (2023c) ** Statistics Canada (2023b).

Trade and Carbon Pricing

Misaligned carbon prices in home and away markets can give rise to competitiveness risks during the low-carbon transition. To the extent that Canada imposes a carbon price on domestic producers that is not faced by their foreign competitors, these costs may put them at a temporary competitive disadvantage, leading to lost market share. Over the longer term, however, carbon pricing would be expected to lead to improved competitiveness, as firms make the investments needed to compete in a low-carbon economy.

Competitiveness analysis of climate policy often assumes there is no carbon pricing operating in other jurisdictions. However, this is a false assumption, with recent data indicating that there are over 70 national and subnational carbon pricing programs operating (World Bank, n.d.).

Those sectors that trade more heavily with markets in which there is carbon pricing, other things being equal, may face less risk of losing market share. But there are important caveats. Carbon pricing schemes worldwide, as in Canada, have a wide range of prices and a variety of protective provisions that lower effective prices, or average carbon costs, including export rebates, free allocations, and liberal use of offsets.

As such, there is no guarantee that the schemes surveyed here are equivalent to Canada's regime. Using carbon pricing also misses part of the picture, as emissions regulations in some jurisdictions will impose costs additional to (or instead of) carbon pricing. Moreover, not all foreign carbon pricing schemes directly cover the nine sectors on which we focus; some cover only fossil fuels, and others cover only the electricity sector. Finally, our analysis includes not just countries with carbon pricing but also those actively considering carbon pricing.

Despite those caveats, the figures below are still meaningful. It is fair to assume that any jurisdiction that has—or is planning to have—a carbon price is more likely to blunt the risk of carbon leakage either now or in future. The world's strongest carbon pricing regimes started out at low levels and evolved over time.

The results show a large share of trade occurring with jurisdictions that have implemented or are planning to implement some form of carbon pricing:

- Across all the nine sectors, 37% of imports come from jurisdictions with some form of carbon pricing (Table 4). Imports from jurisdictions with carbon pricing range from a low of 16% for oil and gas extraction to a high of 74% for aluminum. Cement and concrete also have a high share of imports from carbon pricing jurisdictions, notably Washington state.
- Across all nine sectors, 30% of all exports go to destinations with some form of carbon pricing (Table 5). Petroleum refining has the highest share of exports going to carbon pricing destinations at 67%, while oil and gas has the lowest at 19%.

Table 4. Imports and share from jurisdictions with carbon pricing

	Total imports		From carbon pricing jurisdictions		
	Annual in 2022 ($M)	**% CDN goods imports**	**Total from the United States ($M)**	**Total from non-U.S. countries ($M)**	**% with carbon pricing**
Oil and gas extraction	$27,364	4%	$2,391	$2,006	16%
Petroleum refineries	$26,665	4%	$4,836	$2,102	26%
Basic chemical manufacturing	$19,447	3%	$7,634	$1,769	48%
Pesticide, fertilizer, and other agricultural chemical manufacturing	$7,206	1%	$1,447	$431	26%
Cement and concrete product manufacturing	$953	0%	$507	$161	70%
Iron and steel mills and ferro-alloy manufacturing	$16,327	2%	$7,267	$1,572	54%
Alumina and aluminum production and processing	$7,604	1%	$4,380	$1,281	74%
Pulp, paper, and paperboard mills	$4,950	1%	$887	$1,617	51%

Sources: Government of Canada, n.d.; World Bank, n.d.

Table 5. Exports and share to jurisdictions with carbon pricing

	Total exports		To carbon pricing jurisdictions		
	Annual in 2022 ($M)	% CDN goods exports	Total to the United States	Total to non-U.S. countries	% with carbon pricing
Oil and gas extraction	$181,383	23%	$31,302	$3,959	19%
Petroleum refineries	$32,338	4%	$18,577	$3,148	67%
Basic chemical manufacturing	$14,540	2%	$2,835	$3,851	46%
Pesticide, fertilizer, and other agricultural chemical manufacturing	$3,020	0%	$682	$30	24%
Cement and concrete product manufacturing	$1,056	0%	$581	$4	55%
Iron and steel mills and ferro-alloy manufacturing	$11,092	1%	$2,185	$788	27%
Alumina and aluminum production and processing	$15,182	2%	$4,798	$634	36%
Pulp, paper and paperboard mills	$16,288	2%	$4,141	$5,517	59%

Sources: Government of Canada, n.d.; World Bank, n.d.

Decarbonization Pathways

Climate policies are meant to incentivize decarbonization. Through policy, governments must create conditions that favour the transformation of carbon-intensive industries and facilities into low-carbon producers. This transformation is essential for Canada's long-term prosperity. Low-carbon producers will be able to seize opportunities in expanding global markets. Conversely, if investments are not made, Canada's heavy industry faces significant demand-side risks as an emissions-intensive producer in markets that are increasingly focused on the carbon embodied in industrial goods.

While each industry faces a different set of decarbonization pathways, for most, significant capital investment is required to convert carbon-intensive facilities to low-carbon production. In some cases, additional research and development is needed for promising technologies to become commercially available.

The nine sectors included in our analysis face different pathways for decarbonization. Table 6 gives a glimpse of that variety, including a wide spread of technology readiness levels and incremental costs. In the long-run time frame that allows firms to invest in new technologies, those with clearer and more immediately available decarbonization pathways may face less competitiveness risk from climate policies.

The table outlines the main sources of Scope 1 and Scope 2 emissions for each of the sectors, the main technological contenders for reducing those emissions, as well as the readiness of those technologies to be deployed in the sectors under consideration in this paper. Emissions-intensive processes are broadly divided into industrial energy requirements (heat and physical work) and process emissions (released as part of chemical reactions inherent to production).

Innovation in clean technologies is constant; the list of technologies and readiness levels provided below is a snapshot based on recent analyses by experts. We would expect both the technologies and their readiness to change, perhaps significantly, over the coming years.

These are important differences to bear in mind when considering what policies might be appropriate for the different sectors both to help in the transition to low-carbon production and to help maintain the sectors' competitiveness along the way.

Table 6. Sectoral decarbonization technology options

Sector or subsector	Scope 1 emissions (MT CO_2e)[20]	Scope 2 emissions (MT CO_2e)	Industrial Processes of Greatest GHG Intensity	Technology Alternatives (Technology Readiness level)******
Oil and gas (conventional and non-conventional)	Conventional: 76,452,457	Conventional: 650,661	Process Emissions: Venting, Flaring, and Fugitive Emissions Industrial Energy Requirements: Drilling, Production, Upgrading	Electrification of Drilling Motors/Production Pumps (9)
				Leak Detection and Repair (10)
	Non-conventional: 80,176,641	Non-conventional: 1,239,231		Flaring/capture of fugitive emissions (10)
Heavy Crude			Drilling 5%, Production 4%, Upgrading 4%, Venting, Flaring and Fugitive Emissions 87%**	
In-Situ Bitumen			Drilling 54%, Production 45%, Venting, Flaring and Fugitive Emissions 1%***	
Mined Crude Bitumen			Drilling 11%, Production 23%, Upgrading 49%, Venting, Flaring and Fugitive Emissions 18%****	
Petroleum Refining	16,935,030*	417,676	Process Emissions: Hydrogen Demand (Grey Hydrogen) (5- 20%)	Fluid Catalytic Cracking-CCUS (5)
			Industrial Energy Requirements: Heat (30-60%): Fluid Catalytic Cracking (20-35%)*****	CCUS-SMR (3-4)
				Electrolytic Hydrogen (3-4)
Chemical Manufacturing	18,600,038	1,626,561	Multiple GHG Intensive Products Produced: see below	Multiple GHG Intensive Products Produced: see below
Petrochemical Manufacturing			Industrial Energy Requirements: Steam Cracking (For Ethylene, Propylene, and Benzene/ Toulene/Xylene "BTX")	Steam Cracker Electrification (4)
				Chemical Depolymerization for Plastics (7-9)

Sector or subsector	Scope 1 emissions (MT CO_2e)[20]	Scope 2 emissions (MT CO_2e)	Industrial Processes of Greatest GHG Intensity	Technology Alternatives (Technology Readiness level)******
Industrial Gas Manufacture			Process Emissions: Steam Methane Reformation	Auto Thermal Reforming with CCUS full capture (9), Electrolytic Hydrogen Alkaline & PEM (9)
				Methane Pyrosis "Turquoise Hydrogen" (8)
Other organic chemicals			Process Emissions: Steam Methane Reformation	Methanol CCUS-SMR (7-8)
				CO_2-Green Hydrogen Syn Methanol (7)
				Methanol Pyrolysis (7)
Ag Chemicals & Fertilizers			Process Emissions: Hydrogen Demand (Grey Hydrogen)	CCUS Auto Thermal Reforming (9)
			Industrial Energy Requirements: Heat (Haber Bosch Process)	Electrolytic Hydrogen "Green Hydrogen" (8)
				"Turquoise Hydrogen" for Ammonia (8)
Iron and Steel	13,423,249	566,599	Industrial Energy Requirements: Heat	Direct Reduced Iron-Electric Arc Furnace (DRI-EAF): 100% H2 (7-8)
			Process emissions: reduction of iron ore using coke in BF-BOF	Direct Reduced Iron-Electric Arc Furnace (DRI-EAF): DRI-EAF CCUS (9)
				BF-BOF: CCUS/some injection of H2 (5)
				BF-BOF: Closed Loop Carbon Recycling (3)
Cement & concrete	11,826,010	261,622	Process Emissions: Calcination Reaction Clinker Kiln 60%	Cement Kiln CCUS (5-7)
			Industrial Energy Requirements: Heat (for Clinker kilns) 40%	Electrified Cement Kiln (5)
Aluminum	7,315,505	1,320,513	Process Emissions: Smelting 93%	Smelting: Inert Anode (7)
				Smelting: EnPot/heat exchangers (8)
			Industrial Energy Requirements: Heat (for Refining) 7%	Refining: Hydrogen for high temperature alumina refining (3)
				Refining: CCUS, Electrification (7)

Sector or subsector	Scope 1 emissions (MT CO_2e)[20]	Scope 2 emissions (MT CO_2e)	Industrial Processes of Greatest GHG Intensity	Technology Alternatives (Technology Readiness level)******
Pulp and Paper	7,840,688	1,670,039	Industrial Energy Requirements: pulping, heat for pulp drying	High temperature heat pumps (5-6)
				Use of biofuels for lime kilns (7-8)

* CCI, n.d.

** Oil Climate Index, 2015c.

*** Oil Climate Index, 2015d.

**** Oil Climate Index, 2015a, 2015b.

***** Güleç et al., 2020.

****** Technology readiness levels are from IEA, 2023.

Figure 2. Technology readiness (TRL) scale (IEA, 2023)

Mature	11	**Proof of stability reached** Predictable growth
Early adoption	10	**Integration needed at scale** Solution is commercial and competitive but needs further integration efforts
	9	**Commercial operation in relevant environment** Solution is commercially available, needs evolutionary improvement to stay competitive
Demonstration	8	**First of a kind commercial** Commercial demonstration, full-scale deployment in final conditions
	7	**Pre-commercial demonstration** Prototype working in expected conditions
Large prototype	6	**Full prototype at scale** Prototype proven at scale in conditions to be deployed
	5	**Large prototype** Components proven in conditions to be deployed
Small prototype	4	**Early prototype** Prototype proven in test conditions
Concept	3	**Concept needs validation** Solution needs to be prototyped and applied
	2	**Application formulated** Concept and application of solution have been formulated
	1	**Initial idea** Basic principles have been defined

Source: International Energy Agency, 2023.

FIVE

Forecasts: Emissions trajectories, GDP impacts, and financial impacts under climate policies

This section projects outcomes for the nine sectors out to 2030 under two different climate policy scenarios and assesses their vulnerability in three ways. We first project emission levels out to 2030 under alternative policies aligned with the federal Emissions Reduction Plan (ERP). Sectors that are not on track to meet Canada's 2030 targets may need to be subject to stronger climate policies, with potential competitiveness implications.

Then, we use two techniques to assess how vulnerable each sector is going out to 2030. First, we look at the differences in GDP growth out to 2030 under two different scenarios for stringency. If stronger climate policy leads to significant reductions in GDP growth, that indicates the risk of losing market share in global and domestic markets. Next, using the Announced Policies scenario, we apply financial impact tests that compare carbon costs to sector-level indicators of profit and output. Thresholds are used to identify where costs relative to profits or sales point to an operational risk and the threat of closure.

Are Projected Emission Pathways Aligned With Canada's 2030 Targets and Net-Zero?

Scenarios using the Canadian Climate Institute's (CCI's) independent assessment of the ERP (Sawyer et al., 2021), which is based on modelling conducted by Navius Research, are used to assess the state of federal, provincial, and territorial policy packages are sufficient to achieve Canada's emissions reduction targets.

Table 7 presents the results from two ERP scenarios:

Legislated Policy Scenario.[9] These are federal, provincial, and territorial policies that are already legislated, where the coverage of emissions, the timing of implementation, and the stringency of the policy are already known and published. In these cases, there is certainty as to policy design, which makes modelling results much more straightforward. In this scenario, revenue from industrial carbon pricing is recycled back to industry, and known subsidies are incorporated. This lowers the average cost of compliance.

Announced Policy Scenario. These policies are much less certain as they are not clearly defined; they have yet to enter a planning cycle, and we have little information on the specifics of coverage and stringency. Examples include the announced zero-emission vehicle mandates, the Clean Electricity Standard, and the oil and gas cap. The announced ERP policies scenario, therefore, has to make significant assumptions about the design and implementation of policies such as the proposed national oil and gas cap, and it may significantly overestimate (or underestimate) the emissions impacts. The results should, therefore, be treated with caution; in some respects, it might even be considered an optimistic scenario, as it assumes effective design and implementation—and no material changes by future governments prior to 2030. This scenario puts Canada on a path to -36% to -39% below 2005 levels in 2030. As above, revenue is recycled back to industry and subsidies are incorporated, effectively lowering the average cost of compliance.

The model used to project the macroeconomic impacts of policy is a dynamic recursive general equilibrium model operated by Navius Research. The model, gTech, starts with the structure of the Canadian economy in 2015 adopted from Statistics Canada, where the complex relationship between making and using inputs and outputs and final consumption is represented. Trade between provinces and territories, with the United States, and the rest of the world is represented and calibrated to historical trade patterns. The economy grows at a rate that is aligned with historical averages of, say less than 2% per year, and then each sector grows according to its relationship with other sectors. Policy is then introduced which alters relative prices and then realigns the structure of the economy, as well as changes macroeconomic outcomes such as output GDP, employment, investment, and trade.

Table 7 shows the compounded annual change in emissions between 2020 and 2030 that is anticipated for each sector under each of the policy scenarios outlined above. Also presented is the emissions reduction needed by each sector to achieve its equal share of the nationally set target for emissions reduction. This equal share is defined as the average annual change in emissions required between 2021 and 2030 to achieve the -40% below 2005 target set out in Canada's commitment to the Paris Agreement, or -4.6% per year. The size of the gap between modelled emissions reductions and the equal share target is then identified for each sector.

We note that achieving a 40% reduction for the economy does not necessarily mean each sector needs to individually reach 40%. Indeed, the federal ERP envisioned deeper cuts in some sectors (e.g., electricity) and fewer cuts in others (e.g., agriculture). Nevertheless, Canada's heavy industrial sectors, taken together, account for a very large share of Canada's total emissions, and under the ERP announced scenario account for about one third of total reductions. If they do not collectively reduce emissions by approximately 40%, it will be difficult for Canada to meet its overall target.

9 Note for each scenario, the "less-stringent" ERP scenario is used.

The ERP also contemplates generating a portion of emissions reductions from land use and land-use change, offsets from the Western Climate Initiative, and nature-based solutions, none of which factor into our modelling. These potential sources of emissions reductions collectively generate a 4% reduction by 2030, according to government modelling.

As the table indicates, even in the Announced Policy scenario only conventional oil and gas extraction and iron and steel are likely on a trajectory to achieve reductions aligned with achieving the 2030 target. Even so, taking the oil and gas sectors as a whole, non-conventional oil is so far off target as to imply that the combined sectors are also off track. In the case of conventional oil and gas, it is the methane regulations that drive deep reductions coupled with the proposed oil and gas cap, which we have modelled as a limit of 130 Mt in 2030. The iron and steel sector in both scenarios benefits from over $800 million in investment by the federal and Ontario governments to electrify two facilities and convert one of them to direct-reduced iron (DRI). With most sectors off path to the 2030 target, more policy effort will be needed if Canada is to achieve the 2030 target with respect to its high-EITE sectors.

The question then becomes what level of competitiveness risk arises for high-EITE sectors from policies that align with the 2030 target. This question is the focus of the next section.

Table 7. Average annual change in emissions between 2021 and 2030

Avg annual change in emissions between 2021 and 2030	ERP Legislated Policy scenario		ERP Announced Policy scenario**	
	CAGR%	Gap between modelled results and equal share target	CAGR%	Gap between modelled results and equal share target
	-4.6% average annual change gets all sectors to -40% by 2030 target			
Conventional gas extraction	-3.5%	**Needs -1.1%**	-5.2%	**On track**
Conventional oil extraction	-5.0%	**On track**	-7.7%	**On track**
Non-conventional oil extraction	2.0%	**Needs -6.6%**	-0.6%	**Needs -4.0%**
Petroleum refineries	-2.1%	**Needs -2.5%**	-3.2%	**Needs -1.4%**
Basic chemical manufacturing	-0.3%	**Needs -4.3%**	-0.4%	**Needs -4.2%***
Pesticide, fertilizer, and other agricultural chemical manufacturing	-0.3%	**Needs -4.3%**	-0.4%	**Needs -4.2%***
Cement and concrete product manufacturing	0.1%	**Needs -4.7%**	0.2%	**Needs -4.8%***

Avg annual change in emissions between 2021 and 2030	ERP Legislated Policy scenario		ERP Announced Policy scenario**	
	CAGR%	Gap between modelled results and equal share target	CAGR%	Gap between modelled results and equal share target
	-4.6% average annual change gets all sectors to -40% by 2030 target			
Iron and steel mills and ferro-alloy manufacturing	-5.7%	**On track**	-5.7%	**On track**
Alumina and aluminum production and processing	1.5%	**Needs -6.1%**	1.5%	**Needs -6.1%**
Pulp and paper	-1.4%	**Needs –3.2%**	-1.2%	**Needs -3.4%**

* Credit trading under large-emitter programs allows some sectors to reduce emission less in the Announced Policies scenario while other sectors reduce more. Overall, there are more total reductions in the Announced Policies scenario relative to the Legislated Policies scenario, while the distribution of reductions changes with credit trading.

**The "less stringent" version of the Announced Policies scenario was used in modelling.

Source: Navius Research (2022)

How Vulnerable Are the Nine Sectors on an Emissions Trajectory to the 2030 National Target?

In this section, we use forward-looking projections to identify risk through macroeconomic outcomes under the two policy scenarios used above. Then, financial ratios are applied to assess the nature of the carbon cost risk relative to profits and sales. We apply the following two competitiveness tests:

GDP Impact. Modelled projections are used to measure the impact of climate policy on the GDP of sectors under our two alternative policy scenarios to 2030. The indicator looks at changes in the compounded annual growth in GDP between 2020 and 2030. Large drops in the Announced Policies scenario point to a risk of carbon leakage under stronger Canadian climate policy. Some subsidies to industry are included in this economy-wide modelling, for example revenue recycling from large-emitter programs.

Profit and Sales Tests. These tests are applied by several regulatory agencies within the country to assess the potential competitiveness impacts of climate policy. In our application of the tests, we use the Announced Policies scenario from CCI to assess whether the carbon costs embodied in direct (Scope 1), indirect (Scope 2), and upstream supply chains (upstream Scope 3) emissions pose an operational risk, with the threat of closure. In these tests, we apply a range of emission intensities that reflect the real-world range of emission intensities at the facility level within the Canadian sectors. These tests, therefore, provide a better view of the distribution of potential competitiveness impact across facilities within each of the high-EITE sectors. Note, policies that provide subsidies to industry, such as investment tax credits or technology grants, are not included in this analysis, which would lower the compliance costs. Our estimates under this test thus overstate the cost impact on industry.

The Impact of Climate Policies on GDP

One of the best indicators to assess the risk of carbon leakage is to look at the impact on the value of GDP. The GDP of a given sector measures the market value of all final goods and services produced in that sector. In this section, we use modelling from CCI's independent assessment of the federal ERP to track the impact on the GDP of the nine high-EITE sectors.

As in the analysis above, two climate policy scenarios are assessed: Legislated Policy, and Announced Policy.[10] These two scenarios provide a good view of how increasing stringency impacts the value of the GDP of the sectors. The change in GDP is a standard measure of competitiveness impact.[11] To the extent a scenario shows large annual reductions in GDP from the various sectors, it points either to the risk of losing market share and/or to declining demand. Where global demand is expected to remain flat or grow, declining production in Canada implies increased production elsewhere. Where demand is expected to decline, declining Canadian production simply reflects a smaller market. Finally, increasing GDP above historical levels in the simulations implies the sectors are resilient to climate policy and can continue to expand GDP. Table 8 provides the compounded annual growth rate between 2020 and 2030 for the nine EITE sectors we assess. It also shows the growth in the sector relative to 2020, where a value greater than one indicates the sector has expanded its GDP in 2030 relative to 2020 (i.e. 2020=1).

The following observations can made.

1. **The risk of carbon leakage is low, given the small decline in GDP growth rates between scenarios.** All sectors are larger under both scenarios in terms of the size of GDP in 2030 relative to 2020, except petroleum refining. This result implies that the current trajectory of climate policy does not significantly impact the competitive position of the sectors. Sectors are still able to expand GDP and compete in home and away markets. Stronger policy does slow down GDP, but these reductions are a small fraction of GDP and cumulatively do not significantly alter the growth trajectory of the sectors.

2. **It's not just policy. Shifts in market demand influence competitiveness.** Petroleum refining experiences a decline under all scenarios driven by increased fuel economy outstepping the growth in kilometres driven. This impact on petroleum refining is the result of both market trends and policy-induced shifts in fuel demand.

[10] For more details on the modeled level of stringency for the scenarios, see Navius Research (2022).

[11] See, for example, Rivers (2010).

Table 8. Change in GDP by sector under ERP scenarios, 2020 to 2030

	Legislated		Announced		% change in size of 2030 GDP between scenarios
	CAGR%	Size in 2030 (2020=1)	CAGR%	Size in 2030 (2020=1)	
Conventional oil extraction	5.9%	1.77	5.3%	1.68	**-5.1%**
Non-conventional oil extraction	6.7%	1.91	6.0%	1.80	**-5.9%**
Petroleum refineries	-3.2%	0.72	-3.7%	0.68	**-5.4%**
Basic chemical manufacturing	2.0%	1.21	0.9%	1.09	**-10.0%**
Pesticide, fertilizer, and other agricultural chemical manufacturing	0.8%	1.09	0.3%	1.03	**-5.7%**
Cement and concrete product manufacturing	4.3%	1.52	4.3%	1.52	**-0.2%**
Iron and steel mills and ferro-alloy manufacturing	2.9%	1.34	2.6%	1.29	**-3.2%**
Alumina and aluminum production and processing	3.4%	1.39	3.2%	1.36	**-2.0%**
Pulp and paper	1.7%	1.19	1.0%	1.10	**-7.6%**

Source: Navius Research (2022)

Financial Impact: Is the cost impact material to operational viability?

This section assesses whether announced climate policies (Announced Policy scenario) are material to the operational viability of each high-risk sector, looking at the impact of all announced ERP climate policies on sales and profits sector-wide. Our sales and profit tests follow a standardized approach to assessing competitiveness impacts across facilities and sectors.[12] These ratios and the approach are consistent with Alberta's TIER program, where sales and profit tests are used to determine whether the level of the output-based pricing benchmarks and, therefore, stringency should be decreased to limit operational vulnerability (Government of Alberta, 2020). The federal OBPS uses a sales (or output) ratio[13] as one test for inclusion to opt into the OBPS, and so avoid the federal fuel charge.

The tests estimate compliance costs and indirect carbon costs passed through to facilities in the covered sectors and calculate how significant they are relative to estimated sales and profits for the facilities or sectors. Beyond our specified thresholds, those ratios indicate potential carbon cost vulnerabilities.

The tests also highlight instances where vulnerability is low, and the transitional assistance afforded by benchmarks under LETS can be reduced to increase the average carbon cost and thus send stronger long-term signals to invest in low-emitting processes.

[12] See for example, Proposed Rules (2015).

[13] "Carbon costs are large relative to revenue – i.e., facilities that make up 10% or more of the sector's revenue face carbon costs that exceed 3% of revenue."

In this approach, the **carbon cost facing a facilit**y or sector includes direct and indirect compliance costs on facility emissions (whether stationary combustion, process, or fugitives), carbon costs embodied in purchased energy, and supply chain carbon costs, including:

- **direct compliance costs** on facility emissions (Scope 1 GHGs covered by the carbon price) include abatement costs made to avoid the carbon payment and payments on the remaining emissions covered by the carbon price.
- **indirect costs on carbon embodied in purchased energy** (Scope 2 GHGs) stemming from increased fuel costs as the carbon price is applied upstream of the facility. Typically, costs stem from purchased electricity, heat, or hydrogen that is imported by the facility and where the carbon cost is passed along in the energy price.
- **supply chain price impacts** (Scope 3 GHGs excluding embodied downstream emissions) as the carbon price (OBPS and fuel charge) works its way through the economy and manifests as an increase in the cost of goods and services used in production (intermediate inputs).

Our approach also accounts for **tax interactions** and the ability of some facilities to pass on some or almost all these costs to customers (the **cost pass-through**). The cost pass-through reduces the average cost of the carbon price. The tax interaction also reduces the average cost of the carbon price, where increased operating costs from climate policy reduce taxable income. In effect, the government shoulders some of the cost of the proposed carbon price to the extent that tax receipts fall.

Estimating the carbon costs facing each sector involved the following steps:

1. **Estimate 2021 emission intensity (Scope 1, 2, and upstream 3) as a range reflecting the spread in emissions intensity for facilities in the sector.** For example, oil sands in-situ plants have differing emissions intensity based on the reservoir in which they are operating, where more energy is needed in poor-quality reservoirs and hence higher emissions per barrel produced. Expert opinion and a literature review are used to specify a range of facility emissions intensities for each sector. Practically, this means low, medium, and high Scope 1 and 2 emission intensities are specified for each sector. Ranges are not specified for Scope 3 emissions.
2. **Estimate economic and emissions trends to 2030.** Output, GDP, and operating profit margins for 2021 are taken from Statistics Canada (2023b) and projected to 2030 based on sector economic trends from the Announced Policy scenario in the CCI ERP modelling. Emissions are then projected to 2030 using the economic projections applied to the three emissions intensities for each sector.
3. **Estimate covered emissions, compliance costs, and carbon costs passed through supply chains.** The covered emissions subject to a compliance obligation are estimated for each sector from CCI's expert assessment of carbon pricing systems (Sawyer et al., 2021). For each sector, estimates of benchmark levels and average costs are applied to 2021 emissions. Consistent with federal announcements, the carbon price rises to $170 per tonne in 2030 from $65 today, and benchmarks are ratcheted at 2% annually to 2030.

4. **Estimate cost pass-through and tax interactions.** Accounting for how carbon cost is passed through supply chains is important, given that facilities do not necessarily shoulder the entire cost burden. Sensitivity testing is conducted for three levels of cost pass-through, from no cost pass-through all the way to full cost pass-through. Statistics Canada Make and Use tables (Sawyer et al., 2021) allow the analysis to capture costs passed through for both the large-emitter systems and the fuel charge. Combined federal and provincial tax interactions on compliance costs reduce the carbon cost to the facility by an effective rate of 26%. One important caveat to keep in mind is that we do not account for revenue recycling or other carbon finance programs, both of which would offset the gross carbon costs we estimate.

With the facility or sector costs estimated, the financial impact testing is conducted. Two indicators, the **profit test and sales test**, explore the likely financial impact on the facilities for the carbon pricing scenarios modelled. In both cases, the estimated carbon costs are divided by baseline profits and revenue to develop a ratio of **impact relative to the no climate policy baseline:**[14]

The tests and thresholds are defined as follows:

1. **The operating profit test:** if the estimated carbon cost as a share of operating profit is greater than 10%, there is likely a significant competitiveness risk.[15] With low profit levels, firms will have a limited ability to reinvest in productive capital and therefore continue to operate.

2. **The sales test:** if the estimated carbon cost as a share of revenues (or output) is greater than 3%, this implies an operational threat within the sector, where profits are likely close to 0 and capital will definitely not be available to replace aging equipment or make investments in new productive assets.

To conduct the sales and profit tests, we had to address a number of uncertainties in the assumptions we used, and we therefore turned to Monte Carlo analysis. We generated probability distributions for the key uncertainties and assumptions: emissions intensity, cost pass-through, sector emissions coverage reflecting actual coverage in provincial and federal large-emitter programs, and profit margins based on 5 or 6 years of historical data. The Monte Carlo analysis samples these ranges[16] and calculates the spread of possible outcomes for the tests. We report the 20th, 50th, and 80th percentiles to bound the range of likely outcomes.

[14] For examples of the approach see Government of Alberta (2018), Section 5.4 and 6.0

[15] The EU ETS uses a 5% threshold relative to GVA, which is analogous to gross operating margin used in this test.

[16] A probability distribution function is set of key parameters, and each is then sampled independently 5,000 times to determine how the range of input uncertainty impacts the outcome of the sales and operating profit margin tests.

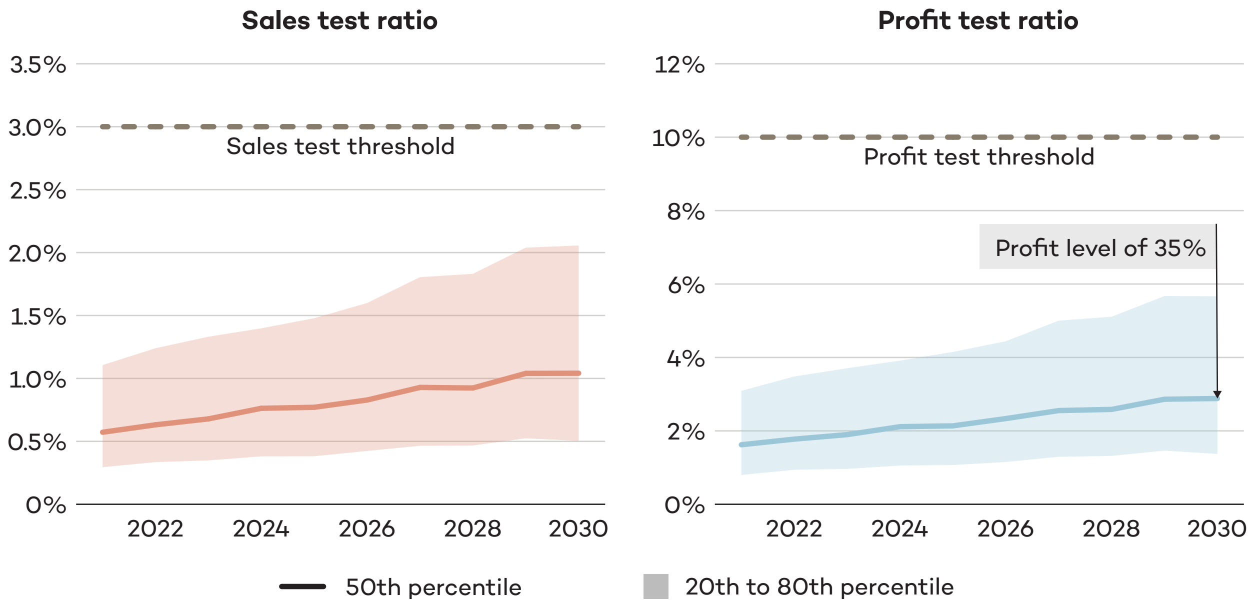
These two tests are complementary, where either a failed profit or sales test points to operational risk and the threat of closure. In cases where both thresholds are exceeded, there is likely a significant risk to the sector, especially when one considers some firms within a sector will be more vulnerable than others, due to, for example, high compliance costs or lower-than-average profits. To the extent the test thresholds are met under a scenario, there's likely a risk of lost market share as the climate policy reduces operational viability within the sector.

The estimated sales and profit tests reflect a broad possible range of outcomes for each sector, and as discussed above, are reflective of the distribution of facilities within a sector. Note that the profit test should be interpreted as reducing the level of the profit by the nominal reported value. If, for example, the profit impact is 2%, a profit level of 10% would be reduced by 2% of that amount, with a new firm profit level of 9.8%.

The results for each sector are graphically displayed in the series of charts below. Summary results include:

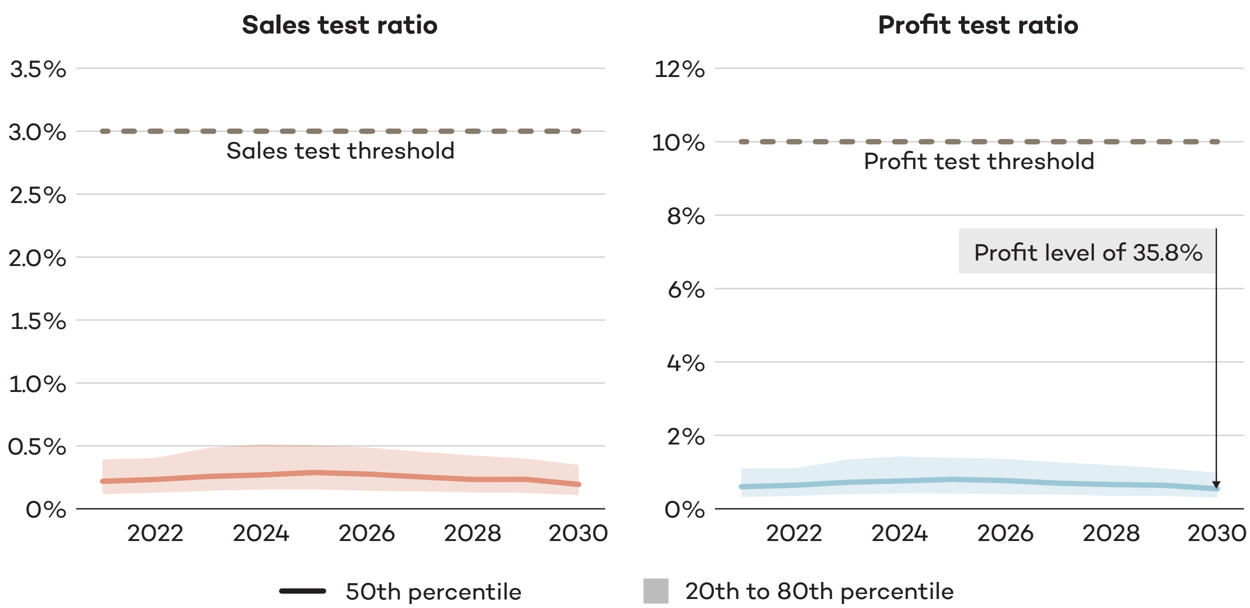
- Conventional gas extraction shows a medium level of impact, but results do not point to operational risk with the threat of closure.
- Conventional oil extraction shows very low profit and sales impacts.
- Results for non-conventional oil extraction (oil sands) do not point to operational risk but do imply a medium level of risk for the facilities.
- Petroleum refining shows the potential for high operating profit margin impacts in 2030 (6% to 11%), whereas the sales test does not show as much vulnerability.
- Basic chemical manufacturing shows a medium impact on sales and profits.
- Agricultural chemicals, including fertilizer, shows a low to medium impact.
- Cement and concrete have the potential for significant profit and sales impacts and, therefore, could have operational risk.
- Iron and steel shows a significant operational risk.
- The aluminum sector shows a medium level of risk across both tests.
- The pulp and paper sector shows a high level of risk with the profit test.

Figure 3. Profit and sales test distribution for conventional gas extraction



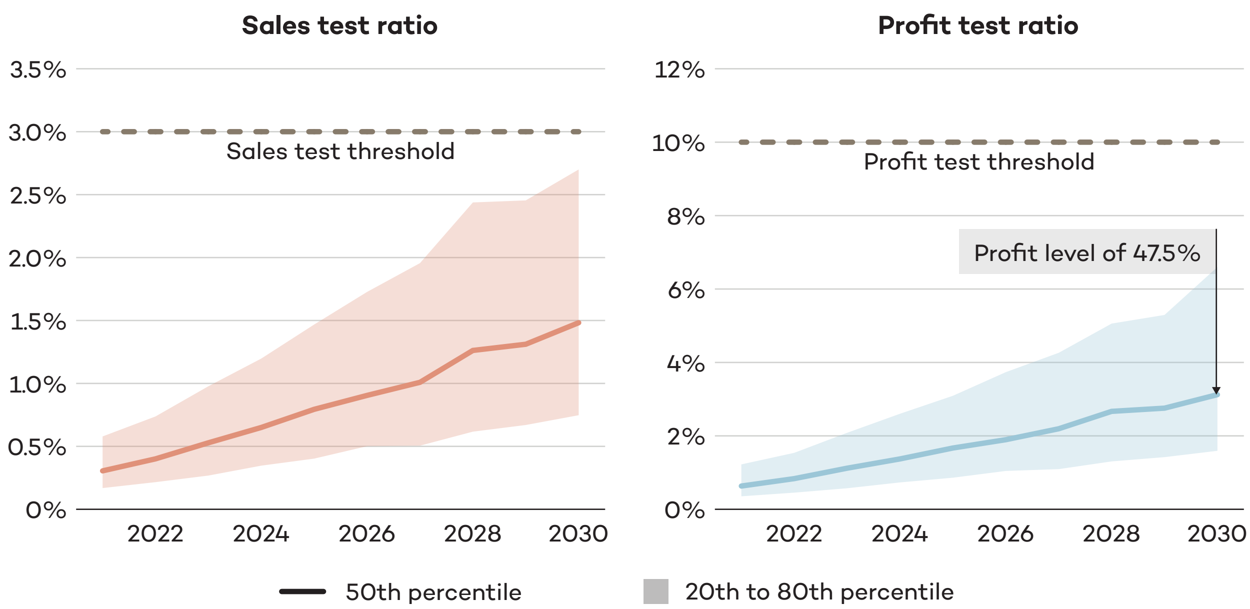
Source: Author diagram

Figure 4. Profit and sales test distribution for conventional oil extraction



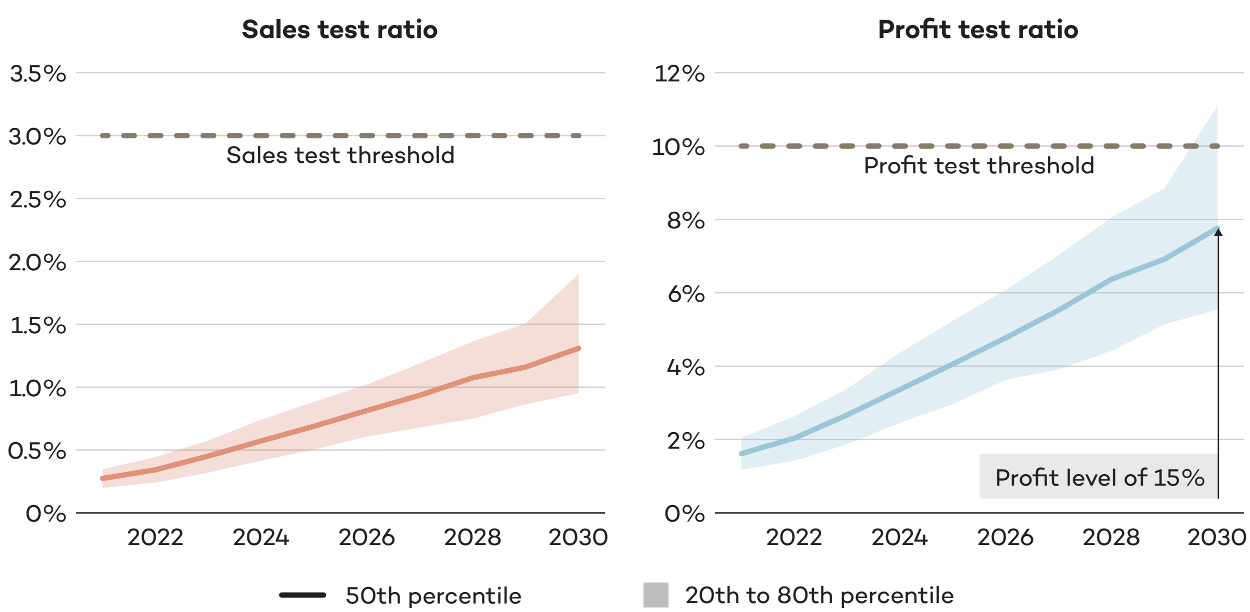
Source: Author diagram

Figure 5. Profit and sales test distribution for oil sands



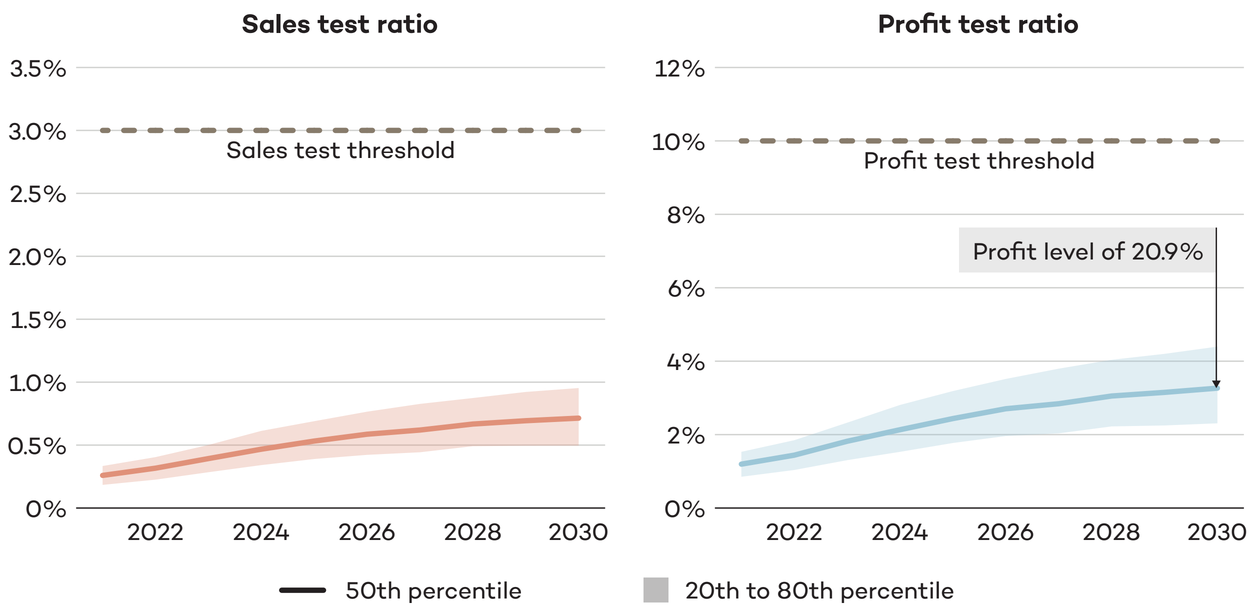
Source: Author diagram

Figure 6. Profit and sales test distribution for petroleum refineries



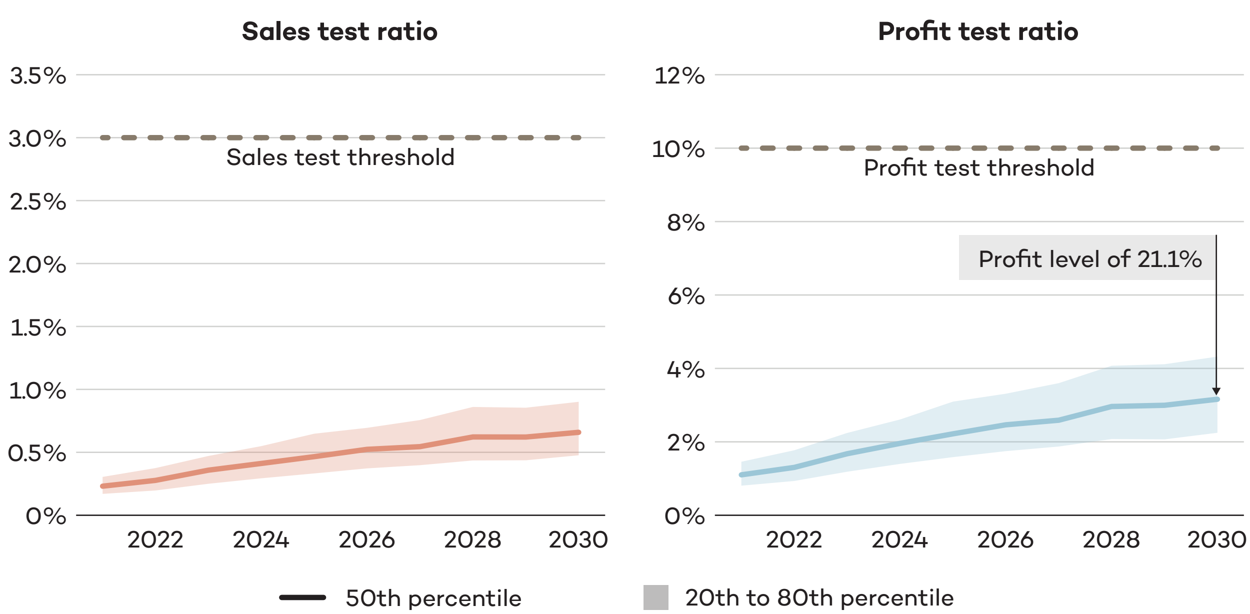
Source: Author diagram

Figure 7. Profit and sales test distribution for basic chemical manufacturing



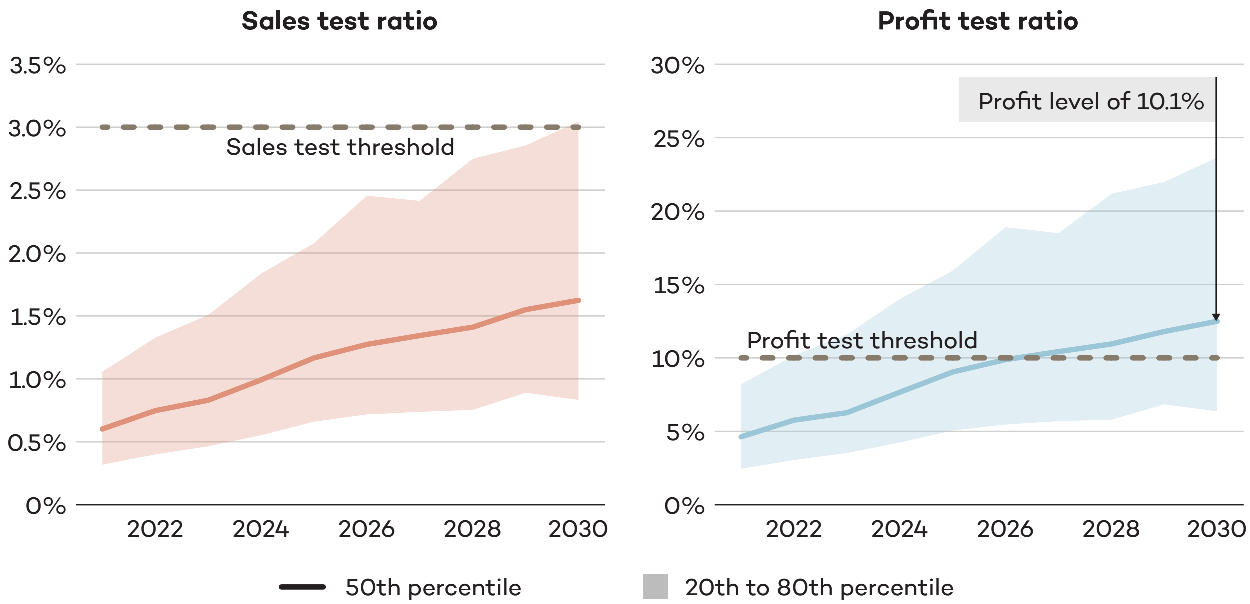
Source: Author diagram

Figure 8. Profit and sales test distribution for pesticide, fertilizer, and other agricultural chemical manufacturing



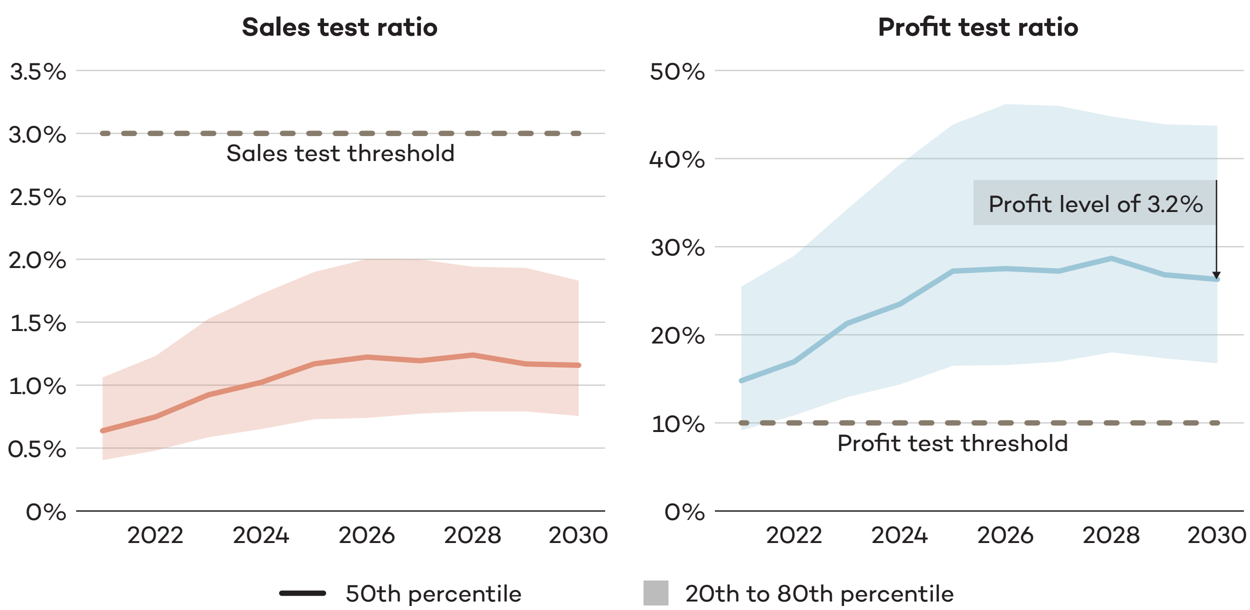
Source: Author diagram

Figure 9. Profit and sales test distribution for cement and concrete product manufacturing



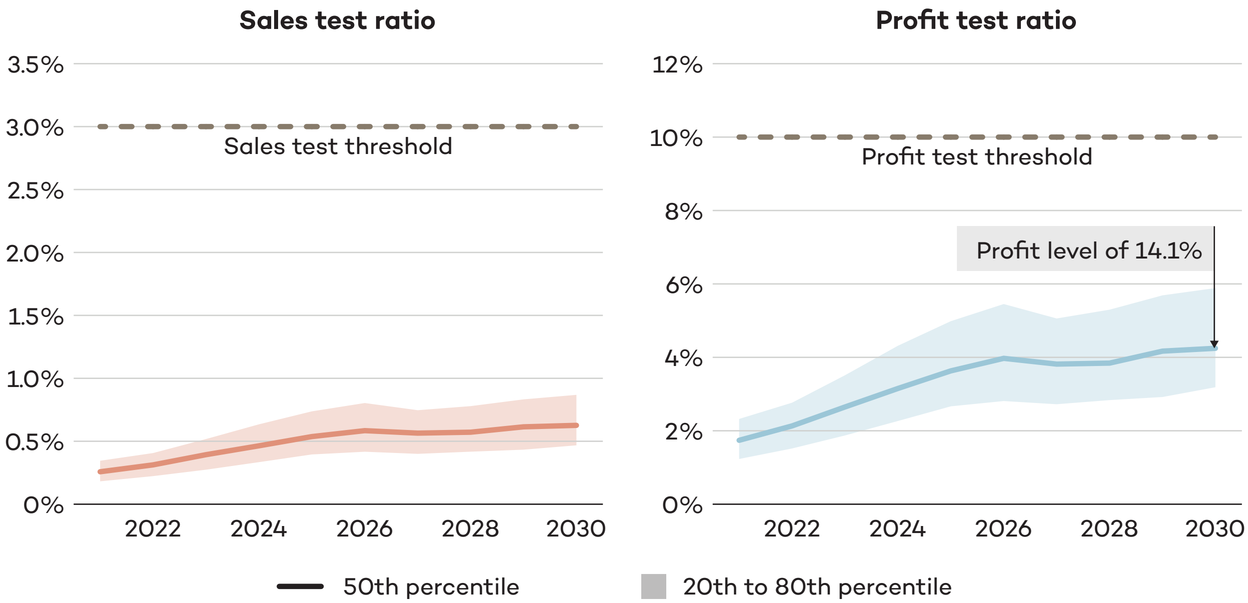
Source: Author diagram

Figure 10. Profit and sales test distribution for iron and steel mills and other ferro-alloy manufacturing



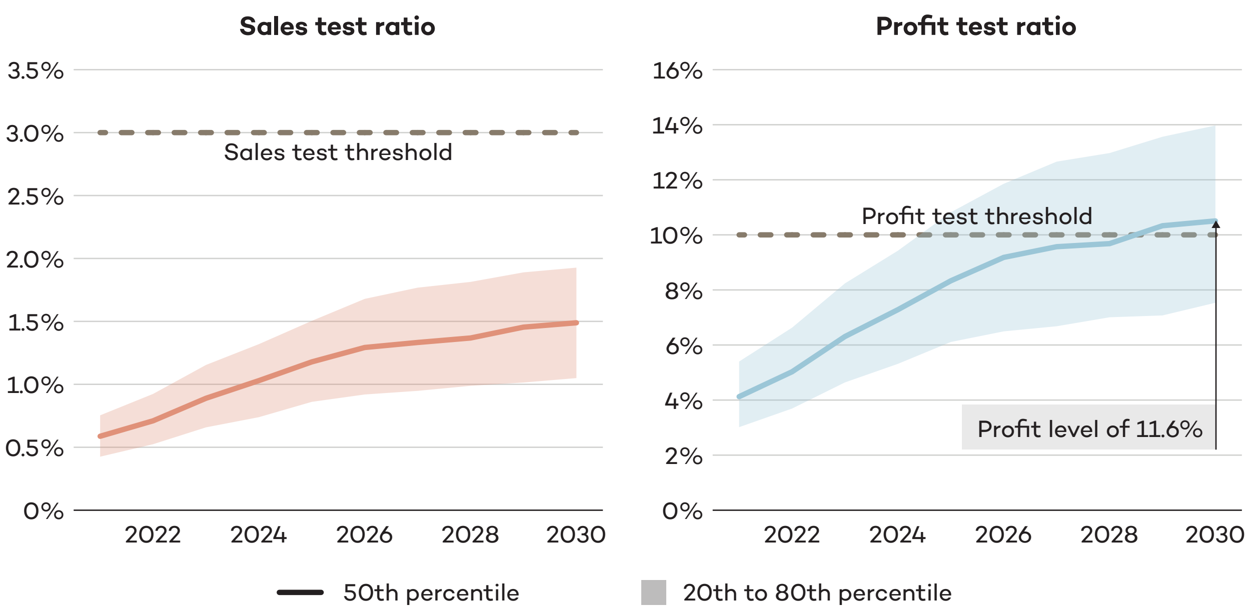
Source: Author diagram

Figure 11. Profit and sales test distribution for alumina and aluminum production and process manufacturing



Source: Author diagram

Figure 12. Profit and sales test distribution for pulp and paper



Source: Author diagram

Sectoral Summaries

In this section, we bring together all the threads of analysis to provide overall summaries of impact and vulnerability for each of the nine sectors. First, we collate seven indicators from the quantitative analysis undertaken in Sections 2, 3, and 4. We then take into account some qualitative considerations: relevant sector-specific characteristics and the available sector decarbonization pathways. The result is an overall assessment of the various sectors' vulnerability to competitiveness impacts from climate policy.

Quantitative Indicators

There are no hard and fast rules about estimating the competitiveness impact of climate policy on large emitters. Consequently, this report introduces a series of seven indicators to provide a picture of the ability of sectors to respond to climate policy, as well as their response to climate policy based on modelling and analysis. Putting it all together starts to convey a picture of where industry is likely able to absorb additional policy ambition and where additional analysis is necessary to assess the impact.

Figure 13 provides a summary view of the seven relevant indicators:

- **year high-EITE threshold triggered.** This indicator uses the federal OBPS opt-in EITE criteria from Section 2 to determine when an increasing carbon price to $170 per tonne and with increasingly stringent benchmarks pushes the sector into the high or very high impact category. The earlier the year the threshold is triggered, the more vulnerable is the sector.
- **historical macroeconomic performance.** In Section 3, two indicators were developed that compare the macroeconomic performance against a benchmark. For GDP, it is the national economy, and for operating margin it is all of manufacturing. The indicators can be interpreted as follows:
  - **GDP 2016 to 2022.** The higher the GDP index, the more the sector has outperformed the total economy. For example, all sectors except iron and steel mills and pulp and paper have outperformed the growth in the total economy in terms of GDP.
  - **operating margin 2016 to 2021.** If revenue growth is exceeding expense growth, operating margins (profits) will likely be healthy. For all sectors except iron and steel, operating margin growth significantly exceeds that of the rest of the manufacturing. The oil and gas sector clearly has high profit levels compared to the rest of the economy. Once again, iron and steel mills are the outlier with very low profit levels: about half that of the average level in all of manufacturing.
- **trade with carbon pricing jurisdictions.** In Section 3, two indicators were developed that measure the share of sectoral exports and imports to and from jurisdictions with carbon pricing systems in place. The values presented are the share of either imports or exports that are destined to or from national and subnational jurisdictions with carbon pricing, either operating or in advanced stages of development. Other things being equal, the higher the ratio, the less risk there is of misaligned carbon prices and, therefore,

adverse competitiveness impacts attributable to carbon pricing. Caveats apply to this indicator: the percentages pick up some foreign carbon pricing schemes that do not currently have the same stringency and coverage as the Canadian carbon pricing regime, as well as some schemes that are not yet fully implemented.

- **ERP policy to 2030.** These two indicators provide the results of modelling and analysis completed on the federal ERP, as described in Section 4. The policies as presented in the ERP are modelled, and any impact on emissions and GDP is estimated. The two indicators include:
  - impact on emissions. For this indicator, the compounded annual change in emissions up to 2030 is used to rank the sectors. Sectors with a greater emission reduction under the ERP scenario (Announced Policy) are ranked more highly than those with low emission reductions. This indicator reflects both the level of policy being applied in the ERP but also the differing marginal cost of emission reductions within each sector.
  - GDP impacts. The sensitivity of the growth of GDP to climate policy is assessed here. We look at GDP growth under the Legislated Policy scenario and then under the more stringent Announced Policy scenario. Sectors that show a higher drop in growth rates under the Announced Policy scenario compared to the Legislated Policy scenario are more vulnerable to competitiveness impacts arising from climate policy.
- **financial impact tests with increasing carbon price**. These tests are used by regulatory agencies to assess whether or not special provisions should be given to contain costs for large emitters. We use them here to assess the impacts of the Announced Policies scenario. These are static tests that compare fully loaded compliance costs against sector-level metrics such as profits and sales. In our tests, we include Scope 1, 2, and 3 carbon costs as the numerator. Thresholds for both profit and sales are taken from regulatory documents used by Canadian jurisdictions. The profit test threshold is set at 10% and when triggered indicates that firm profits would likely be significantly impacted by the assessed policy. The sales threshold is set at 3%, and any exceedance of this threshold usually points to a significant operational issue, meaning the carbon cost may pose a closure risk within the sector. The indicator points to the year in which the test is triggered by the average profit or sales level.

Overall Sectoral Results

The final stage in our analysis pulls together the quantitative indicators summarized above and adds qualitative considerations, in particular, an assessment of the technology readiness levels of the sector's most likely decarbonization technology and any unique sectoral characteristics that might be relevant to its vulnerability to competitiveness impacts.

The results are displayed in the "overall ranking" column of Table 9, using a traffic light indicator:

- **green light:** These sectors could go even further on emissions reductions with low risk of experiencing serious competitiveness pressures: conventional and non-conventional oil and gas, and aluminum.
- **yellow light:** These sectors can weather more stringency, but competitiveness pressures are likely, and policy responses should be tailored to reduce average costs and monitor risks: cement and concrete products.
- **red light:** These sectors look to be highly at risk from increasing policy stringency and will require tailored policy to both deliver emission reductions and keep balance sheet costs down: chemicals, agricultural chemicals and fertilizers, iron and steel mills, and pulp and paper.

Table 9. Overall ranking of competitiveness indicators

	Context (historic & present)				Forecast impacts						
	2016 - 2021 macroeconomic performance (avg annual)		Trade with C-pricing jurisdictions			Impacts of ERP by 2030 in different policy scenarios			Year threshold reached (median result)		
	GDP growth: total economy = 1	Operating margin: all industry = 1	Exports	Imports	Year reaches high EITE status	Emissions reductions (Announced)	CAGR of GDP (Developing)	CAGR of GDP (Announced)	Sales test	Profit test	Overall Ranking
Oil and gas extraction (except oil sands)	2.52	3.64	19%	16%	2026	-6.40%	5.9%	5.3%	0	0	
							drop of 0.6%				
Oil sands extraction	3.48	4.96	19%	16%	2030	-0.60%	6.7%	6.0%	0	0	
							drop of 0.7%				
Petroleum refineries	1.24	1.64	67%	26%	2030	-3.20%	-3.2%	-3.7%	0	0	
							drop of 0.5%				
Basic chemical manufacturing	1.19	2.19	46%	48%	2026	-0.40%	2.0%	0.9%	0	0	
							drop of 1.1%				
Pesticide, fertilizer and other ag. chemicals	1.37	2.2	24%	26%	2023	-0.40%	0.8%	0.3%	0	0	
							drop of 0.5%				
Cement and concrete products	3.32	1.33	55%	70%	2030	0.20%	4.3%	4.3%	0	2026	
							no change				
Iron and steel mills and ferro-alloy	0.67	0.44	27%	54%	2023	-5.70%	2.9%	2.6%	0	2023	
							drop of 0.3%				
Alumina and aluminum production	2.16	1.49	36%	74%	2023	1.50%	3.4%	3.2%	0	0	
							drop of 0.2%				
Pulp, paper and paperboard mills	-2.73	1.36	59%	51%	2023	-1.20%	1.7%	1.0%	0	2026	
							drop of 0.7%				

The overall "traffic light" rankings assigned in the last column of Table 9 are an assessment taking into account all relevant data, including the qualitative considerations discussed in Section 5.2.1. As an exercise in triangulation, we also calculated an overall ranking based solely on quantitative indicators, using a summary of the ordinal ranking each sector achieved in the various categories shown in the figure's rows. The two sets of results were completely aligned.

Oil and Gas Extraction

The oil and gas sector showed healthy growth between 2016 and 2021, with conventional oil and gas and non-conventional (oil sands) oil extraction growing at, respectively, 2.5 and 3.5 times the rate of growth for the economy as a whole. During that time, non-conventional oil had operating margins five times as high as the manufacturing sector as a whole; for conventional oil and gas the number was 3.6 times.

Looking forward, under the stricter Announced Policies scenario, oil and gas maintain a strong performance out to 2030. Conventional oil and gas and non-conventional oil show compound annual growth rates of 5.3% and 6%, respectively, with total GDP growth of 68% and 80%. Sales and profit tests show only marginal impacts; operating profit margins for conventional oil fall to an average of 35.8%, a drop of just 0.5%. Operating profit margins for non-conventional oil fall to an average of 47.5%, an average decline of 3%. It's important to note that even these small losses overstate the competitiveness risk from domestic policy; the impacts stem not only from climate-policy-induced loss of market share, but also from the impacts of international climate policies that lower the demand for oil and gas, such as automobile efficiency standards and promotion of heat pumps for home heating.

Conventional oil and gas are on track for an equal-share achievement of the ERP target of 40% by 2030. Non-conventional oil is not on track, with projected annual emission reductions of just 0.4% compared to the needed 4.6%, suggesting that there is a risk of increased policy stringency for this sector. Both sectors have favourable technology pathways for significant decarbonization, with important technologies at TRLs of 9-10 (early adoption/mature): electrification, methane leak detection and repair, methane capture, and flaring.

Risk of carbon leakage in these sectors is significantly dampened by the prevailing patterns of export. Fully 98% of exports go to the United States, mostly through pipelines, but with a small but increasing portion going by rail in the case of oil.[17] More than half of Canada's oil exports go to Midwest U.S. refiners that are tooled to process Canada's oil sands crude and that have few viable alternative supplies in the near-term. These patterns, coupled with the high operating profit margins in these sectors, suggest that any increase in costs from climate policy is likely to mean a small decline in profit rather than lost market share.

Overall ranking of risk: green

17 If the TMX pipeline comes into full operation, those exports plus the exports of oil through the Gulf of Mexico will mean roughly a quarter of Canadian oil exports have the potential to find non-U.S. markets.

Petroleum Refineries

Under the Announced Policies scenario, the petroleum refining sector experiences negative GDP growth by 2030—the only sector of our nine to do so. It shows a 32% contraction. Sales and profit test results for petroleum refining show the potential for high operating profit margin impacts in 2030 (6% to 11%), while the sales test does not show as much vulnerability.

It's important to note that these losses overstate the risk of carbon leakage in two ways. First, the impacts stem not only from climate policy-induced market share loss but also from the impacts of climate policies that lower the demand for gasoline, such as automobile efficiency standards and support for electric vehicles. Second, they assume a low ability to pass on costs to consumers, but that assumption does not fully reflect the reality of refining markets.

Petroleum refining looks to be slightly off track to meet an equal-share ERP emissions reduction target of 4.6% per year, at 3.2%.

86% of the sector's exports go to the United States—primarily to the Northeast—and 67% go to regions with carbon pricing. Exports to regions with carbon pricing could indicate less risk of lost market share, if those regions ultimately have prices on par with those in Canada, though much of Canada's refined petroleum exports go to the U.S. Northeast, where carbon pricing primarily covers electricity, not industrial emissions. Looking to the future, those numbers indicate the share of exports going to regions that are enacting significant climate policies and which are, therefore, more likely to someday implement low-carbon fuel standards, underlining the potential risk of failing to decarbonize both refining and upstream production.

Overall ranking of risk: green

Alumina and Aluminum Production and Processing

The aluminum sector experienced strong growth between 2016 and 2021, at rates 2.1 times that of the whole economy. It also enjoyed an average operating margin five times larger than Canadian manufacturing as a whole.

Looking forward, under the Announced Policies scenario, this sector is expected to have strong fundamentals out to 2030, with compound annual growth rate of GDP of 3.2% per year, for a total growth of 36%. Negative impacts on sales and profits are not expected to be significant, with an average drop in sales of 0.9% and an average drop in profits of 4%, going from 14.7% to 14.1%.

Overall, 70% of imports are from jurisdictions with some form of carbon pricing, indicating the possibility that if those foreign prices in future are equivalent to Canadian carbon prices, the risk of losing market share through imports will be minimized. Exports to the United States comprise 96% of this sector's exports, and Canadian aluminum has a relatively low GHG intensity relative to U.S. aluminum. If the United States eventually adopts border measures that restrict high-carbon aluminum and those measures fairly reflect Canadian GHG intensity, aluminum exports to the United States will not be impaired.

Decarbonization pathways for aluminum are relatively positive, with new technologies at TRLs of 7 or 8 (demonstration level) in areas such as cathodes, heat exchangers, electrification, and carbon capture, utilization, and storage.

Overall ranking of risk: green

Basic Chemical Manufacturing

The chemicals sector has performed relatively well between 2016 and 2021; its operating margin has been 2.2 times that of the manufacturing sector as a whole, but its GDP growth has been only 19% higher than that of the economy as a whole.

Looking forward, the Announced Policies scenario sees this sector with anemic growth relative to the other EITE sectors: its rate of GDP growth per year out to 2030 is less than 1%, and absolute growth by 2030 is only 9%. Sales and profit test results show a medium impact; maximum sales impacts are in the order of 1.1% in 2030, while the profit impact maxes out at 5%. The profit impact reduces the operating profit margin from 21.6% with no policy to 20.9% with policy in place. The impact of moving from the legislated policies scenario to the Announced Policies scenario is significant for this sector, creating an estimated loss of 9.9% GDP by 2030. This is the highest level of vulnerability on that criterion of any of the nine sectors.

This sector is not on track to meet a 2030 equal share ERP target of 40% emissions reductions. Projected reductions under the Announced Policy scenario are only 0.4% per year, in contrast to the needed 4.6%. This suggests that the sector may be subject to increased demands under future climate policy.

Overall ranking of risk: red

Cement and Concrete Product Manufacturing

Cement and concrete products manufacturing performed relatively well between 2016 and 2021; its operating margin was 1.3 times that of the manufacturing sector taken as a whole, which is low for the nine sectors we examined. But its GDP growth has been outstanding, at 3.3 times higher than that of the aggregate economy.

Looking forward, the Announced Policies scenario sees this sector performing relatively well, with a projected compound annual growth rate of GDP by 2030 of 4.3%, resulting in growth by 2030 of over 50%. The difference between the Legislated Policy scenario and the stricter Announced Policy scenario is almost zero—the lowest of any of the nine sectors, indicating low sensitivity of GDP to increasingly strong climate policy. Sales and profit test results under the Announced Policy scenario, however, show the potential for impacts significant enough to constitute operational risk. With low profit margins and high compliance costs, there's a medium to high level of potential exposure starting immediately, with the profit test threshold exceeded on average by 2025 and, in the worst-case scenario, by 2023.

This sector is further away than any of the nine we examine in terms of meeting an equal share emissions reduction target by 2030 of 40%; rather than the needed annual reduction of 4.6%, we project a slight annual increase. Other things being equal, this suggests a risk of future policy impacts in terms of compliance costs and competitiveness impacts.

This sector's products are heavy relative to their value, and so are not shipped far over land—99% of Canadian exports go to the United States, mostly to neighbouring states. From the perspective of lost market share, this means there are essentially two markets for this sector's products. The producers near ports and near to U.S. manufacturers or buyers may be vulnerable to carbon leakage via lower-cost imports and competition in foreign markets in the event of cost increases. Producers further inland, who do not export or import, are less susceptible to these changes.

Overall rating of risk: yellow

Iron and Steel Mills and Ferro-Alloy Manufacturing

The iron and steel mills and ferro-alloy manufacturing sector did not fare well between 2016 and 2021, with an average operating margin of less than half that of the overall manufacturing sector. Compound annual growth rate of GDP for this sector was 1.2%, or about two thirds of that experienced by the overall economy.

Looking forward, the Announced Policies scenario sees this sector having a compound annual growth rate by 2030 of 2.6%, meaning sectoral growth over that time of 29%. Sales and profit test results show a significant operational risk. The sales test does not point to a threat of operational closure, with the threshold never achieved. However, the profit test shows very high risk; the entire distribution of outcomes exceeds the threshold at the start of the simulation in 2021 and deviates further from there.

Exports to the United States comprise 92% of this sector's exports, and Canadian steel is only slightly higher in GHG intensity relative to U.S. steel on average. If the United States eventually adopts border measures that restrict high-carbon steel and those measures fairly reflect Canadian GHG intensity, steel exports to the United States will not be significantly impaired.

Decarbonization pathways in steel are viable, with direct-reduced iron/electric arc furnace production teaming up either with green (electrolytic) or blue (methane reforming plus carbon capture and storage) hydrogen, at technology readiness levels of between 7 and 9 (demonstration/early adoption). Potential cost impacts of that pathway have been softened by federal funding, announced in 2001 and 2002, of over $800 million to support converting two of Canada's largest steel mills from basic furnace blast oxygen furnace production to cleaner electric arc furnace production. In the case of ArcelorMittal's Hamilton mill, the conversion will also involve the use of DRI feedstock, which can be fed by electrolytic hydrogen.

Overall rating of risk: red

Pulp and Paper Manufacturing

Pulp and paper manufacturing did not perform well between 2016 and 2021, with negative average annual growth rates of GDP. However, operating margins during this period were relatively strong, exceeding those of the broader Canadian manufacturing sector by more than one third.

Looking forward, under the Announced Policies scenario, this sector is expected to achieve a relatively low compound average growth rate of 1% per year, achieving just 10% growth by 2030. Profit test results for the sector show a high level of risk; the mean result crosses the test threshold in 2026, and the 80th percentile result does so in 2024. The sales test shows less vulnerability, indicating there is a low threat of actual closure across the sector. The sector in 2023 is already past the OBPS threshold for high-EITE status.

Overall rating of risk: red

SEVEN

Policy Implications

The preceding analysis makes it clear that some sectors are at higher risk of eroded competitiveness than others. Those sectors at greater risk are in particular need of policy support to protect their competitiveness as they transition to low-carbon production in a world of uneven climate ambition. This section discusses the key policy tools that could be deployed.

Canada's approach to climate policy for heavy industrial sectors is currently based largely on the OBPS, which subjects a portion of total emissions (those above a benchmark) to the carbon price. This system is the cornerstone of the 2030 Emissions Reduction Plan and was deliberately designed to provide a strong price signal at the margin while keeping average costs low (Government of Canada, 2021). In so doing, the OBPS creates an incentive for EITE sectors to gradually reduce emissions in the most cost-effective way possible. The tradeability of emission credits under this system ensures that facilities with relatively lower abatement costs will reduce emissions first and then sell the credits generated to higher-abatement-cost facilities who can continue emitting, at least temporarily. Gradual increases to the carbon price and to the proportion of total emissions covered by it, ensure that large emitters continue to have an incentive to improve their emissions performance over time and meet emissions targets (World Bank, 2023). Predictable increases to prices also provide a critical signal to capital markets, helping to attract the billions of dollars in investment in clean technologies that are needed to decarbonize heavy industry (Clark et al., 2022).

Canada's OBPS, like other pricing systems, is a flexible and efficient market-based mechanism that can effectively incentivize low-cost emissions reductions. It puts an explicit price on GHG emissions and allows large emitters flexibility in determining how they will respond to that price. Carbon pricing systems are favoured over other climate policies for their efficiency.[18]

However, as our preceding analysis has shown, the OBPS (along with announced companion policies) does not provide a sufficient incentive to reduce emissions in line with Canada's 2030 target, let alone net-zero by 2050. If Canada is to meet its targets and do its part to keep global warming within safe levels, Canadian climate policies must be strengthened.

[18] Carbon pricing in climate policy: seven reasons, complementary instruments, and political economy considerations - Baranzini - 2017 - WIREs Climate Change - Wiley Online Library

When considering how best to strengthen climate policies, pricing-based mechanisms should remain at the forefront. These are the most cost-effective tools available, and Canada can little afford to abandon a policy approach that has the potential to yield more bang for its buck than any other. Strengthening the OBPS over time through tighter benchmarks and higher prices should remain a pillar of Canada's climate policy.

However, and as our preceding analysis has also made clear, not all sectors are equally able to bear increased climate policy costs without engendering (or worsening) competitiveness problems. Some sectors, such as oil and gas, petroleum refining, and aluminum, are relatively better positioned to manage some increase in climate policy costs. Others, including iron and steel, pulp and paper, and chemicals, face greater competitiveness risks under announced climate policies.

As Canada strengthens its climate policies it must take these different levels of vulnerability explicitly into account by prioritizing complementary policies for those sectors that face the highest competitiveness risks. For reasons of both efficiency and fiscal prudence, Canada should continue to rely on pricing as the central pillar of climate policy for all industrial sectors: the key question is how output-based pricing can be paired with complementary policy to address competitiveness. Options to complement OBPS include continued output-based allocations, a border carbon adjustment, and emissions-intensity standards. These complementary policies would assist the most vulnerable sectors, in particular, to manage the competitiveness risks they face through the net-zero transition by levelling the playing field between Canada and other countries and ensuring that those companies investing heavily in decarbonization are not inadvertently penalized for doing so. For example, border carbon adjustments and emissions-intensity standards reduce the likelihood that high-carbon imported products will capture domestic market share.

In our subsequent paper, we will dive deeper into these complementary policies, examining the role they could and should play in Canada's climate policy mix for heavy industrial sectors. We will assess border carbon adjustments, output-based allocation, and emissions-intensity standards in terms of their potential effectiveness, feasibility, cost, and impact on international trade relations. We will identify the main barriers to the adoption of these policies and consider whether and how they could be overcome. Finally, we will make recommendations regarding which of these policies are most worth pursuing, and for which sectors. We will ground our recommendations in a thorough analysis of the competitive circumstances the sectors face.

EIGHT

Conclusion

The decarbonization of heavy industry is a key global challenge. Countries around the world are grappling with how best to ensure that essential commodities such as cement, steel, basic chemicals, and fertilizers are profitably produced without high GHG emissions. Ever mindful of the risk that large emitters will simply shift operations to jurisdictions that do not restrict emissions and increasingly concerned about the national security implications of lost industrial capacity, policy-makers are typically very cautious in their approach to climate policy for heavy industries.

However, in Canada as elsewhere, it is imperative that those policies be effective in incentivizing decarbonization, both because industrial emissions are such a large part of our national profile and because if those industries do not decarbonize, they will face competitiveness pressures of a different kind in a world that implements policy to account for the carbon embedded in traded goods.

We find that in almost all cases Canada's existing climate policies are not enough to ensure that EITE sectors achieve emissions reductions consistent with climate targets. Canada must go further by implementing all announced policies and/or stronger versions of existing policies, such as carbon pricing.

But what does that imply for the competitiveness of those sectors? Some of them clearly face competitiveness challenges under a scenario that sees Canada's announced climate policies come into play out to 2030. In this category, we identified basic chemicals, agricultural chemicals, iron and steel, and pulp and paper. For these sectors, there is a need to craft policies that complement climate policies by protecting the competitiveness of Canadian producers through the transition.

Other sectors are at lower risk of significant competitiveness challenges from Canada's announced climate policies out to 2030. For these sectors, competitiveness pressures are not a near-term barrier to implementing needed climate policies. In this category, we identified oil and gas, petroleum refineries, and aluminum.

These findings strongly suggest that Canada's approach to decarbonization of heavy industry should be differentiated by sector. In crafting both climate policy and any complementary policies aimed at ensuring competitiveness through the transition, the unique characteristics of the sectors matter.

In addition to managing the near-term competitiveness risks, Canadian policy needs to position its economy to succeed as the global economy reorients to net-zero over the next quarter century. While 2050 may seem far away, many companies active in heavy industry face investment decisions in the near term that will shape their emissions trajectories for decades to come. If investments in low-carbon production technologies do not happen soon and at scale, Canada's heavy industrial sectors risk becoming uncompetitive in global markets that will punish GHG-intensive production.

Future research by the Commission on Carbon Competitiveness will examine the specific policy solutions that, when combined with industrial carbon pricing, have the potential to position Canada's heavy industrial sector for success through the low-carbon transition. We will systematically compare complementary policy approaches, including output-based allocation, border carbon adjustments, and emissions-intensity product standards to see which of these have the most potential to address the specific risks faced by Canada's heavy industrial sectors, as well as positioning them to capitalize on the significant opportunities that will be available to low-carbon producers.

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Appendix A. Detailed EITE Test Result for 42 Sectors

Table A1. EITE results using federal OBPS metrics

		EI>3% & TE>20%			EI>15% & TE>10%			EI>30% & TE>0%			Is TE >80%
		2023	2026	2030	2023	2026	2030	2023	2026	2030	
Summary	# sectors (of 42)	4	12	16	1	1	4	0	1	1	23
	% EITE GVA	4%	62%	66%	0.3%	0.3%	4.1%	0.0%	0.3%	0.3%	76%
	% national GVA	0.7%	10.12%	10.7%	0.05%	0.05%	0.7%	0.0%	0.05%	0.05%	12%
Oil and gas extraction (except oil sands)		-	Yes	Yes	-	-	-	-	-	-	Yes
Oil sands extraction		-		Yes	-	-	-	-	-	-	Yes
Coal mining		-	-	-	-	-	-	-	-	-	Yes
Iron ore mining		-	-	-	-	-	-	-	-	-	Yes
Gold and silver ore mining		-	-	-	-	-	-	-	-	-	-
Copper, nickel, lead, and zinc ore mining		-	-	-	-	-	-	-	-	-	Yes
Other metal ore mining		-	-	-	-	-	-	-	-	-	-
Stone mining and quarrying		-	-	-	-	-	-	-	-	-	-
Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying		-	-	-	-	-	-	-	-	-	-
Diamond mining		-	-	Yes	-	-	-	-	-	-	Yes
Other non-metallic mineral mining and quarrying (except diamond and potash)		-	-	-	-	-	-	-	-	-	Yes
Potash mining		-	-	Yes	-	-	-	-	-	-	Yes
Animal food manufacturing		-	-	-	-	-	-	-	-	-	-
Grain and oilseed milling		-	-	-	-	-	-	-	-	-	Yes
Sugar and confectionery product manufacturing		-	-	-	-	-	-	-	-	-	Yes

	EI>3% & TE>20%			EI>15% & TE>10%			EI>30% & TE>0%			Is TE >80%
	2023	2026	2030	2023	2026	2030	2023	2026	2030	
Fruit and vegetable preserving and specialty food manufacturing	-	-	-	-	-	-	-	-	-	-
Dairy product manufacturing	-	-	-	-	-	-	-	-	-	-
Meat product manufacturing	-	-	-	-	-	-	-	-	-	-
Seafood product preparation and packaging	-	-	-	-	-	-	-	-	-	Yes
Bakeries and tortilla manufacturing	-	-	-	-	-	-	-	-	-	-
Other food manufacturing	-	-	-	-	-	-	-	-	-	-
Other wood product manufacturing	-	-	-	-	-	-	-	-	-	-
Pulp, paper, and paperboard mills	Yes	Yes	Yes	-	-	Yes	-	-	-	Yes
Converted paper product manufacturing	-	-	-	-	-	-	-	-	-	-
Petroleum refineries	-	Yes	Yes	-	-	-	-	-	-	-
Petroleum and coal product manufacturing (except petroleum refineries)	-	Yes	Yes	-	-	-	-	-	-	-
Basic chemical manufacturing	-	Yes	Yes	-	-	-	-	-	-	Yes
Resin, synthetic rubber, and artificial and synthetic fibres and filaments manufacturing	-	-	-	-	-	-	-	-	-	Yes
Pesticide, fertilizer, and other agricultural chemical manufacturing	Yes	Yes	Yes	-	-	-	-	-	-	-
Pharmaceutical and medicine manufacturing	-	-	-	-	-	-	-	-	-	Yes
Paint, coating and adhesive manufacturing	-	-	-	-	-	-	-	-	-	-
Soap, cleaning compound, and toilet preparation manufacturing	-	-	-	-	-	-	-	-	-	Yes
Other chemical product manufacturing	-	Yes	Yes	-	-	-	-	-	-	Yes
Plastic product manufacturing	-	-	-	-	-	-	-	-	-	-

	EI>3% & TE>20%			EI>15% & TE>10%			EI>30% & TE>0%			Is TE >80%
	2023	2026	2030	2023	2026	2030	2023	2026	2030	
Rubber product manufacturing	-	-	-	-	-	-	-	-	-	Yes
Non-metallic mineral product manufacturing (except cement and concrete products)	-	-	Yes	-	-	-	-	-	-	Yes
Cement and concrete product manufacturing	-	-	-	-	-	Yes	-	-	-	-
Iron and steel mills and ferro-alloy manufacturing	Yes	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes
Steel product manufacturing from purchased steel	-	-	Yes	-	-	-	-	-	-	Yes
Alumina and aluminum production and processing	Yes	Yes	Yes	-	-	Yes	-	-	-	Yes
Non-ferrous metal (except aluminum) production and processing	-	Yes	Yes	-	-	-	-	-	-	Yes
Foundries	-	Yes	Yes	-	-	-	-	-	-	-

Source: Authors' own calculations using data as in Table 1

Table A2. EITE results using Ontario metrics

		Low EI <1,000 & TE <10%	Medium EI <1,000 & TE≥10%	High EI ≥1,000 and TE ≥10%	Is TI >30%
Summary	**# sectors (of 42)**	0	27	15	37
	% EITE GVA	0%	35%	65%	97%
	% national GVA	0%	6%	10%	16%
Oil and gas extraction (except oil sands)		-	-	Yes	Yes
Oil sands extraction		-	-	Yes	Yes
Coal mining		-	Yes	-	Yes
Iron ore mining		-	Yes	-	Yes
Gold and silver ore mining		-	Yes	-	Yes
Copper, nickel, lead, and zinc ore mining		-	Yes	-	Yes
Other metal ore mining		-	Yes	-	Yes
Stone mining and quarrying		-	Yes	-	-
Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying		-	-	Yes	-
Diamond mining		-	Yes	-	Yes
Other non-metallic mineral mining and quarrying (except diamond and potash)		-	Yes	-	Yes
Potash mining		-	Yes	-	Yes
Animal food manufacturing		-	Yes	-	-
Grain and oilseed milling		-	Yes	-	Yes
Sugar and confectionery product manufacturing		-	Yes	-	Yes
Fruit and vegetable preserving and specialty food manufacturing		-	Yes	-	Yes
Dairy product manufacturing		-	Yes	-	-

	Low EI <1,000 & TE <10%	Medium EI <1,000 & TE≥10%	High EI ≥1,000 and TE ≥10%	Is TI >30%
Meat product manufacturing	-	Yes	-	Yes
Seafood product preparation and packaging	-	Yes	-	Yes
Bakeries and tortilla manufacturing	-	Yes	-	Yes
Other food manufacturing	-	Yes	-	Yes
Other wood product manufacturing	-	Yes	-	Yes
Pulp, paper, and paperboard mills	-	-	Yes	Yes
Converted paper product manufacturing	-	Yes	-	Yes
Petroleum refineries	-	-	Yes	Yes
Petroleum and coal product manufacturing (except petroleum refineries)	-	-	Yes	Yes
Basic chemical manufacturing	-	-	Yes	Yes
Resin, synthetic rubber, and artificial and synthetic fibres and filaments manufacturing	-	Yes	-	Yes
Pesticide, fertilizer, and other agricultural chemical manufacturing	-	-	Yes	Yes
Pharmaceutical and medicine manufacturing	-	Yes	-	Yes
Paint, coating and adhesive manufacturing	-	Yes	-	Yes
Soap, cleaning compound, and toilet preparation manufacturing	-	Yes	-	Yes
Other chemical product manufacturing	-	-	Yes	Yes
Plastic product manufacturing	-	Yes	-	Yes
Rubber product manufacturing	-	Yes	-	Yes
Non-metallic mineral product manufacturing (except cement and concrete products)	-	-	Yes	Yes

	Low **EI <1,000 & TE <10%**	**Medium** **EI <1,000 & TE≥10%**	**High EI** **≥1,000 and TE ≥10%**	**Is TI >30%**
Cement and concrete product manufacturing	-	-	Yes	-
Iron and steel mills and ferro-alloy manufacturing	-	-	Yes	Yes
Steel product manufacturing from purchased steel	-	Yes	-	Yes
Alumina and aluminum production and processing	-	-	Yes	Yes
Non-ferrous metal (except aluminum) production and processing	-	-	Yes	Yes
Foundries	-	-	Yes	Yes

Source: Authors' own calculations using data as in Table 1

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