Opportunities for Decarbonisation of Canadian Heavy Industry

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1 Project Context and Objectives

Many IGUA members have publicly committed to net-zero by 2050 and have started to implement detailed plans for major carbon reductions by 2030. Meanwhile, federal policy has evolved substantially on carbon pricing and complementary policies. In addition, other instruments such as carbon border adjustments are now widely being discussed (GoC, 2021).

The objective of this project is to consider policy options for facilitating the decarbonization of trade exposed energy intensive industry that improves (or at least doesn't harm) competitiveness, rewards industry actors that have and are taking action and improving performance and also recognizes the transformational change and investment that is required to meet net zero targets.

There is already broad agreement on the major sectoral strategies that will be required. In this study we are interested in identifying the major alternate or complementary options to carbon pricing and CBAM that can capitalize on Canada's competitive advantages and create a robust market for lower intensity commodities. A review of these policies will help to indicate how they can be implemented to contribute to decarbonization and industry competitiveness in Canada and provide a framework for more detailed sector analysis.

Future, Phase 2, work proposes to employ the framework developed from this project, to conduct an integrated quantitative analysis of net-zero options for a number of key industrial sectors in Canada.

Finally, we'd like to note that the objective of this paper is to better understand the options for transformative decarbonization, not for offsetting heavy industry emissions with even high quality permanent, verifiable, and additive negative emissions. This is based on the premise that +1.1°C from preindustrial temperatures has already been exceeded, the Paris Agreement requires "well below 2°C and well towards 1°C", very little carbon budget remains for 1.5°C, and therefore any offsets that can be truly negative will be needed to go below zero emissions to meet global CO_2 ppm targets and to provide carbon budget room for developing nations.

2 Background and Current State of Affairs

Canada has recently enhanced its pledge to reduce its greenhouse gas (GHG) emissions by 40 to 45 percent below the 2005 level by 2030 and achieve net-zero by 2050. These targets are enshrined in law through the Canadian Net-Zero Emission Accountability Act and require that credible, science-based emission-reduction plans be created.

Canadian GHG mitigation policy is extremely complex, however, with shared federal-provincial-territorial jurisdiction and many economic, sectoral and geographic considerations. Below we expand on the current state of affairs of a rapidly evolving combination of GHG mitigation policies as they relate to heavy industries, particularly those that are emission intensive, trade exposed and therefore have competitiveness issues related to carbon policy.

The Canadian provinces and the federal government have worked together to implement economy wide carbon pricing in Canada, and the Pan-Canadian Framework on Clean Growth and Climate Change imposes varying marginal and average carbon price incentives across Canada to achieve emission reductions in every heavy industry sector. This market-based signal is a key pillar of Canadian climate policy and was strengthened with the introduction of a schedule to increase the carbon price to $170 per tonne CO_2 by 2030, providing a degree of certainty around long-term investment costs. However, for heavy industries the system is anything but simple, and across Canada there is a complex and fragmented provincial and territorial system, with different coverage, prices, rules, boundaries, and incentives. In addition, trade exposed and emissions intense heavy industries are typically shielded from 80% to 90% of the full federal carbon price in Canada so they can compete in world markets (where most other actors do not yet internalize the costs of GHG pollution). The system is designed to maintain the marginal carbon price (practically the carbon price faced when tuning current operational practices and new and replacement investment that falls within the sector's covered portion of emissions, i.e. under 10-20%) close to the broader economy carbon price faced by households and less energy intense and traded business. In this way it works to drive project based abatement technology at facilities and reduce emissions. However, for investment in new and replacement greenfield facilities and technologies that represent a larger portion of the sector's covered emissions (i.e. over 10-20%) the average price is also important as it drives long-term capital decision making related to the cost of ownership. In this case carbon pricing alone is certainly not enough and just the beginning of a foundation for investments in a net-zero transition.

To address emission gaps, there is also a myriad of additional, new and emerging federal policies under various stages of development that are intended to complement carbon pricing. The first Emission Reduction Plan (ERP) published in April 2022, provides a broad roadmap for Canada's greenhouse gas emissions reduction efforts and identifies what the government is planning for different economic sectors. There are a few new

announcements for building retrofits and zero-emission vehicles; however, relatively little new detail is provided in the plan on policies that impact large industrial emitters. However, various federal policies are under development. The Clean Fuel Standard (CFS) looks to decarbonize liquid fossil fuels, methane regulations target oil and gas emissions not covered under carbon pricing, and innovation and technology funds seek to incentivize low-carbon investment. These policies have both direct and indirect costs and benefits to heavy industry sectors.

Carbon Border Adjustments (CBA) are being reviewed as a way to simultaneously protect large industrial emitter competitiveness by leveling the playing field with foreign production, while maintaining -and increasing the marginal carbon price incentive for reductions in Canada. While the EU has announced it will introduce a BCA in January, 2023, it should be recognized that initially it is planned to only cover a few products (currently steel, cement, aluminum and electricity) and Canada will need to make sure that whatever system emerges is compatible with our largest trading partner, the United States. New financial incentive instruments are also being proposed, such as cutting corporate tax rates in half for zero-emission products to help to de-risk new technologies and attract investment to Canada. Budget 2022 announced an investment tax credit for capital invested in carbon capture, utilization, and storage (CCUS) projects. The tax credit rate would be 60% for investment in equipment to capture CO_2 in direct air capture projects, 50% for investment in equipment to capture CO_2 in all other CCUS projects and 37.5% for investment in equipment for transportation, storage and use.

Preliminary work is also being done in Canada to plan the low-carbon energy infrastructure of the future including: carbon capture and storage transmission grids, net-zero electricity standards by 2035, and industrial clusters with hydrogen production and storage (GoC, 2022).

Provincial programs continue to evolve as well, with Ontario's Emission Performance Standards Program (EPS) having replaced the federal Output-Based Pricing System (OBPS) on January 1, 2022. We do not detail them here because officially they have to be as strong and broad as the federal backstop. In reality as of 2020 there were substantial differences in stringency (ECCC, 2021), but the Minister of NRCan has ordered that the largest negative discrepancies to be rectified within 6 months (ECCC, 2021a).

Globally many governments have committed to similar targets, are facing similar challenges, and are acting on policy packages, notably the EU with its ETS and various complementary strategies, but the pressure to decarbonize is not only coming from governments. Many global and domestic heavy industries and companies have net-zero targets by 2050 and interim targets. More than two thirds of companies on the S&P 500 have set emission targets and 30% have implemented or plan on implementing science-based targets. The number of companies publishing sustainability reports increased from 20% in 2011 to 90% in 2019 (Visual Capitalist, 2021). Even if companies have not

announced targets or released plans, they know their competitors are working towards decarbonisation. Competitive risk and the increasing pressure from investors who are actively managing the carbon risks of their investments and activist shareholders means that all Canadian heavy industry participants are actively engaged and looking for solutions so that they can remain globally competitive.

As a consequence of the globally increased interest in climate policy since the Paris Agreement was implemented in 2017, Canada is hastily erecting a myriad of policies and measures from which to build a foundation for a net zero economy in 2050. If we take stock of the last twenty years of Canadian climate policy, a tortuous journey of slow incremental steps forward and many steps back, we can understand the pressing need for governments at all levels and the private sector to coordinate and act as soon as possible on an integrated strategy and transition plan, that provides a fair, consistent, effective and long-term signal for investments in net-zero production. It is clear that carbon pricing alone is insufficient to engender the transition particularly for heavy industry, because of the focused risk of new technologies, because of the uncertainty around future prices, because of the highly traded nature of some of their products, and partly because of the discounting of future carbon prices.

Incrementalism (adding small new policies to try to fill the gaps) also won't get us to this future. Investments to build new net-zero production facilities and to transition capital to net-zero have barely begun and there is less than a 30 year time horizon available until net-zero emissions need to be achieved. Reaching net-zero targets for heavy industry effectively requires a systematic, directed and societally chosen industrial revolution. It will be a global transformation that poses both big opportunities and big risks.

Canada is not ready for the net-zero transformation and is particularly vulnerable because of our high trade dependency and the high emission intensity of our exports. If we fail to pay enough attention to global competitiveness, we will also fail to invest in Canada's future and risk the ultimate collective failure of not reaching net-zero globally. We also need to pivot our climate policy, from focusing on merely regulating current production as a means to reaching net-zero to instead enabling large-scale new net-zero investment and facilities. Current facilities and capital investment will (for the most part) not be able to make orderly neat, incremental investments to net-zero. In most cases, completely new investments in new technologies and processes will need to be made and costs of production will rise depending on fuels and any extra processing required. Here low carbon competitiveness is more about attracting new investment to Canada, focusing on companies as the vehicles of change, whether by incubating new companies and low carbon products, helping existing companies transition and adapt or shifting capital towards companies that are ready to make net-zero compatible products. This is both an enormous risk and an opportunity. Get it right and Canada gains innovative, competitive companies that capture significant production value, long-term export potential and

technology rights. Get it wrong and heavy industries and their supply chains are at risk of moving production to lower cost and/or lower risk jurisdictions.

This report seeks to take stock of the existing policies and measures in place and identify additional policy options that are needed to close the significant emissions gap and identify a viable pathway for net zero heavy industry production while ensuring Canada remains competitive in these sectors.

3 Review of Policy Options

The objective is to identify policy options that Canadian actors (federal government, provincial and territorial governments, municipalities, corporations, public interest groups) could implement to achieve heavy industry emission reductions consistent with net-zero targets while:

1. Improving (or at least not harming) Canada's global competitiveness for trade related products. In the context of net-zero this implies that either there is a market and low carbon pathway for existing industry products or there is an opportunity to transition to new low carbon products;
2. Rewarding industry actors that have and are taking action and improving emission intensity performance consistent with Canada's strategic direction. This implies that there are appropriate signals for existing lower carbon production, net-zero investments and that there is a viable net-zero strategy;
3. Ensuring that individual and cumulative polices are consistent with the transformational change and investment that is required to meet net zero targets; and,
4. Leveraging Canada's competitive advantages and opportunities to become a world leading exporter and producer of low carbon products and technology.

In a carbon constrained world Canada must shift from industrial products based on unabated fossil fuels and emission intensive resource production. Canada is in an excellent position to make this shift as we have both vast renewable energy resources (e.g., hydropower, wind, solar, biomass, uranium) and strategic material inputs for low carbon technologies (e.g., lithium, nickel, copper, high quality iron ore for direct reduction, biomass, etc.) . These comparative advantages provide scope for a large-scale low-carbon export industry for many heavy industry products.

Canada has already implemented one of the most ambitious long-term carbon pricing systems in the world. This policy review does not include carbon pricing and trade competitiveness instruments such as carbon border adjustments; however, it indirectly considers how other policy options fit within this carbon pricing framework. It is also not an exhaustive review, focusing on the most credible, high impact and salient policy options that apply for Canadian heavy industry.

Potential policy options include a broad range of instruments that are designed to push and pull (i.e., "sticks" & "carrots") heavy industry towards a net-zero carbon pathway. One can see these options as more or less prescriptive. There is an extra-ordinary degree of uncertainty in what heavy industry sectors (e.g., steel, cement, chemicals, large manufacturing) will look like in Canada by 2050, but this very little uncertainty that their

products will be required and demand may grow overall. However, the argument here is that the more consistent, integrated and well thought through policy actors in Canada can lay planks in the direction of a net-zero future, the more likely the opportunity for a prosperous future will be. The corollary here is that both inaction and inconsistent, badly implemented, or mutually incompatible policies are likely to do the opposite, and reduce the likelihood of a successful and prosperous outcome. The objective is clearly not to just reduce emissions but to attract new investment, prevent the off-shoring of heavy industry sectors to other jurisdictions and to create and maintain prosperity for companies and workers that are part of Canada's current heavy industry sectors.

Table 1 identifies a comprehensive list of policy options that have been used to target heavy industry emissions. These policy options were identified in an extensive literature review of net-zero emission reduction strategies across the world and are categorized into numerous classes of policies.

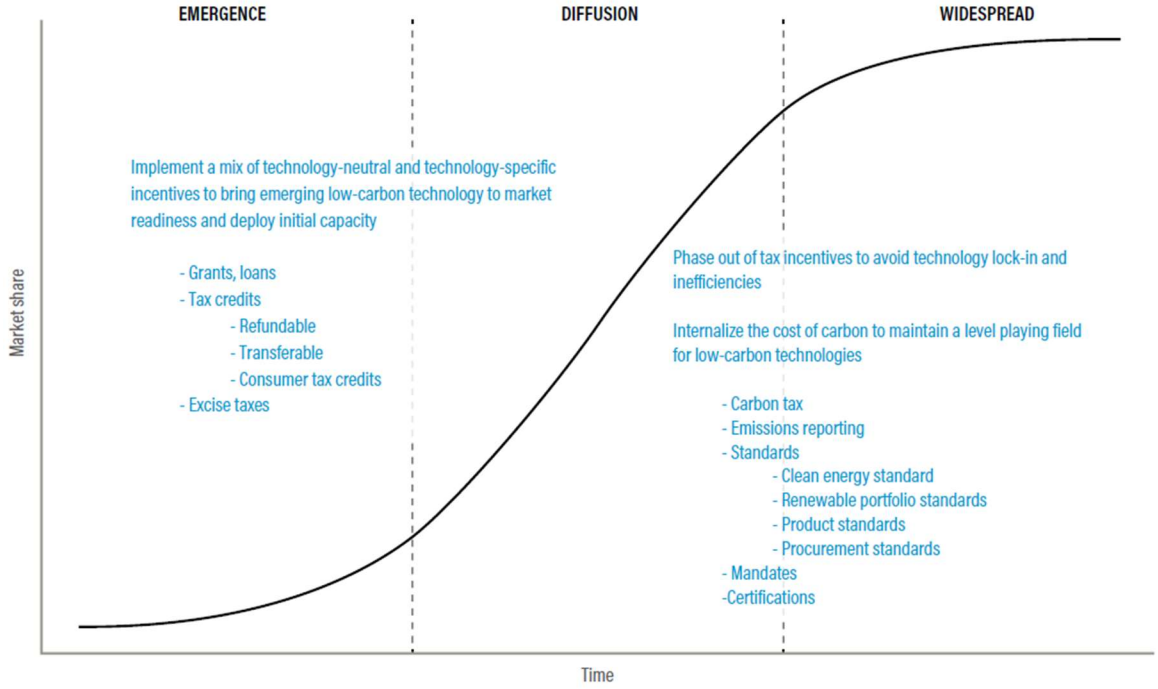
Table 1: Policy Options for Heavy Industry Decarbonisation

Classes of Policies for Heavy Industry Decarbonisation	**Policy Options / Instruments**
Carbon Pricing (Direct Taxes and Charges on Carbon, also tradeable permits)	- Not covered directly in review
Carbon Border Adjustments	- Not covered directly in review
Regulations and Standards These specify the technology or performance standards necessary for reducing emissions.	Performance Standards
	Technology Standards
	Fuel standards
	Building and infrastructure building codes
Voluntary Actions by Industry	Declaration of Net Zero Targets
	Sector/facility net zero strategies
	Sector research and development ventures
Public Disclosure Required or voluntary public disclosure of environmentally related information, generally by industry to consumers, investors or the government. These include labelling programmes and rating and certification systems.	Reporting of emission intensities of products (Scope 1, 2 and 3)
	Product Codes and Labelling
Subsidies and Incentives Direct payments, tax reductions, price supports from a government to an entity for implementing a practice or action that is not otherwise regulated.	Subsidies, grants, funding for research, development, commercialization and deployment
	Tax incentives and capital cost allowances
Green Procurement and Marketing of Net Zero Products	Green procurement by government and private sector for net zero products

Classes of Policies for Heavy Industry Decarbonisation	Policy Options / Instruments
	Contracts for difference for sales of low carbon intensity production
	Strategies for market preparation / intervention and enabling
Research, Development & Commercialization \ Planning Activities that involve direct government funding and investment aimed at generating innovative approaches and technologies for mitigation and/or the physical and social infrastructure to reduce emissions.	Government led investment in research and development
	Government or Stakeholder led Sector or Technology Roadmaps and Strategies
	Government led & supported accelerated retirement of non-retrofittable high GHG facilities (both private and government owned), and general aid with capital turnover strategies
	Measures to improve material efficiency, including up-front reduction in material use in manufacturing or construction, but also longevity, reusability, and design for end-of-life disassembly for recycling. See "building codes" above.
	Measures to reduce end-use demand.
	Green Jobs training and retraining programmes.

It is generally agreed that many policy tools can have different levels of effectiveness depending on the stage of development and market share of the net-zero technology. As shown in Figure 1 there is a stronger need for "carrot" policies for emerging net-zero technologies that can pull industries towards net-zero earlier in the development (e.g., subsidies, incentives and tax credits), and more needs for "sticks" as technologies mature (e.g., carbon pricing or emissions trading).

Figure 1: Complementary Policies to increase the development and adoption of low-carbon technologies



Source: (Saha et al., D., R. Shrestha, and J. Feldmann, 2021)

The ultimate package of policy options to be implemented in Canada needs to consider the political constraints, geography, natural-resource endowment, industrial structure and government institutions that are particular to Canada. In order to identify specific policy options that are most appropriate for Canada, interviews were conducted with heavy industry stakeholders to identify opportunities and policy gaps. Interviews were conducted with IGUA member representatives of the chemical, oil and gas, mining, fertilizer and forest product industries, as well as external representatives of the electricity and natural gas energy suppliers. Collectively these interviews identified opportunities and critical barriers (financial, regulatory, institutional, planning) to maintaining competitiveness in Canada and achieving deep decarbonization by 2050 for their corresponding sectors. The interviews also revealed requirements for enabling infrastructure.

Figure 2 summarizes the three main areas of policy gaps and opportunities that were identified and maps them to the policy options identified in our literature review. The overarching policy consideration is that the combination of policy options, including carbon pricing and CBAs which is outside of the review, collectively provide each heavy industry sector a clear and equitable signal for achieving net-zero and maintaining competitiveness.

Figure 2: Main Policy Gaps and Opportunities Identified and Policy Options for Canada's Heavy Industry Sectors

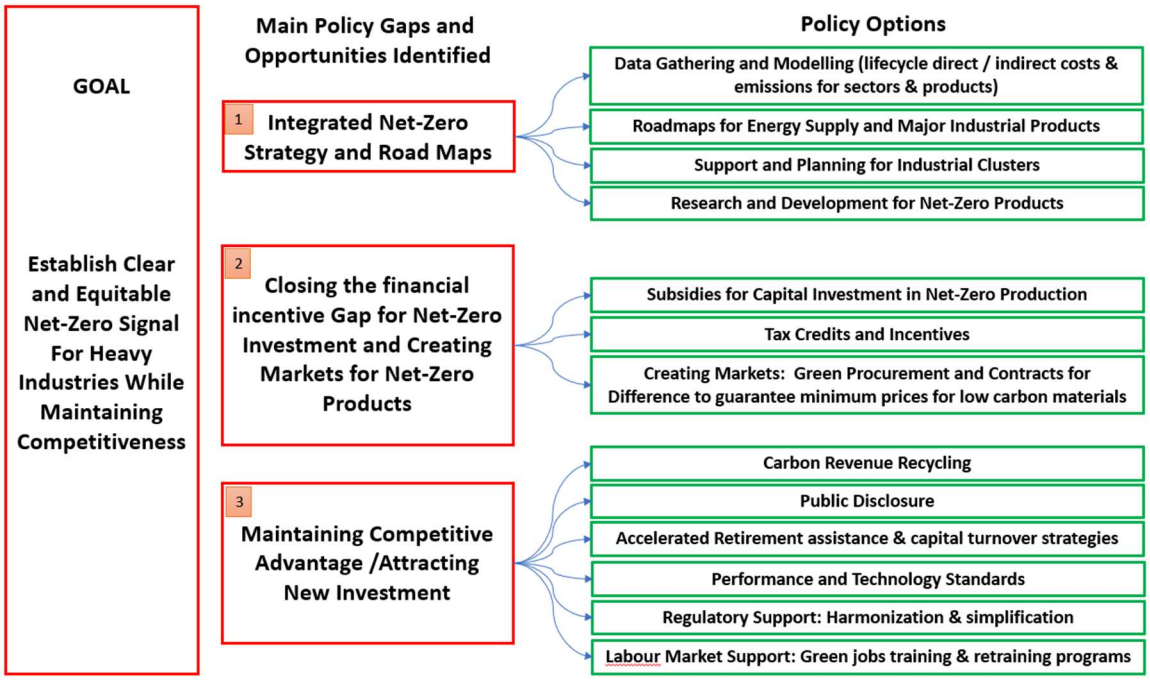


Figure 2 provides a structure for the review of policy options. First, we discuss some of the challenges of establishing a clear and equitable net-zero signal for heavy industry that can maintain competitiveness. Then we review each of the three main areas of policy gaps and opportunities and briefly outline the relevant policy options that can be implemented to address the gap or capitalize on the opportunity.

The review of policy options then informs a policy options framework that can be used to recommend a comprehensive package of polices that recognizes the opportunities and challenges for a specific heavy industry sector (See Section 4).

3.1 A Clear and Equitable Signal

One of the main challenges that government faces in developing net-zero policy is how to ensure that different sectors, companies and households all have an equitable incentive and burden to transition to net-zero. The net-zero transition implies many billions of dollars of costs and additional investments annually. Reports vary on what the transitional costs will be by sector and industry. McKinsey estimates that globally the net-zero transition implies an additional $9.2 trillion US dollars every year, equivalent to half of current global corporate profits (McKinsey, 2022). Specific estimates to consider the cost of the net-zero transition for heavy industry sectors in Canada has not been widely published or disaggregated in detail and are still poorly understood.

There is some limited opportunity for investment in heavy industry that can reduce emissions and costs and increase the potential for export revenue, but overall deep emission reductions are estimated to significantly increase overall average production costs from today, especially for production which does not have clear, already commercialized technology pathways to net-zero. The federal government has an important role in ensuring that costs for pathways to low carbon production are borne relatively equitably across the whole economy but also that we protect the competitiveness of products with high transitionary costs that are the building blocks of our economy.

Heavy industry is a particularly difficult sector for which to ensure a clear and equitable signal because their products are heavily traded on world markets. If we impose high carbon prices on these sectors to transition to emerging net-zero technologies, new investment is not likely to be directed to Canada, but moved offshore to global competitors, who aren't aligned with us on carbon markets. For this reason, border carbon adjustments (a.k.a., BCAs, CBAs, CBAM) are being examined as an important tool for the net zero transition to equalize carbon costs for heavy industry products across the globe.

However, CBAs have many challenges and will not be able to close the gap to make emerging net-zero technologies competitive in all sectors. There are numerous implementation challenges (e.g., equitable benchmarking of carbon policy costs and products, retaliatory or uncompetitive measures by trading partners, leakage through uncovered supply chains), and it is not likely that CBAs will be mature for more than a few sectors before 2030, leaving considerable policy gaps.

While Canada has announced one the highest long-term carbon prices ($170 per tonne CO_2e in 2030) of any jurisdiction in the world, this carbon price is likely inadequate to incentivize net-zero capital investment for many heavy industry products.

Unless the long-term average carbon costs imposed by carbon pricing are higher than the anticipated increased cost of net-zero production over existing production, companies are not likely to build new greenfield low carbon production facilities covering the bulk of their emissions unless there are additional incentives. This is the case today for many heavy industry products, which means for these products new net-zero production technology will be deployed in jurisdictions that have a long-term integrated strategy for reducing production costs or creating premium priced markets for net-zero products. Carbon pricing is not going to be enough, especially because of the significant differential in carbon pricing between trading partners. Ultimately this means that there is a financial incentive gap, where future market product prices are simply too low and uncertain to pull the trigger on net-zero investment without some guarantee of price support or additional incentive.

3.2 Integrated Decarbonisation Strategies for Heavy Industry Sectors

Globally there is an increased recognition that industrial decarbonization is a key pillar to transforming the societal economic model towards green/clean growth. There is also an acknowledgement that companies on their own, are not well positioned to consider the broader and economic benefits of coordinated action and that governments need to establish platforms for collaboration. Government will need to provide more certainty about the policy environment within which climate investments take place to effectively de-risk the necessary net-zero investment.

At a high level, the United Kingdom has developed a 10-point plan to prepare for a green industrial revolution (UK DBEIS, 2020). The European Green Deal promises a transformation to a modern, resource-efficient, and competitive economy (European Commission, 2021b). The United States has linked its climate action to job creation and economic growth (Aton, 2021). Canada has different federal initiatives, but not a detailed integrated plan with coordinated policies in provincial jurisdictions that can address critical research and development, market and institutional barriers. Investissement Québec is an example of a provincial economic development agency with a clear provincial strategy intended to drive low-carbon heavy industry.

In this section we briefly review evolving industrial strategies and plans in different countries that have emerged through years of dialogue and policy development between government, civil society, academia and industry. Five individual policy options are examined as part of an overall integrated decarbonization strategy package: data gathering and modelling, roadmaps for energy supply and products, planning for industrial clusters and research and development programs.

3.2.1 Data Gathering and Modelling

Integrated planning for net-zero heavy industry products requires foresight of both risks and opportunities. These risks and opportunities are not unique across sectors and products but are differentiated. To have an equitable understanding of the net cost burden of all policies, government regulators in Canada will need to expand their ability to model direct and indirect costs of emission reductions through the economy not just by sector but also by product. Governments and collaborators will need the following data for scenario modelling to inform the design of efficient, equitable and overlapping policies:

1. Net-zero technological readiness of sectors and products, and roughly what innovation and commercialization effort is need to bring the technology to market
2. Estimates of the short and long run costs of production (capital, fixed and variable operating) net of carbon pricing and other climate policies.

3. Lifecyle emission accounting for major products and opportunities for product circularity and use and material efficiency
4. Cost pass through of direct and indirect costs to upstream supply chains and consumers
5. Impacts of increased prices on trade, industries and consumer goods

Enhanced data and modelling will help to understand competitive risks and opportunities and also help investors as well as consumers make informed decisions. Specifically, modelling can be used to explore what packages of policies are able to provide the necessary transition to net-zero for different products and sectors without creating significant leakage and unequitable cost burdens within the economy.

3.2.2 Roadmaps for Energy Supply and Major Industrial Products

The international experience of creating roadmaps for decarbonizing industry began in earnest during the 2010s. The last decade has seen the both the EU and the UK pivot from a largely "hands off" regulatory management approach towards one that explicitly provides strategic direction and support to industry, as evidenced by the European Green Deal (European Commission, 2019) and the UK Clean Growth Strategy (BEIS, 2017). Within this new paradigm, industrial decarbonization is positioned as a key means of achieving not only environmental targets but also a broader range of societal and economic objectives. These include improving industrial competitiveness, job creation, export opportunities and the chance to support the regeneration of communities experiencing prolonged economic decline.

Key building blocks of the EU's Industrial Strategy include a focus on a more circular economy (European Commission, 2020), and to combine increased digitalization of the economy with decarbonization. In the EU's case, it appears that the COVID-19 pandemic has substantially delayed the necessary policy development of a detailed industrial decarbonization strategy roadmap (European Commission, 2021), particularly one that addresses the requirement to support a transformation for energy intensive industries. This is likely to be substantially explored in a forthcoming revision to the EU Industrial Emissions Directive (European Parliament, European Council, 2010) but is not available at the time of writing. The high-level approach however can be inferred from other EU documents and is likely to involve green public procurement, funding for testing and demonstration projects, infrastructure for clean energy use, and fuel switching (European Commission, 2019a).

The international experience to date has shown that decarbonisation of industry plans must be linked to having an economy wide electrification, hydrogen, and CCS roadmap or set of linked roadmaps, with sector roadmaps that consider these strategies. The

potential use of hydrogen and CCS also require consideration of spatial transport and storage requirements, with a focus on industrial clusters to minimize early infrastructure costs. These critical strategic roadmaps are urgently required and currently only at a nascent stage of development within Canada.

On electrification, Canada has announced its aim to make Canada's electricity grid net-zero by 2035 and approximately double production of electricity by 2050, but because electricity is a provincial jurisdiction unless it crosses a provincial or international border, there is no detailed or integrated federal roadmap. This is a significant gap in what is promoted as a clear and safe bet for industrial decarbonization. While the decline in costs of generation for renewables is promising and there are many proposed projects and developers, the principal barrier now is to connect these projects to our existing electricity transmission and distribution infrastructures, that are run by many disparate utilities that in most cases have limited capacity for rapid growth, technology adoption, investment and integrated regional planning. A roadmap to understand the infrastructure requirements and full cost of delivering electricity to all the projected new end-users (e.g., heat pumps, electric vehicles, new industrial processes) is critical.

Clean Energy Canada suggests using the proposed Pan Canadian Grid Council to bring together provinces, territories, indigenous nations, local governments, utilities, industry and the clean energy sector to define regional clean electricity pathways that can maximize reliability and affordability (Clean Energy Canada, 2021).

On hydrogen, Alberta has released a Hydrogen Roadmap that identifies an ambition to establish a clean hydrogen economy and to position itself as global supplier of clean hydrogen exports by 2030 (Alberta Ministry of Energy, 2021). The roadmap for hydrogen is still in the early stages of establishing policy foundations, closing technology gaps, and accelerating commercialization and deploying clean hydrogen into the most promising end-use markets. The second phase will shift to achieving scale through technology maturation and commercialization. Canada's federal hydrogen strategy provides a framework for action and promises to lay a foundation for the hydrogen economy in Canada (NRCan, 2020). This includes developing supply and regional hub distribution infrastructure to encourage early deployment. Long-term targets of 20 Mt/year of low carbon intensity hydrogen are set for the period 2030 to 2050.

On carbon capture and storage, Canada's first roadmap for CCS was published in 2006 (Natural Resources Canada, 2006) and anticipated that more than 40 $MtCO_2e$ would be injected per year by 2030. Globally today there are 27 facilities worldwide with a capacity to sequester 40 $MtCO_2e$ annually, with many more facilities planned or

announced. Early CCS projects have mostly focused on natural gas processing[1], but there are plans for applications in the fertilizer, chemical, power generation, bioethanol, steel and hydrogen sectors. Recent opposition to CCS & CCUS in Canada (MacLean, J., 2022) has centered around its failure to deliver a high capture rate at existing facilities (it has however met its design target at Quest and Weyburn, while Boundary Dam has been problematic) and the concern that subsidies for enhanced oil recovery divert resources for more cost effective and proven net-zero solutions.

There are currently no purely technological limitations blocking major decarbonization routes across any industrial sector (Rissman, J et al., 2020, Bataille, C. 2020). The barriers are political & economic and not technological; we have the technologies today, but they are more expensive than business as usual practise. Roadmaps for industrial products that show pathways to net-zero are available but have limitations in that they focus generally on technology, rather than the mix of appropriate policies necessary to overcome higher production costs, interlinked infrastructure requirements as well as supply chain and trade issues. The most GHG intensive products (Iron and Steel, Cement and Fertilizers) have numerous roadmaps led by global coalitions (GCCA, 2021, IEA, 2020). Specifically in Canada the Cement association has partnered with Innovation, Science and Economic Development to develop a roadmap to lead the way to net-zero carbon concrete by 2050 (Innovation, Science and Economic Development Canada, 2021).

Recommendations for Canadian Policymakers:

- Incremental planning based on short intervals will not produce long-term decarbonization, since heavy industry facilities built today will still be operational beyond 2050. Pathways must take a long-term perspective and prioritize early, deep, sustained, and technologically feasible reductions in every sector.
- The government should assess for each industry sector and set of products the necessary investment to 2050 to maintain or grow production to meet forecasts and understand when net-zero investments are required. These estimates should consider operational lifespans of existing facilities and ensure that all new investment with operational lifespans greater than 25-30 years should be net-zero or net-zero compatible (i.e., have the possibility of retrofitting to net-zero).
- All important heavy industry products that have Output Based Pricing System (OBPS) benchmarks should have a government and/or industry led net-zero roadmap. Products within an economic sector can be grouped together if they share similar risks and opportunities and net-zero technology pathways.

[1] Raw formation gas from underground deposits comes up with a varying amount of CO_2, usually much more than is allowable in a pipeline. This CO_2 is removed and generally released to atmosphere. It is one of the cheapest and easiest potential early applications for CCS.

- Roadmaps should identify the costs of emissions reductions opportunities and technologies and identify policies and research and development efforts, including capital and supply chain mobilization to make technologies commercially available in the medium and long term for each sector. Since heavy industries rely on competitive energy prices, roadmaps should consider forecasts of energy prices related to different decarbonisation pathways and requirements for energy infrastructure.
- Develop a national electricity roadmap that outlines how stakeholders can develop regional and local electricity transmission and distribution infrastructure that can meet the massive new demand for electricity that is projected, at a reasonable cost to rate payers.
- Roadmaps for CCS should prioritize sectors where there are limited options and consider full lifecycle emissions of products.
- Roadmaps should evaluate market readiness for new low carbon products and identify steps to overcome identified barriers.

3.2.3 Industrial Clusters

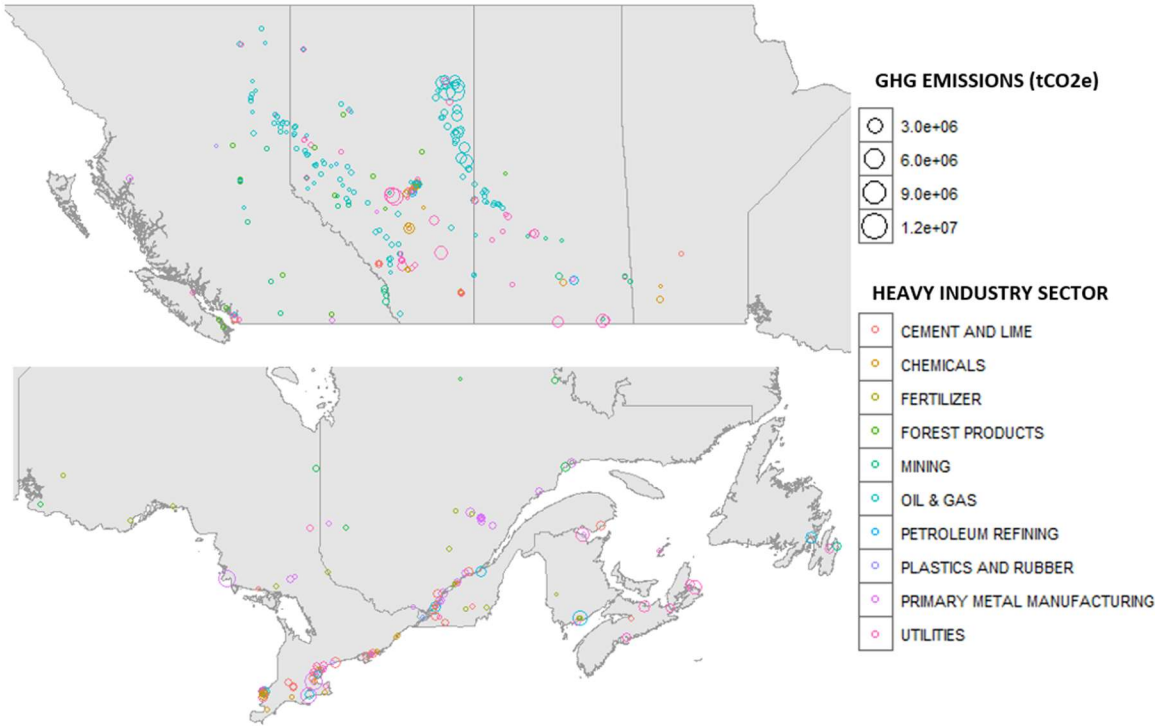
Decarbonisation of heavy industry is expected to involve the creation of low carbon industrial clusters for at least CCS and hydrogen production and storage, and broader visions include a heat sharing/cascading system to be exploited by small and medium enterprises using industrial heat pumps. Both the EU and UK place emphasis on the creation of low carbon industrial clusters, as detailed in the EU's Hydrogen Strategy [ref] and the EU's Energy System Integration Strategy (European Commission, 2020).

In the case of the UK, spatial analysis of industrial emissions shows that around 50% of the UK's emissions come from just six identifiable clusters. The UK government views this as an opportunity to share costs and risks of deploying CCS and hydrogen technologies amongst multiple industrial players, and it also ties into the broader social agenda of addressing regional inequalities by attracting inward investment to areas of the country where for example, household incomes and the condition of public infrastructure are below average.

Different countries are also implementing industrial clusters with circular industrial supply chains to maximize reuse of by-products such as heat and sludge and produce biogas and biomass fuel (Accenture, 2021). Other industrial clusters are implementing distributed clean energy microgrids that integrates renewable energy solutions including combined cooling, heating and power, wind power, solar, ground heat pumps and energy storage. The Suzhou Industrial Park in China for example has a renewable energy microgrid that is over 1 GWh in scale.

In Canada, there is a similar concentration of industrial facilities and emissions and five industrial clusters Fort McMurray, West Edmonton, Sarnia, Hamilton and Northeast Montreal account for 30% of Canada's industrial emissions.
Figure 3 provides a spatial distribution of industrial facilities in Canada that are larger than 60,000 tCO_2e.

Figure 3: Spatial Distribution of Heavy Industry Emissions in Canada 2019



Source: Data is from Canada's Greenhouse Gas Reporting Program 2019.

Recommendations for Canadian Policymakers:

- Governments can help to build working groups of representatives from all stakeholders (e.g., industrial partners, government, financiers and communities) to align on common goals and develop cluster-specific roadmaps to achieve net zero targets.
- Governments can assist in building commercial models for risk-sharing initiatives such as joint venture formation, public-private partnerships, long-term power purchase agreements (PPAs) and take-or pay agreements that accelerate implementation of roadmaps.
- Net-zero energy supply infrastructure will be central to successful industrial clusters and governments can help ensure that low-cost electricity for direct electrification, low cost renewable heat for processes, district waste heat

capture & sharing, and hydrogen infrastructure is planned and built. Additionally, where regional resources are available they can support infrastructure for carbon, capture, utilization and storage (CCUS).

- Government can help with prezoning & approval of premapped and approved areas for very low and net-zero emissions industry.

3.2.4 R&D Programs

Technological progress in low-carbon technologies is essential to achieving net-zero targets globally. Many technologies, such as carbon capture and storage, smart grids, and batteries to store intermittent renewable power are socially desirable but currently not financially attractive to private investors and at present, incentives for innovation are grossly insufficient. Significant increases in public support for research and development in low-carbon technologies are a viable policy option and evidence suggests that there is high public support for such policies.

In the United States the Infrastructure Investment and Jobs Act of 2021 includes significant support for clean hydrogen, advanced nuclear, direct carbon air capture and other technology demonstration projects and regional research hubs. The US Innovation and Competition Act boosts funding for research on key technology focus areas.

Strategies for deep decarbonization of heavy industry in Europe focus on government providing direct support for R&D on technologies that are not yet commercially viable but have considerable social benefits (Agora Energiewende, 2021). It is recognized that supporting the deployment of new technology promotes learning by doing that will benefit other firms adopting the technology later on as prices fall. It is also recognized that increased risk tolerance is required to meet net-zero targets and as a consequence some net-zero projects and research and development will not ultimately succeed, but that higher-risk, higher-reward bets on net-zero technologies is warranted to be an early market leader. Figure 5 identifies key technologies and their possible market readiness for some industry sectors.

Figure 4: Key Heavy Industry Technologies for Targeted Research and Development (Indicative and not meant to be exhaustive)

Overview of possible key technologies for a predominantly carbon-neutral basic industry — Table ES.1

Steel	Key technology	Earliest possible market readiness
	Direct reduction with hydrogen and smelting in the electric arc furnace	2025 – 2030 (phase-in with natural gas)
	Alcaline iron electrolysis	likely after 2050
	HIsarna® process in combination with CO_2 capture and storage	2035 – 2040
	CO_2 capture and utilisation of waste gases from integrated blast furnaces	2025 – 2030
Chemicals	**Key technology**	**Earliest possible market readiness**
	Heat and steam generation from power-to-heat	From 2020
	CO_2 capture at combined heat and power plants	2035 – 2045
	Green hydrogen from renewable energies	2025 – 2035
	Methanol-to-olefin/-aromatics-route	2025 – 2030
	Chemical recycling	2025 – 2030
	Electric steam crackers	2035 – 2045
Cement	**Key technology**	**Earliest possible market readiness**
	CO_2 capture with the oxyfuel process (CCS)	2025 – 2030
	CO_2 capture in combination with electrification of the high temperature heat at the calciner	2030 – 2035
	Alternative binders	2020 – 2030 (depending on product)

Agora Energiewende/Wuppertal Institute, 2019

Recommendations for Canadian Policymakers:

- Develop research and development programs for products where Canada has competitive advantage and where Technology Readiness Levels (TRL) pathways are less certain and/or less competitive globally.
- Support R&D activities of research institutions and academia and funded by private or public sector. These activities should aim at promoting breakthrough innovation that continuously advances the process of decarbonization and controls any risk of lock-in to solutions that may fail to contribute to total decarbonization in the long run.
- Government support should be phased out as low carbon technologies build market share and their costs evolve towards comparable to higher carbon versions including existing climate policy measures.

3.3 Closing the Financial Incentive Gap

Even with rising carbon prices and measures to balance global competitiveness such as CBAs, there is likely to be an insufficient signal over the next decade to incentivize low carbon production in heavy industry for many products (See Section 3.1). While governments can adjust performance standards that apply to large industrial emitters to raise average costs and the incentive to achieve reductions for existing production, total combined direct and indirect carbon costs are relevant when a firm weighs the decision of whether to build a facility in Canada or in another competing jurisdiction.

Both the EU and UK experiences emphasize the criticality of the 2020s as a decade for significant public spending on pilot projects, balancing incentives that encourage private investment with regulatory sticks (e.g., performance benchmarks, sunset clauses, program reviews, monitoring). In the UK the Industrial Decarbonisation Strategy (BEIS, 2021) is designed to align with the UK's net-zero and hydrogen strategies, and is backed by a direct funding commitment of GBP 12bn (CAD ~20bn), with the UK government hoping to create 250,000 jobs in low carbon industry by 2030. The broad outline of the strategy can be summarised as:

- **Carbon pricing and comprehensive competitiveness support:** Setting a net-zero aligned cap within the UK's Emissions Trading Scheme while also providing targeted relief and allowances for industries to overcome sector-specific barriers and to enable fuel switching to occur without loss of competitiveness or carbon leakage.
- **Demonstration and deployment funding:** ring-fenced funding for technology, infrastructure and business model development, particularly for Carbon Capture and Storage (CCS) and hydrogen projects, e.g. GBP 1bn (CAD ~1.7bn) for CCS projects from 2021-2030.

Facilitating access to low carbon finance needs to be an important part of Canada's decarbonisation strategy. While lenders and investors are becoming increasingly comfortable with zero-carbon finance (e.g., the Glasgow Financial Alliance brought together 160 financial firms with assets in excess of $70 trillion and who are committed to making the 2050 net-zero transition), government needs to understand where gaps in financing are likely to occur and where public financing is appropriate. Over the past five years a growing number of central banks have been exploring their role in confronting the climate crisis and enabling net-zero (Robins N. et al., 2021).

Recommendations for Canadian Policymakers:

- Canada should explore the role of banking to provide low-cost financing for net-zero compatible projects and to measure the financial risks stemming from climate change for all new projects.

3.3.1 Subsidies for Capital Investment in Net-Zero Production

Targeted financial supports through programs such as the federal Net Zero Accelerator or Investissement Québec may be the most efficient way to provide support for large industrial projects that face barriers to private investment. Such programs offer greater flexibility to evaluate the specific considerations relevant to a given project. Interaction with project proponents also provides the potential for program administrators to encourage cross-company collaboration and support first of-their-kind commercial-scale technology deployments that may not be envisioned today.

Canada has already demonstrated a willingness to fund capital investment in net-zero heavy industry production. The Strategic Innovation Fund and Net Zero Accelerator supports large-scale, transformative projects that promote long-term competitiveness and clean growth of Canadian industries (Innovation, Science and Economic Development Canada, 2021). In 2021 the fund announced $800 million for two iron and steel projects to transition them to net-zero compatible pathways. Together the projects are expected to reduce GHG emission by up to 6 million tonnes per year. While, the total capital investment is expected to decrease the near term emission intensity of iron and steel production by more than half, it should be noted that it is only net-zero compatible (setting these secondarsy steel production facilities up for a transition to renewable hydrogen DRI supplementation in the future). Based on a thirty year operating lifespan of direct reduced iron-fed electric arc furnaces, the subsidy amounts to an expected impact in the order of $\$10/tCO_2e$ reduced when compared to a standard blast and basic oxygen furnace. One should note that this level of subsidy was provided to a heavy industry sector with relatively clear and available technological options (high technological readiness and relatively low costs of abatement). The level of subsidy also doesn't consider expected baseline improvements in average emission intensity for the sector. Even a modest 2% per year improvement in emission intensity increases the subsidy to $18/tCO2e over 30 years. For sectors with lower technological readiness and with higher costs and greater uncertainty, it is clear that government should be prepared to fund pilot plants and production with likely much higher per tonne subsidy levels.

Recommendations for Canadian Policymakers:

- Governments should identify a means to equitable incentive rates of different industrial products in Canada with significant technological and financial barriers. The overall level of incentive/subsidy should be dynamically linked and change in time relative to emission reduction potential, technological readiness and the cost premium above market prices.

- Policies that use subsidies should be orientated to activities with export and growth potential that face barriers to private investment. Existing fossil fuel energy subsidies should be shifted to subsidies for emission intensive production of clean energy and low emission intensive production. These clean innovation subsidies could be effective at maintaining key competitive advantages in Canada (e.g., low cost energy supply) as well as helping reduce global emissions through technology spillovers.
- Subsidies for emerging low carbon technologies should apply equitably across sectors. For example, electric vehicle incentives are popular in Canada for passenger cars and are justifiable while EVs remain more expensive than incumbent internal combustion vehicles. Similar EV Incentives by the same token should also be available to industry (e.g., mining vehicles).

3.3.2 Tax Credits

Tax credits for a range-of low-carbon technologiess, combined with government investment in climate-smart infrastructure, can improve the adoption of net-zero technologies (Saha et al. 2021). Tax credits have been shown to be particularly successful for supporting early-stage deployment of emerging technologies that have not yet reached widespread deployment. In general, they should be technology-neutral, performance-based rather than investment-based, refundable, equitable—that is, accessible to all —and contain clear phaseout criteria based on achieving market penetration or emissions-reduction goals (Saha et al. 2021).

Emerging industries and technologies that are in the “pre cost-competitive” phase (almost all of Canadian industrial sectors with possible exception of iron and steel) require strong supply-side incentives to deploy initial capacity, scale up production, and reduce per-unit costs through economies of scale (Saha et al. 2021). Tax policy may need to incentivize both demand and supply for emerging clean technologies. Compared to demand-side tax credits, supply-side incentives such as a manufacturer tax credit could better accelerate the adoption of emerging industrial production technologies. A manufacturer tax credit lowers prices at the time of sale, whereas a consumer tax credit requires buyers to claim the credit when filing their taxes. Manufacturer credits, because they generally reduce the wholesale price of products, will also often reduce markups added at subsequent stages in the supply chain.

United States tax credits like the federal production tax credit and the investment tax credit have helped drive down the cost of wind and solar energy and electric vehicles (Saha et al., 2021). However, they have also suffered from some critical design deficiencies that make them less effective. Government credits can be caught in a cycle

of expirations and extensions (sometimes retroactively), that can create uncertainty and discourage long-term planning.

To create jobs and support the growth of clean technology manufacturing in Canada, Budget 2021 proposed to reduce — by half — the general corporate and small business income tax rates for businesses that manufacture zero-emission technologies. These technologies include solar, wind, hydro, geothermal, ground source heat pumps, energy storage, green hydrogen, zero-emission vehicles and fuels from waste.

Since 2018 there has also been an accelerated capital cost allowance for clean energy equipment for a broad range of low carbon equipment.

Recommendations for Canadian Policymakers:

- Tax incentives need to be periodically reviewed to ensure that eligibility and duration keep pace with rapidly changing technologies and markets.
- Tax incentives should be phased out once a technology has reached a sufficient level of market penetration.
- Tax incentives should be where possible technology-neutral (apply to all net-zero technologies) and long-term to help with long-term capital investment planning.

3.3.3 Green Procurement and "Smart Subsidies" through Contracts for Difference

There are several ways that policymakers may be able to help create industrial product demand and price supports that can help to reduce new production investment risk and the financial incentive gap between existing production and net-zero production. Demand support can initially come from green procurement strategies, whether they are government or private industry purchasers of industrial products.

Public green procurement policies recognize that governments are often significant buyers of industrial products (e.g. for construction or defense projects), and that they can play a role stimulating demand for low carbon products, helping to achieve economies of scale and drive down costs for the whole economy and opening the door for wider market development. The European Union has a well-established set of guidelines for Green Public Procurement (GPP) and how this translates from the EU to individual Member States. Currently EU Green Public Procurement covers a variety of sectors, notably road transport and buildings (European Commission, 2016), but has yet to extend to cover heavy industry. It is clear that the EU is exploring this angle and that Green Public Procurement for industrial products are under active consideration, as evidenced by the recent agreement with the United States to create a joint EU-US market for green steel and green aluminum trade (European Commission, 2021a). The EU also has a clear

aspiration to make “sustainable” consumer products the norm rather than the exception (European Commission, 2020), although how these are to be defined and the policy implementation detail at the EU and Member State level remains at the early stages of development.

The UK is at the early stage of developing green public procurement guidelines specifically for industrial products, with the UK Industrial Decarbonisation Strategy (European Commission, 2021a) aiming to have firm definitions for what constitutes a “low carbon product” completed in 2023 with a view to implementing a clear labelling system for industrial buyers and end-use consumers in 2025. The UK government has left the door open for industry to propose voluntary standards but has also left the option of setting mandatory standards on the table. Key elements of the UK strategy are to develop streamlined standards for certification and labelling, that reflect embodied energy, emissions or other measures of environmental impact in a way that is clearly understandable by industrial buyers and end-use consumers, alongside a broader diplomatic push to creating international markets and reciprocal recognition of low carbon products for export.

Key examples of private green procurement have been Volvo’s commitment to buy green steel from the Hybrit green hydrogen DRI project, and BMW & Mercedes’ commitments to buying from other low GHG steel projects. Responsible Steel is working with UK & EU architectural and construction firms to establish a standard by which they can guide their steel purchasing decisions.

Government can also engage in dynamic, “smart” subsidization through contracts for difference for public or private procurement. Contracts for difference (CfD) are a financial instrument that is based on the paying the difference between the current market price and a previously determined contract price. They give investors the confidence and certainty they need to invest in net-zero production. They can be awarded in a reverse auction to allow price discovery, limit government’s maximum financial exposure, and are only paid if the market price is lower than the contracted strike price.

Germany is using a pilot program for its steel and chemical industrials that offers carbon “contracts for difference” that guarantee investors a fixed and predictable carbon price (LeadIt, 2021). The program is intended for risky net-zero technologies that have not been tested at scale and which have CO_2e abatement costs well above foreseeable carbon costs. Companies receive projected related operating subsidies for a fixed period (e.g., 10-20 years). The operating grants are determined based on the difference between the average carbon price and the price determined by the auction (usually the actual CO_2 abatement costs for the industry product). The amount of subsidy provided is determined through auction. This subsidy would be additional to the carbon credits they would receive under the EU ETS system. After evaluating this pilot phase, tenders that are open to all types of technology should be launched for all energy intensive sectors. To cover

costs associated with the CfD, the German government has proposed introducing a climate surcharge on the end products (e.g., steel, cement, plastics).

Recommendations for Canadian Policymakers:

- The government (and public-sector companies) are a large consumer of basic materials through construction activities (especially for infrastructure development). Mandatory green public procurement could create reliable outlet markets for sustainably produced materials (e.g. steel, cement and wood) and sustainably manufactured consumer products (e.g. vehicles). Canada has already publically committed to green public procurement through the UNIDO Industrial Deep Decarbonization Initiative (IDDI)[2].

- If green public procurement is to be part of a wider industrial decarbonisation strategy, Canada will need to develop transparent methods of collecting data on products to enable environment assessment, certification and labelling

- Sustainability has many dimensions. The UK approach appears to be steering industry in the direction of understanding the GHG content of industrial and consumer products, whereas the EU approach is much more focused on enabling mass consumption of products that are reusable, repairable and recyclable and do not become waste. Canada will need to develop its own national approach and strategy, either to align with other top level policy directives from Federal or Provincial governments or to take advantage of standards required for international trade in low carbon products.

3.4 Supporting Competitive Advantage and Attracting Net-Zero Investment

Canada and its provincial and territorial jurisdictions have many competitive advantages for heavy industry production. It is rich in energy and material resources, with relatively low cost clean energy and material inputs of most types, access to geology for CCS, and a stable financial system that can play a pivotal role in financing Canada's transition. International exports and foreign direct investment are critical to Canada's economy, with the total stock of foreign direct investment in Canada surpassing $1 trillion in 2019 (Statistics Canada, 2021). This trade and investment activity is essential to millions of well-paying jobs for Canadians and generates tax revenues to support our health care, education, infrastructure, and social services.

[2] https://www.unido.org/news/worlds-largest-steel-and-concrete-buyers-make-game-changing-push-greener-solutions

3.4.1 Carbon Revenue Recycling

Revenues from carbon pricing in Canada (i.e., carbon levy on fuels as well as carbon payments by EITE under OBPS or provincial equivalents), were estimated to be nearly $10 billion in 2020 (ECCC, 2021). With the rising carbon price these revenues will increase significantly in the future. The fuel levy revenue comprises most of this revenue and is 90% rebated directly to household through income taxes or direct payments (~90%), and around 10% is directed to climate change programs for light manufacturing, commercial and institutional businesses. The EITE carbon revenue is primarily recycled back to programs that drive down emissions for industrial emissions in each province. However, the accountability of the recycling of this revenue and equity around its distribution is variable. Revenue recycling very likely disproportionately subsidizes net-zero technology and infrastructure for different industries. Industries that are closest to having solutions and in-hand proposals for greenhouse gas emission reduction projects, are likely to gain almost all of the revenue, while harder to abate industry sectors that don't have readily available technologies may receive very little support.

Recommendations for Canadian policymakers:

- Governments that control carbon revenue recycling should set the objective and work to ensure that revenues are distributed to all of their contributing industries in an equitable manner overtime. Equity here could be defined as providing a roughly similar price incentive per unit of emission reduction for different products as well as recognizing where different industries are in their net-zero transition and their relative cost to achieve reductions. For example, it may be necessary to fund research and development and pilot plants for sectors without commercial net-zero technologies, versus subsidies for production in more mature sectors. Funds and programs that recycle carbon revenue to industry should also work to reduce the burden of onerous application requirements and funding conditions. These barriers can easily contribute to worthwhile projects not moving forward or advantage some firms with more resources.

3.4.2 Public Disclosure

Markets can only allocate resources efficiently if market participants are informed about the risks and potential returns of any given asset. Climate risk disclosures – pertaining to both physical and transition risks – are thus essential to ensuring efficient incentives for climate mitigation and adaptation. For example, investors seeking to reward firms for advanced technologies and lower carbon footprints need access to comparable, high quality measures of such investments. Disclosure of GHG emissions by corporate and financial institutions ensures a transparent basis for assessing these risks.

There is growing momentum across several G20 economies to develop harmonized

climate risk disclosure frameworks. Governments in the European Union, the United Kingdom, and New Zealand, for example, have made climate-related reporting mandatory. Canadian publicly traded companies may be falling behind international peers on GHG disclosure (Arnold J., 2021).

Recommendations for Canadian Policymakers:

- Canada needs a more coordinated and strategic approach to address disclosure gaps. Requirements could be linked to the existing facility-level federal Greenhouse Gas Reporting Program, but with company-specific information packaged in a more accessible and comparable format for investors (ECCC, 2021). This would help institutions that invest in both public and private companies make informed decisions.
- The proliferation of financial products with varying labels such as ESG, sustainable, and green requires oversight. Work by the CFA Institute on ESG standards is a helpful starting point for voluntary action to improve market transparency. Standards may eventually need to be regulated by provincial securities commissions to protect investors.
- The federal government should weigh in with labelling guidelines and criteria that better align with climate, environmental, economic, and social policy objectives.

3.4.3 Accelerated Retirement and Capital Turnover

Orderly phasing out of high emission production where net-zero alternative production exists. Phase outs require that a plant-by-plant consideration be conducted to avoid costly early retirement and stranded assets.

Carbon retirement portfolios (CRPs) could be a potential solution to managing these risks (WEF, 2021). A CRP would buy a collection of carbon-emitting assets with the commitment to retire them more quickly than their business-as-usual case and with incentives in place to lower GHG emissions while the assets are operating.

Recommendations for Canadian Policymakers:

- Modelling should be conducted to determine what industrial products and facilities are at risk of accelerated retirement
- Communities with disproportionately high vulnerability should also be identified

3.4.4 Performance and Technology Standards

Industrial production benchmarks are already enshrined in the federal OBPS, but performance and technology standards could be introduced in other areas such as downstream supply chain products or in production equipment to drive additional incentives for emission reductions. For example, minimum efficiency standards for industrial machinery and process standards to facilitate the phasing out of high emissions practices where affordable alternatives are available.

Standards for recyclable products could also be introduced where basic industrial materials have low recycling rate. There are various underlying causes of this, including impurities (e.g., copper in the case of steel) or a high proportion of composites (in the case of plastics). Most plastic products are incinerated, and impure steel is currently downcycled (i.e., post recycling use restricted to certain applications). Product design standards should be introduced that make it easier and cheaper to recycle product components at high volume and quality levels. Vehicle manufacturers in particular should be required to design vehicles so that is easy to remove recyclable electronics, copper wiring, plastics, glass and other materials; to not reinvent the regulatory wheel, Canadian governments could adopt Canadianized version of EU standards, as we do for Californian/US energy efficiency and GHG standards. Over the long term, there should be a strategic plan to close material loops and create circular economies.

For investors, reliable outlet markets are crucial for the planning of production plants, which have long operating lifecycles. Section 3.3.3 discusses contracts for difference and green procurement strategies for developing markets for low-carbon material, but in addition quotas or content standards could also be an appropriate instrument. For example, manufacturers of certain products (e.g. vehicles) would be obliged to purchase a fixed percentage of used or recycled materials (e.g. steel and plastics) from green production plants in order to sell the product in Canada.

3.4.5 Regulatory Support

Effectiveness of regulations and standards relies on providing clarity. Firms rely on meaningful information on regulations and standards to predict their costs and impacts. This requires a consistent, timely, predictable system of laws, policies, regulations and administrative practices as well as information on rulings and judicial decisions (World Bank, 2021).

Figure 5 provides an example of WorldBank indicators of the Business and Investment climate in Canada.

Figure 5: Examples of Indicators to Assess Business and Investment Competitiveness

Source: World Bank (2021).

Recommendations for Canadian Policymakers:

- Streamlining the regulatory process for net-zero projects is essential given the timeframe required for action. Planning approval must be granted quickly and this will require adjusting permitting rules and associated review and appeal procedures. A coordinated effort within government to fast track net-zero and especially associated clean electricity supply projects may be required.
- Navigating climate policy for a company engaged in heavy industry in Canada is complex and becoming even more complex all the time. There are many different layers of provincial and federal climate and tax policies and support programs at different stages of deployment and development. Having a designated heavy industry policy support group with representation for all important sectors would help companies navigate and align their plans with federal and provincial policies.

3.4.6 Labour Market Support

The next thirty years will see many new green jobs emerge while some traditional roles will change or decline. There is an urgent need to study this changing demand for skills as even if green employment options are plentiful the shift into new occupations may have high structural adjustment costs (NationalGrid UK, 2020). US studies have shown that so far the lion's share of green employment is highly skilled jobs requiring high levels of formal education, work experience and training (e.g., heat pump installers). Skill gaps and shortages are already recognized as a major bottleneck in a number of sectors such as renewable energy, energy and resource efficiency, renovation of buildings, construction, environmental services and manufacturing.

The United States has developed a career pathways framework for green jobs that provides a series of connected training opportunities, aligned with industry credentials, that combine traditional college training and short-term term modular training (Palamar, M., Pasolli, K., 2018). This allows workers to enter training at different points in their careers and creates wider access, as workers can gain access at multiple entry points at different points in time. The program also provides support services to encourage retention, completion, improve transferability across sectors and enhance the ability to successfully relocate as needed.

Addressing emerging skill gaps proactively is an important step in supporting the net-zero transition and can remove potential bottlenecks, enhance productivity, open up new opportunities and ensure a smooth transition for workers (UK Green Jobs Task Force, 2020).

Recommendations for Canadian Policymakers:

- Government should publish a clear long-term net-zero strategy that signals how and where market demand will be generated and what skills and training are needed to match this vision. This includes studying changing demand for employment and skills.
- Government and education providers should ensure that educators at all levels have the expertise, curriculum and resources to teach climate change and the knowledge and skills in STEM and other key subjects necessary for the net-zero transition.
- Industry and the education sector should collaborate to build lasting relationships dedicated to drawing industry talent, inspiring students and maximizing net-zero career opportunities. For tertiary education masters and doctorate level studies should be aligned to net-zero careers and underpin R&D needs.

- Governments should develop programs for re-training, that are accessible, tailored and flexible and align with vulnerable workers. These programs should have modular qualifications, free standing short courses and options for non-continuous study recognizing prior achievement.
- Sector industry bodies should bring together large and small employers to develop skill development strategies for the sector transition.
- Governments should work with local government, employers and workers to diversify and support local economies that are vulnerable and disproportionately impacted by the transition away from carbon-intensive activities.

4 Policy Options Framework

The policy options review identifies instruments and tools that could be leveraged by stakeholders to achieve an orderly and equitable transition to net-zero by 2050 and exploit the opportunity for Canada to be a world leading exporter and producer of low carbon products and technologies in heavy industry.

The question now becomes one of implementation. For a specific sector or product, how can we develop a comprehensive package of policies to capitalize on this opportunity and address significant barriers and requirements, while not negatively impacting competitiveness and also reward consistent actions towards achieving net-zero?

In this section we develop a policy options framework that can be employed to answer this question for any given sector. The framework uses the following high-level steps that are similar to the structure used to develop the policy options review:

1. **Develop An Integrated Net-Zero Baseline and Understanding of Challenges and Opportunities**: Identify the current barriers, requirements and opportunities for the sector or group of products of concern including potential pathways to net-zero.
2. **Close the Financial Incentive Gap**: Understand and estimate the financial incentive gap between (a) the baseline costs of production under all existing policies and (b) the costs of production for equivalent net-zero compliant products. Link the financial incentive gap to policies that can be employed to close this gap.
3. **Maintain Competitiveness**: Identify how various policies could be used to support long run (i.e. innovation & investment) and short run (i.e. operating cost) competitiveness for the sector and products and how they could be effectively implemented.

In addition to these analytical steps we recommend that the policy framework also include a final stage of "ground-truthing" with stakeholders including IGUA members and network as well as government officials. We expand on each of these high-level steps in the following sub-sections.

4.1 Develop Integrated Net-Zero Baseline and Understanding of Opportunity

For a specific sector or group of products we would assess the current competitiveness and baseline of production in Canada and consider opportunities to transition the sector to net-zero by 2050. The steps to complete this analysis are as follows:

1. **Gather Baseline Data**: An analysis of competitiveness requires gathering data on emissions, production, emission intensity and market prices. This data would need to be facility specific (e.g. age, size and location) to understand how costs and production are distributed in Canada. Estimates of the costs of production will need to be generated. This includes unit CAPEX, fixed OPEX, variable OPEX costs, as well as gross revenues. It also includes undertaking a review of what producers have announced in terms of climate related commitments, actions and investment in Canada.
2. **Baseline Setting**: To look into the future, it is necessary to understand what are likely to be the actions of producers. Under existing policies and carbon prices what is the likely abatement response in time and opportunities for cost effective emission reductions? What are indirect and direct carbon costs for the sector and what is their ability to pass on these costs to their consumers, with resulting impacts to competitiveness? Metrics such as comparing carbon costs to sales (revenue) would be developed to compare sectors and products.
3. **Net-Zero Production Opportunities**: For the sector and group of products under review, what are the current net zero technology options available (e.g., the TRL rating of possible production technologies)? What is the maturity and state of research and development globally and in Canada? What is the expected developmental progress of these technologies and forecast of unit production costs? What are the barriers and requirements to implementation?
4. **Pathways to Net-Zero**: Considering existing production and competitiveness opportunities in Canada and industrial clusters, identify opportunity pathways to transition to net-zero. Analysis would include estimating broad ranges of total costs of net-zero production in the 2050 time horizon, including forecasting future renewable and non-renewable energy prices and infrastructure.

4.2 Close the Financial Incentive Gap

Between the baseline and the net-zero pathway scenarios identified in the integrated net-zero strategy for the sector or group of products, there is likely to be a difference or gap between the market price for the product and the cost of production for net-zero products in any given time period. Market prices for products are unlikely to be sufficiently high for firms to invest in net-zero production on a cost basis alone, even if they are rising in time to reflect global climate policy stringency and even if border carbon adjustments (BCAs) are introduced in an attempt to levelize carbon costs of production with trading partners. In this section we estimate what this gap may look like and what policies could be employed to close the gap for a particular product or group of products. The steps to complete this analysis are as follows:

1. **Forecasting the Gap**: Using the baseline developed and the production costs for net-zero developed in Section 4.1, it is possible to estimate the difference between future market prices and different costs of production over time.
2. **Identifying Policy Options and Design**: How do we provide roughly equal support to sectors? How do we determine this? Different financial incentive mechanisms can be compared based on how they could potentially close the gap above equitably (between sectors) to achieve net-zero while remaining competitive and harnessing opportunities. The analysis would include a qualitative discussion of implementation considerations. The policies include but are not limited to targeted R&D, green procurement, and "smart" subsidies, e.g. using contracts for difference linked to policy stringency and the net-zero goal instead of fixed lump subsidies.

4.3 Maintaining Competitiveness

In the policy options review, six groups of policy options were identified that could help to maintain competitiveness for heavy industry in Canada:

1. Climate Policy Revenue Recycling
2. Public Disclosure
3. Accelerated Retirement and Capital Turnover
4. Performance and Technology Standards
5. Regulatory Support
6. Labour Market Support

In this section we would review these categories to identify how different policy options could be implemented in the sector of interest to help with competitiveness and harness competitive advantages. The analysis would include qualitative descriptions of the policy goals, timing, resources and actors.

5 Recommendations for Further Work

- Identify and assess 1-4 sectors (products or group of products). The outcome would be an integrated package of policies that could deliver a net-zero future for the sectors of interest with supporting quantitative and qualitative analysis and recommendations.
- The cost range of the sector assessment is expected to be in the range of $15k to $25k per sector depending on the complexity of the sector and products and depending on the number of sectors. A detailed cost proposal, which has fixed and variable costs elements, can be made once a package of sectors is identified by IGUA.
- Canada's 2030 emission reduction plan was recently published. A useful piece of future work in this context would be to compare the policy options discussed in this study and assess for likely gaps/omissions and strengths as they relate to heavy industry.
- For maximum policy effectiveness, we suggest that at least an informal stakeholder consultation phase be held, reflecting input from this Phase I work. Potentially this could target having conversations with relevant government officials using Chris Bataille, Seton Stiebert and IGUA's network. These conversations would provide an opportunity to "ground truths" our general findings with these stakeholders, especially those who have been exposed to IGUA's earlier collaboration with Chris and Seton in 2017, 2018.

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