December 19th, 2022

Leveraging Contracts for Difference for Heavy Industry Deep Decarbonisation

Report Prepared for CAC

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1 Executive summary

Investments to build new net-zero GHG emissions production facilities and to transition Canada's industrial base to net-zero have barely begun, and there are now less than 30 years before net-zero CO_2 emissions needs to be largely achieved. While there is a high degree of uncertainty over what heavy industry sectors will look like in Canada by 2050, there is little uncertainty that their products (e.g., steel, cement, chemicals, glass, masonry) will be required, and demand will grow overall. Carbon price uncertainty is a real problem but even if we assume full implementation of announced carbon pricing and complementary policies to protect Emission Intensive Trade Exposed (EITE) sectors and their global competitiveness, such as the Clean Fuel Standard (CFS) and Carbon Border Adjustments (CBAs), **these signals aren't strong enough to incentivize "first-of-a-kind" and early ultra-low-carbon production in heavy industry.** This issue was well recognized in the Department of Finance Canada Growth Fund technical backgrounder[1] that accompanied the 2022 Fall Economic Statement[2].

Large-scale first-of-kind low-carbon projects for the highest emitting industrial products must be built and demonstrated over the next decade to allow all new projects to be low emitting by the early 2030s, otherwise 2050 net-zero targets will not be achieved. **Canada will either participate in the race for global decarbonisation and attract the necessary investments or govern over a declining heavy industry base and rely on trade to import low-carbon industrial products.** While initial costs to build first-of-kind plants are risky, uncertain, and normally unprofitable without contracted "off-take" agreements with consumers, economies of scale and learning could position Canada as a competitive producer and exporter of low-carbon goods and technology globally. This paper identifies how targeted support over the next crucial decade using Contracts-for-difference (CfDs) as a tool could help revitalize Canada's heavy industry sectors and prepare them for the coming low-carbon global economy.

Contracts for difference (CfDs) are a financial tool derived from the options market that have been applied in several jurisdictions with substantial success in increasing market uptake of clean electricity technologies. In these situations, they are used to guarantee a minimum price derived through reverse auctions. If the market price for electricity is lower, the electricity authority pays a minimum price or "top-up" based on the agreed strike price. If it is higher, the electricity authority gets to keep the extra amount to help fund the program. This analysis, combined with financial modelling of a case study carbon neutral cement plant, describes how CfDs can be used

[1] https://www.budget.gc.ca/fes-eea/2022/doc/gf-fc-en.html

[2] https://www.budget.gc.ca/fes-eea/2022/home-accueil-en.html

in Canada as a policy instrument to reduce the production incentive gap, i.e., the additional risks and costs associated with new very low emissions industrial processes over and above announced carbon pricing or other climate policy. Our focus in this paper is CfDs for early, transformative projects that are too risky or unprofitable to pursue with anticipated policies and carbon pricing. While ultimate mitigation costs to decarbonize heavy industry basic materials are expected to be in the rough range of $70-$200 per tonne of CO_2e reduced (IPCC, 2022), very low to zero-emission technologies will require 5-15 years of intensive innovation, commercialization and policy at even higher costs to ensure uptake. In other words, these are projects characterized by new technologies, steep learning curves, and inherently risky investments that are likely to need an incentive greater than existing policies to become "investable" or "bankable". CfDs designed to close this production incentive gap for these first-of-kind projects can help to accelerate capital and technology deployment and lower the costs for subsequent generations of projects. However, in Canada with the announced federal carbon price schedule that is set to rise to $170 per tonne of CO_2e by 2030 (with no adjustments for inflation), there is some debate about whether a back-stop to this policy is necessary to make first-of-kind projects that can take 5-10 years from inception to operation bankable. As a result, this paper also needs to address the linked problem of **carbon price uncertainty,** where CfDs have also been recently proposed as a solution.

To address **carbon price uncertainty (as distinct from "investability/bankability")**, a subset of CfDs have been proposed called carbon contracts for difference (CCfD) that are intended to provide industrial facility proponents with carbon price insurance, such that if they make low-carbon investments, their emission reductions below a baseline will be valued near the scheduled carbon price. CCfDs in this context are more like a policy backstop as opposed to traditional CfDs that are a public-private risk sharing mechanism to hedge the future market value of production. **A key thing to note, however, is that Canada could have a high scheduled carbon reference price, but for most industrial projects it is the market credit price applicable to their jurisdiction (i.e., what they can sell credits for) that is relevant for their business case.** If the supply of these credits and offsets is not sufficiently limited, e.g., by insufficient tightening of the TIER or OBPS benchmarks, large ultra-low emissions facilities could flood the local market with compliance credits, and this oversupply could crash the market price and devalue the credits. To address this and maintain CCfD value, the "strike price" of a CCfD with an industrial facility or firm, which determines the support to be given, should therefore not be based on the federal schedule price, but on the average market value of credits for the governing carbon pricing system. Finally, to address this carbon credit price **uncertainty**, these forms of CCfDs should be designed as long-term insurance for all product producers and consequently should have broad eligibility**.**

To close the **production incentive gap and make "first-of a-kind" projects investable,** we focus in this paper on a CfD that is designed to ensure the market value of production, a Product

Contract for Difference (PCfD), similar to what Germany and the EU more broadly are actively soliciting. The transformative social justification for a PCfD is highest for the first application of a new process in each situation and sector, slightly lower for the following 2-3 plants to prove replicability in different circumstances, and then falls to the stringency of announced policy, which is when the carbon price uncertainty element should apply. Production incentive gap CfDs should be restricted to production process applications that are at the scale-up stage and have achieved Technology Readiness Levels (TRL) of 7-9. This indicates that there may be 1-2 "breakthrough" plants for each major sector (e.g., steel, cement, various chemicals, synthetic fuels, fertilizers, glass and ceramics, etc.), and a couple more that need incentive gap CfDs for each sector over and above existing carbon policies. This would indicate a total of 5-10 breakthrough plants, and 15-30 plants that are less risky but still with costs higher than the carbon price schedule and a long-term social justification. This contrasts with the carbon price uncertainty CCfDs, which could cover 100s of plants.

PCfDs should be viewed as a conditional volume and time-based subsidy to address the extra costs and risks associated with first-of-kind projects that promise to reduce the cost of new technologies and open up new export markets. They should also have a much narrower eligibility based on competition and demonstrated potential of long-term benefits that accelerate and enable a successful net-zero transition, possibly as part of Canada's contribution to global industrial decarbonization. The eligibility should also consider potential additional costs for infrastructure to support the project and direct contributions to the project from other sources, such as from the provinces and their respective investment supports. Any calculations of a CfD should consider that public funding and incentives may be stacked and that these need to be accounted for when setting strike prices.

Our financial modelling of a carbon-neutral cement plant (95% CCS with some biomass fuel input) in Figure **1** provides an analysis of the average internal rate of return (IRR) with respect to either a CCfD based on the value of emission reductions or a PCfD based on the value of cement .[3] In the central case, the project is unprofitable if emission reductions are not worth more than \$137/tCO_2e *on average*. The central case modelling assumes that there is an additional investment tax credit for CCS that is worth \$31/tCO_2e reduced. If the government agrees that the project investment is a first-of-kind project likely to contribute significantly to Canada's net-zero goal (as per the Clean Growth Fund mandate[4]) and lower the future costs for subsequent low-carbon projects globally, then it could offer a separate (or combined higher) incentive gap strike

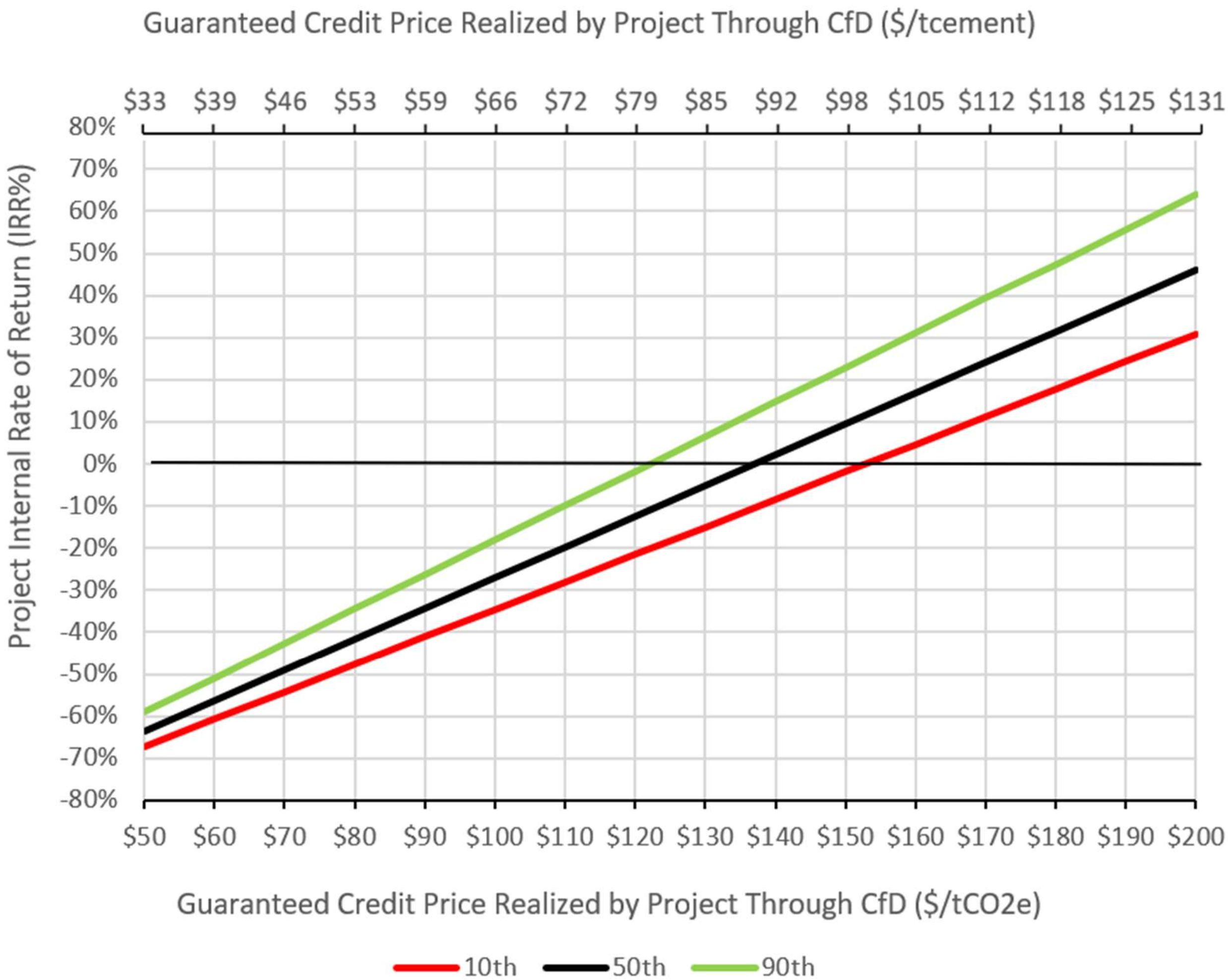
[3] A Monte Carlo based uncertainty-based analysis was conducted, and full results are provided in the main report.

[4] https://www.budget.gc.ca/fes-eea/2022/doc/gf-fc-en.pdf

price, either as a PCfD or a CCfD. We can illustrate how a CCfD or PCfD could potentially work with a few examples:

- Through reverse auction or negotiation, the project is awarded a CCfD that stipulates a strike price of $154 per t$CO_2$e reduced. In the central modelled example (black line), the project would realize a 13% IRR. If the project is able to realize emission reduction credits or offsets in a given year at a price of $97 per tonne of CO_2e reduced, the project would gain the CCfD difference or $154-$97=$57 per t$CO_2$e. However, if the project is able to realize emission reduction credits or offsets at $170 per t$CO_2$e, the project would *pay* the government $154-$170=$26 per t$CO_2$e. Note that if the CCfD were based on the federally scheduled carbon price, the project would have to take on the additional risk that their credit or offset prices significantly diverge from the scheduled carbon price.
- Through reverse auction or negotiation, the project is awarded a PCfD that stipulates a strike price of $162 per tonne of low-carbon cement produced. If the project is able to realize a price of $125 per tonne of low-carbon cement, the PCfD would pay the project the $37 per tonne of cement difference. In our central modelling example, this is equivalent to achieving a combined guaranteed credit price of $154 per t$CO_2$e reduced above if we assume that the credit/offset value ends up being $97 per t$CO_2$e or $64 per tonne of cement. (In other words, $64 + $37 = $101 per tonne of cement = $154 per t$CO_2$e).

Figure 1 **Project Internal Rate of Return for different levels of Guaranteed Carbon Credit Prices Realized by a carbon neutral Cement Project**



CfDs offer major advantages over direct government subsidies as they are designed to only pay when verified emission reductions and production occur. In the case of PCfDs they also hedge whether market prices reflect carbon or "green" product premiums. Developing PCfDs for the production incentive gap to address major industrial commodities as opposed to renewable electricity generation PCfDs that are based on a homogenous product, megawatt hours (MWh) with transparent pricing, will present some design challenges. Each low-carbon project for commodities such as cement, reduced iron and various chemicals will have a different starting level of emissions and product pricing and likely a range of co-produced products. In this case developing strike prices and market price benchmarks that are the same across production facilities for the same product may not be possible nor desirable, and each project would need to be assessed separately. However, if the eligibility criteria are clear and the overall strike price reflects a similar value for an emission reduction and balances risk and reward for both investors and the government, PCfDs for the production incentive gap can be designed in a way that provides equitable treatment across projects and sectors.

Finally, in order for CfDs to be effective at reducing carbon price uncertainty and overcoming the production gap incentive, while not overly subsidizing the project and protecting the public purse, best practices should be looked to worldwide. The UK and European Union have been successfully implementing reverse auctions for price discovery in renewables for two decades now, and those lessons should be heeded. The Inflation Reduction Act provides expansive low-carbon investment incentives without imposing a national carbon price. Modelling work should also be done in advance of any new major climate policies to understand how they might interact with CfDs. For example, border carbon adjustments, Clean Fuel Standard offset credits, and the proposed oil and gas cap may potentially all affect the final incentive gap of a new project. It should be noted that the Fall Economic Statement has introduced a broader 30% investment tax credit, and the Canada Growth Fund will introduce a variety of tools – CfDs are one way to help mitigate the investment risk for first-of-kind facilities, but there are others. **The essential point is we need an effective and accessible set of tools for companies to build net-zero projects in Canada.**

2 Introduction – carbon price uncertainty vs. the inherent incentive gap after existing policies

Decarbonising emission-intensive industrial products like cement, steel, fertilizers and chemicals is crucial for Canada to achieve the goal of net zero by 2050. While numerous technologies and pathways are emerging and we know that it is technically feasible, the challenge is to commercialize first-of-kind low-carbon facilities and kick-start the investment that will be required. For this capital to flow it will be necessary to develop markets that are willing to pay the higher production costs for low-carbon industrial products.

Canada has implemented a hybrid carbon pricing system for non-traded, less GHG intense sectors and its energy-intense and trade-exposed sectors (EITEs). It has developed a long-term schedule for carbon pricing that is intended to provide heavy industry with a clear incentive for low-carbon production. This carbon price, scheduled to rise to a nominal $170 per tonne CO_2e in 2030, as well as complementary policies such as the Clean Fuel Standard and more targeted measures, are expected to close the gap and provide a viable business case for commercial scale investments for a number of industrial products.

However, there are two intrinsically different problems that many industrial products face on the road to net-zero decarbonisation. First there is the **carbon price uncertainty** problem addressed by the recent Clean Prosperity and Canadian Climate Institute report.[5] This problem can be subdivided into two parts: first, the issue of the durability of the scheduled carbon price in carbon pricing systems (e.g., will the carbon price rise to the headline federal carbon price of $170 per tonne CO_2e in 2030) and second, the issue of the value of credits that may be generated by a project under the different carbon pricing systems in Canada (e.g., how much are low-carbon projects able to sell their credits for?). This credit value could substantially diverge from the headline carbon price if there is an oversupply of credits in the market and therefore threaten the economics of the decarbonization project. Industries are understandably wary to base investments on a future $170 carbon price when there is little assurance of the durability of the schedule carbon price or that credit values will be near to that price. This wariness is reasonable, given the cancellation of the WCI cap and trade apparatus in Ontario in 2018, the stated opposition to carbon pricing of the Official Opposition, and that there is significant disagreement over jurisdictional implementation of carbon pricing.

Second, however, even if the carbon price schedule to 2030 remains intact and thereafter and even if the value of credits generated by the low-carbon project are in line with the schedule price, **the cumulative impact of a $170 per tonne CO_2e carbon price and all existing and**

[5] https://cleanprosperity.ca/heres-how-to-kick-canadas-low-carbon-transition-into-high-gear/

announced policies may still not be enough to support and accelerate near-term investment in some first-of-a-kind low-carbon projects that are compatible with a net zero pathway to 2050. First-of-kind low carbon industrial projects are characterized by new technologies, steep learning curves, and inherently risky investments. While ultimate mitigation costs to decarbonize heavy industry basic materials are expected to be in the rough range of \$70-\$200 per tonne of CO_2e reduced (IPCC, 2022), very low to zero-emission technologies will require 5-15 years of intensive innovation, commercialization, and policy at even higher costs to ensure uptake. This means that for First-of-kind low carbon industrial projects, addressing carbon price uncertainty by providing some type of guarantee of the value of emission reductions (e.g., at the federal carbon price of \$170 per tonne CO_2e) may or may not be enough to trigger investment assuming existing and announced policies depending on the industrial sector and product. This differentiation that not all sectors face the same financial hurdle is important.

There should also be the careful consideration of how different policies stack together to provide projects the financial case to proceed. For first-of-kind projects carbon pricing is rarely the only price support. Take as an example the investment tax credit for CCUS which is essentially a capital subsidy relative to other investment for first-of-kind CCUS projects. This subsidy may be worth as much as \$25-\$50 per tonne of CO_2e for a given project. So as an example, let's say a first-of-kind CCUS project is determined to be "investable" with the CCUS investment tax credit that contributes \$35 per tonne of CO_2e to the project **and** a guaranteed carbon price of \$150 **and** a one-time funding contribution of \$100 million dollars worth \$10 per tonne of CO_2e. The actual total cost in this case isn't less than \$170/tCO_2e it's 195\$/tCO_2e. This is why we need to look beyond carbon price uncertainty in determining what is the actual production incentive gap faced by first-of-kind projects.

This is particularly true for Emissions Intensive and Trade Exposed (EITE) sectors, because market prices are governed by global forces and competitors may not have equivalent carbon pricing and policies such as Carbon Border Adjustments (CBA). For these cases, we should consider that there may remain a **production incentive gap** to making necessary investments, and that additional policies may be required. Also note that CfDs, such as have been used in Europe and the US for bringing forward renewable electricity, have historically been designed to solve the production incentive gap issue, e.g., for renewables in electricity.

This paper focuses on first-to-third of a kind low-carbon industrial projects and explores how Contracts-for-Difference (CfDs[6]) could be designed in Canada as an additional incentive for complementary, effective, timely and efficient decarbonisation tool. Contracts for difference

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[6] Also known in a more specific context as carbon contracts for differences, CCfDs. CCfDs are more tailored to carbon price uncertainty.

(CfDs) are a financial tool derived from the options market that has been applied in several jurisdictions with substantial success in increasing market uptake of clean electricity technologies. In these situations, they are used to guarantee a minimum price derived through reverse auctions. If the market price for electricity is lower, the electricity authority pays a minimum price or "top-up" based on the strike price established through reverse auction. This paper examines how CfDs could be employed for early, transformative projects that are unprofitable to pursue given announced and existing policies. **In other words, these are projects characterized by new technologies, steep learning curves, and inherently risky investments that need an incentive above this price to overcome their production incentive gap above existing policies and become "investable" or "bankable".** CfDs designed to close this production incentive gap for these first-of-kind projects can help to accelerate capital and technology deployment and lower the costs for subsequent generations of projects. However, because the carbon price will hopefully be operating in the background as part of the incentive structure, the paper also needs to address the linked problem of **carbon price uncertainty,** where a subset of CfDs called contracts for difference (CCfD) are being developed as a solution. The study is targeted towards Canadian policymakers and industry stakeholders and focuses on practical guidance for employing CfDs for first-of-kind and new low-carbon technologies for emission intensive Canadian products that struggle to attract investment under existing and planned policies, e.g, the application of 95% carbon capture and storage to cement plants.

The paper first examines why additional policies and incentives are still needed to achieve deep decarbonisation for many industry sectors (**Section 3**). Then we look at how CfDs have been used nationally and globally to help develop markets and adopt new technologies (**Section 4**). A detailed consideration of how CfDs can be used as an instrument to solve both the Carbon Pricing Uncertainty and the Production Incentive Gap is outlined (**Section 5**). Finally, the last section advises Canadian stakeholders on how they can design CfDs for complementary, effective and efficient heavy industry decarbonisation (**Section 6**).

3 Why do we need additional policies and incentives for heavy industry decarbonisation?

The 2015 Paris Agreement's objective of (para) "limiting global temperatures to +2°C and towards +1.5°C above preindustrial norms" radically changed global mitigation goals for industry. Whereas before Paris they could use some negative emissions from bioenergy with carbon capture and storage (BECCS)[7] in the electricity sector or subsist in the last 20% of emission allowed with the "-80% by 2050" reduction targets prevailing before then, now they must go to zero emissions by 2050 or buy expensive additive, permanent and verifiable offsets. This increases the need for accelerated commercialization and investment in highly sectorally specific near-zero emissions technologies, which in turn requires policy incentives, but also removal of policy barriers.

Heavy industry investment decision-makers, however, are struggling to understand the ever-evolving suite of new carbon pricing and complementary policies, which can have complex interactions, while at the same time weighing risks that these same policies may not endure to benefit their potential investments. They also can face uneven treatment under these policies, whether it is average or marginal costs of emissions, coverage, revenue recycling funding (i.e., compliance costs collected by various carbon pricing systems in Canada are not necessarily returned to the same sectors that paid them), access to technology or market-based incentives. As this is the case today for many heavy industry sectors, this means that new net-zero production technology will be deployed only in jurisdictions that have a long-term integrated strategy for reducing production costs or by creating dedicated or premium priced markets for net-zero products.

Making and accelerating investments in new low-carbon heavy industry production also requires the removal of barriers, including fiscal/financial barriers, regulatory/legal barriers, institutional barriers and planning/information barriers. Policies and incentives will be needed to overcome all these types of barriers, but this study focuses specifically on the key financial and regulatory barriers. Canada must also recognize that the investment playing field for industrial decarbonisation is rapidly changing. The United States Inflation Reduction Act now provides expansive low-carbon investment incentives and could directly draw investment away from our trade exposed heavy industry sectors, e.g., especially in the areas it directly subsidizes, such as CCUS and blue and green hydrogen.

The report introduction highlights two intrinsically different barriers that CfDs could help reduce: **carbon price uncertainty** (i.e., uncertainty around the durability of the scheduled carbon price as

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[7] Biomass combustion with carbon capture and storage

well as complementary policies) and the **production incentive gap** (i.e., the cumulative impact of all policies may still not be enough to support and accelerate near-term investment in first-of-kind low-carbon projects).

The two key barriers and why CfDs could be used as an additional policy tool to overcome them are reviewed in further detail below.

Problem 1: Carbon Price Uncertainty

Industrial carbon policy in Canada has a legacy of federal and provincial governments developing climate action plans with a suite of regulations and incentives aimed at lowering heavy industry emissions, only for successive governments to retract and abandoned policies in favour of a new plans and policies. **This constantly changing policy environment has done significant harm to the goal of enabling a stable and long-term investment environment for deep decarbonisation.**

Canada's 1995 National Action Program on Climate Change (NAPCC) was the first national strategy on GHG mitigation, stemming from Canada's signatory to the 1992 Rio framework that created the United Nations Framework Convention on Climate Change (UNFCCC). This was followed by the 1998 National Climate Change Process (NCCP), and later by the National Implementation Strategy on Climate Change (NIS), National Climate Change Business Plan, and Action Plan 2000. Action Plan 2000 was projected to reduce emissions by 65Mt per year during the 2008-2012 period, to meet Canada's Kyoto target of 6% below 1990 levels over the same period. Instead, emissions rose 27% above 1990 levels by 2004. Canada had cemented the Kyoto-protocol era GHG reduction commitment into law under the Kyoto Protocol Implementation Act in 2002, but the law was repealed in 2012. In 2006, the new Conservative government tabled Canada's Clean Air Act, promising a 'Turning the Corner' on climate policy through regulations on 'all major sectors,' including through an emissions trading system for industry. The market-based policy for industry was abandoned in 2009, when the U.S. proposed Waxman-Markey cap-and-trade bill failed to clear Congress, with the government citing alignment concerns with its largest trading partner. Instead, it instigated regulations on the electricity, building and transport sectors before the Liberal government took power in 2015. The Liberals introduced a carbon tax under the Greenhouse Gas Pollution Pricing Act starting at $20 per tonne in 2019, with the output-based pricing system (OBPS) applying to large point source industry. Parliament passed the Net Zero Emissions Accountability Act (NZEAA) in June 2021, committing the government to setting five-year incremental GHG targets on a pathway to net zero by 2050 and routinely publish Emissions Reduction Plans (ERPs). The first ERP was published in March 2022, establishing a roadmap towards a 40% reduction in GHGs by 2030 compared to 2005 levels, which includes emissions falling in every sector.

While some policies have been very successful, such as the provincial and federal coal-phaseout regulations in electricity generation, most industry sectors and facilities across Canada have been trapped in the multi-decade policy revolving door described above, with core climate policies and programs being cancelled or overhauled by new federal governments as outlined above as well as by provincial governments. For example, Alberta's heavy industry policy evolved from the Specified Gas Emitters Regulation (SGER) to the Carbon Competitiveness Incentive Regulation (CCIR) to the Technology Innovation and Emissions Reduction (TIER) program in a single decade between 2009 and 2019. Ontario's legislated cap and trade system was enacted in 2016 but then dismantled by the successive government in 2018, where it was then captured by the federal backstop program, only to be replaced by a new Emissions Performance Standard (EPS) program in 2022. Currently only Manitoba and Prince Edward Island have the same type of industrial large emitter program with the same rules (i.e., the federal Output Based Pricing System), while Québec has had the longest consistent industrial pricing framework, sharing the Western Climate Initiative cap and trade system with California since 2008. While some provincial programs have similar pricing and coverage, companies investing in Canada must navigate each provincial and territorial jurisdiction separately.

The probability that a new federal government in 2025 will dismantle a number of pillars of Canada's industrial carbon policy is significant. The Conservative Party of Canada has committed to dismantling the consumer portion of the federal carbon levy, and it is unclear what they will do with the industrial pricing system, although it did at one point say that it intended to keep the industrial price schedule up to $50/tonne. However, this price level is much lower than the 2030 $170 price target, would do significantly less to attract new investment in most heavy industry sectors, and is simply not sufficient to pull forward transformative technologies like CCUS for cement making or hydrogen direct reduction for steel making. **It is also important to understand that Canada could have a high scheduled carbon reference price, but for most industrial projects it is the market credit price applicable to their jurisdiction (i.e., what they can sell credits for) that is relevant for their business case.** If the supply of these credits and offsets is not sufficiently limited, e.g., by insufficient tightening of the TIER or OBPS benchmarks, large ultra-low emissions facilities could flood the local market with compliance credits, and this oversupply could crash the market price and devalue the credits. **To address this carbon uncertainty risk with CCfDs requires that the "strike price" of a CCfD be based not on the federal schedule price but on the average market value of credits for the governing carbon pricing system**.

With this significant uncertainty in the carbon price durability beyond 2025, it is easy to understand how CCfDs could be used to backstop industrial heavy emitter programs in each province. A CCfD in one example could be set as the difference between the currently proposed schedule to $170 in 2030 and what turns out to be the actual value in that year. While this system would still have some issues in defining the eligible facility or project emission reductions (i.e., against what baseline) and exactly which low-carbon facilities would be embraced by the program, this type of CCfD could apply a uniform price insurance/backstop across all heavy industry sectors. However, broad eligibility of industrial projects to a CCfD close to a $170 strike price relative to the average market value of credits or emission reductions presents a potentially enormous liability for the federal government that is coordinating CCfDs. The challenge of keeping both the headline $170 carbon price intact as well as maintaining credit or offset markets near to this price in Canada's disparate provincial industrial carbon pricing systems should not be underestimated, especially since competing provinces have incentives to employ this backstop to pass on costs.

Problem 2: Production Incentive Gap to Accelerate Investment in First-of-Kind Plants

It is unclear what policies will emerge to address the carbon price uncertainty problem. It is possible that some type of broad eligibility CCfDs will emerge at a high enough carbon price for some first-of-kind carbon projects to trigger net-zero investment. However, for some first-of-kind low-carbon projects, carbon pricing even at $170/tCO_2e$ may not be enough, partly because of the significant differential in carbon pricing between trading partners, and partly because of the huge risks attached to commercializing new industrial processes, which can take billions and up to a decade from planning to operation. We also have to consider the possibility that the average guaranteed market value of credits or emission reductions will be significantly below $170/tCO_2e$ and below what is considered "investable" for first-of-kind projects. In either case, this means that there is a production incentive gap, where future market product prices are simply too low and uncertain to pull the trigger on net-zero investment without some additional guarantee of market demand, price support or other additional incentives.

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 before net-zero CO_2 emissions needs to be largely 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 particularly vulnerable because of the high trade dependency and high portion of industrial products that are exported that are emission intensive. **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 approach to climate policy for industrial emitters, from focusing on 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 and focusing on companies as the vehicles of change. This may be 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.**

There is an extra-ordinary degree of uncertainty in what heavy industry sectors will look like in Canada by 2050, but there is very little uncertainty that their products, such as steel, cement, chemicals and synthetic low GHG fuels, will be required and demand may grow overall. Even without questioning rising carbon prices and other policies and measures to balance global competitiveness such as the Clean Fuel Standard (CFS) and Carbon Border Adjustments (CBAs), there is likely to be an insufficient signal over the next decade to incentivize low-carbon production for early facilities (IPCC WGIII Chapter 11, 2022). 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.

In the case of a risky net-zero compatible low-carbon facility, if the financial incentive gap per unit of production or unit of expected emission reductions can be estimated, then a Product Contract for Difference (PCfDs) or a Carbon Contract for Difference (CCfD) could guarantee investors a fixed and predictable price so that they can make these investments with a more predictable return on their investments. There are many challenges to estimating a financial incentive gap for first-of-kind low-carbon facilities, but uncertain technology, capital and operating costs and uncertain production/demand are the likely main drivers. The value of accelerating first-of-kind investment and developing new low-carbon production opportunities in Canada for domestic consumption and export is most likely above the long-term average carbon price for some key technologies, e.g., Denmark's early focus on wind that had now turned into a multinational export industry, or even the Alberta government's early push to develop in-situ oil sands (Hastings-Simon, 2019). If such a price could be established, then we may find that there are ready investors.

4 PCfDs and CCfDs in Practice

In this section we review case studies of PCfDs and CCfDs in practice to describe how they have been used to stimulate investment in new technologies both domestically and globally.

Where possible, we report on cost-effectiveness and outcomes and detail how these different PCfDs and CCfDs have been designed to be complementary to other policies, and how they are designed to effectively and progressively reduce subsidy costs.

UK LESSONS

The UK's PCfD policy targets clean electricity development, and specifically offshore wind and some solar, and is designed to protect project proponents from changes to the wholesale electricity price.

Eligibility – Renewable electricity generators located in the UK can apply for a PCfD. Payments are only made for the electricity output that is produced from sustainable non-fossil fuel sources, with targeted requirements for offshore wind, biomass, and advanced conversion technology. Developers will also need a letter from the Secretary of State approving their supply chain plan, where UK sources are greatly preferred.

Methodology – Renewable generators submit a 'sealed bid' that represents the price they would need to be paid per kilowatt hour to make the project profitable. This is the so-called "strike price." The PCfD subsidy is then designed to fill the gap between the average wholesale market price for electricity and the generator's strike price. The revenue stabilising policy locks-in the price that successful proponents receive for each unit of electricity they produce, removing uncertainties related to fluctuating wholesale electricity prices, that are otherwise determined by the marginal supplier on a volatile wholesale electricity market.

Awarding – PCfD auctions commenced in 2014 in the UK and are now committed to be held annually from 2023. Results from the 4th allocation round were published on July 7, 2022, confirming 93 new contracts, more than in the previous three auctions combined. The allocation round is expected to result in nearly 11GW of additional generating capacity – sourced from offshore wind, onshore wind, solar, remote island wind, and – for the first time ever – tidal stream and floating offshore wind.

Governance – Successful project proponents enter into a private law contract with the Low-carbon Contracts Company (LCCC), a government-owned private company. LCCC reports to the Department for Business, Energy and Industrial Strategy (BEIS), and its primary purpose is to issue the contracts, manage them during the construction and delivery phase, and deliver PCfD payments.

Terms and Adjustment – Successful developers are paid a flat, price-indexed rate for the electricity they produce over a 15-year period. The amount of the subsidy equals the difference between the agreed 'strike price' and the 'reference price' (a measure of the average market price for electricity in the UK market). Note that generators are required to make payments back to the LCCC when the wholesale electricity price rises above the strike price.

Lessons and Impact – A review of the policy through an external exercise found that the UK's CfD policy is expected to reduce the cost of renewable electricity to consumers by £3 billion over 2016-50, compared to the previous Renewable Obligation (RO) policy – rising to £10 billion in savings when considering the additional contracts expected to be signed through 2050.

The certainty provided by the PCfD makes the project more attractive to investors, lowering interest rates for project developers, and attracting new entrants, with increased competition in delivery rates. As a result, the 4th allocation round saw the average strike price of successful bidders for offshore wind fall by almost 70% compared to the first CfD auction in 2015.

The UK experience also demonstrates that CfD policy takes time for emissions reductions to materialise. Contracts awarded in Oct. 2019 see full committed capacity coming online only by 2027, with a gradual ramp up over 2024-26, with a minimum five-year delay to seeing any mitigation results to be expected. Industrial investment decisions can take years, with price certainty over a longer time frame needed before construction or development can start. GHG mitigation outcomes follow in years later.

EUROPEAN UNION

The European Union provides grants to low-carbon technologies through its Innovation Fund which aims to allocate over €38 billion by 2030 and is financed through revenues stemming from the bloc's Emissions Trading System (ETS). The fund has announced its intentions to soon set up auctions to reward competitive bids through a CfD structure.

Eligibility – The Innovation Fund provides support for both small- and large-scale projects over 2020-30 for the commercial demonstration of innovative low-carbon technologies. It aims to finance a varied project pipeline over a wide range of technologies in all eligible sectors and Member States, Norway, and Iceland. At the same time, the projects need to be sufficiently mature in terms of planning, business models, as well as financial and legal structures.

Methodology – CfD auctions have not yet started under the Innovation Fund, with current funding doled out primarily via grants that will cover up to 60% of a project's additional capital and operational costs. The commitment to explore CfDs was included in July 2021 as part of the sweeping reform proposals to the EU's ETS – required in order to meet the bloc's target of reducing GHGs by 55% below 1990 levels by 2030. CfD's were again positioned within the Commission's REPowerEU scheme, proposed in May 2022 to help accelerate the shift from the current dependence on Russian natural gas. In both instances, CfDs were noted as the "preferred instrument" to help roll out green hydrogen. Specifically, the RePowerEU targets 10 million tonnes of domestic renewable hydrogen production by 2030 and 35 bcm of biomethane by 2030.

Previously in July 2020, the European Commission released a hydrogen strategy that included the consideration of a tendering system using CfDs for industrial decarbonisation, particularly for steel and basic chemicals, as well as to support clean fuels for the transport sector.

Under this analysis (which now reflects prices that are two years out of date), the Commission estimated costs for grey hydrogen in the EU today at €1.5/kg, costs for blue hydrogen at €2/kg, and the costs for green hydrogen at €2.5-5.5/kg. They note that this implies that a carbon price in the range of €55-90 per tonne of CO_2 would be needed to make blue hydrogen competitive with grey hydrogen, and a much higher carbon price for green hydrogen.

The analysis then recommends that a CCfD could be linked to the carbon price, in order to fill this incentive gap. Investors would bid to receive CCfD financing, and if successful would then receive be remunerated through the difference between the market price of EU ETS carbon allowances (EUAs) and an agreed fixed "strike" price.

The proposal is also expected to include rules that stipulate where or how green hydrogen's clean power can be sourced. This would alleviate the risk that green hydrogen plants will suck up existing renewable energy resources, putting pressure on the grid.

Awarding – The European Commission publishes regular calls for proposals under its Innovation Fund where applicants are invited to submit the details of their project. Calls are separated into large-scale projects and small-scale projects. The detailed scoring and ranking methodology used to choose projects varies slightly in each call for proposal, but is based on factors such as effectiveness, degree of innovation, project maturity, scalability, and cost efficiency.

Governance – The European Commission, assisted by the implementing bodies CINEA and EIB, is tasked with the overall management of the Innovation Fund. The Innovation Fund will provide around EUR 38 billion of support from 2020-30 (estimated at an ETS allowance price of EUR 75/tCO_2).

Terms and Adjustment – The EU has not yet determined the best methodology for the deployment of CfDs, with ongoing work commissioned on the setup of a competitive bidding mechanism for contracts for difference or other comparable schemes under the Innovation Fund. The findings of this work are expected to help prepare the related legislative act, as well as its Impact Assessment, that are expected to be published once the broader ETS revision package is agreed – with the final step of the legislative negotiations expected this fall, the so-called 'trialogue negotiations' between the EU parliament, the committee representing member states, and the European Commission.

Lessons and Impact – The European Commission uses a flexible approach to Innovation Fund financing, with specific eligibility requirements, funding availability, and funding mechanisms changing from one funding round to the next.

The EU rules encourage technology-specific tenders, where different technologies do not need to outbid one another. This allows technologies to scale up in parallel, where having them compete in the same auctions could be "counterproductive" to an 'all of the above' technology-solutions approach, the Commission has said.

"As politicians and as public authorities, we can and will help to bridge the cost difference between green hydrogen and dirtier forms of energy in the start phase," the Commission's climate chief Frans Timmermans told the World Hydrogen Congress in Rotterdam in May 2022. "We have concrete instruments for that – carbon contracts for difference – and we will make proposals to roll them out massively so that green hydrogen gets the kick-start that it needs."

OTHER EXAMPLES

There have been other real-world examples of government subsidies that resemble CfD, where the level of funding provided by the government fluctuates depending on market prices or other conditions.

The Netherlands, for example, has used its 'Stimulation of Sustainable Energy Production and Climate Transition Subsidy.' Under the programme's methodology, the subsidy can be linked to the EU ETS price, where expected revenues from excess allowances are guaranteed through the government contract. The programme has a budget of €13 billion for 2022 and accepts projects requiring up to €300 ETS allowance price to be profitable.

Germany, has announced plans to award energy-intensive industries like chemicals, steel and cement a 15-year carbon contract for difference (CCfD) based on a competitive auction process (Reuters, November 30, 2022). Germany's Climate Protection Act of 2021 set the goal of achieving carbon neutrality by 2045, an ambitious agenda that is being complicated by Russia's war in Ukraine and the related gas crisis in the German market. The publication notes that climate protection contracts could be issued to "hedge the CO_2 prices required to cover additional operational costs of plants to be as innovative and low-carbon as possible compared to a conventional reference." The publication notes that the Federal Ministry of Economics and Climate Protection continues to target 2022 for CCfD contract initiation. However, the final design of the instrument has not yet been released.

Portugal, last year through the Energy Secretary of State, performed a Portuguese hydrogen auction. The auction targeted energy consumers, such as large industrial firms. The auction is based on the CCfD model, where participants bid in forward contracts for a certain amount of hydrogen, based on their expectations of the EU ETS allowance price. The difference between the awarded bid (strike price) and the carbon price will be paid through public funds.

5 Design and Modelling of CfDs

This section first describes a financial modelling exercise for a carbon-neutral cement production plant to consider how CfDs for first-of-kind plants could potentially be applied. Section 5.2 reviews design options and considerations.

The analysis discusses two different subsets of CfDs, Carbon Contract for Difference (CCfDs) that are based on the value of emission reductions, and PCfDs that are based on the market value of production. Note that while PCfDs in practice have been based on overall production costs and revenues and are calculated based on a strike price and average market prices achieved by a project, the carbon neutral cement production plant example uses additional or incremental costs of the project only. However, this additional approach can still be used to define a PCfD in fundamentally the same way, the only difference is that the "PCfD average market price" is not the market price paid for cement, but the unit market value of the credits and revenue generated by the project.

5.1 Modelling of a carbon neutral Cement Production Facility

Financial data was gathered from the literature and cement industry stakeholders for a hypothetical low-carbon cement production plant that could be located markets, limestone, and a good nearby reservoir for permanent CO_2 storage. The data was used to construct a financial model to estimate the net present value (NPV) and simple internal rate of return (IRR) based on cashflows of typical ranges in OPEX, CAPEX and revenues, including the anticipated value of carbon credits.

Physical unit production costs were calculated in the model to compare with market prices and understand the potential gap in profitability on a production unit basis, reflecting how PCfDs are typically designed. In addition, we also compare costs and revenues on an emission reduction basis to reflect how CCfD are designed. Minimum, central and maximum values or ranges are entered for important project variables. A sensitivity analysis of the major variables is conducted to understand how each variable effects the project economics. Monte Carlo analysis is employed to understand the probability of different outcomes based on the range of minimum, central and maximum values. By running many different simulations within the range of values, the analysis can determine a histogram or distribution of the outcomes for the NPV or IRR of the project.

The financial model considers a 1 million tonne per year cement production facility. While the onsite CO_2 capture rate is set to 95% the project also captures and sequesters biogenic carbon in the cement plant fuel and as a result, has a net lifecycle impact for cement production that is carbon neutral. The assumption is that construction of the project would be completed by the end of 2026, and the commissioning and operation of the plant would commence in 2027 for an initial lifetime period of 25 years.

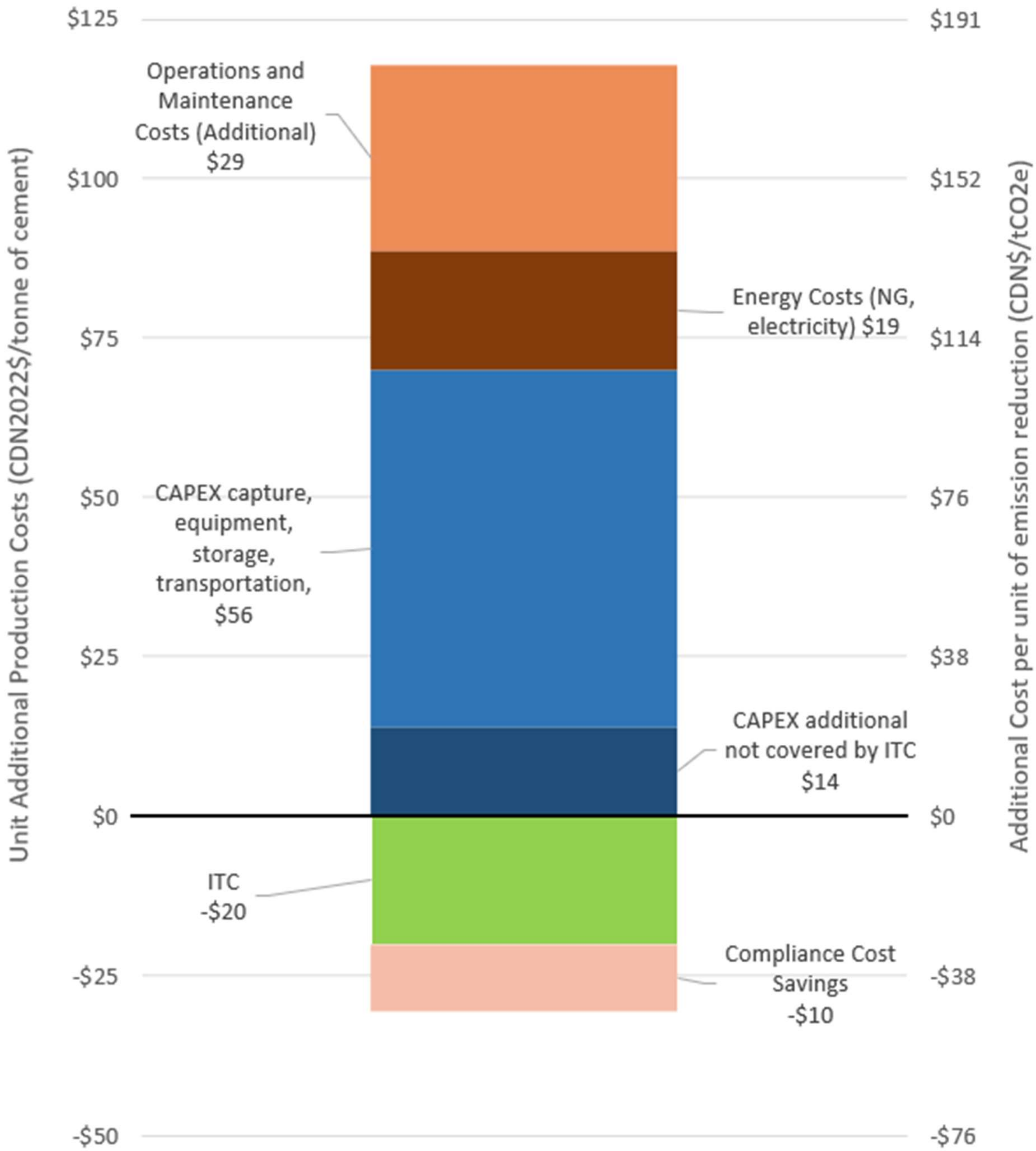
Carbon capture and storage (CCS) lifecycle emission reductions from the plant are estimated to be 0.79tCO_2e/tonne of cement. This is the baseline emission reduction assumed at the start of production; however, over time the verified emission reductions from the project decline to reflect increased stringency of cement carbon pricing benchmarks (e.g., federal OBPS benchmark).

Modelled project CAPEX and OPEX costs are additional to baseline cement production. All costs are in current dollars unadjusted for inflation. These component costs were varied across a range in the analysis to consider uncertainty. Ultimately, the ranges used (minimum, central and maximum values) are intended to represent reasonable costs that can be expected for the archetype project design, location and investment period. The investment tax credit for carbon capture, utilization and storage (CCUS) updated in the federal 2022 budget is also included. This specific tax credit is 50% for eligible capture equipment installed between 2022 and 2030 and a rate of 37.5% for eligible transportation storage and use equipment. There are questions regarding how much of the CAPEX would be covered by the tax credit, to address this uncertainty, we model a range of coverage between 50% and 100%, with a central value of 80% coverage.

The project generates revenues from emissions reductions relative to the baseline (declining benchmark industry threshold with a 2% central value stringency or decline factor) for the production of carbon-neutral cement. These are the value of the emission reductions to the carbon pricing market and involve generating credits within the applicable provincial regulatory mechanism. A range of carbon prices are used in the analysis that considers the announced federal schedule of $170 in 2030 but also considers **carbon price uncertainty** related to the durability of carbon pricing policies, cost pass through and supply of credits in the market. The central value of emission reductions and compliance costs used in the baseline analysis over the lifetime of the project was $97/t$CO_2$e.

The estimate central change in the production cost of cement for the project is $118/tonne of cement, that is, the cement would cost $118 per tonne more to produce. It does not include baseline costs for cement production, which are typically in the range of $90-125 per tonne cement. However, if ITC credits and compliance cost savings are applied against the costs the total cost of the project is $87/tonne of cement. This is the average unamortized additional cost of production over the lifetime of the project, including all capital and operating costs for carbon capture, storage and sequestration. The distribution of unit production costs is indicated in Figure 2. CAPEX costs are the dominant cost of the project even with the generous investment tax credit for CCUS. Note that the y-axis of the graph indicates the equivalent production costs expressed per unit of lifetime emission reduction, where the central unit change in production cost is $179/t$CO_2$e, but only $133/t$CO_2$e after ITC credits and compliance cost savings.

Figure 2 Change in Unit Production Costs due to Project

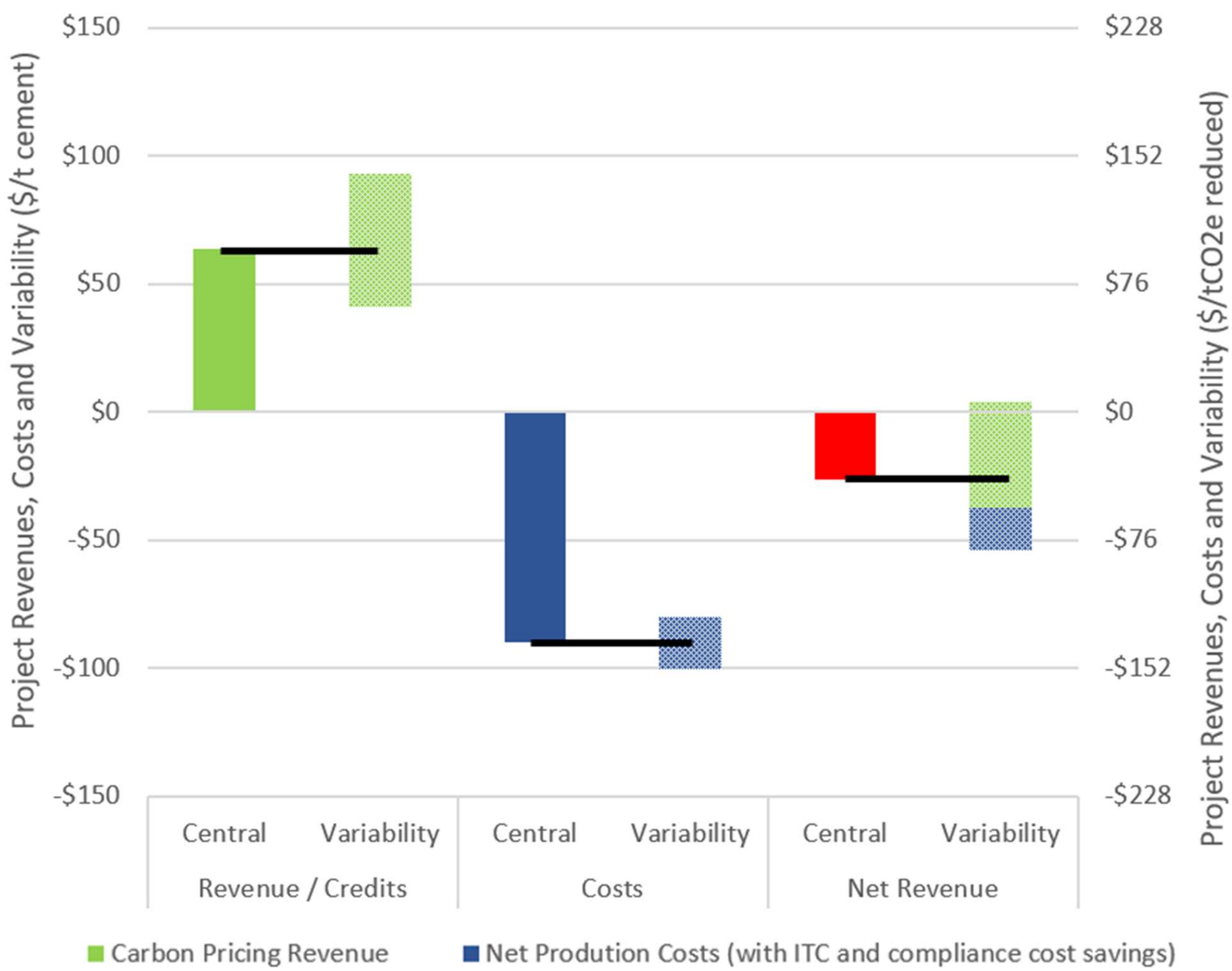


However, there is a substantial range in the additional unit production costs of cement for the project as shown by the Monte Carlo analysis that considers ranges in the CAPEX and OPEX costs and revenues.

Figure 3 presents a comparison of the 50th percentile or mean result for total revenues, total costs and net costs for the production of carbon-neutral cement in the baseline case. The adjacent shaded columns indicate the contribution of variables and indicates the range of the

10th and 90th percentile Monte Carlo simulations. In this case the net unit cost of the project is $-26/tonne of cement, indicating that the project is expected to lose $26/tonne of cement produced. The central case illustrated in Figure 3 considers an ITC credit worth $20/tonne of cement, compliance cost savings of $10/tonne of cement and an average lifetime value of emission reduction credits of $64/tonne of cement or $97/t$CO_2$e reduced.

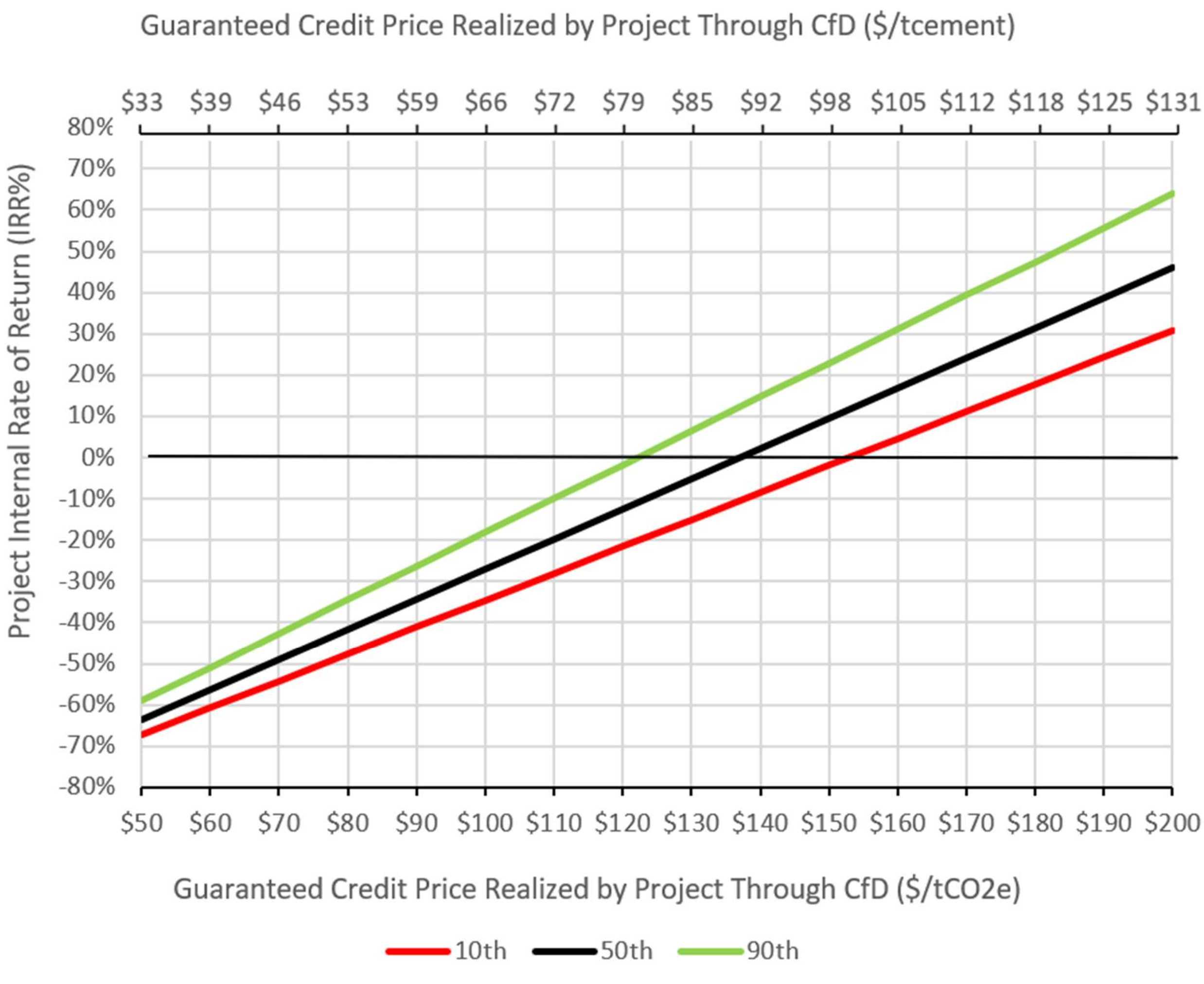
Figure 3 Monte Carlo range of carbon neutral additional production costs (tonne of cement) – Baseline Case without CfD



Carbon pricing uncertainty has the greatest overall impact on project performance. Without additional incentives or some way to guarantee a high value of the emission reduction credits the project would not proceed.

CCfDs or PCfDs for first-of-kind projects could be designed to ensure that the project is "bankable". Investors are seeking out projects that will have a reasonable return on investment. For example, the Canadian cement manufacturing industry in 2020 had a reported average "ex post/after the fact" internal rate of return (Total Revenues / Total Expenses) of approximately 6.5%[8]. The risk adjusted threshold project "ex ante/before the fact" internal rate of return (IRR) necessary for the project to move forward is likely to be higher than this level – 12-14% is a normal threshold rate of return for choosing amongst capital intense projects. Employing the model, it is possible to calculate strike prices for a CfD or a PCfD that would provide the project a specific internal rate of return (IRR). **Error! Reference source not found.** illustrates the relationship between a CfD at a specific guaranteed price expressed as either a carbon value ($/t$CO_2$e) or a product value ($/tonne of cement). The distribution of results around the mean 50th percentile value is indicated by the black line.

Figure 4 Project Internal Rate of Return for different levels of Guaranteed Carbon Credit Prices Realized by Project



[8] Statistics Canada Financial Performance Data. Accessed Oct 13, 2022 at: https://www.ic.gc.ca/app/scr/app/cis/performance/rev/32731

Error! Reference source not found. identifies that in order to achieve an IRR of 6.5% for the project for the 50th percentile case, the guaranteed lifetime carbon credit value would need to rise to $146/tCO_2e. To achieve an IRR of 13% the guaranteed carbon price would need to be $154/tCO_2e. There are some additional points to interpreting this figure:

- A federal carbon price schedule of $170 by 2030 does not imply a guaranteed credit value of $170/tCO_2e for the project. First the rising scheduled carbon price level ($125 in 2027 rising to $170 in 2030) means that the average discounted price over the operating period (2027-2051) of the that federal carbon price is $163/tCO_2e. Second, credit prices in Canada's industrial provincial carbon trading systems are tied to demand and restrictions on use, they will trade at a discount to the federally scheduled price. If the supply of credits and offsets is not sufficiently limited, e.g., by insufficient tightening of the TIER or OBPS benchmarks, large ultra-low emissions facilities could flood the local market with compliance credits, and this oversupply could crash the market price and devalue the credits. CCfDs based on the schedule price therefore are not "bankable".
- Compliance cost savings which are included in the modelling results in Figure **4** vary based on assumptions of the benchmark stringency (1-4% is modelled) and the prevailing carbon price. In cases where stringency and prices are low it is likely that savings are overestimated, and the IRR would be worse than indicated.

5.2 CfD Design Options and Considerations

The modelling of a carbon neutral cement plant presented in Section 5.1 is an illustration of a first-of-kind project that is "bankable" at a guaranteed credit price somewhere in the range of $140 to $160/tCO_2e if we account for existing and announced policies, the uncertainty in costs, the value of CCUS investment tax credits (~$31/tCO_2e) and a return of investment that is high enough to attract investment.

In this case if the government were to broadly address **carbon price uncertainty** for industrial facilities, ensuring both the durability of the scheduled carbon price in carbon pricing systems and that project credits for emission reductions are valued somewhere in this range of $140-$160/tCO_2e, then additional financial instruments may not be required for this project. As discussed in Section 3 the government may consider some type of broad eligibility CCfD that could serve the purpose of back-stopping the carbon price - if it were at a high enough carbon price would trigger net-zero investment in some first-of-kind carbon projects.

However, note that costs for first-of-kind facilities are variable and, in some cases, are likely to exceed whatever value is stipulated in a broad based CCfD. It is also worth noting that the example of the carbon neutral cement plant benefits from a CCUS investment tax credit valued at around $31/tCO_2e reduced. One could argue that the effective additional carbon price is in the range of \$171 to \$191/tCO_2e for an "apples" to "apples" comparison to another industrial product that may not be able to stack incentives to the same degree.

In this section we explore how both a CCfD or PCfD could potentially be designed to address a **production incentive gap** that is not otherwise addressed by other policies. If this is the case we are concerned primarily with how close the project is to some threshold that would trigger investment in the project. Here a carbon contract for difference (CCfD) is an option, but it is different from a traditional CfD that is based on the product (e.g., tonne of cement), henceforth a Production CfD, or PCFD. A CCfD is essentially insuring the value of emission reductions (in this case at a price greater than the scheduled policy value), whereas a PCfD is insuring the market value of production. Each may have different advantages, but PCfDs are more directly linked to a company's economic performance. For example, if the future market pays a premium for low-carbon cement (carbon costs greater than the carbon price are passed down to consumers), the government would be the beneficiary, whereas if the market price doesn't price in carbon or is low, the company might lose money with a CCfD but be whole with a PCfD. In developing either a CCfD or a PCfD for first-of-kind projects with the intent of closing the production incentive gap there needs to be consideration of a number of important factors that could be used as eligibility criteria:

- Will the CCfD or PCfD help to accelerate capital and technology deployment of a first-of-kind facility that is consistent with achieving a net-zero transition in the sector? Would this acceleration help to lower costs of similar projects in Canada? Would support of the project help to develop potential export markets for technology and further justify the potential subsidy? Does the project align with global net zero scenarios and anticipated future demand?
- Is the specific project being considered competitive with other proposed projects in Canada (i.e., regional competitive advantages in labour, input supply chain, energy costs, low operating costs)? The same level of CfD should generally be available for the product nationally.
- Is the cost of low-carbon production in Canada competitive with global facilities? If the cost in Canada is significantly higher it may be more important to consider how the technology or products could be imported to Canada.
- Does the project compete with other low-carbon transition projects for feedstocks and energy inputs, that may make more economical or better use of these feedstocks and energy inputs? Are there additional infrastructure costs to operate the facility that are not otherwise considered?

Carbon contracts for difference (CCfD) could be designed in the following way:

- The difference between the strike price (i.e., the current federally scheduled price in any given year, or a specified market credit price) and the actual prevailing average price of credits realized by the project for that year could be used to determine a CCfD. The strike price could also potentially be adjusted to below the carbon price to create a form of insurance for government where companies could theoretically pay a premium in return for the CCfD that de-risks their projects, but this isn't central to the goal of sending a long-term carbon price signal.
- In the modelling example (Figure 3), the 50th percentile average lifetime carbon credit value realized by the project in 2030 is \$97 per tCO_2e reduced or \$64 per tonne of cement produced. This means, if the intention is that the project should be able to bank on a lifetime average carbon price of \$154/tCO_2e for all emission reductions from a baseline threshold, then a CCfD of \$57 per tCO_2e reduced or \$37 per tonne of cement is necessary over the full 25 operational year life of the facility. Again, note that any long-term carbon strike price stipulated in the CCfD does not have to align with the \$170/tCO_2e federal scheduled price. It could be lower or higher depending on the signal strength desired for the CCfD policy.
- In this case the CCfD considers a credit price roughly in line with the federally scheduled carbon price of \$170/tCO_2e in 2030 that governs carbon taxes on fuels and the marginal cost of credits under aligned provincial OBPS and cap and trade systems in Canada. The reader should note that the scheduled price is not synonymous with actual credit prices. Credit prices typically trade at a discount to the scheduled price. They are also typically highly uncertain, because of credit market supply and demand, varying cost pass through, and other compliance mechanisms (e.g., offsets).
- Another major uncertainty in the carbon price valuation is that eligible emission reductions will likely decline for the project, but it is difficult to know by how much in advance. This analysis assumes a central declining stringency of 2% per year starting with a baseline lifecycle emission reduction level of 0.79 tCO_2e/ tonne of cement in the first year. What actual annual verified emission reductions will be for a project are unknown and will vary by sector, but for project certainty, a stringency rate could be assigned in the CCfD.
- If the calculated CCfD is negative (the realized credit value is higher than the long-term strike price identified in the CCfD), there are options for what might happen:

1. The government could collect the full difference of the strike price and the credit value from the owners of the project. The government then is using the CCfD as a hedge to provide carbon price certainty but also to contain potential costs and generate revenue. This was the path taken for the UK electricity CfDs, where the policy is not just a subsidy but has potential government revenue benefits.
2. The government could not collect the difference in the carbon price from the project. While in this case the government is then allowing the project to see the same carbon price signal as all other projects and industries this contravenes the idea that the CCfD is a risk sharing mechanism and may be unfair to companies not covered under the arrangement.
3. The government could collect the full difference of the carbon price up to a specified threshold.

Product contracts for difference (PCfD) could be designed in the following way:

- A PCfD is ultimately calculated as the strike price ($/unit of production) minus the average market price ($/unit of production). The level of the strike price could be set to achieve a specific return on investment for the project defined by the following equation:

CfD = Strike Price – Unit Revenue

Where Strike Price = (1 + IRR%) * Unit cost

Or

CfD = ((1 + IRR%) * Unit Cost – Unit Revenue

In the example of **Error! Reference source not found.**, the net central unit additional cost (after ITC and compliance cost savings) is estimated at $90/ tonne of cement and the central unit revenue $64/tonne of cement. However, in order to estimate a PCfD strike price we need to have some insight into the baseline cement production cost and the IRR of cement production. Assuming that current market conditions are at approximately $125/tonne of cement and the current baseline cement production is $110/tonne of cement, the baseline project would achieve an IRR of 13%. We could then use the formula above to calculate a PCfD strike price to achieve the same level of IRR. Here the strike price would be = (1+13%)*($110+$90/t cement) = $226/t cement. With a PCfD in place with a strike price of $226/tonne of cement, it would then be necessary to evaluate all project revenues per annum. So for example, if the market price cement was sold at turned out to be $140/tonne of cement (possibly including a premium value over regular cement) and the revenue from the sale of emission reduction credits was \$97/tCO_2e or \$64/tonne of cement per if prices The PCfD per tonne of cement = \$226 - \$140 - \$64 = \$22/tonne of cement. Alternatively instead of an *ex-ante* strike price (before the event based on estimated cost data for the project) based on achieving a specified IRR the strike could be determined through reverse auction or even possibly *ex-post* using revealed costs of the project.

CCfDs (based on emission reduction credit values) and PCfDs (using unit of production market prices) are calculated *ex-post* using prices revealed at the end of each year. Current PCfDs for electricity generation define an appropriate strike price (*ex-ante through reverse auction*) and then in each year of the contract the regulator calculates the wholesale electricity market price achieved for each project. Because the electricity sector is centralized and has a high degree of transparency, calculating the market price for individual projects is relatively straightforward. It also much easier to discount carbon price revenue, by either not allowing credits or having this value included in the price. For other industrial output, calculating an average market price for a project is more complex. There is not likely to be a centralized market and each project will have different customers, different sub-products, different prices and different distribution and transportation costs. In preparation of the PCfD for a specific product it will be necessary to define an independent index price that is applicable to the project and its competitors. For cement it may be appropriate to consider the PCfD on a tonnes of clinker basis (which is the most emission intensive process of cement production) using price data that can be captured and monitored by a central agency. Average credit value prices realized may be equally difficult to determine given that the company is unlikely to have sold them all at a reported value in the same given year. In this case it is necessary to establish an index value for credit value prices that reflects their true market value over the year. This requires accurate market data collection on prices of credits and offsets over the year that are eligible for compliance within the governing provincial industrial carbon pricing system.

Additional Versus Total Cost Approach for the Production Incentive Gap

The low-carbon cement plant modelling example uses costs and revenues that are additional and not total. Fundamentally, they are similar, in that both CfDs can be defined as follows:

CfD = (Unit Strike Price – Unit Revenue) / Revealed Market Price

The major difference is that the **Additional Cost Approach** doesn't include the baseline cost of cement production and the revealed market price is based only on the additional revenue from carbon credits attributable to the project instead of total revenues.

The **Total Costs Approach** is the way that CfDs have been traditionally deployed for renewable electricity generation. It may also prove to be easier to calculate for projects as there can be complex boundary issues in defining additional projects. For example, there may be significant additional revenue that is not included in the **Additional Cost Approach** if it is expressed in the market price of cement (e.g., difference in the price of carbon neutral cement versus baseline cement). This is likely to occur as differentiated markets where low-carbon products have higher market prices. The **Total Cost Approach** is also more desirable where there are competing projects that can be evaluated using the same strike price and because it encompasses all costs and revenues for the product it provides a better opportunity to balance the overall risk and reward to investors and government.

A detailed consideration of how PCfDs or CCfD can be used as an instrument to solve both the Carbon Pricing Uncertainty and the Production Incentive Gap is outlined (**Section 6**).

Based on the previous financial analysis we propose in

Table 1 some definitions for key design considerations for implementing CfDs for complementary, effective and efficient heavy industry decarbonisation. The design considerations are considered separately for the **Carbon Pricing Uncertainty** and the **Production Incentive Gap** problems as they have fundamentally different requirements.

Table 1 CfD Design Elements for Heavy Industry Products

Design Element	Description and Considerations	
	Carbon Pricing Uncertainty	Production Incentive Gap
Eligibility	CCfD applied broadly to backstop a scheduled carbon price (e.g., $170 by 2030) for all or select heavy industry products • What determines ineligibility given that the goal of carbon pricing is to establish a national economy-wide price signal that for industry is sufficiently stringent to create strong markets and maintain a price signal aligned with the scheduled price? • How can the public purse be protected to ensure that CCfDs are not a subsidy without significant benefits?	Applies only to first-of-kind net-zero compliant plants that have technology, infrastructure, financial or market risk that would otherwise delay their investment • What determines "first-of-kind" and "net-zero compliant" status? • How do you limit free-ridership participation?[9] • Is there a target for participation? Set amount of funding or % of total existing production or physical cap production levels? • Are eligibility requirements different for different provinces given that large final emitter programs are different across jurisdictions? • Can public procurement or private "off take" agreements be used as a complementary or alternative strategy? • Are facilities that will receive significant federal or provincial funding under other programs excluded?
Methodology for Setting CfD	A CCfD applies in theory either to the difference between the scheduled carbon price and actual carbon price or the difference between the scheduled carbon price and the credit value of emission reductions. Low-carbon projects are most interested in the difference between the scheduled carbon price and the credit value of emission reductions since their returns	Option to apply to either the value of emission reductions greater than the scheduled carbon price (CCfD) or to the market value of production (PCfD). A PCfD insures the value of production and applies to the product price, so the difference between the CfD strike price and the actual market price in a given year. A CCfD insures the value of emission reductions and applies to the credit value,

[9] If first-of-kind is narrowly defined but generous, free ridership is a lesser issue.

Design Element	Description and Considerations	
	Carbon Pricing Uncertainty	Production Incentive Gap
	on investments are based primarily on the value of credits. • What determines emission reductions? Lifecycle or direct emission reductions? Existing industry performance or OBPS benchmarks? • How are other carbon policies that impose costs or benefits accounted? For example, the interaction with tax credits, the Clean Fuel Standard (CFS)? • What are the impacts to covered facilities if the credit market is oversupplied and credits crash in price? • Audit and verification of emission reductions and prices realized are required.	so the difference between the CCfD strike price and the credit price realized in a given year. • Is there a cap on price? For example, expected long-term cost of direct carbon air capture? • How are other carbon policies that impose costs or benefits accounted? For example, the interaction with tax credits, the Clean Fuel Standard (CFS) • How is the CCfD or PCfD strike price set? Based on economic analysis to achieve a project returns on investment? Expected sector abatement cost curves? Auctioning (market price discovery)? • Audit and verification of emission reductions, prices and to validate project cost estimates if strike price set ex-ante without a competitive process such as auctioning • Which type of CfD (PCfDs or CCfDs) is easier to implement and design given the existing fragmented provincial carbon pricing systems and legal constraints? • Are payment transfers above and below the strike price adjusted in any way to help cover social costs or to provide incentive to participate?
Awarding of CfDs	Presumably awarded to all facilities/companies that meet eligibility requirements.	Multiple options available, including reverse auctions, auctions, targeted to multiple or individual sectors, or granting through a criteria application process. • Unless mandated, would a competitive process attract enough entrants (i.e., make a difference in investment) and reduce costs?

<table>
<tr><td rowspan="2">Design Element</td><td colspan="2">Description and Considerations</td></tr>
<tr><td>Carbon Pricing Uncertainty</td><td>Production Incentive Gap</td></tr>
<tr><td></td><td></td><td>How do you ensure relatively equal treatment for different sectors?
Does the design of the CfD avoid free-ridership where industries join only because there is no downside (not risk sharing)?</td></tr>
<tr><td>Terms and Adjustments (Timeframe)</td><td colspan="2">Terms are likely to be shorter than 20 years but at least 10 years based on research and companies are very much focused on early capital returns on investment due to costs of financing.
What analysis, conditions determine appropriate term length for CfDs? 10 years is a reasonable default, but a longer span could be argued for on a project basis.
Are there renewal periods?</td></tr>
<tr><td>Governance</td><td colspan="2">A central/federal organization is required to implement CfDs.
What is the appropriate organization that has expertise and resources to implement CfDs? Finance would have to approve them. The Business Development Bank of Canada (BDC)? Sustainable Development and Trade Canada (STDC)? ECCC & Finance? NRCan & Finance?
The clean growth fund that is a subsidiary of the Canada Development Investment Corporation and identifies CfD as a potential investment instrument, proposes to establish a permanent independent structure in the first half of 2023.</td></tr>
<tr><td>Source of Funding</td><td>Funding requirements are highly uncertain given the uncertainty of future carbon and credit prices.
How does government evaluate and consider potential liability?
Funding could be from large final emitter programs by sector</td><td>Funding requirements are uncertain. If based on CCfD then the uncertainty originates from future credit prices. If based on CfD on products the uncertainty originates from future market prices for different products which indirectly also reflect carbon prices depending on how they are passed through to consumers.
How does government evaluate and consider potential liability or potential revenue?
Funding could be from large final emitter programs by sector
Is a CfD production incentive appropriate for risky capital intensive projects where attracting finance is difficult?</td></tr>
</table>

Design Element	Description and Considerations	
	Carbon Pricing Uncertainty	Production Incentive Gap
Policy Interaction and Trade Implications	New federal policies such as CBAM or CFS and new provincial policies have potentially very material impacts on project economics. CfDs should not purely benefit exporters but should also benefit Canadian markets • Are there any stipulations that adjust CfDs based on new announced policies put in place? • Is CfD design compliant with Canada trade agreements?	

6 Design Recommendations for CfDs for Canadian Industry

The previous financial modelling and review of how CfDs have been applied in different jurisdictions indicates they could be used in Canada as a policy instrument to reduce both the **carbon price uncertainty** and the **production incentive gap** problems that are outlined at the beginning. Both these problems are of such strategic importance to a successful net-zero decarbonisation transition of Canada's emission-intensive industrial products that the federal government should at least consider how CfDs could be successfully designed to tackle both problems.

A focus on developing CfDs to address only the **carbon price uncertainty** problem **(i.e., limited CCfDs)** will help to provide investors a business case for developing projects that look profitable with announced policies in place, providing insurance to them that if carbon pricing policies prove not to be durable that they will still have the expected value of project emission reductions in the future. However, having a scheduled explicit price on carbon does not necessarily mean an industrial project in Canada realizes this price for emission reductions below a baseline: carbon price pass-through differs by market, supply chain and product, and market systems differ by region. In undertaking the design of CfDs for any sector and product, the government should consider the mechanisms by which the project realizes revenue from carbon pricing to ensure that carbon pricing policies are working and that the carbon price realized by the project can be appropriately measured relative to a strike price. Carbon price uncertainty CCfDs should be designed as a long-term insurance for all producers of a product to address **carbon price uncertainty** and should have wide eligibility across industry**.**

CCfD to address the carbon price uncertainty problem could potentially help first-of-kind low carbon projects if the strike price were high enough to close their production incentive gap. For example, if the strike price were aligned with a \$170/tCO_2e scheduled price and guaranteed the value of emission reductions, there are likely many first-of-kind projects that would be "investable". However, broadly guaranteeing industrial emission reductions close to \$170/tCO_2e presents a liability to the public purse that may prove to be unacceptable, especially given the political challenge of keeping the headline \$170 carbon price intact. There is also the challenge of maintaining credit or offset markets near this price in Canada's disparate provincial industrial carbon pricing systems where competing provinces may have incentives to use the backstop to pass on costs. However, even if the carbon price schedule to 2030 remains intact and even if the value of credits generated by the low-carbon project are similar to the schedule price, **the cumulative impact of a \$170 per tonne CO_2e carbon price and all existing and announced policies may still not be enough to support and accelerate near-term investment in some first-of-a-kind low-carbon projects necessary for a net zero pathway to 2050**. This differentiation that not all sectors face the same financial hurdle is especially important considering that all industrial production needs to decarbonize to achieve 2050 net-zero targets. In the absence of investment in these sectors to accelerate capital and technology deployment and lower costs for subsequent generations of projects, Canada is at increased risk of being uncompetitive and reliant on imports of low-carbon industrial technology and products.

CfDs designed to close this **production incentive gap** for these first-of-kind projects can help to accelerate capital and technology deployment and lower the costs for subsequent generations of projects. Both carbon contracts for difference (CCfD) based on emission reductions or production contracts for difference (PCfD) that are based on the product (e.g., tonnes of cement) can be employed to address this **production incentive gap**. Each may have different advantages but the choice of which type of CfD to employ will likely come down to ease of implementation and consistency with regulatory powers. However, we note that CCfDs for the production incentive gap could be an easier choice for running reverse auctions for a range of products that share similar first-of-kind production costs, as they are all valued in emission reductions, while PCfDs have the advantage they are based on production value that is more directly linked to the company's economic performance. For example, if the future market pays a premium for low-carbon cement (carbon costs greater than the carbon price are passed down to consumers), the government would be the beneficiary, whereas if the market price doesn't price in carbon or is low, the company might lose money with a CCfD but be whole with a PCfD.

CfDs that have both a carbon-based strike price and a product market-based strike price to be met could potentially respond directly to both problems at once.

For both CCfDs and PCfDs (or combinations) rules regarding how emission reductions are going to be measured for the duration of the CfD contract need to be established. For example, will the baseline emission intensity decline with announced stringency rates for production (e.g., benchmark under the OBPS)?

Production incentive gap CfDs should be viewed as a conditional volume and time-based subsidy to address the extra costs and risks associated with first-of-kind projects that offer the promise of reducing the cost of new technologies and opening new export markets. Consequently, CfDs for the production incentive gap should have much narrower eligibility based on competition and demonstrated potential of long-term benefits that accelerate and enable a successful net-zero transition.

The transformative social justification for a production incentive gap CfD is highest for the first application of a new process in a given situation and sector, slightly lower for the next 2-3 plants to prove replicability, and then falls to the stringency of announced policy, which is when the carbon price uncertainty element only should apply. Production incentive gap CfDs should be restricted to ready to scale production facilities that have achieved Technology Readiness Levels (TLR) between 7-9. Smaller scale facilities with lower TRLs require additional direct support for R&D to bring them to commercial viability. This indicates that there may be 1-2 "breakthrough" plants for each major sector (e.g., steel, cement, various chemicals, synthetic fuels, fertilizers, glass and ceramics, etc.), and a couple more that need incentive gap CfDs for each sector over and above the carbon price schedule. This would indicate a total of up to 5-10 breakthrough plans, and 15-30 plants that are less risky but still with costs higher than the carbon price schedule and a long-term transformative social justification. This contrasts with the carbon price uncertainty CCfD, which could cover 100s of plants.

The terms of the agreement may also be shorter for CfDs that address the **production incentive gap** as the concept is to accelerate the capital investment for economies of scale and learning. Periods longer than 10 years or renewals would require significant justification; Germany has announced it will be using 15 years as the duration for its production incentive gap CfDs, where the strike will be indexed to the EU ETS but determined by reverse auction.

CfDs that address the **production incentive gap** are essentially contracts where government is a financial partner. Government agrees to provide the project insurance that will allow the project to achieve a profit. Should the project be successful it is arguable that it should also be able to share in the profits. The UK renewables CfDs allocated all the upside to the covering government entity to help cover their cost. CfDs offer major advantages over direct government subsidies as they are designed to only pay when verified emission reductions and production occur. PCfDs have the added benefit that they hedge whether market prices reflect carbon or “green” product premiums and only pay if this value is not captured in product revenues.

CfDs for the **production incentive gap** should be designed to consider all other federal or provincial funding and incentives that may be stacked together to reduce the costs of the project. In other words, this funding (including direct contributions to the project as well as potential infrastructure support) should count as revenue to the project in calculating the CfD and setting strike prices.

For first-of-kind low-carbon facilities, it may be favourable for the government to use CfDs that are based on a prespecified minimum market price per unit of production (the strike price to be indexed to) that is sufficient to attract investment and also independent from carbon pricing systems. The reason is that when large low-carbon facilities that are part of industrial carbon pricing systems in Canada come online, they will likely flood and possibly over-supply the market with new credits, crashing the very source of revenue meant to pay back investments. It will be extremely difficult for government to manage credit markets fairly and concurrently for all covered facilities to maintain a stable price in this scenario. If the government tries to do this through guaranteeing credit prices by either buying credits or broad industry CCfD they are likely to be exposed to high liabilities. Applying high tightening rates (above 2% per year) and increasing coverage to dampen supply will mean that existing facilities that have limited economical abatement options will be forced to pay significantly increasing costs or be shut down because they are uncompetitive. In this case CfDs could both secure the investment to build the facilities, while simultaneously removing their credit supply (i.e., CfD projects based on minimum market prices would be ineligible for producing credits) and making it easier to manage credit and offset supply for existing facilities.

CfDs should be designed only where there is confidence that emissions, costs, revenues and production can be estimated with a significant degree of accuracy over the lifetime of the CfD. For many industrial products calculating a PCfD for the production incentive gap may be complex. In theory, the annual PCfD is calculated as equal to the strike price ($/unit of production) minus the average market price ($/unit of production). The strike price could be determined *ex-ante* based on modelling by the government or through reverse auctions. The average market price however needs to be determined *ex-post*. In the absence of a centralized market with clear and easy to calculate prices at a project level (e.g., the electricity market) it will be necessary to develop a reliable independent index price to represent the average project price that both the government and the project have confidence. Ideally the index price should be standardized, measurable by central agencies and representative of competitor prices. How the average market price is calculated must be detailed in the PCfD.

Finally, for CfDs to be effective for reducing carbon price uncertainty and overcoming the production gap incentive, while not overly subsidizing the project and protecting the public purse, best practices should be looked to worldwide. The UK and European Union have successfully implemented reverse auctions for price discovery in renewables for two decades now, and those lessons should be heeded. Sectorally differentiated reverse auctions could be considered to aid price discovery, minimize costs and communicate the need for very low emissions across the economy despite widely varying marginal costs. Modelling work should also be done in advance of any new major climate policies to understand how they might interact with CfDs. For example, border carbon adjustments, Clean Fuel Standard offset credits, and the proposed oil and gas cap will affect the production incentive gap for almost all important industrial products.

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APPENDIX A

Financial Modelling Monte Carlo Analysis

The financial model is a cash flow model that accounts for capital depreciation, tax credits, operating expenses and revenues over the lifespan of the project. The net present value of the cash flow can be interpreted as net earnings before taxes and is suitable for calculating a simple internal rate of return for the project. The model uses Monte Carlo analysis to consider a range of inputs for sensitive variables. Minimum, central and maximum values or ranges are entered for important project variables. The Monte Carlo simulation considers a triangular distribution or a continuous probability distribution shaped like a triangle between minimum, central and maximum values to provide a distribution of NPV and internal rates of return for the project. Table 1A summarizes the important variables and the ranges modelled and provides a brief description of the source of the data.

Table 1A: Important Variables and Ranges Included in Financial Model

Monte Carlo Variable	Data Source and Description	Min	Central	Max
Discount Rate & Financial Cost of Capital	Discount rates are used in financial modelling to calculate the present value of future cash flows. The rate depends on the expected rate of return or the hurdle rate that investors can expect to earn relative to the risk of the investment. In many cases an investor will use a company's weighted average cost of capital (WACC) as the required rate of return. Discount rates used by individual investors are typically significantly higher than rates used for public policy assessment. Our modelling of low GHG fuel archetype projects considers a range of discount rates between 5-9% based on weighted average cost of capital (WACC) reported for industry (KPMG, 2019).	5%	7%	9%
Production Rate	Production rate is primarily impacted by potential unplanned downtime to address processing issues related to CO2 capture, liquefaction and delivery to pipeline. With first-of-kind CCUS projects this has been a noted issue. First year production rate in 2027 is 5% lower than subsequent years.	-10%	0%	10%

Monte Carlo Variable	Data Source and Description	Min	Central	Max
Total CAPEX Cost	Total capital costs based on minimum, central and maximum ranges identified from literature for first-of-kind low-carbon industrial projects.	-20%	0%	30%
Capital Tax Credit Adjustment Rate	This project is eligible for the announced CCUS tax credit, This specific tax credit has an eligible rate of 50% for eligible capture equipment installed between 2022 and 2030 and a rate of 37.5% for eligible transportation storage and use equipment. The modelling expresses this tax credit adjustment rate as a level paid out over a 20 year amortization life equal to a percentage of eligible component capital expenditures.	33%	36%	39%
Proportion of CAPEX eligible for Tax Credit	Not all project CAPEX costs may be eligible for the tax credit. We assume a central eligibility of 80% of total CAPEX costs.	50%	80%	100%
OPEX Energy	Most fossil energy input is natural gas. Significant electricity required from either self-generation or from the grid. We do not define whether electricity is generated on site or offsite. If on-site, the resulting electricity emissions would need to be captured. A range of energy prices are used based on historical rates for natural gas and electricity in Alberta.	-25%	0%	25%
OPEX – Operations and Maintenance Costs	Facility O&M Costs based on data provided by stakeholders. The +-30% range is an assumption.	-30%	0%	30%
Annual Baseline Emission Reduction Stringency (Tightening Rate)	The project generates revenues from emissions reductions relative to the baseline. The baseline is a declining benchmark industry threshold between 1% and 4%, with a 2% central value.	1%	2%	4%

The Monte Carlo Simulation indicates that the 50th percentile IRR of the project is -29% with a per unit of production net revenue of -26$/tonne of cement (See Figure 3). This is the scenario that considers an average lifetime credit value of $97/tCO2e for the project (range of $48 to $163). The histogram of probabilities for 10,000 simulations that consider the range of inputs and outputs indicated in Table 1A is indicated below in Figure 1A. The 10th percentile and 90th percentile IRR are -67% and 77% indicating that the project is profitable in about 32% of the simulations. The value of emission reduction credits has by far the most important impact on project financial performance. With all variables held at their central value and adjusting only for the value of emission reductions, the project achieves break-even (0% IRR) at $137/tCO2e.

Figure 1A: Histogram of Expected IRR for 10,000 Simulations (Baseline Case without CfD)