October 2024

# Getting to Final Investment Decisions

## for carbon capture and storage projects

INTERNATIONAL CCS KNOWLEDGE CENTRE

The report was developed using publicly available information, expertise from the International CCS Knowledge Centre in developing and advising CCS projects, and a series of events called the Getting to FID Executive Series. The Executive Series, held in collaboration with Emission Reductions Alberta, gathered CCS leaders, experts and executives to discuss topics, under Chatham House Rules discussed in this report. Key findings and paraphrased quotations are included throughout the report. The report was funded by the Government of Alberta. It was developed independently and does not reflect the views or position of the Alberta government.

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# About Us

The International CCS Knowledge Centre is leading the world to a sustainable future by sharing insights and expertise on carbon capture and storage (CCS) and other solutions to address climate change.

We are independent, trusted advisors with unparalleled experience developing CCS projects, fostering collaboration and the exchange of knowledge to cut greenhouse gas emissions and achieve global net-zero goals.

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# Executive Summary

Approximately a decade ago the world's first commercial scale carbon capture and storage (CCS) facilities were being built and coming into operation. With large pilot facilities and storage being demonstrated both on and offshore, the economics of the next generation of CCS then saw a gap in ramp-up – until now. As timelines for global climate ambition and net zero goals grow closer, for 2030 and 2050 timelines respectively, countries and companies alike are turning to CCS as a more viable option. Hence, now is a new and exciting stage where incentives and private investments are driving emission reductions through CCS.

CCS is an emission reduction solution across industries. It can reduce emissions while maintaining production. It can be applied to hard-to-abate sectors and is sometimes the only technology available to target process emissions. In a time in which, the developed economies of the world are striving to deploy CCS, the speed at which projects are announced appears to be increasing. However, reaching a final investment decision (FID) for projects is not an easy road. Getting to FID is a complex and case-specific venture, and this report aims to navigate that journey.

In an attempt to compress the many globally nuanced approaches to having projects reach a positive decision to proceed, this report will highlight the foundational questions and key decision points any project will need to consider. As the regulatory and incentive frameworks play a critical role in developing CCS projects, this report utilizes the example provided by the Government of Alberta as a specific microcosm for deployment. The purpose is to take generalities a layer deeper, enabling decision-makers to understand the degrees of complexity and how they may parallel, shape, or differ from future applications in other jurisdictions. By including details, this report aims to explore the key technical and financial factors that impact the costs and risks of project development balanced against the benefits and ultimate need for CCS technologies to reduce emissions from key industrial processes.

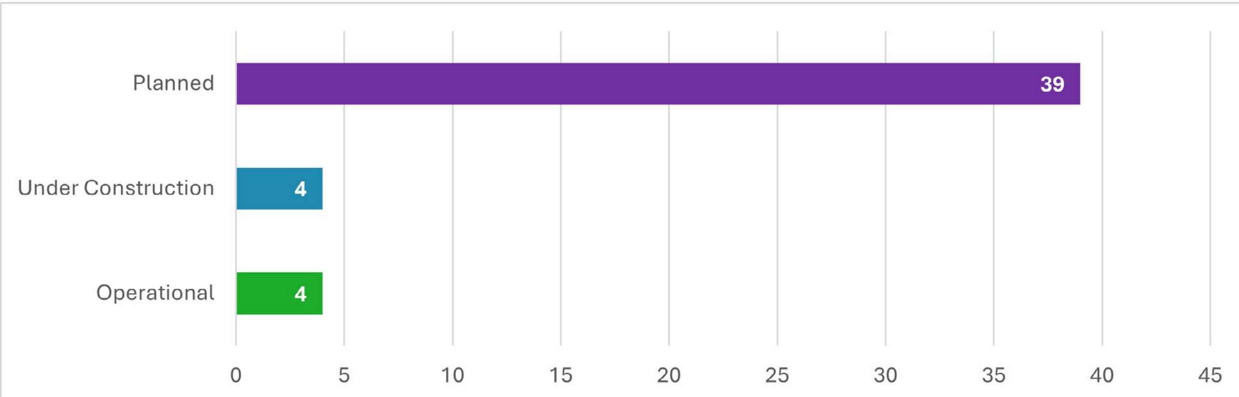



*Figure-1: Carbon Capture Project Development Status in Alberta*

The Alberta context is relevant to global CCS development as industries and government within the province are early adopters of and investors in commercial-scale CCS projects and developed a robust regulatory, permitting, incentive and carbon credit system. The Alberta government has enabled its high-emission industrial facilities to access ample storage capacity, and as such, new hub opportunities are driving the next wave of CCS projects. As of August 2024, four commercial capture facilities serving industrial emitters are under construction, and the province has granted two sequestration leases to storage hub operators. The realities of a division of responsibilities related to emission reduction policies within Canada's federation can prove challenging. However, both federal and provincial levels of government have demonstrated support by creating regulatory frameworks and incentives for CCS projects.

The key questions guiding this journey: Why do we need CCS? And what is the pathway to FID?

The report explores the global value and urgency of CCS, including an explanation of how long it takes from conception to storing $CO_2$ in the ground. The Alberta-specific landscape is considered as well as the announced projects to date. This example sets the stage to explore what drives and differentiates projects, what aspects of a regulatory framework foster investment, what factors impact project economics and what risks need to be mitigated to ensure project success.[1]

The starting point of any project starts with a company's emission reduction strategies. Having a top-down approach to corporate decision-making with informed insight from technical experts can make or break a project. Tying emission reductions to corporate strategies also gains buy-in for fully integrated projects that are often out of a business's efficacy. Regulatory compliance is another driver, and CCS is often considered an option to address corporate operations and government emission reduction requirements.

In knowing the starting point, a detailed understanding of storage and transportation access becomes the first step, coupled with an evaluation of capture technology options. The inherent risk layered with timelines has meant near-term projects are considering mostly proven amine-based post-combustion technologies and known engineering procurement partners, with a desire to still see new technologies take off in the next decade.

After the starting considerations, projects attempting to reach FID must then look to more specific project requirements. This is where it is important to cover regulatory oversight mechanisms and safety considerations. Permitting of projects can be streamlined or burdensome depending on the level of readiness of a government to accept $CO_2$ storage and capture processes in their region. Places with set regulatory structures for permitting and monitoring measurement and verification plans are seeing earlier FIDs than those who are, arguably, catching up.

With government dollars often tied to CCS projects abetting investment at this point in its global deployment lifecycle, there is also an understanding that public knowledge sharing, and other "strings" can be attached. Knowledge sharing acts as a tool to ensure cost reductions through iterations in this, debatably, "one and done" setting in the near term given the large capital expenditure of projects. Additional requirements attached to government assistance are seeing a growing presence such as corporate climate reporting, labour requirements, local content provisions, and social and environmental justice considerations.

A critical step on the path to "getting to FID", is the business case for CCS. To greenlight a CCS project a company relies on the balance between the value for the investment surpassing the opportunity cost of investing in other capital projects. Importantly, those making such decisions will have different expectations as to what represents a sufficient return on investment and what strategic value can be gained from building and operating CCS projects.

Every leader of a company tasked with finding out if their company should consider CCS usually starts at this stage – how much will it cost? When in fact, the earlier sections of this report are perhaps a better starting point than being informed of cost by an internal engineering team without CCS expertise. But ultimately costs – both capital and operating – do matter. This includes the cost of energy as well as any impact on production or operations.

Costs also need to be offset by potential revenue. Many mechanisms beyond direct government investment can also support projects. Carbon credit markets, low-carbon products, developing utilization opportunities and green procurement measures are all gaining momentum in furthering the business case for CCS.
The final stage before reaching FID is mitigating risks to investment. The "finer" nuanced factors that often find their way onto the desks of decision-makers concerning investment risks are matters of uncertainty, constraints, and liabilities. Whether there is a desire to have certainty in carbon price to justify operating costs, or the need for insurance on long-term liabilities to unlock corporate dollars, risks to investment often require certain levels of assurance to be mitigated. The need to mitigate and manage risk appropriately can be found at all corners of a project from community engagement to labour and supply chain contracting provisions.

Finally, the report concludes by reviewing the key takeaways from each of the sections and how the Alberta government has been able to see projects expertly navigate the intricate balance that is Getting to FID.

# 1. Introduction

As the world grapples to address climate change, a suite of carbon management technologies, including carbon capture and storage (CCS) have emerged as internationally recognized technologies to reduce greenhouse gas (GHG) emissions from critical industrial processes. For the scale of CCS projects required to meaningfully reduce industrial emissions, CCS projects need to reach a final investment decision (FID) as soon as possible. CCS projects are complex, although they use proven and safe technologies, they often involve novel engineering, financial structures or regulatory perspectives.

Executing large-scale carbon capture projects requires substantial capital, labour, and planning. The purpose of this report is to explore the foundational questions that need to be answered by all projects at a global scale. Using Alberta, Canada as an example illustrates the policy, regulatory and business navigation required to proceed with a final investment decision.

The Alberta government and industries within the province are global leaders in CCS with a history of innovation and investment, exemplified by two of Canada's first commercial-scale CCS projects, the Alberta Carbon Trunk Line and Quest CCS projects.[2] With an established regulatory regime and significant geological capacity, Alberta is poised for CCS and other carbon management investments in the near term. Over twenty CCUS hubs are in the evaluation stage to support various industries' decarbonization plans and several projects have announced FID in 2024, how projects are "getting to FID" is crucial to understand and advance more projects.

Throughout this report, foundational questions are posed that emitters will need to answer before making an FID. Answering these foundational questions, identifying key decision points and the data required to make these decisions can help emitters advance projects more quickly

The role that other carbon management technologies, including the utilization of captured carbon for products[3] and carbon dioxide removal (CDR)[4] projects, is internationally recognized and complimentary to the development of CCS projects. Both CDR and carbon utilizations are included where relevant and needed, to add context for options emitters have when considering the development of CCS projects. The focus of this report, however, is on CCS as a solution for point source capture from large emitters.

## CCS, CCUS, CDR and Carbon Management

The terms CCS, Carbon Capture, Utilization and Storage (CCUS), Carbon Dioxide Removals (CDR), and Carbon Management are used throughout this report, though the main focus of the report is on CCS. These terms are related but have key distinctions.

**Carbon Capture and Storage** – CCS is capturing carbon dioxide ($CO_2$) from point-source industrial emission sources and storing the $CO_2$ in dedicated geological storage.

**Carbon Capture, and Utilization, Storage – CCUS** is capturing $CO_2$ from point-sources and using the $CO_2$ for enhanced oil recovery or other utilizations such as cement production, as well as storing $CO_2$ in dedicated geological storage.

**Carbon Dioxide Removal** is capturing $CO_2$ directly from the atmosphere (Direct Air Capture or DAC) or from biomass energy projects (BECCS) and storing $CO_2$ in dedicated geological storage.

**Carbon Management** is the suite of engineered activities aiming to utilize or store captured $CO_2$. For the purpose of this report, Carbon Management includes CCS, CCUS, and CDR projects.

## 1.1 The Need for Carbon Capture, and Storage

The Paris Agreement[5] at the United Nations Climate Change Conference in 2021 required all participant countries to establish Nationally Determined Contributions (NDC), to reduce Greenhouse Gas (GHG) emissions and adapt to the impacts of climate change.[6] These commitments show the need for developing large-scale emission reductions for industrial activities, with CCS playing a role in reducing $CO_2$ emissions. Globally, there are more than 45 operating CCUS projects, reducing $CO_2$ emissions by 50 Mt, and more than 500 projects at varying stages of development.[7]

International climate organizations including the Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA) both state carbon management technologies play a considerable role in efforts to limit global temperature increases and meet countries' respective NDCs. For example, by 2030, the IEA's Net Zero Emissions Scenario has CCUS facilities globally capturing and storing approximately 1,000 Mt of $CO_2$ annually, a 20-fold increase in current facility capacities.[8]

The Carbon Management Challenge exemplifies the growing recognition of the role CCS is to play in working toward a net-zero future. The challenge is an international effort and call to action to accelerate the deployment of carbon management technologies to keep a global temperature rise of 1.5°C within reach. The challenge's 20 participant countries and the European Commission call for an increase in current capture and storage capacity to reach a gigaton scale by 2030 and a 200-fold increase to reach net-zero emissions globally by 2050.[9] Countries committed to the challenge represent a growing momentum to enable CCS through the increase in resources invested and policies created.

As we are using the context of Alberta as a microcosm for the world's development of CCS projects, it is important to explore the plans of both Canada and Alberta. Both jurisdictions play a role in enabling CCS as a tool to reduce GHG emissions from industrial sources.

Canada has two climate targets, focusing on different time scales. The first is the NDC commitment under the Paris Agreement to reduce national greenhouse gas emissions by 40% to 45% relative to 2005 levels by 2030. The NDC was enhanced in 2021 with specific inclusion of carbon capture, utilization and storage as a technological solution to meet the commitment.[10] The second is a legislated commitment to achieve net-zero greenhouse gas emissions by 2050. To deliver on this, the federal government has developed the 2030 Emissions Reduction Plan and forwarded a suite of regulations, tax incentives, programs, and strategies to deliver GHG emission reductions.

The 2030 Emissions Reduction Plan includes Canada's Carbon Management Strategy - a strategy that identifies carbon capture as a critical emissions reduction tool for many industrial sectors and in permanently removing GHGs from the atmosphere. In the strategy, carbon management technologies are described as an opportunity "to decarbonize many industrial sectors and develop new ones in support of a prosperous, net-zero economy of the future."[11]

In Canada's Energy Futures 2023 report from the Canada Energy Regulator (CER), carbon management is highlighted for the key role it will play in domestic emissions reductions. In the CER's Global Net-Zero Scenario, in which Canada and the rest of the world achieve net-zero emissions by 2050, 60 Mt of GHG emissions are sequestered via CCUS annually. In the Canada Net-Zero Scenario, in which Canada reaches net-zero emissions by 2050 but the rest of the world moves more slowly, the CER estimates that CCUS will be needed to sequester as much as 80 Mt annually due to the greater global demand for fossil fuels.[12]

Alberta's 2023 Emission Reduction and Energy Development Plan[13] recognizes the importance of CCUS and CCS in reducing the province's industrial emissions, its role in attracting investment, and providing a pathway for existing and new industries to grow in the province.

In the aforementioned reports and forecasts, CCS represents the bulk of the emissions reduced using carbon management solutions in the near term, with novel utilizations beyond enhanced oil recovery (EOR) and CDR technologies still developing to permanently store $CO_2$ at a mega-tonne scale.

## Alberta's CCS Overview

Alberta is an ideal representation for getting CCS projects to FID due to many factors, not least of which is the significant geological capacity for storage layered with its industrial point sources of emissions. Alberta has a combination of inherited resources, including abundant pore space, and has taken deliberate steps to create regulatory and incentive frameworks to enable CCS projects.

**Emission Sources:** The province has a substantial number of industrial facilities, producing diverse and critical products in the cement, manufacturing, clean hydrogen, petrochemicals, upgrading and refining, power, steel, fertilizer, biodiesel, and oil and gas sectors. In 2022, Alberta had 58 facilities emitting more than 400,000 tonnes of $CO_2$ annually. CCS is one of the few commercially available solutions for step-change emission reductions for several industrial processes within these industries.

**Available Storage:** Alberta has suitable geology for extensive $CO_2$ storage, with the capacity to theoretically store all industrial $CO_2$ emissions for decades. A large section of the province is located over the Western Canadian Sedimentary Basin, which has been estimated to exceed 400 billion Tonnes of $CO_2$ storage potential.[14]

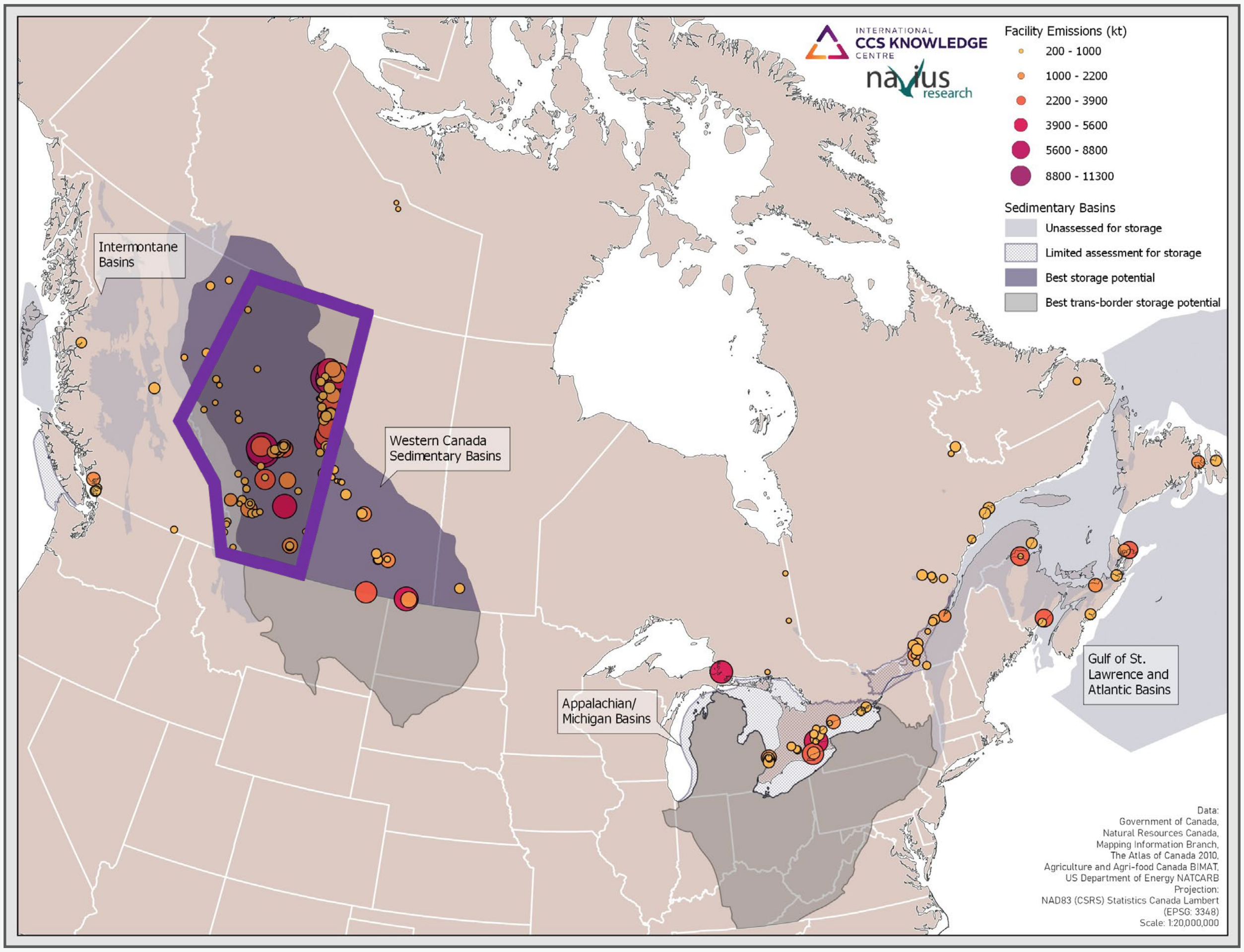



*Figure-2: Carbon Storage Potential in Canada*

**Early Adopter:** Alberta has been at the forefront of commercial-scale CCS projects with major investments in large-scale projects starting in 2008. Alberta has used underground reservoirs since the 1950s and is home to four of Canada's five largest capture projects.

*Table-1: Alberta Operating CCUS Projects*

| CCUS Project | Shell Quest | Alberta Carbon Trunk Line | | Entropy Glacier CCS[15] |
|---|---|---|---|---|
| | | NWR Sturgeon Refinery | Nutrien | |
| **Capture Facility Commissioning** | 2015 | 2020 | 2019 | 2024[i] |
| **$CO_2$ Stored to Date** | 9 million tonnes (May 2024)[16] | 5.5 million tonnes (August 2024) utilized in EOR[17] | | TBD |
| **Provincial Investment** | ~$750 million | ~$500 million | | ~$20 million |

i Phase 1a began operation in 2022 with phase 1b in 2024

**Regulatory Framework:** Alberta boasts a comprehensive and evolving regulatory environment, Canada's first, that covers each aspect of the CCUS value chain. The Mines and Minerals Act[18] and the Carbon Sequestration Tenure Regulation[19] govern $CO_2$ sequestration in Alberta. Additionally, the Oil and Gas Conservation Act, Pipeline Act, and various Regulator Directives set out the necessary licences and approvals for CCS projects.

**Existing Incentives for CCS Projects:** Both the Governments of Alberta and Canada have developed CCS-specific incentives and GHG emission pricing systems to enable and attract private investment in CCS projects, which often can be stacked to strengthen support (explored further in Section 4.2).

**Numerous Prospective Projects:** There are several proposed CCS projects in Alberta, providing a rich field for analysis and many opportunities for innovation and development in the sector. As of July 2024, Alberta had 39 planned CCS projects at varying degrees of development (from pre-feasibility to completed front-end engineering and design (FEED)), two under construction, and four operational projects.

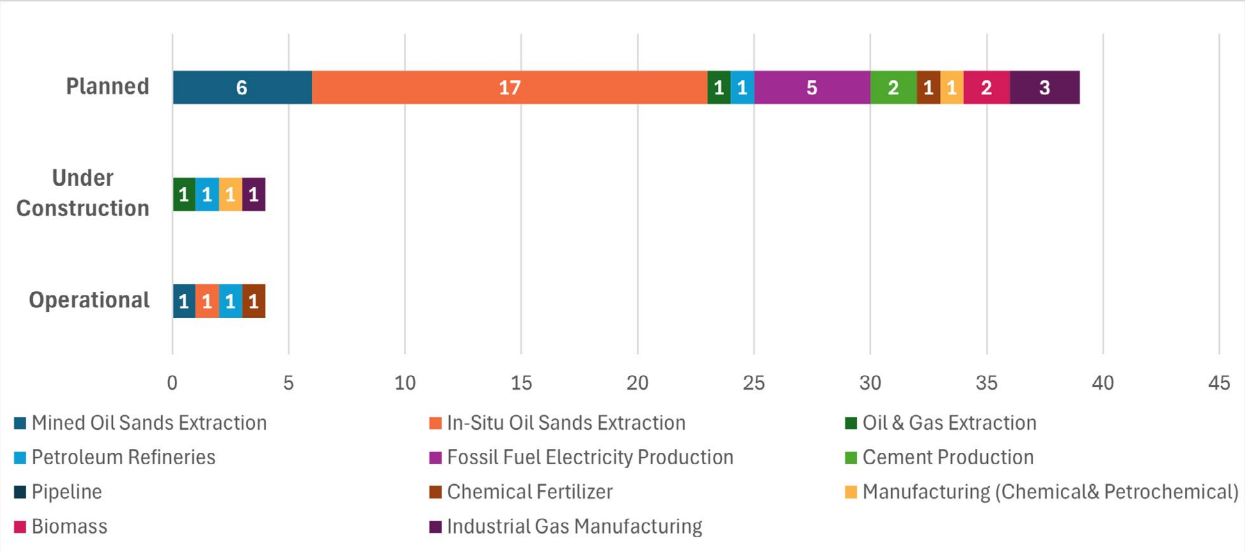



*Figure-3: Planned, Under Construction, and Operational Capture Projects in Alberta*

## 1.2 The Need for Final Investment Decisions in CCS

**CCS is a proven emissions reduction technology that can be deployed today across industrial sectors.** CCS projects are, in the simplest terms, waste removal projects that reduce or offset GHG emissions created by fossil-fuel-intensive industrial processes. The window for CCS projects is opening worldwide due to:

- A growing number of jurisdictions are developing carbon management strategies, regulatory frameworks and incentives;
- A growing recognition that carbon management is a necessity for any net-zero future;
- The readiness of CCS technology for key industrial processes compared to other fossil-fuel-based solutions; and most importantly,
- The severe consequences of global temperature rising and the decreasing likelihood that we limit global temperature increases to less than 1.5°C.

Globally, the number of CCS project announcements has not yet matched the number of actual projects being developed. The IEA monitors clean energy advancements, and in 2023, the IEA stated that, despite an increase in developing, under-construction, and operational projects, CCUS deployment is "not on track" to meet the agency's Net Zero Emissions by 2050 scenario. This is also true for clean energy transitions in sectors like steel, cement, chemicals, oil and gas, low-emission fuels, and paper.[20] Capture projects announced to potentially begin operations by 2030 have a total of 430 Mt of capacity. However, the projects beyond FID only represent one-fifth of the announced capacity. With the window opening for CCS projects, the questions remain: why is there a gap between announced and post-FID CCS projects and what challenges need to be overcome to bring more projects to realization? **To answer these questions, we start by exploring why CCS is an answer for some industrial facilities and what differentiates various CCS projects.**

## Carbon Capture Projects Reaching FID in Alberta

Capture capacity is the total availability of all facilities in a jurisdiction to capture $CO_2$ which would otherwise be released into the atmosphere and does not always match known or developed storage capacity and/or transportation capacity. The construction and commissioning of capture facilities, particularly post-combustion capture facilities, are the largest capital and operating expenses along the CCUS chain.

Over the last 15 years, 49 capture projects have been announced in Alberta, two of which were publicly cancelled and four are operational at commercial scale. Four projects are currently under construction,[i] [21] while 39 are at some stage of planning. Eight projects in Alberta have reached or are expected to reach an FID in 2024.

Table 2 lists companies and capture facilities that have publicly announced an anticipated FID timeframe or have made an FID and are considered under construction

i Additionally, Deep Sky is developing Deep Sky Labs, a cross-technology carbon removal facility is under construction in Innisfail, Alberta.

*Table-2: Upcoming Capture Projects with Announced FIDs*

| Company Partner | Facility Name | Industrial Sector | Facility Emissions $CO_2$ tpa (2021) | Capture Development Status | Announced Year of FID | Expected Commercial Operations Start |
|---|---|---|---|---|---|---|
| **Air Products Canada Ltd.** | Edmonton Hydrogen Facility | Industrial Gas Manufacturing | 1,153,621 | Under Construction | 2022 | 2024 |
| **Dow Chemical Canada ULC** | Western Canada Operations | Petrochemical Manufacturing | 1,002,921 | Under Construction | 2023 | 2029 |
| **Advantage Energy Ltd.** | Glacier Gas Plant CCS Phase 2 | Oil and Gas Extraction | 160,000 | Under Construction | 2024 | 2026 |
| **Shell Canada** | Shell Scotford facilities | Petroleum Refineries & Industrial Gas Manufacturing | 650,000 | Under Construction | 2024 | 2028 |
| **Heidelberg Materials** | Edmonton Plant | Cement Production | 1,300,000 | Planned | 2024 | 2027 |
| **Lafarge Canada Inc.** | Exshaw Cement Plant | Cement Production | 1,212,333 | Planned | 2026 | 2030 |
| **Moraine Initiative Ltd. (GE)** | Moraine Power Generation | Fossil Fuel Electric Production | 1,121,084 | Planned | 2024 | 2027 |
| **Pembina Pipeline Corporation and Marubeni** | Pembina Low Carbon Complex | Industrial Gas Manufacturing | Greenfield Facility, No emissions yet | Planned | 2024 | 2027 |
| **Strathcona Resources Ltd.** | All SAGD Facilities | In-situ Oil Sands Extraction | Multiple facilities | Planned | 2025 | 2030 |
| **Nutrien** | Redwater Fertilizer Operations (Phase 2) | Chemical Fertilizer (except Potash) Production | 967,632 | Planned | 2025 | Unknown |
| **Alberta Power 2000 Ltd.** | Battle River Generating Station | Fossil Fuel Electric Production | 1,096,072 | Planned | 2024 | 2028 |

## What does the project development timeline for CCS projects look like?

Implementing commercial-scale carbon capture technology generally requires over six years to complete. Depending on an organization's risk tolerance, additional time may be necessary to sufficiently mitigate potential risks associated with the technology. It is essential to manage this schedule while considering the timeline for transportation, storage, and utilization of the captured $CO_2$.

Additionally, it is reasonable to anticipate an optimization phase later in the project to address deficiencies and enhance the effectiveness of the capture solution.

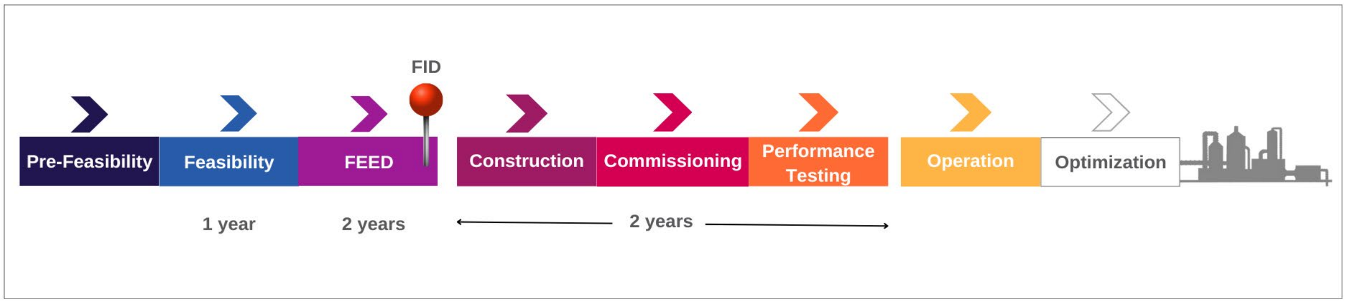



*Figure-4: CCS Project Development Timeline*

# 2. Knowing the Starting Point: CCS Drivers and Differentiators

The decision to proceed with an FID for CCS projects hinges on a variety of key drivers and differentiators. Understanding these elements is crucial for stakeholders aiming to navigate the complexities of implementing CCS initiatives. This section explores the pivotal factors that influence the adoption and success of CCS projects. It begins by examining corporate emission reduction strategies, highlighting how major companies incorporate CCS into their plans to maintain production while achieving substantial emissions reductions. Subsequent subsections delve into essential pre-capture activities, $CO_2$ storage and transport options, and capture location considerations. Analyzing these components provides a comprehensive overview of what drives and differentiates CCS projects, setting the stage for informed decision-making and strategic planning in the pursuit of sustainable carbon management solutions.

## 2.1 CCS Driver: Corporate Emission Reduction Strategies

In 2022, more than 700 of the world's largest publicly traded companies had set net-zero targets, including many of Canada's largest businesses.[22] These companies can already understand that business and industry must both reduce and manage $CO_2$ emissions to remain competitive in a lower carbon economy.

The role of CCS in corporate emission reduction strategies is to maintain production while substantially reducing emissions. In the words of an Executive Series participant, they see **CCS as a tool to decarbonize without the need to deindustrialize**. Major worldwide industries in hard-to-abate sectors such as steel, fertilizer, cement and concrete, hydrogen production, oil and gas, power, and chemical and petrochemical production have identified carbon management as critical for emission reduction plans.

For example, the Global Cement and Concrete Association's roadmap for net zero concrete, Concrete Future[23] indicated that 36% of emission reductions will need to come from CCUS at cement plants.[24] This is the single biggest action alongside emission reducations in clinker production, efficiency improvements in concrete production, electricity decarbonization, cement substitution, storage of $CO_2$ in cement and improved efficiency in design and construction. Carbon management is not the silver bullet in reducing all emissions, but it is a necessary reduction for critical products that make up our built environment.

### What Early Activities Should Emitters Conduct Before Considering Capture Projects?

Before spending capital or resources on any technical study for a point-source capture project, there are some early-stage activities that emitters should take to move their starting point forward.

Fundamental Facility Emissions and Energy Analysis

- **Research and Education:** Gain knowledge about the basics of capture technologies and their applications.
- **Emissions Profile and Energy Assessment:** Understand the facilities' emissions profile by performing stack testing, evaluating the availability of cooling mediums, and analyzing energy consumption to identify areas for improvement and establishing a baseline for comparison.

- **Long-term Planning Alignment:** Align the facility's long-term plans with future production capacity, fuel usage, and the compatibility of capture technologies with conventional measures. For instance, if there is a scheduled maintenance or replacement downtime, aligning CCS-related integration at those times can best manage operations.
- **Facility Modifications:** Investigate necessary modifications to ensure the facility can operate efficiently for the next 20 to 30 years.

Stakeholder and Regulatory Analysis

- **Stakeholder Analysis:** Conduct preliminary analysis to identify local communities, partners, and hubs that may be affected by the project for consultation.
- **Regulatory Review:** Review regulatory requirements, environmental laws, and permitting requirements for the selected project location.

Market and Incentive Opportunity Identification

- **Incentives and Funding:** Identify applicable incentives and funding programs for the potential project.
- **Market Analysis:** Conduct a market analysis of future conditions for utilization technologies and low-emissions products, including demand, pricing, incentives, and partnership opportunities.
- **Financial Assessment:** Conduct early financial assessments to determine if there is sufficient financial capacity or access to financing for these larger projects.

Knowledge and Capacity Gap Identification

- **Internal Capability Evaluation:** Evaluate internal resources and capability to conduct or lead a feasibility study and identify any gaps in capability.

## 2.2 CCS Driver: Regulatory Compliance for Reducing Emissions

Companies, on a global scale, may seek to reduce their emissions profile for any series of reasons, whether it be corporate and sustainable governance tied to performance measurements, and/or to comply with government oversight mechanisms. Focusing primarily on the latter, in pursuit of reducing industrial GHG emissions, governments often opt to use regulatory levers to mandate emission reductions from specific industrial facilities, broader industrial sectors, or the economy as a whole. These regulatory mechanisms can be strict limits such as specific facility emission intensity limits or flexible market-based systems such as emissions trading schemes. Many of these regulatory structures seek to be technology agnostic, allowing industrial emitters to determine their own path for reducing emissions. CCS projects represent one pathway for facilities to meet emission reduction regulations and avoid potential penalties.

In jurisdictions that have emission trading systems like the European Union[25] and Canada,[26] reducing emissions below the required amount can create an opportunity for CCS project operators to generate credits which can be traded to others and be used as compliance. Such systems have been developed with special consideration for carbon management projects, with quantification protocols designed or being designed for CCS, utilizations such as EOR, and CDR technologies.

## Sample Regulatory Compliance Mechanisms for Emission Reductions in Canada and Alberta

In Canada, the GHG emissions from large industrial facilities across industrial sectors are subject to federal and/or provincial regulations. Across Canada, 327 policies have been developed with a focus on reducing emissions with more than 70 developed by the federal government and applied across the country and the remainder developed by respective provinces and territories.[27] The majority of these policies are abatement support programs and incentives, such as rebates, funding calls, and tax incentives. However, some of the most influential policies related to CCS are mandatory compliance policies including federal and provincial GHG pricing systems for industrial emitters.

Several proposed federal regulations may add to the regulatory regime and are in different stages of consultation. These may impact the development of CCS projects. Many proposed regulations include recognizing CCS projects as an opportunity to reduce direct facility-level GHG emissions and/or to generate carbon credits eligible for use as compliance. There are industrial sector-specific regulations such as product-specific performance emission performance benchmarks within emissions pricing systems as well as stand-alone regulatory levers such as the federal Clean Fuel Regulation (CFR), proposed Oil and Gas Emissions Cap, and proposed Clean Electricity Regulations. Several current and proposed regulations are introduced below.

1. *The Greenhouse Gas Pollution Pricing Act*

In 2019, Canada introduced the Greenhouse Gas Pollution Pricing Act (GGPPA)[28], a nationwide legislation for the pricing of GHG emissions. The GGPPA has two parts: a regulatory charge on retail fossil fuels like gasoline and natural gas, known as the federal fuel charge, and a performance-based large emitter system for industrial facilities, known as the Output-Based Pricing System (OBPS). Facilities that emit more than their annual emissions limit must address their regulatory obligation through several options including submission of eligible offset credits.

The federal government has developed and administers an emissions trading system known as Canada's Greenhouse Gas Offset Credit System. Parties regulated under the OBPS can utilize offsets generated from the federal offset system as compliance. To generate Emission Offset Credits project proponents must register their project and use a recognized federal offset quantification protocol. Environment and Climate Change Canada (ECCC) has begun the development of a quantification protocol for DAC and has announced a proposal to also develop a BECCS protocol. The federal government has not yet proposed to develop quantification protocols for either CCS or EOR under this federal offset system.

2. Alberta Technology Innovation and Emissions Reduction Regulation (TIER)

Under the federal GGPPA legislation, the provinces and territories have the flexibility to develop their own GHG pricing systems, but the provincial systems must meet minimum national standards including an escalating price schedule. These criteria are known as the 'federal benchmark'. If a province or territory introduces regulations that meet the federal benchmark, the federal and provincial regulations are deemed to be equivalent. In this case, the federal regulations will not be applied, the federal system is superseded by the provincial industrial GHG pricing system. If a province or territory decides not to price GHG emissions or proposes a system that does not meet these standards, the federal system is applied. This is known as the 'federal backstop'.

- Alberta has developed a provincial-level GHG regulation that meets the federal benchmark. The Alberta

TIER imposes an output-based emissions benchmark on large facilities. Regulated facilities can comply with requirements through:

- Improving its facility operating efficiency;
- Submitting emission performance credits (EPCs);
- Submitting emission offsets; or
- Paying for fund credits.

Emission offsets are generated by projects that have voluntarily reduced their GHGs. Emission offsets are quantified using Alberta-approved quantification protocols. There are currently 18 active protocols, including protocols for CCS and EOR.[29, 30]

3. Federal Clean Fuel Regulations

In 2023, another regulatory mechanism was introduced across Canada, which may incentivize CCS development, the federal Clean Fuel Regulations (CFR). The sector-specific regulations apply to parties that produce or import retail gasoline or diesel in Canada, primarily refining facilities. The objective of the CFR is to reduce the carbon intensity of gasoline and diesel use in Canada. Obligated parties will have an annual emissions reduction requirement based on the amount of gasoline and diesel fuels they produce or import. From 2023 to 2030, entities affected by the CFR will face increasingly stringent emission reduction requirements each year. Regulated parties satisfy their regulatory requirement via submission credits and the credits represent GHG reductions within the system.

There are three compliance categories within CFR. Most notably for CCS, category 1, Action Along Life-Cycle of a Fossil Fuel, allows for CCUS projects, including utilization for EOR, to generate credits.[31] There are scenarios whereby CCS activities generate credits both in TIER and the CFR.[32]

4. Clean Electricity Regulations

While there are already specific regulations to deal with unabated coal and natural gas in Canada, the proposed Clean Electricity Regulations aim to ensure increased stringency on emissions while driving increased electrification.

The Canada Electricity Advisory Council's Powering Canada[33] report indicated in order to electrify vast amounts of the economy and match population and economic growth, electricity generation may need to increase as much as 2 times to meet demand. As such, the Clean Electricity Regulations will apply to any fossil-fuel electricity generation units of a certain size that are grid-connected.

Though the legislation has yet to be finalized, the government has publicly consulted with industry initially on an annual basis emission performance standards of 30 tonnes of $CO_2$ per GWh of electricity produced (30 t/GWh). The government is considering measures to increase the flexibility of the system including allowing credits, and pooling of facilities, among other changes.

Depending on the details of the regulation, CCS may be one of the few options for natural gas-fired power generating units, including many cogeneration units at other industrial facilities in Canada, to continue operation long-term and meet the Clean Electricity Regulations.

## 2.3 CCS Differentiators: $CO_2$ Storage Options

CCS projects operating at a large scale permanently store captured $CO_2$ by injecting it into geologic reservoirs or utilizing the $CO_2$ in an enhanced oil recovery process while permanently storing the $CO_2$. Globally, it is anticipated that the vast majority of captured $CO_2$ will need to be stored in geologically dedicated storage locations. Ensuring potential access to a storage site is the first criterion that needs to be confirmed before considering the feasibility of a capture facility. Without access to store captured emissions, projects lack the necessary full-chain solution.

Factors to be assessed when choosing how to store $CO_2$ include:

- Regulatory access to $CO_2$ storage: Identifying potential storage sites is a prerequisite to developing any CCS project. Jurisdictions vary in who owns the rights to storage sites and how access is granted. Proponents need to consider the specific pathway to access $CO_2$ storage sites in their jurisdiction.
- Proximity to storage and access to $CO_2$ transport: The farther projects are from storage opportunities, the higher transport costs are. There are various forms of transport – pipeline, boat, truck, train. Securing viable transportation is paramount.
- Monetization opportunities: Economic considerations for the storage of $CO_2$ may weigh on their profitability. Proponents need to consider if there is an opportunity to monetize verified net $CO_2$ reductions via compliance or voluntary carbon markets and options to sell the $CO_2$ for utilization.
- Incentives: Proponents need to consider opportunities to access government programming and financial incentives. Programs and compliance mechanisms vary based on the methodology of storing or utilizing captured carbon.
- Scale: With the large amounts of $CO_2$ that CCS can reduce, proponents need to consider if the storage or utilization opportunities have the capacity to take the full $CO_2$ volumes anticipated from the capture facility, as well as the injectivity, or rate at which $CO_2$ can be introduced into the subsurface, the proximity of other storage sites, and the overall containment capacity for the lifetime operations of the capture facility.
- Shared transportation and storage: There is the potential in various regions to share transportation infrastructure and storage sites also referred to as “hubs”. Regional hubs for transporting and storing $CO_2$ from multiple sources can lower costs, share risks, and enable scaling more quickly.

## 2.4 CCS Differentiators: CCS Hubs

As noted in Section 2.3, evaluating an emitting facility’s proximity and access to geological storage sites is a key step in evaluating the economic viability of any CCS project. The shorter the distance to an accessible sequestration location the lower the costs for a CCS project. Similarly, it is beneficial for multiple emitting facilities to access shared $CO_2$ transportation and storage infrastructure to lower costs and manage and share risks, resulting in stable support for an emitter to achieve economies of scale and emissions reduction targets.

CCS hubs can be both location and/or purpose-driven:

a. **Location:** Location-driven CCS hubs are a result of industrial clusters or geological significance. Industrial clusters are either designed by jurisdiction or formed organically due to location advantages. A cluster can be industry-specific or consist of cross-industry facilities. Industrial clusters catalyze decarbonization, provide significant economic benefits, develop trust among different industrial sectors, and encourage the sharing of common resources and knowledge.

b. **Purpose:** Purpose-driven hub archetypes[34] include:
    i. Large emitter-dominated hubs: serving clusters of major emitters.

ii. Cross-industry hubs: providing access to a wide range of industries and emission profiles.
iii. Storage-led hubs: taking advantage of a location close to or with transportation access to geological storage.
iv. High-purity emitter hubs: providing storage access or utilization opportunities to industries with high-concentration $CO_2$ streams (primarily ethanol, hydrogen, urea, and bioethanol production).
v. Carbon removal hubs: built to support direct air capture (DAC) and bioenergy with CCS projects (BECCS).

An example of hub-focused CCS development comes from the United Kingdom (UK) which is developing projects to serve industrial clusters with shared transportation to shared offshore storage sites. This type of development matches the UK government's approach to heavily regulate the operations of $CO_2$ transportation and storage hubs while taking an active role in mitigating financial and operational risks for operators of such hubs. Another offshore example, set to open in 2024, is the open-source Northern Lights transport and storage site – part of Norway's Longship project to open up full-scale CCS in Norway.[35]

### Carbon Storage Hubs in Alberta

Clusters of emitters can act as an impetus for creating a CCS hub with the goal of shared infrastructure lowering costs for project development. The Alberta Government has vested ownership of the pore space in which $CO_2$ can be sequestered within the province. In 2021, Alberta began to advance the development of strategically located carbon storage hubs through competitive processes. This storage hub concept was driven by a desire to meet the growing demand for pore space in a manageable fashion.

The Alberta government has since hosted two competitions to grant the pore space rights for storage hubs starting in 2022. Through these competitions, more than 20 Carbon Sequestration Evaluation Agreements were entered into between the Alberta government and project proponents.[36]

In the summer of 2024, these evaluation projects began to convert into Carbon Sequestration Agreements, meaning successful applicants can now move forward with the regulatory approvals needed to begin injecting $CO_2$. In July 2024, the Atlas Carbon Sequestration Hub, a project of Shell Canada and ATCO was the first of the Carbon Sequestration Evaluation Agreements to be converted to a Carbon Sequestration Agreement. The Meadowbrook Carbon Storage Hub, by Bison Low Carbon Ventures, received its Carbon Sequestration Agreement in August 2024. Figure 5 shows the areas in which evaluations are being conducted for hub development as well as the two areas in which Carbon Sequestration Agreements have been signed.

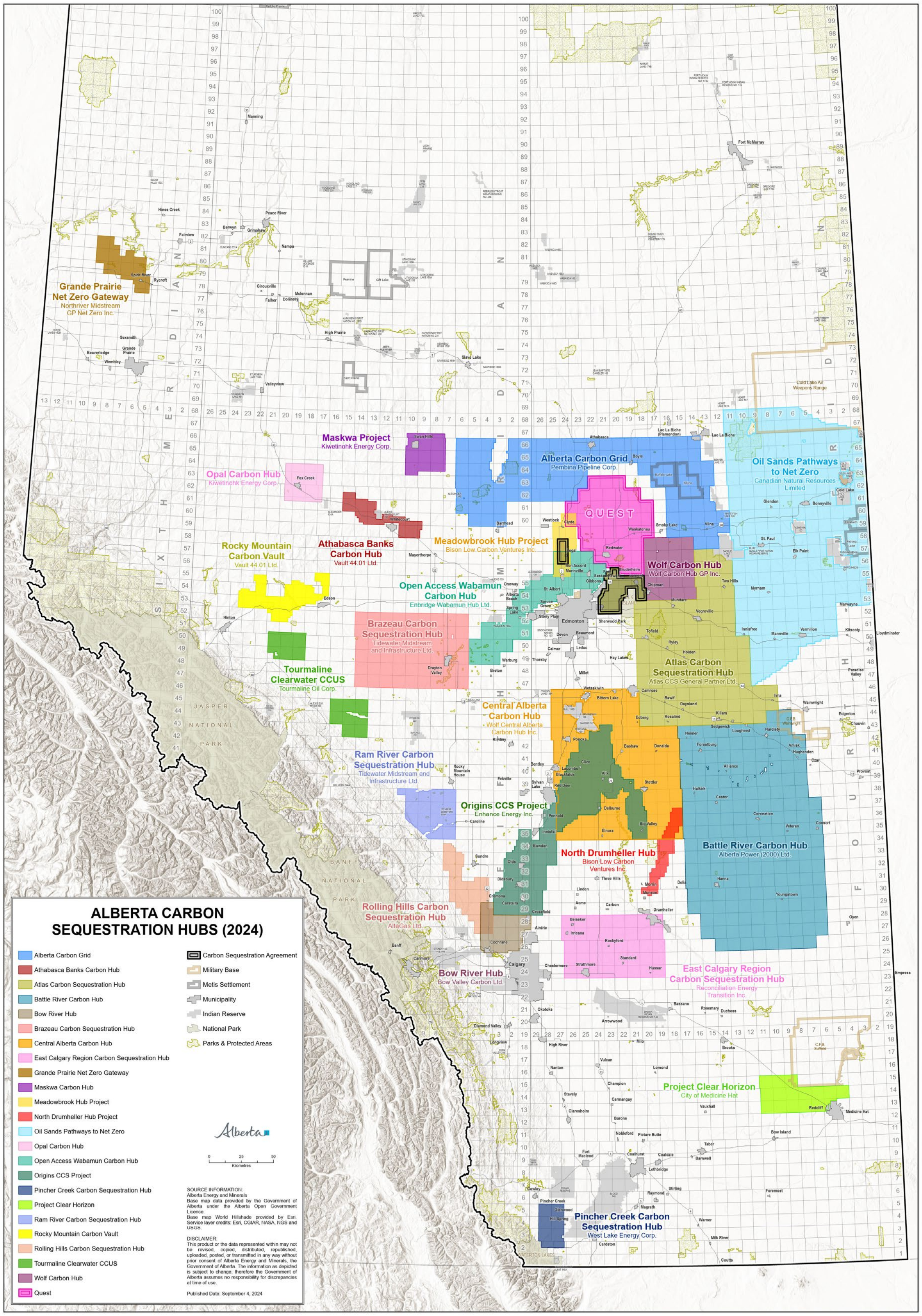



*Figure-5: Map of Alberta Sequestration Hubs (2024)*[37]

## 2.5 CCS Differentiators: $CO_2$ Transportation Options

Many early CCS projects were fully integrated single source and sink projects pursued by individual proponents developing and operating most portions along the $CO_2$ chain. As technologies have matured a growing distinction in specialization between capture, transport, and storage development and operations is forming, with $CO_2$ transport and/or storage often contracted on a merchant basis. This enables projects without the capabilities to engage in either $CO_2$ transport or sequestration to focus on core business and develop a capture facility at the site. Overall, this model enables expanded opportunities for $CO_2$ capture across the economy and relies on business partnerships and competitive contractual relationships.

A recent journal article identifies $CO_2$ transport and storage costs together could range from USD $4 - $89/tonne of $CO_2$, depending upon many factors including scale and distance of $CO_2$ transport, scale of sequestration, reservoir properties, and scale of monitoring required for the $CO_2$ sequestration facilities.[38]

### $CO_2$ Transportation in Alberta

In addition to the $CO_2$ hubs that have been proposed in Alberta (see Section 2.4 above), Alberta also has current and proposed $CO_2$ transport networks that, if all were developed, would extend across much of the provincial industrial base and connect with many of the proposed $CO_2$ sequestration hubs.

The Alberta Carbon Trunkline (ACTL)[i], is a 240km high-capacity $CO_2$ mainline that was commissioned in 2020.[39] Significant funding for the ACTL was provided by both federal and provincial governments. The ACTL was developed with merchant $CO_2$ transport intended and extends from the Alberta Industrial Heartland to the Lacombe area in Southern Alberta. The pipeline was created with a “build it and they will come” infrastructure and currently has 10% of its capacity filled as it awaits future clients.

The owner/operator of the ACTL, Wolf Midstream, has commenced development of a 40km extension west through Alberta’s Industrial Heartland. This extension will enable Wolf Midstream to take $CO_2$ from additional proponents in the Edmonton, Alberta area.

In addition to ACTL, there have been several large-scale transportation projects proposed in Alberta. Pembina and TC Energy have proposed the Alberta Carbon Grid- a $CO_2$ transport network that would serve multiple customers, industries, and sectors. The transport line proposes to deliver as much as 20 Mt of $CO_2$ annually to $CO_2$ sequestration hubs.[40] Pathways Alliance and its member oil sand producers have proposed to connect facilities in northeastern Alberta to a shared 400km $CO_2$ pipeline to a storage hub managed by the consortium.[41]

i Distinct from the ACTL project which also includes two capture facilities operated by Nutrien and the North West Partnership and sequestration for EOR operated by Enhance Energy.

## 2.6 Capture Technology Options

The selection of capture technology is a key determinant of the capital cost of capture projects. With a push for adoption by a 2030 timeline and even into the early 2030s, most capture projects are expected to use commercially proven technologies based on a drive for lower technology risk coupled with known capabilities. However, such capture technologies have some limitations and applicability to industrial processes such as $CO_2$ concentration, energy requirements, pressure, etc. Depending on a company's risk tolerance and specific context, emitters have a range of capture technologies to select for their projects.

The selection of capture technology in hard-to-abate industries is highly specific to the industrial location dynamics, including access to utilities, post-capture transportation, storage, and usage protocols. As a result, moving towards a 2050 timeline, a mix of technologies is expected. Technology Readiness Levels (TRL) are measures used to compare the development of technologies from an idea to commercial viability. For application in capture facilities, TRLs represent a range because each level varies for application to different industrial processes. Common capture technology options[42, 43] are:

- **Liquid Amine** utilizes chemical bonds to selectively separate $CO_2$ from flue gas and the solvent is regenerated with applied heat. Currently, at a TRL of 9, an amine capture system is a commercially available technology. A key challenge of this technology is the rate of amine degeneration, frequent replacement of the solvent, and the need for heat in the form of steam in the process. This is the most used capture technology and most widely demonstrated across industrial processes and at large scales. There are multiple liquid amine developers and new formulas are being developed and tested regularly.
- **Calcium Looping** is a type of chemical looping that involves two reversible reactions between calcium oxide and $CO_2$ called carbonation and calcination. Currently at TRL 6-7, this technology is optimal for low-concentration $CO_2$ streams. Challenges include a fast calcium sorbent deactivation rate, hence requiring a steady solvent supply and significant thermal power requirement.
- **Cryogenic Capture** is the process of compressing the flue gas and cooling it to low temperatures at high pressures, resulting in a liquid or solid $CO_2$ stream. With a TRL of 5-7, this technology has a higher $CO_2$ recovery and purity than amine. Cryogenic capture has substantial energy requirements for both the compression and cooling stages.
- **Membrane Capture** is the process of passing flue gas through a thin semipermeable barrier, called a membrane, with selective permeability for $CO_2$ gas. Currently at TRL 5-7, this technology is optimal at high-pressure flue gas feed. Key challenges are developing a membrane which is only selective to $CO_2$ and widely applicable.
- **Solid Adsorbent** can be used to perform chemical or physical adsorption, the adsorbent used is specific to the process and flue gas composition. Currently at TRL 4-6, this technology is relatively less energy intensive. Key challenges include significant research required to develop proper and inexpensive metal-organic frameworks (MOFs) to be used as adsorbents.

### CCS Innovation in Canada and Alberta

Canada's Carbon Management Strategy[44] notes that the near-term plan is to deploy higher TRL technologies to secure the supply chain and deliver emission reduction targets. Currently, liquid amine ranks highest on the TRL scale with proven demonstrations around the world and will likely stay a facility's first choice for capture to meet 2030 emission targets.

Beyond 2030, the 2050 net-zero emission target is the next milestone for 120 countries, including Canada. Continuous development and demonstration of lower TRL capture technologies, such as cryogenic and calcium looping technologies, is part of Canada's strategy. This is backed by a history of commitments by Canada including over $300 million in research and development funding since 2021, and support alongside provincial governments for Canada's first wave of CCUS projects including Boundary Dam CCS, Quest CCS and the ACTL project. In October 2022, the Canadian CCUS Research and Technology Network launched. The Network connects technology innovators and industry with organizations that provide expertise, facilities, and equipment to help demonstrate, scale, and validate new technologies.[45]

The Alberta government, other provincial governments and publicly funded post-secondary institutions are also continuing to invest in research, development and deployment of CCS technologies. Alberta Innovates and Emissions Reduction Alberta (ERA) have invested more than $200 million in over 100 CCUS projects.[46] ERA, which generally supports in TRL 6 and above projects has targeted funding for feasibility and FEED studies for commercial capture projects, the scale-up of utilization technologies, characterizing storage opportunities, and developing CDR projects within the province. Alberta Innovates has a greater focus on lower TRL technologies including support for the Alberta Carbon Conversion Technology Centre (ACCTC). The ACCTC, operated by InnoTech Alberta, provides its clients with the opportunity to evaluate capture and utilization technologies with additional laboratory and analytical services.[47] Research conducted at Canadian universities, notably at the University of Calgary[48], University of Alberta[49] and the Clean Energy Technologies Research Institute[50] at the University of Regina in Saskatchewan, has been directly applied and commercialized into existing CCS projects across North America.

## What are some initial considerations when selecting an engineering, procurement, and construction (EPC) partner for a project?

CCS project proponents often hire EPC partners to support the feasibility and FEED studies, construction, and commissioning of capture projects. As was revealed in our CCS Executive Series, many EPC companies are vying to work within CCS which can make selecting one confusing. Participants noted selecting and structuring the EPC contract as one of the most important decisions

Key considerations when selecting an EPC can include experience with CCS projects and within the industry; experience with a capture technology; and the ability to provide labour, access equipment and materials needed from the supply chain and offer fabrication services. An EPC may rely on sub-contracting which can create the need for increased oversight and vetting.

EPC companies tend to specialize in one industry and have a capture technology they're most familiar with. Selecting an EPC with the right experience and expertise can unlock lessons learned from previous work to be applied to the project. An EPC company should be a partner throughout the process, assisting with driving down costs and creating efficiencies. Many EPCs also offer fabrication services, which can improve access to the supply chain and create opportunities to modularize the capture facility, potentially saving time and costs.

# 3. Project Requirements

The purpose of CCS regulations and legislation to govern CCS projects varies depending on how involved the government is in building and incentivizing projects. Overall, regulatory oversight helps build assurance for projects to be developed responsibly and for public benefit. Governments have developed regulatory frameworks to strengthen protections for the environment and mitigate risks from CCS project development. Regulations can also address potential challenges for CCS developers including risks, liabilities, infrastructure sharing and open access storage sites.

The government can play a proactive role in managing challenges by creating open access transport and storage networks and regulating economic and technical terms. The government can also play a passive role, with fewer regulations, where the responsibility for managing challenges falls to the private sector. Though essentially all jurisdictions fall somewhere in between these two categories, European countries operate in a more regulated environment with a larger role for governments in planning projects compared to the more competitive and open regulatory structures in Canada and the United States. [51]

Importantly, many jurisdictions are still experimenting with different regulatory approaches, often using subsidies for specific projects to refine their strategies before committing to more comprehensive legislation. Alberta, for example, developed and legislated much of its regulatory framework for CCUS projects alongside the development and investment in the Quest CCS and ACTL projects in the early 2010s. Regulations have continued to develop and adapt to the changing needs of industry.

This section explores the common requirements that CCS projects need to overcome in the early stages of project development.

## 3.1 Pore Space Access

Access to pore space is a crucial element in any CCS project. Like other subsurface resources, governments play a key role in managing access and resolving disputes related to pore space. While granting licenses for $CO_2$ storage typically focuses on technical, environmental, and public safety aspects, the allocation of pore space is more about managing the resource and the associated rights. For example, in the UK, the North Sea Transition Authority grants licenses for offshore $CO_2$ storage, while the Crown Estate and Scottish Crown Estate manage leases for offshore pipelines, seabed, and subsurface rights for CCS developers.[52] In offshore projects, pore space rights are usually held by governments, as seen in Norway, where the Norwegian state holds exclusive rights.[53]

However, onshore storage locations present more complex legal situations, where pore space rights may be held by surface rights holders, mineral rights holders, governments, or a combination of these. In the US, for instance, pore space ownership rules vary between states, and many have not yet settled on clear ownership structures.[54] Regardless of ownership, governments play a vital role in granting rights to use pore space for sequestration and in establishing pathways for accessing storage rights when these are privately held. In heavily industrialized regions, pore space is a limited resource, and governments need to establish processes to manage allocation in an orderly, fair manner, ensuring the greatest benefit to the public.

Additionally, some jurisdictions, including the UK and Alberta, have developed two-stage processes whereby rights to develop evaluations of pore space are first granted to allow CCS proponents to evaluate injection sites and characterize geological formations. If successful, proponents can then pursue rights whereby they can sequester $CO_2$ at scale.

### Pore Space Access in Alberta

Large areas within the province of Alberta have ideal geology for sequestering $CO_2$. To manage this pore space resource, the Alberta Government has developed a process for granting the rights to pore space, which are needed before entering the regulatory process.

There are two pathways, one for storage hub projects and one for small-scale and remote projects, to be granted pore space rights.

To allocate pore space for storage hubs, the Alberta government held competitions whereby potential proponents could submit requests to establish areas in which they could manage an open-access sequestration hub. Section 2.4 describes the results of this process in more detail. The process resulted in the awarding of Carbon Sequestration Evaluation Agreements which allowed proponents to assess the area for carbon sequestration. After evaluations are complete, pore space rights can be granted through the signing of a Carbon Sequestration Agreement.

To serve CCS projects whereby the hubs may not best address the needs of sequestration proponents, the Alberta Government accepts applications for small-scale and remote projects. These could arise from a variety of factors including a lack of injectivity, storage capacity, or distance from a capture entity. Applications for small-scale and remote carbon sequestration tenure must provide information on the area, the proposed activity, overlapping interests in the area and a business case addressing the rationale why the use of a hub is not viable.[55] Two agreements must be signed before small-scale and remote agreements are completed, a tenure agreement that grants the right to sequester $CO_2$ and an agreement that verifies the interests and activities within the identified location.[56]

## 3.2 Permitting

Permitting, as related to CCS development, is defined as a series of approvals, consents, and licenses that a project must achieve after attaining pore space rights and before operation can begin. This can include permits for evaluating, testing, constructing, operating, and eventually closing CCS projects. The main purpose of permitting processes is to ensure compliance with environmental and safety standards. Permitting occurs throughout the duration of a project, ensuring CCS proponents conduct comprehensive due diligence before projects are built, meet high standards during operations, and mitigate risks to close a project.

Though permitting has benefits to both CCS proponents and the public at large, permitting processes can cause delays and impact CCS project timing. Sequestration permitting for $CO_2$ can be a multi-year process and requires significant time and resources. In the US, for example, the permitting for a Class VI well – one specifically for $CO_2$ injection, includes a proponent submission, a completeness review, a technical review, the preparation of a draft permit, a public consultation period and preparation for a final permit decision.[i] The Environmental Protection Agency (EPA), which processes many Class VI wells noted that the technical

i The process can vary depending on the jurisdiction within the US where the Class VI well application has taken place with some state permitting processes superseding federal processes.

review of a permit application is estimated to take 18 months.[57] In states where the EPA handles Class VI well applications, the agency has received more than 150 well applications and has 138 currently in the technical review phase. From 2021 until August 2024, the EPA has issued only four final permit decisions. Some of the technical reviews have entered their third year, which may impact well applications and in turn any potential capture project looking to access storage sites in the permitting process.[58]

### Key Permitting Processes in Alberta

The permitting process in Alberta provides an example of how permitting processes can be used to manage pore space resources and maintain public and environmental safety while balancing the administrative requirements for CCS project proponents CCS projects within Alberta need to apply for and receive several regulatory permits from the Alberta Energy Regulator (AER), an independent body responsible for ensuring activities are safe and environmentally responsible. This includes a host of directives which apply to CCS as well as other activities and CCS-specific requirements including MMV plans, Site Suitability Risk Assessments, and Closure Plans.[59] The key permits are introduced in Table 3.

*Table-3: Key AER permits for CCUS projects in Alberta*[60] [i]

| Permit | Description |
|---|---|
| **Measurement, Monitoring and Verification Plan** | • An MMV plan is submitted to the Alberta Energy Regulator<br>• Details the MMV that the proponent will undertake during operations<br>• The plan addresses risks, how performance will be evaluated and what evidence that the site can be moved to closure<br>• Updated at intervals throughout the operation of the project |
| **Closure Plan** | • A Closure plan is submitted to the Alberta Energy Regulator<br>• Lists all activities the proponent will undertake to close down operations at the end of the project<br>• Lists the specific criteria that must be met to secure a Closure Certificate and for the Alberta government to assume ownership of project assets and project liabilities<br>• Outlines specific informational requirements the project will be required to track and report on throughout the life of the project – based upon a site-specific risk assessment<br>• Becomes a touchpoint for proponent and government through project operations<br>• Is adaptive and must be updated/renewed every three years |
| **Directive 65 Subsurface Requirements** | • A $CO_2$ sequestration scheme application should do the following:<br>  ∘ Define storage capacity, containment, injectivity<br>  ∘ Predict extent of $CO_2$ plume underground<br>  ∘ Calculate the maximum injection area, to be used for notifications<br>  ∘ Ascertain that the scheme will perform effectively and safely<br>  ∘ Establish site-specific risk assessment<br>  ∘ Establish baseline conditions, to be used in monitoring the program<br>  ∘ Assess risks associated with storage and remediation strategies<br>• Demonstrates a full understanding of the geology including a detailed description of the reservoir and complex seals<br>• Defines a range of project descriptions that may be developed and refined over time, depending on $CO_2$ volumes and operational outcomes<br>• Required consultations with stakeholders will be based on the greatest potential project description and the modelled maximum extent of the $CO_2$ plume |
| **Directive 56 Well License Application** | • Application for the development and operation of the evaluation wells, $CO_2$ injection wells, and $CO_2$ monitoring wells<br>• Each will require separate applications and consultation with stakeholders |
| **Directive 51 Injection and Disposal Wells** | • After the $CO_2$ injection wells have been developed, proponents can apply to utilize that well for the disposal of $CO_2$<br>• Sets out the requirements for wellbore design, wellbore integrity logging, operational monitoring, and reporting requirements of injection wells for the purposes of enhanced recovery, hydrocarbon storage, and disposal<br>• Based on a system of classifying injection and disposal wells, the operating and monitoring requirements are consistent with the type of fluid injected |
| **Directive 56 Development** | • Application for the construction and operation of the lengths of the $CO_2$ pipeline as would be needed for the project |
| **Application: Pipeline** | • Must follow Canadian standards related to $CO_2$ and metallurgy (CSA Z662) and will be reviewed by the regulator<br>• Includes consultation and notification of stakeholders, as per regulatory guidelines |
| **Directive 71 Emergency Response Plan** | • A project-specific plan for emergency preparedness and response, specific to CCS and the proposed $CO_2$ operations<br>• Ensures an effective response and to prevent injury/damage to site personnel, site facilities, the public, and the environment in case of an incident<br>• Includes emergency planning zones (EPZs) around the $CO_2$ wells, $CO_2$ pipelines and $CO_2$ capture and compression facilities<br>• Requires consultation with parties within the EPZs who may be impacted by $CO_2$ release |

i Other Alberta government legislation and AER directives that may apply to CCUS projects within the province include the Mines and Minerals Act, the Oil and Gas Conservation Act, the Water Act, the Environmental Protection and Enhancement Act, the Public Lands Act, the Surface Rights Act, Directive 020: Well Abandonment and Directive 87: Well Integrity Management and other aspects of Directive 65: Resources Applications for Oil and Gas Reservoirs.

## 3.3 Measurement, Monitoring and Verification Requirements

An MMV plan is a multi-step framework designed to ensure the safety and effectiveness of ongoing CCS operations, primarily for $CO_2$ sequestration. MMV plans describe the suite of technologies intended to monitor the environment and $CO_2$ once sequestered. MMV plans are developed by the project operator in response to identified risks, are generally a regulatory requirement and provide the data and assurance that conditions specified in project approvals are satisfied.

The purpose of MMV plans is to evaluate several key aspects of $CO_2$ sequestration. These include conformance, which assesses the performance of sequestration and compares it to the predicted behaviour of the $CO_2$ plume; permanence, which evaluates the long-term stability of $CO_2$ sequestration; reversals, which provide the operator with opportunities to identify instances of non-permanence in $CO_2$ storage; and closure, which requires evidence demonstrating the site's suitability for permanent closure.

Key principles for consideration by CCS project proponents when developing MMV plans are:

- Regulatory compliance – to demonstrate they are operating within permit parameters
- Risk-based – to address project-specific risks that should be monitored
- Fit-for-purpose – to address the projects' geological and geographical context
- Adaptive – adjusted in response to changes in project operations and changes in project-specific risks
- Timely – to provide timely warning of $CO_2$ containment and conformance anomalies
- Comprehensive – to monitor the geosphere, hydrosphere, biosphere, and atmosphere
- Transparency – to provide $CO_2$ plume performance and containment information to relevant stakeholders

## 3.4 Knowledge Sharing

Sharing insights from carbon management projects is a common practice for projects receiving public investment in their projects.

Sharing lessons learned ensures public accountability. Projects receiving government funding have a responsibility to demonstrate transparency, accountability, and good stewardship of public funds. This transparency in project outcomes and performance also helps to build public trust in CCS.

Sharing also accelerates technology development. Knowledge sharing can hasten the development, deployment, and adaptation of CCS technologies by identifying challenges, barriers, and potential solutions, as well as facilitating the transfer of best practices and innovation across the industry.

Moreover, knowledge sharing can reduce uncertainties and costs for future projects. By sharing experiences and lessons learned from CCS projects, future projects can benefit from a better understanding of potential risks and optimize project planning, design, and execution. Ultimately knowledge sharing can improve the overall efficiency and cost-effectiveness of CCS. These insights will also be critical for the implementation of CCS projects in less-developed economies of the world.

With the large costs associated with CCS projects, many companies only have one project on the near-term horizon. To achieve substantial cost reductions through iterations in a space that requires integrated, facility-specific and sometimes novel applications of technology, knowledge sharing is one of the only avenues to realize the benefits of second-generation step-changes in cost.

Knowledge sharing also encourages collaboration and fosters partnerships among project developers, government agencies, research institutions, and other stakeholders. This collaborative environment can lead to the creation of synergies, shared resources, and coordinated efforts that drive the growth and success of the CCS industry.

Knowledge sharing can also inform policy development. Policymakers and regulators can be informed about the real-world challenges and opportunities associated with CCS projects. This information can help guide the development of, or amendments to, policies, regulations, and incentives that promote the widespread adoption and scaling of CCS technologies.

Knowledge sharing requirements can apply even at the development stage of projects. Norway's Longship project includes reports, studies, funding agreements and socioeconomic analyses of two capture projects and a joint partnership transportation and storage project.[61] The US Department of Energy requires sharing lessons learned from its public investments – the department hosts all of the funded FEED studies on its website.[62]

### Knowledge Sharing in Alberta

In Alberta, knowledge sharing is an important public benefit of CCS investments. Early project investments including in the Quest and ACTL projects have required both summary and detailed project reports. According to Executive Series participants, these reports saved years in companies' initial approach to CCS projects both in Canada and internationally.[63] Existing programs from the governments of Alberta and Canada have knowledge sharing requirements, such as the Emission Reduction Alberta's Carbon Capture Kickstart program, the CCUS-ITC, and Natural Resources Canada's Energy and Innovation Program's CCUS-related funding calls.

Beginning in 2022, The Government of Alberta, through Emissions Reduction Alberta, launched Carbon Capture Kickstart (CCK) investing $40M in 11 feasibility and FEED studies for carbon capture projects in the oil and gas, power, cement, forestry, and fuels and chemical sectors. The purpose of the program is to accelerate large-scale carbon capture projects at industrial facilities towards FID. ERA and the International CCS Knowledge Centre are currently developing a paper summarizing the learnings from feasibility and FEED studies that were part of the program. At the start of the program, all projects aimed to complete FEED over a 2-year period, reach FID in the mid-2020s and achieve operations by 2030. The report will provide insights to allow future project developers to make decisions that optimize project outcomes and mitigate risks.

## 3.5 Labour and Social Justice Requirements

Carbon management funding in several jurisdictions, particularly in the US and Canada, has included provisions to shape and extend the socio-economic benefits of investing in CCS projects. These requirements typically include labour requirement provisions related to wages and job training, particularly apprenticeships as well as engagement requirements with the community during the planning and development of CCS projects' development.

The intent of these requirements may include a desire for workforce skill development, social values related to collective bargaining, alignment with other policy goals, and assuredness that public investment should benefit as many citizens as possible. For CCS project proponents, labour and social requirements can increase social value, ensure greater economic impacts on a local level, and build overall acceptance of CCS projects.

In the US, the Justice40 Initiative is a commitment by the U.S. Federal government, to ensure that 40% of the overall benefits from Federal investments in climate, clean energy, housing, and other areas flow to disadvantaged communities. Key investments under Justice40 include CCS and US federal agencies are required to engage with local communities, ensuring their involvement in decision-making and reporting on how benefits are distributed. The US Department of Energy (DOE) requires Community Benefit Plans covering topics such as community and labour engagement, investment in quality jobs, diversity, equity and inclusion and Justice40. These plans must contain goals and metrics that projects must work toward alongside their DOE funding projects.

Additionally, the major CCS tax incentive in the US, known as 45Q provides a base credit of $17 per tonne of $CO_2$ for point-source capture and $36 for DAC. This increases to $85 or $180 for DAC for facilities that pay prevailing wages during the construction phase and the first 12 years of operation as well as registered apprenticeship requirements.

### Labour Requirements in Canada's CCUS-ITC

Canada's CCUS-ITC, as an example, has labour requirements that ensure workers on CCUS projects receiving the ITC are paid at levels at or above similar collective bargaining agreements and where possible that 10% of the project's workforce are apprentices. As an example, a capture project may be eligible for investment tax credits of up to 50% of capital costs. Choosing not to meet labour requirements would lower the value of such credits by ten percentage points (40% for capture), and grossly neglecting to meet the requirements after committing to them, could result in a penalty equivalent to a 15-percentage point reduction in eligible costs.[i] Table 4 and Table 5 explain the labour requirements and indicate the conditions that would result in various penalties for failing to meet the CCUS-ITC for project proponents. Greater detail on CCUS-ITC is provided later in the paper.

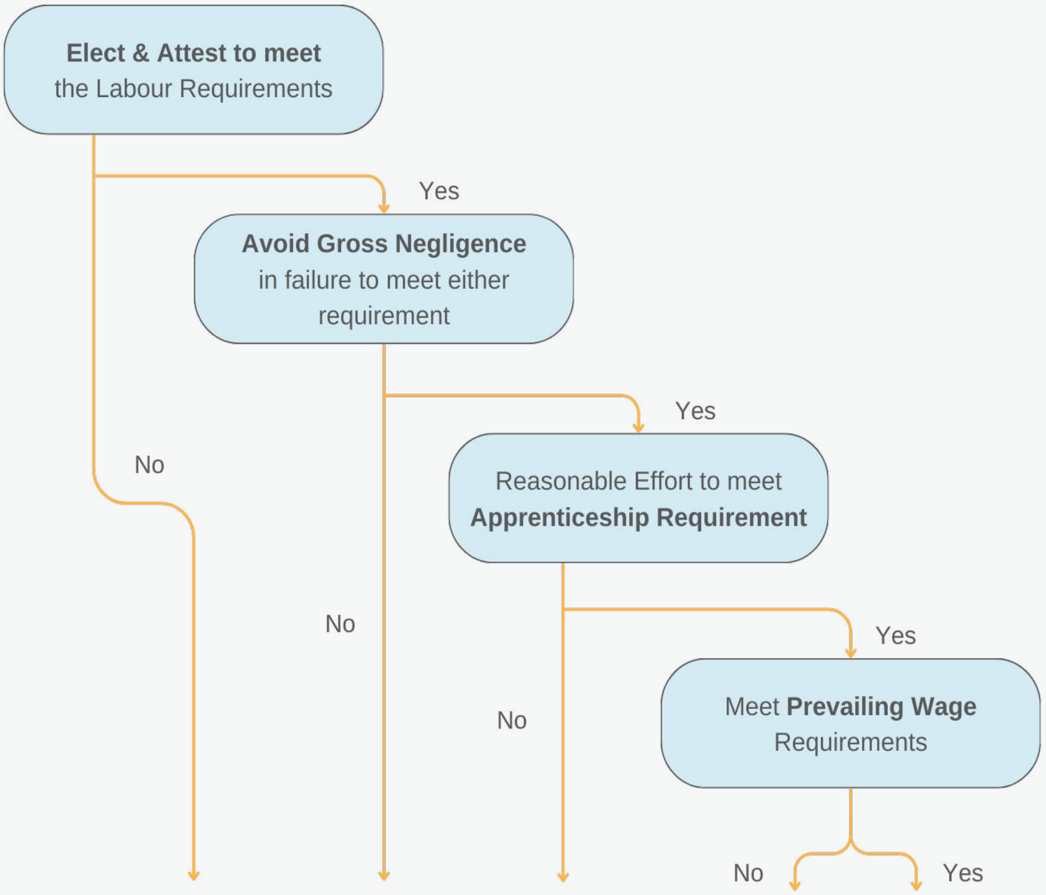
i Up to 60% for DAC capture costs

*Table-4: Labour requirements to meet CCUS-ITC for project proponents*

| Prevailing Wage Requirements | Apprenticeship Requirements |
|---|---|
| **Compensation:** Covered workers must be paid (excluding overtime but including benefits) equivalent to a relevant eligible collective agreement.<br><br>• **Outside Quebec:**<br>◦ Based on the most recent collective bargaining agreements or project labour agreements with a building trade union<br><br>• **In Quebec:** Defined according to provincial law.<br><br>**Communication:** The prevailing wage requirements must be communicated to employees. | **Work Hours:** Recipients must make reasonable efforts to ensure apprentices work at least 10% of total hours.<br><br>**Reasonable Efforts**: Every four months, a project must:<br><br>• **Advertise** for apprentices to fulfill the required hours.<br><br>• **Communicate** with at least one trade union and one educational facility for hiring apprentices.<br><br>• **Confirm** with a trade union that as many apprentices as possible have been provided. Unions have 5 business days to respond.<br><br>**Exceptions**: Reasonable efforts are not required if laws or collective agreements limit the proportion of apprentices. |

*Table-5: Labour requirement penalties for the CCUS-ITC*

| Type of Expenditure | Between 2022 & 2031 | | | Between 2031 & 2040 | | |
|---|---|---|---|---|---|---|
| | Regular Rate | Reduced Rate | Reduced Rate w/ Gross Negligence Penalty | Regular Rate | Reduced Rate | Reduced Rate w/ Gross Negligence Penalty |
| **Qualified Direct Air Capture Expenditures** | 60% | 50% | 45% | 30% | 20% | 15% |
| **Qualified Capture Expenditures** | 50% | 40% | 35% | 25% | 15% | 10% |
| **Qualified Transportation, Storage & Use Expenditures** | 37.5% | 27.5% | 22.5% | 18.75% | 8.75% | 3.75% |




| Resulting ITC Credit Rate | Reduced Rates | Regular Rates with Gross Negligence Penalties | Regular Rates with Apprenticeship Penalty* | Regular Rates with Prevailing Wage Penalty* | Regular Rates |
|---|---|---|---|---|---|
| **Penalty amount compared to Regular Rates** | 10 percentage point reduction | 15 percentage point reduction | $50 per hour of unmet apprenticeship hours below 10% of total Red Seal trade hours** | 1) $20 per worker per day<br>2) Pay workers the difference between prevailing wage and actual pay | N/A |

*A project could receive penalties for failing to meet both the apprenticeship and prevailing wage requirements

** Exceptions related to collective agreements and provincial rules may negate this penalty

*Figure-6: Conditions to meet the labour requirements and associated penalties for project proponent*

## 3.6 Climate Disclosure Reporting

Corporations considering CCS projects may also be required to publicly post climate risk disclosures. The purpose of these disclosures is to magnify and standardize climate or emission-reduction-focused disclosures made by corporations. This provides clarity to investors, insurers and other interested parties related to the corporation's operations long-term.

In the late 2010s, the Financial Stability Board[64] developed the Taskforce on Climate Financial Disclosures (TCFD)[65] to provide recommendations on the types of information companies should disclose in assessing and pricing risks related to climate change. The task force's recommendations covered four areas including governance, strategy, risk management, and metrics and targets. The task force has since been disbanded but has passed the monitoring of such disclosures to the IFRS Foundation, a not-for-profit that develops international standards for companies to follow to provide investors with transparent and comparable information about the companies. The IFRS Foundation and its International Sustainability Standards Board (ISSB) released its first two sustainability disclosure standards in June 2023 laying out international standards on sustainability-related financial information and climate-related disclosures.[66]

At the same time, several jurisdictions have been developing sustainability directives and reporting standards that may be required by companies including but not limited to the European Union,[67] the US,[68] India,[69] and Canada.[70] Such standards are at varying stages of development, with some already in place while others are set to change from voluntary to mandatory in the coming years. Such reporting requirements would likely impact CCS project proponents in their respective jurisdictions, but they are not CCS-specific requirements in most cases.

In June 2024 Canada's CCUS Investment Tax Credit (CCUS-ITC) was passed and includes a climate risk disclosure reporting requirement for projects that expect to have capital costs exceeding $20 million. The draft legislation that included the ITC provides the only available requirements for climate risk disclosure which include the TCFD's recommended areas, listed above, and how "corporate governance, strategies, policies and practices contribute to achieving Canada's commitments under the Paris Agreement and goal of net-zero by 2050." The consequence for not meeting this requirement is a penalty of up to $1 million.

These requirements are topical because of public greenwashing concerns. Governments and climate-focused organizations are looking for corporate recognition of their potential impacts on climate change and commitments to reduce emissions moving forward – while ensuring their claims and commitments are credible.

# 4. The Business Case – Costs, Returns, and Incentives

When considering using CCS as an emission reduction solution, the project must make dollars and sense. Large emitters must consider the overall project costs, revenues and other incentives to understand the value of such an investment. CCS business cases require consideration of capital and operating costs for $CO_2$ capture, transport and storage/use; revenue in the form of compliance with GHG pricing systems, the sale of carbon credits, investment and/or production tax credits; government investments; and utilization of captured carbon. CCS projects can provide project owners with other benefits such as market access for selling low-emission products and environmental and social advantages. This section explores factors that contribute to the business case for CCS projects from a large emitter perspective, identifying factors that drive costs, impact returns and less direct incentives.

The bar for corporations in greenlighting CCS projects becomes the value for the investment surpassing the opportunity cost of investing in other projects. Participants of the Executive Series extolled this point with several participants emphasizing that dollars for CCS projects need to be competitive with other emission reduction and capital projects. Importantly, industries and corporations have different expectations as to what represents a sufficient return on investment and what strategic value can be gained from building and operating CCS projects.

## 4.1 Costs

Every project's financial viability is evaluated through capital costs or capital expenditure (CapEx) and operating costs or operating expenditure (OpEx).

Capture costs vary due to many key factors, including the type of industrial process, capture technology selected, flue gas characteristics (e.g. $CO_2$ concentration and presence of trace constituents), and availability of heat and power. Megatonne-scale CCS projects can reach multibillions of dollars. Emitters must consider the cost of capitalizing on such projects and other productive uses, including other emission reduction projects. Executive Series participants noted that reducing the overall costs of capture is critical if they are to move forward with their proposed projects.

Transport and storage costs will vary based on the proximity of capture facilities to storage sites, mode of transportation, whether transportation infrastructure is shared, whether the storage site is onshore or offshore, the cost of accessing pore space, and storage complex characteristics (e.g. depth, injectivity, etc.). In the context of CCS development in Alberta, and in several other locations around the world, where storage sites are being developed as hubs, emitters considering the construction of a capture facility will likely have opportunities to access third-party $CO_2$ transportation and storage.

Capture-related expenses during both construction and operation account for the majority of costs in CCS projects, representing approximately 70% of the total costs across the entire CCS chain. By way of examples within Alberta: the Quest CCS project allocated 79% of its total capital costs to the capture facility, including tie-in and commissioning expenses, with 5% directed to subsurface work and 16% to $CO_2$ pipelines.[71] Conversely, the ACTL project which transports $CO_2$ far from the capture locations and includes a pipeline with the capacity to transport nearly fifteen times the current load (approximately 1 Mt in 2022), had only 44% of its capital costs related to capture and compression.[72]

In addition to the cost of capture-related expenses, procurement of specialized equipment can present challenges. In past amine capture projects, procuring $CO_2$ compressors and conditioners has been difficult. As other capture technologies begin to commercialize, due to their low experience rate, capital costs may rise.

OpEx for most capture facilities depends not only on the capture technology used and the presence of particulates in the flue gas but also on the cost of energy needed to operate the facility. For example, amine capture systems may require larger solvent volumes, more built in redundancies, and more maintenance to manage the presence of particulates. Proprietary amines, that is amine technology developed to have better performance than base amines, are a critical and potentially high price input for capture projects.

Capture systems, regardless of the capture technology selected, require energy (such as heat and electricity) to capture the $CO_2$ from flue gasses. Therefore, variable inputs such as the cost of electricity, natural gas, and other feedstocks like biomass can have a major impact on project economics.

In many industrial processes, there is an opportunity to use waste heat for the capture process or to utilize heat from the carbon capture process in the industrial process. These thermal integration opportunities can significantly reduce OpEx and improve the overall business case, though they can add complexity to the scope and overall capital cost of the project. Understanding this aspect can be critical in developing a successful project.

### How Are Projects Reducing the Cost of Capture?

A key focus for many prospective CCS projects is finding solutions to reduce the cost of capture compared to existing primarily amine-based systems. Many researchers and companies are also exploring and developing new capture technologies, as explored in Section 2.6, with the explicit goal of finding less energy-intensive and more cost-effective methods of capturing $CO_2$ than with amine-based systems. However, projects looking to reach an FID in the near term are looking for solutions that can reduce the cost of capture of commercially available amine-based systems.

A critical factor in keeping the operating costs of capture low is to ensure facilities are utilized continuously and with minimum disruptions. Some notable steps to keep costs low and predictable include:

- Characterization of the emissions from the stack (i.e. the flue gas);
- Requirements for the pretreatment of flue gas to maximize the capture technology's access to the $CO_2$ for capture;
- Sufficient redundancies built into the capture system;
- Access to secure energy to power the capture process; and
- Abundant supply of chemical feedstock (like amine and water).

In particular, flue gas characterization can be essential for uncovering any impurities present which may increase the costs for pre-treatment. Flue gas streams with high concentrations of $CO_2$ are more cost-effective to capture. This is why hard-to-abate sectors such as steel or cement carry a relatively higher cost of capture. Innovative capture technology options exist to lower the pre-treatment requirements, but the deployment of new technology has a higher risk and struggles to meet the scale of capture necessary to decarbonize hard-to-abate sectors in the next few years.

CCS Executive Series participants noted modularization can lower capital costs throughout the construction of capture facilities. Another Executive Series participant noted they were conducting a FEED study that included a flue gas recirculation system to increase the concentration of $CO_2$ in the flue gas stream prior to entering the amine capture system as a way to reduce energy costs and the size of capture equipment and facilities. Reducing amine degradation, optimizing heat integration between the industrial facility and capture system, and lowering maintenance costs, were also noted as key drivers in cost reductions

Collectively, CCS projects need to build off the lessons learned from building and operating CCS projects, particularly first-of-a-kind facilities and novel applications of technologies will be imperative for CCS projects. As shared in Section 3.3, knowledge sharing is an important tool to reduce costs of capture and overall improve CCS business cases moving forward.

### What Impacts will a Capture Facility have on an Industrial Facilities Production and Operation?

Assessing the impact of carbon capture implementation on overall plant operations is a required step in evaluating the viability of capturing emissions at any industrial facility. Integrating capture technology can influence aspects of production, including energy consumption, process efficiency, and maintenance schedules. Understanding potential impacts provides insight during the planning stage for required adjustments or identifying temporary disruptions.

Capture facilities have the potential to reduce an industrial facility's production and may not have aligned facility ramping periods or maintenance schedules. For example, to provide energy to run the capture facility, a power generator may face a parasitic load reducing the electricity it can export to the market. Additionally, many power-generating facilities are utilized intermittently and ramp faster than conventional capture facilities have been designed to or can economically.[i] This is likely to result in a higher cost to substantially all emissions from an industrial facility.

Moreover, incorporating the continuous monitoring and evaluation of the capture system's performance is essential to identify any operational inefficiencies or unexpected issues. This proactive approach allows for timely interventions and optimizations, minimizing the impact on overall plant operations and maintaining the balance between carbon capture goals and production efficiency.

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i Actions can be taken by amine capture systems related to facility temperature at start-up, lean amine volumes and steam availability to reduce the impact of frequent start-ups and shutdowns, but not in all situations and with higher energy costs.

## 4.1 Revenue

CCS projects can be thought of as waste removal projects. Value is not created from these projects directly, but they generate public benefits by removing GHG emissions. In recognition of this, governments have created policies, regulations and programs to incentivize large industrial emitters to reduce emissions through CCS specifically. These government initiatives represent the majority of financial incentives for CCS projects.

A common approach that governments have developed to provide operating revenue for CCS projects is GHG pricing systems like Alberta's TIER and the European Union's Emissions Trading System. These emission pricing systems allow CCS projects to generate revenue through verified credits that can be traded for a financial return or used to avoid paying the price on emissions. To avoid uncertainty related to the long-term price of such credits, governments have also begun developing carbon contracts for difference (CCfD) for such projects with the government guaranteeing a credit price for emission reduction projects including CCS. Production tax credits, most notably the US 45Q tax credits can be claimed for a set amount for each tonne of $CO_2$ permanently stored. The United Kingdom has taken a more regulated approach with its regulated asset base model for transportation and storage, which sets tariff rates for $CO_2$ pipeline access and provides an allowed and guaranteed, though limited, revenue for private transportation and storage operators.[73]

To cover some of the construction costs, and encourage private investment in CCS projects, governments have developed a variety of investments and grants, favourable financing programs, and investment tax credits. Some of these incentives are application-based like most funding programs or are universally accessible if the project meets specific criteria, like Canada's investment tax credits and the Alberta Carbon Capture Incentive Program.

The ability to layer the benefits of incentives is an important contributing factor to the investment climate for CCS in most jurisdictions including Canada.

### Regulatory Credits in Alberta

For CCS projects, the ability to generate $CO_2$ and other compliance credits and market those credits is paramount to project economics. CCUS projects in Alberta can generate credits through three different compliance crediting systems. As noted in Section 2.2, Canada's federal OBPS system is not applied to industrial emitters located within Alberta, however, the provincial industrial pricing schedule must be deemed equivalent to the federal system. In practice that would mean that provincial systems would track, at a discount, the ceiling price of the Federal Carbon Pricing Schedule.

It is expected that the market price for the different forms of compliance credits in the federal Greenhouse Gas Offset Credit System will be tracked at a discount to the ceiling price of the Federal Carbon Pricing Schedule.

*Table-6: Minimum National Carbon Pollution Price Schedule (2023-2030)[74]*

| Year | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
|---|---|---|---|---|---|---|---|---|
| **Carbon Price ($/tonne)** | $65 | $80 | $95 | $110 | $125 | $140 | $155 | $170 |

The capture and sequestration of $CO_2$ in Alberta can generate emission offsets utilizing the published CCS and EOR quantification protocols. The sequestration operator and capture operator can then convert those offsets into other fungible credit types. The general crediting pathway for carbon capture in the province is shown in Figure 7 below.

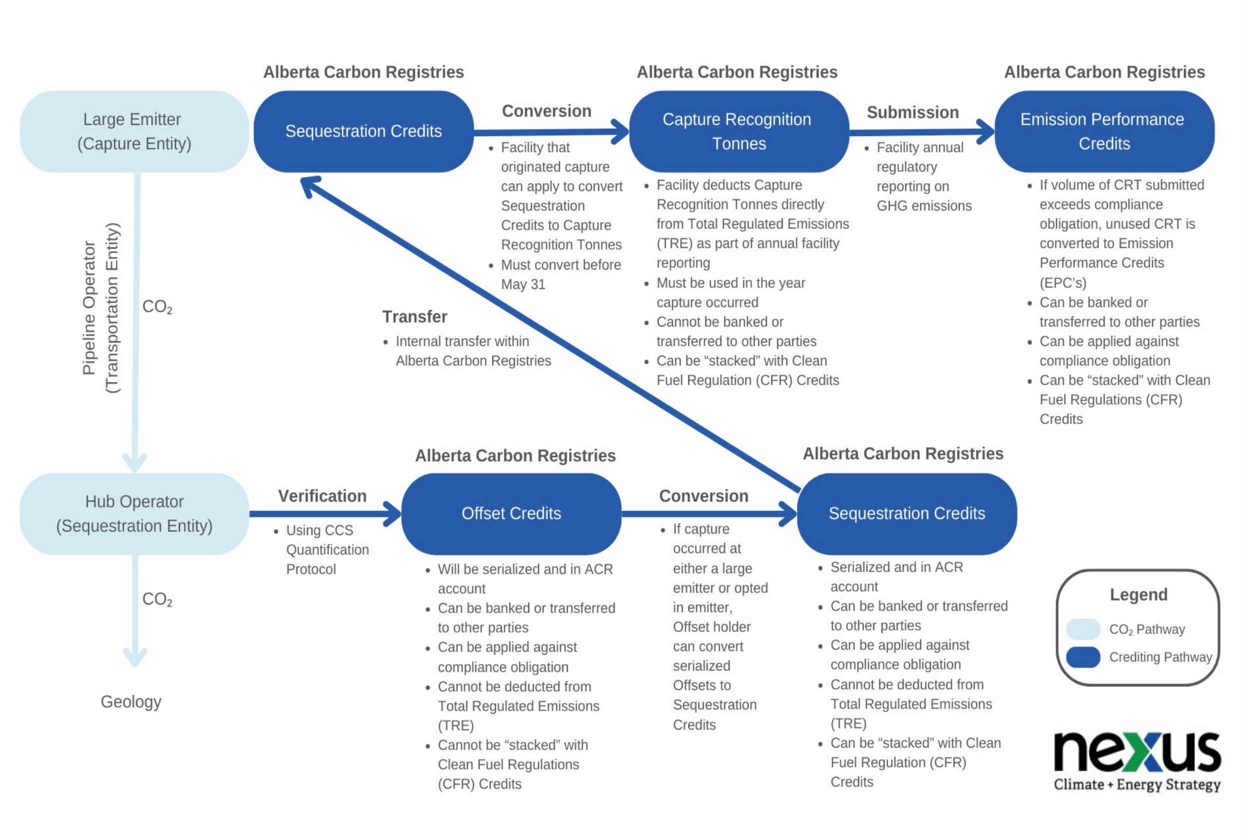


*Figure-7: CCS crediting pathway under the Alberta TIER regulation (Nexus Climate + Energy Strategy)*

Each of the credits along the pathway has different rules related to crediting periods, transferring between parties, applications, double-incenting or stacking with federal credits, and sometimes value.

The price for CFR credits is not tracked to the federal pricing schedule like the Federal OBPS or the Alberta

Emission Offset System. Instead, market pricing for compliance credits under the CFR is a function of supply and demand for credits in the market. Crediting opportunities under the CFR began in 2023, and Executive Series proponents have noted that the ability to generate both provincial and CFR credits from operating CCS projects was positively impacting business cases within the province and bringing eligible projects closer to an FID. Notably, Shell's Polaris CCS project reached FID in June 2024. Polaris will capture emissions from Shell's Scotford refinery and chemicals complex, where the CFR would apply.

### Supports for Capital Investments in Alberta

Canada and Alberta have both funded CCS feasibility and front-end engineering and design (FEED) studies in recent years. As an example, Table 7 shows potential and currently open government revenue sources for a capture facility at a petrochemical plant storing $CO_2$ in Alberta set to begin operation in 2027.

*Table-7: Potential government revenue sources for a petrochemical facility storing $CO_2$ by 2027 in Alberta*

| Program/Regulation | Government | Type | Value |
|---|---|---|---|
| **ACCIP** | Alberta | Grant | 12% CapEx grant for eligible capture expenditures |
| **TIER** | Alberta | Regulatory Credits | Emission reduction credits generated CCS project (per tonne stored) |
| **CCUS-ITC** | Canada | Investment Tax Credit | 50% of CapEx for eligible capture expenditures |
| **Clean Fuel Regulation** | Canada | Regulatory Credits | Credit-based emission reductions along the fuel production pathway |
| **CCUS Capital Cost Allowances and Acceleration** | Canada | Investment Tax Credit | Tax deduction at an 8% declining balance basis, accelerated in the first year |
| **Canada Growth Fund** | Canada | Financing and Investments | $15 billion fund with several tools to invest, finance or provide carbon pricing certainty for projects |
| **Canada Infrastructure Bank** | Canada | Financing | Convertible debt for FEED studies |
| **Strategic Innovation Fund** | Canada | Financing and Grants | Various project-specific supports are possible |

CCS projects in Alberta have access to two major and nearly universal capital support programs. The CCUS-ITC and Alberta Carbon Capture Incentive Program (ACCIP).

The CCUS-ITC is a federal government tax incentive that offsets the costs of purchasing and installing eligible equipment and is available as a refundable tax credit in the year the latter of when expenses are incurred or acquired, regardless of when the equipment becomes operational.

| **Preliminary CCUS Work** | **Apply to Qualify** | **Qualified Project** | **Qualified Expenditure** | **Filing for the CCUS-ITC** |
|---|---|---|---|---|
| • Obtaining permits or regulatory approvals<br>• Performing design/engineering work, including FEED studies<br>• Conducting feasibility studies or pre-feasibility studies<br>• Conducting environmental assessments<br>• Clearing or excavating land | **Create a Project Plan**<br>• Reflects FEED work<br>• Indicates how much carbon dioxide will be captured for eligible and ineligible use each year<br>• Contains information required in the guidelines<br>• Filed before commercial operation begins<br><br>**Calculate Projected Eligible Use Percentage**<br><br>expected eligible use ÷ expected eligible & ineligible use | • Expected carbon dioxide capture based on the project plan<br>• The initial project evaluation was issues<br>• The projected eligible use percentage is equal to or greater than 10% in a year*<br>• Not on a coal plant regulated by the *Reduction of Carbon Dioxide Emissions from Coalfired Generations of Electricity Regulations*<br>• For storage in concrete the process must be evaluated and third party validated by ISO standards | There is a prescribed equation to follow. Briefly:<br><br>• Broken down in to capture, transportation, storage and use categories<br>• Total capital cost of property and equipment listed in Class 57 (Class 58 for use) in the year<br>• The proportion of dual use equipment for CCUS project**<br>• What period the expenditure was made a respective value per period<br><br>If you purchase equipment outside Canada it won't qualify until it is imported | **Cumulative CCUS development tax credits** for the year include all qualified expenditures before the first day of commercial operations<br><br>**Specified percentages:**<br>**direct air capture**<br>2022-2030 = 60%<br>2031-2040 = 30%<br>2040 onward = 0%<br><br>**other carbon capture**<br>2022-2030 = 50%<br>2031-2040 = 25%<br>2040 onward = 0%<br><br>**transportation, storage & use**<br>2022-2030 = 37.5%<br>2031-2040 = 18.75%<br>2040 onward = 0% |
| *(Some activities before the CCUS project qualify under Class 59 & 60)* | **Initial project evaluation issued by NRCan** | **if project starts after September the first period is to December 31 the following year* | ***there are other elements for the equipment to consider in the legislation* | There will be a 10% decrease if labour requirements are not met. |

*Figure-8: Summary of the CCUS-ITC*

*Figure-8 cont'd: Summary of the CCUS-ITC*

| First day of Commercial Operations | Project Periods | Recovery & Other Info | Reporting | |
| --- | --- | --- | --- | --- |
| • The day $CO_2$ is first delivered to transport / storage / use<br>• This starts the first project period<br>• Project plans have to be filed before this day<br>• If an expenditure made on or after this day is considered a refurbishment cost. That amount only qualifies if it is an *eligible refurbishment*<br>• Eligible refurbishment expenses are capped at 10% of the project's cost | The timelines related to review of the project, reporting and recovery are broken into periods<br><br>**First project period**<br>• Day 1 of commercial operations until December 31 four years later (five years, if start date is after October 1)<br><br>**Subsequent Project Periods**<br>• The next 3 five-year segments following the first project period | • Recovery taxation years align to the last year of each project period<br>• If there is ineligible use during the project period of more than 5 percentage points the government can claw back a proportional amount<br>• In extraordinary circumstances (outside direct control with attempts to rectify) the minister can allow an exception to recovery rules<br>• If project shuts down for a period there will be no claw back payment required<br>• If the CCUS project property is sold then the purchaser is deemed to have claimed the tax credits and will be subject to the Act | Tied to receiving a CCUS-ITC are requirements to provide knowledge sharing and climate risk disclosure reports<br><br>**Knowledge Sharing Reports**<br>Required information will be provided in a *CCUS-ITC Technical Guidance Document* to be published by NRCan<br><br>One Construction and Completion Report is due 6 months after the first day of commercial operations covering from the time of the first expenditure to start date<br><br>Annual Operating Reports are due each year on June 30 with five reports required in total (the first year is dependent on a pre- or post-October start date)<br><br>Failing to provide the report could result in a $2 million penalty each year it is not filed | **Climate Risk Disclosure Reports**<br>Annual reporting must be made public for 20 years<br><br>Report must include:<br>• Corporate climate related risks and opportunities, and the associated processes to determine and manage<br>• How the corporation's governance, strategies, policies and practices contribute to Canada's Paris commitments and 2050 net-zero goal<br><br>Failing to make the report available could result in a penalty of the lesser of 4% of the total of all amounts or $1 million |

According to the legislation, costs are considered incurred in the year the property is purchased, paid for, or acquired.

For 2022-2031, the CCUS-ITC rates are:

- 60% for eligible direct air capture equipment
- 50% for other eligible capture equipment
- 37.5% for eligible transportation, storage, and use equipment

For 2031-2040, the rates reduce to:

- 30% for eligible direct air capture equipment

- 25% for other eligible capture equipment
- 18.75% for eligible transportation, storage, and use equipment

After 2040, the rates drop to 0%. The intent of placing timelines on the CCUS-ITC is to drive project deployment in the near term. In the CCUS Executive Series, companies shared that the timeline is quite tight. Participants recommended extending the initial rates to 2035 and/or extending the rates if a project has meaningfully invested in construction by 2030. The thought behind this was to ensure a step-change approach to employing labour and receiving supplies, in hopes that as the timeline compressed costs did not escalate.

The CCUS-ITC is the largest incentive available for CCUS project investment in Canada, though it is currently only available in three provinces which have CCUS regulatory frameworks in place that have been deemed sufficient by ECCC. Its effectiveness will depend on project proponents meeting the outlined timelines. Development timelines from feasibility to operation can take up to seven years, so projects need to start this year to utilize the maximum value of the CCUS-ITC.

ACCIP is a program in development from the Alberta government providing a grant to eligible projects starting one year after the commencement of operations equivalent to  of 12% of eligible capital costs for projects that capture, prepare, compress, transport, store or utilize $CO_2$. Though specific details regarding cost eligibility, such as dual-use equipment are not yet publicly available, CCUS project proponents can apply for pre-approval for the program. Like the CCUS-ITC, ACCIP eligibility is based on meeting program criteria, rather than a competitive application process.

A point-source capture project receiving both ACCIP and the CCUS-ITC could receive up to 62% of its capital costs as grants or refundable tax credits leaving 38% of capital costs to be covered by project proponents or other funding sources.

## Utilizations

Exploring CCUS projects, or projects that utilize captured carbon for the creation of products or EOR, generates revenue from the products produced from the captured carbon. However, suitable locations for EOR represent a small fraction of the needed storage volume for scale in North America, and EOR is not viewed as an acceptable solution in many regions of the world. Utilizations such as permanent storage in concrete and cement although potentially available to wide geographies, have not yet reached the ability to utilize the millions of tonnes of $CO_2$ that some facilities can capture. However, while most captured $CO_2$ will need to be permanently stored to reduce the biggest harms from climate change, utilization can support low-carbon products such as synthetic fuels and feedstocks for the chemical industry.

The objective of $CO_2$ utilization is to allow for low-carbon products to enter the market and over time replace conventional products which contribute to GHG emissions. Three key challenges remain for the low-emissions product market, these are scalability, competitiveness and climate benefits, as shown in Table 8.

*Table-8: Key challenges with $CO_2$ utilization*[75]

| | |
|---|---|
| **Scalability** | • Supply constraints: availability of key inputs ($CO_2$, $H_2$, low-carbon energy), Infrastructure (for transport of $CO_2$ and $H_2$)<br>• Demand for product or service |
| **Competitiveness** | • Cost of technology<br>• Input costs ($CO_2$, $H_2$ and low-carbon energy)<br>• Cost of competing low-carbon products or services<br>• Market price |
| **Climate Benefits** | • Origin of the $CO_2$<br>• Displaced product or service<br>• Energy input<br>• Retention time of carbon in product |

To summarize the challenges, a life cycle assessment is key to $CO_2$ utilization. A low-emission product earns the "low-emission" title when its conventional partner ranks poorly in a cradle-to-grave life cycle assessment. This assessment considers all components relevant to the production of a product, such as the method of procurement and origin of feedstock, carbon emissions of power or energy used, equipment material and their emissions to name a few. Most countries currently have a natural resource-based electricity grid, and the energy-intensive nature of $CO_2$ conversion pathways makes it challenging for companies to justify the low carbon standing of a $CO_2$-utilized product. Although multiple projects have been deployed worldwide that produce low-emissions products, the capital and operational costs of these projects make their widespread deployment challenging.

Continuous research and development are required in the utilization area of CCUS to introduce lower-cost and energy-dependent technologies.

Incentives for CCS projects are generally available for CCUS projects, with some major exceptions. The CCUS-ITC is Canada's largest incentive, and while a capture project can use captured carbon for EOR, the proportion of $CO_2$ used for EOR will reduce the value of the CCUS-ITC proportionally. For instance, if a project built before 2031 uses half of its captured carbon for EOR and the other half for dedicated geological storage over a 20-year period, it could claim ITC for 25% of eligible expenditures, compared to 50% if all captured carbon was used for dedicated geological storage. Projects that exceed 90% ineligible use at any time are disqualified from the CCUS-ITC, and any claimed credits would be repaid.

## 4.3 Low-Emission Products and Procurement

The Government of Canada believes that low-carbon products, especially fuels, will help Canada achieve its 2030 low-emission targets and 2050 net-zero goals.[76] When projects are considering the revenue potential for low-carbon projects in the equation of their CCS final investment decision, the cost of producing the product, and the premium are weighed in the equation.

The most competitive market currently is building materials with $CO_2$ stored within, produced from minerals or waste. Well-defined regulatory guidance exists for low-emission building materials as it qualifies as geological storage in Canada. Multiple companies have come forward with innovative technologies to build a business case around their product, and the market opportunity seems to be growing.

Government procurement for low-carbon products is an opportunity for more incentives for $CO_2$-enhanced cement, or power produced while capturing and storing emissions. Procurement practices and selling products at a premium are the next line of opportunity for CCS to balance costs and support a viable business case.

# 5. Risks to Investment

In any major project, understanding and mitigating risks is crucial to achieving FID. This section outlines key risks that can impact the viability and success of an investment. If CCS project proponents' evaluations identify elevated risk levels it can lead to higher discount rates used in evaluating the cash flows for the project and affect the overall valuation and attractiveness of the project. This chapter delves into various critical areas, each presenting unique challenges and considerations.

## 5.1 Policy Certainty and Carbon Pricing

As noted above, CCS projects rely heavily on government programs to cover the revenue side of business cases. This creates a risk for CCS projects both from a political and policy perspective. Boards of directors called upon to grant a decision to proceed may be wary of "stroke of pen" risks that foundational incentives and enabling regulations for CCS projects may be altered, changed or eliminated in future years.

Carbon pricing systems in Canada are an example of such risks. Changes to the long-term outlook on the price of carbon credits may be impacted by changes in the priorities of both provincial and federal governments. Alberta government's TIER program, North America's oldest industrial carbon pricing system, has been a solid basis for sound investment decisions relating to pricing carbon under a reliable compliance system. While the system has gone through iterations and adjustments upon transparent reflective review, changes to the stringency of emission reduction requirements have been modelled to foretell an impact on the supply and demand of credits.

Uncertainties for any aspect of a CCS project need to be minimized with remedies and assurances. Industry and energy transition think tanks have been advocating for measures to reduce political and policy risks. Some proposed changes include increased transparency and adjustments to make credit markets more understandable and predictable.[77] Other solutions include governments using financial instruments to guarantee credit prices for a period of time such as CCfD. These types of mechanisms can improve the overall return for CCS projects while drastically reducing the financial risks for investment in CCS projects. Used in Europe for off-shore and renewable energy projects,[78] contracts for differences approaches are being adapted to support CCS projects in places like the UK, Europe,[79, 80] and Canada.

Carbon Border Adjustments (CBA) are another policy tool being used or considered by many jurisdictions to ensure a price on GHG emissions is included on all goods entering that jurisdiction. The EU implemented the world's first CBA. CBAs are intended to level the cost of goods produced at a lower cost with higher emissions with goods created at a higher cost with lower emissions. These types of measures are of particular importance for emission-intensive trade-exposed industries considering investment in CCS. CBAs recognize quantification and standards for CCS from overseas jurisdictions. Depending on the proliferation of CBAs, this may be a major incentive for CCS in the future.

### Canada Growth Fund

Maintaining stability and predictability in carbon markets requires ongoing adjustments and upkeep. In Canada, layers of complexity in navigating provincial OBPS and federal pricing benchmarks, along with provincial equivalent industrial emission pricing systems, can influence the long-term carbon market price. This has led to calls from Canadian emitters for measures to reduce risks for investments reliant on carbon pricing systems. One measure taken to mitigate these risks by the Government of Canada is the Canada Growth Fund (CGF). The CGF is a $15 billion strategic financing program to attract private capital and build Canada's clean economy. It was created specifically to mitigate carbon market risks for CCS and other major emission reduction projects. The fund has a variety of financial tools at its disposal to invest in and reduce private investment risk, including $7 billion to support CCfD-type financial mechanisms. Specifically, the CGF is intended to mitigate:

1. *Demand risk associated with uncertainty around end market demand and pricing.*
2. *Policy risk related to perceived uncertainty around climate regulations, such as a carbon price or clean fuel standards.*
3. *Regulatory risk with respect to project assessments and permitting approvals for constructing projects.*
4. *Execution risk from building first-of-a-kind commercialized products and companies.*[81]

Table 9 outlines existing projects committed by the CGF.

*Table-9: Canada Growth Fund Announced Projects Related to CCS*[82]

| Recipient | Financing Type | Funding Details |
|---|---|---|
| **Svante** | Investment (2-tranche convertible notes) | **$100 million**<br>Announced August 2024; CGF will invest in two stages: an initial US$50 million to accelerate and de-risk first-of-a-kind commercial projects, and a potential second tranche based on project-specific needs to support Svante's development and construction efforts with co-development partners. |
| **Strathcona Resources** | Loan with special conditions | **$1 billion**<br>Announced July 2024; Strathcona to build CCS infrastructure on their steam-assisted gravity drainage oil sands facilities across Saskatchewan and Alberta. Strathcona will build and own the CCS projects and receive investment credits while CGF will earn a targeted return over time with the annual cash flows generated. Each project's carbon credit price per tonne of $CO_2$ will be fixed at FID. |
| **Varme Energy Inc. & Gibson Energy** | Project Investment | **Strategic Partnership**<br>Announced June 2024; CGF, Varme and Gibson have a strategic partnership to develop Canada's first waste-to-energy facility with carbon capture technology. This project is expected to have the capacity to process 200,000 tpa of municipal solid waste. If the project reaches a positive FID, CGF will have a 40% ownership interest and provide a Carbon Credit Offtake framework to purchase 200,000 carbon credits generated by the project. |
| **Entropy Glacier** | Investment and Carbon Offtake Agreement | **$200 million (investment) and $85/tonne (up to 185,000 tpa)**<br>Announced December 2023; Entropy has developed a proprietary amine-based, post-combustion, retrofit, and low-cost CCS solution. This investment also consists of a Carbon Credit Offtake framework through which CGF may purchase up to 1 mega-tonne per annum of carbon credits from Entropy's Canadian projects ensuring a high degree of revenue certainty for Entropy. |

## 5.2 Labour Supply

CCUS projects are a major source of employment, requiring a substantial workforce for completion. The construction of the Boundary Dam CCS facility exemplifies the labour-intensive nature of these projects, employing about 1,700 contractors and SaskPower employees at its peak, and accumulating nearly 5 million person-hours of work. This significantly boosted the economy of the rural town of Estevan, Saskatchewan.

In Budget 2021, the Canadian government set a goal to introduce the CCUS-ITC to reduce emissions by 15 Mt of $CO_2$ annually. Considering the scale of CCUS projects, if 15 similar projects to the Boundary Dam CCS were constructed simultaneously, they would require an estimated 11,000 full-time equivalent (FTE) construction positions each year. With increasing competition for skilled labour within Canada and internationally, the demand is anticipated to rise. Policies like the US Inflation Reduction Act (IRA) are attracting capital and resources that might otherwise be invested in Canadian projects. Additionally, the federal government's new tax credits aim to stimulate a variety of emission-reduction technologies, which may create further competition for key trades and construction workers.

The IEA notes that Canada plans to significantly increase its capture capacity, targeting up to 31 Mt of $CO_2$ by 2030, with 4.2 Mt already completed, 3 Mt under construction, and 24 Mt planned. In the broader North American region, the projected capture capacity is 162 Mt per year, accounting for half of the global projected capacity of around 320 Mt per year. This indicates a substantial and growing demand for labour on new and operating carbon management projects.

As noted in Section 4.7, labour requirements exist in Canada for projects that access the CCUS-ITC. Similarly, in the US, the 45Q tax credits for capture and storage also have labour requirements. These labour requirements may cause simultaneous projects in the same regions to plan work and ensure sufficient skilled trades are available. Executive Series participants shared the perspective that in Alberta, economic contraction in the mid-2010s lowered the province's skilled labour pool by up to 30% suggesting projects will need coordination and scheduling with labour organizations to be completed within the CCUS-ITC timelines.

## 5.3 Supply Chain

The supply chain is a critical component in the successful execution of any major project. Disruptions in the supply chain can lead to significant delays, cost overruns, and even project failure. Therefore, a comprehensive understanding of supply chain risks and their mitigation is essential for making an FID on CCS projects.

Ensuring a consistent and reliable supply of materials and equipment is paramount. This involves identifying key suppliers, assessing their reliability, and establishing contingency plans for potential disruptions. Factors such as geopolitical tensions, natural disasters, and market volatility can affect material availability, making diversified supply sources and robust procurement strategies key for contracting strategies. The availability and cost of key materials and equipment for CCS projects, such as mechanical equipment, piping, insulation, electrical equipment, and controls, are particularly critical. These materials are fundamental to completing CCS projects on time and within budget.

The timely acquisition of specialized equipment is another vital aspect. Delays in equipment delivery can stall construction and operational phases, leading to increased costs. Capture facility designs vary depending on the technology chosen; however, common components include mechanical equipment (such as capture equipment and compressors), piping, insulation, and electrical equipment and controls. Executive Series participants noted that compressors have very long lead times that can be multiple years with one participant noting a limited number of vendors who can produce compressors each with a three-year waitlist for purchasers.

Combined heat and power systems are built alongside capture facilities and gas turbines used to produce power. Executive Series participants noted that such turbines can have excessive lead times from purchase to installation with one participant noting that they had to put an order in for a turbine before reaching a project FID to keep the construction timeframe reasonable.

Timing of the acquisition of equipment is a very pertinent issue in Canada for CCS construction, as the CCUS-ITC includes an acquiring rule whereby for equipment to be eligible for the tax credit it must be acquired in the year of the claim. That means that if a multimillion-dollar piece of equipment like a compressor, is delayed and is received after the incentive is set to half on January 1, 2031, the property would be eligible for only a 25% credit compared to a 50% tax credit if received before or on December 31, 2030. For projects looking to reach FID, this change of value on a set date may create greater risks for long-lead-time equipment.

Efficient logistics and transportation systems are necessary to move materials and equipment to the project site. This includes coordinating with transportation providers, ensuring compliance with regulations, and managing customs and import/export requirements. Effective logistics management can reduce lead times and minimize costs. The major building blocks of capture facilities, such as fabricated steel and cement, must be transported and handled efficiently. However, it is the specialized and large equipment that may represent a higher risk due to its complexity and the potential for supply bottlenecks.

By addressing these aspects, the project can reduce risks to its supply chain, thereby contributing to the overall success of the investment. Similar to risks stemming from labour supply, the number of projects moving through construction in the coming years is uncertain and if a large number are completed in Canada in the years preceding 2030, then the risks of backlogs for key CCS project inputs will increase.

## 5.4 Long-term Liabilities

An integral part of CCS technology being a viable climate solution is the fact that the $CO_2$ must be sequestered in perpetuity. To ensure permanence and address any reversals of containment there are operator obligations and liabilities that continue through the post-closure period, long after $CO_2$ injection has ended.

Long-term liabilities are often spoken of as they are a singular concept. There are, however, three key components or subsets of long-term liability:

- **Statutory Obligations:** The continued regulatory obligations of the operator. This would include any remaining site reclamation or remediation, and any ongoing monitoring.
- **Tort Liability:** Any liabilities to third parties for physical or economic harm as a result of the $CO_2$ storage facility. For example, this could include impacts on groundwater caused by $CO_2$ migrating out of the storage container.
- **Climate Liability:** Liability for $CO_2$ impacts on the atmosphere following the $CO_2$ migrating to the surface. This is the responsibility to 'true up' GHG accounting.

Every CCS project will have different geology and different properties and risks, and the long-term liabilities will be specific to the properties of the different projects. A CCS proponent will need to have a view of the potentials and risks for these long-term liabilities in the post-closure period, what can be done to reduce the risks, and how the liabilities will be addressed in the case of migration, and then factor these scenarios into operations and project economics.

To provide clarity and assurance for investors in the technology's deployment, regulatory frameworks have been developed to address liability and other operator concerns. The permitting and MMV requirements in particular jurisdictions help shape the role of governments and commercial approaches to protect CCS projects.[83] Generally, during the operational phase of a project, liabilities are held by operators, while a growing number of jurisdictions have created pathways for the future transfer of full or partial liabilities to governments. Credit holdbacks, discounts and stringent project requirements for periods after project closure are used to mitigate risks to governments in accepting future liabilities. Insurance products from a growing number of providers have also been developed and in some cases have been a requirement for CCS projects.

### Long-term Liability in Alberta

In Alberta, the government has passed legislation and introduced regulations, enabling the government to assume ownership of sequestered $CO_2$ and some of the associated long-term liabilities for storage hubs. Storage hub proponents must meet stringent criteria to transfer ownership and liabilities to the government. A key requirement is the development of a Closure Plan, which project developers must submit to the AER. It lists activities the proponent will undertake to close down sequestration operations and the specific information the operator must track and report on throughout the life of the project.
The criteria the project operator must meet to enable the transfer of ownership and liabilities includes:

- the $CO_2$ is contained;
- there are no significant risks to people or the environment;
- the $CO_2$ is behaving in a predictable manner;
- the project-specific risk profile is decreasing; and
- the required closure activities including surface reclamation are complete.

To deliver on these requirements the project operator must develop a project-specific MMV plan. The proponent must update the Closure Plan and MMV Plan throughout the project operations period and during the closure period.

If the storage hub operator delivers on all requisite criteria, the Alberta Government may elect to issue a Closure Certificate, and in doing so will assume ownership of the remaining facilities and the stored $CO_2$. It is important to note, however, that under current legislation and regulation, Alberta will only assume the first two types of liability listed above- statutory liability and tort liability. Climate liability will remain with the former operator in perpetuity. In September 2024, the Alberta government indicated to emission offset stakeholders that work is underway to create a mechanism to mitigate risks of unintentional release of $CO_2$ from a climate liability perspective. This may require offset developers to apply a discount and/or holdback factor to eligible emission reductions but would release the proponent from some TIER credit liabilities.

The liability transfer in Alberta is an exception to the norm for CCS projects globally. There are a few other jurisdictions, such as the US State of Louisiana and the Province of Saskatchewan, where governments assume the amount of liabilities for stored $CO_2$. The Government of Saskatchewan, through its CCUS Credit Standard, accepts some amount of climate liability while requiring the submission of credit holdbacks during specified years of operation.[84] In Louisiana, along with the transfer of some liabilities, storage facility operators are required to contribute up to USD $5 million per storage facility to a trust fund which is to be used for maintaining, remediating, insuring and other similar costs once liabilities have been transferred. Similarly, the Alberta Government operates a Post-Closure-Stewardship Fund. As of June 2024, the Quest CCS project is the only contributor to the fund with a current value of CAD $2.86 million.[85]

## 5.5 Public Support

Building public understanding and support for CCS projects is critical for several reasons. First, as mentioned above, CCS projects are most often investments that receive public funding to provide a public benefit – major $CO_2$ emission reductions. Second, on-shore $CO_2$ transportation and storage facilities are located below public and private properties. Public opposition to CCS projects noted by Executive Series participants included concerns over the safety of storage and transportation the proven nature of the technology to reduce emissions, and/or a disbelief in the causes and impacts of GHG emissions. Opposition to projects represents a risk to CCS project development, requiring proactive and thoughtful public engagement.

Principles for stakeholder engagement shared by the Executive Series participants included starting as early as possible and listening to concerns, being responsive and following up with concerns, and being relatable and factual in all engagements. A key strategy for building trust in CCS projects was starting with the 'whys' of CCS with a focus on the carbon cycle and how anthropogenic activity impacts the carbon cycle. Participants also noted the importance of conveying the role of regulations and permitting in ensuring that $CO_2$ is transported and stored as safely as possible and the risk assessments and mitigations that CCS projects take.

Understanding the economic and local benefits of CCS projects is also a key consideration in building public support. Initiatives such as Justice40 in the US[86] and labour requirements attached to CCS investments are designed to increase the economic and employment benefits stemming from CCS investments in the communities where they are located.

### Indigenous CCS Project Support in Alberta

Indigenous peoples in Canada have been integral to the conservation of this land's natural resources for thousands of years. This role has greater impact recently, especially considering the constitutional section-35 rights and subsequent case law. These rights and precedents mandate the consultation of Indigenous communities before the commencement of natural resource development in their respective territories.

CCS proponents have demonstrated their desire for partnerships with Indigenous communities, rooted in the spirit of reconciliation,[87] has fostered enduring and mutually beneficial partnerships between Indigenous communities, their enterprises, and major natural resource projects.

The Alberta Indigenous Opportunities Corporation (AIOC) exemplifies such collaboration, offering loan guarantees to Indigenous investments in these projects. This initiative is a progressive step towards economic reconciliation, empowering Indigenous participation in the stewardship of natural resource development and energy transition projects. As of April 2024, the AIOC has supported seven deals providing over $680 million in loan guarantees supporting 42 First Nations and Métis groups in Alberta to take ownership stakes in pipelines and power generating facilities and projects.

Several CCS proponents in Alberta are following this path and have chosen real Indigenous community ownership and participation in project development. Two prime examples are Reconciliation Energy Transition Inc.'s proposed East Calgary Region Carbon Sequestration Hub[88] and Enbridge's proposed Open Access Wabamun Carbon Hub.[89] These two proposed carbon sequestration projects, if moving forward, have committed to offer equity stakes to local First Nation and Métis communities.

# 6. It’s Time for FID

The development of large-scale CCS projects is essential to achieving significant reductions in greenhouse gas emissions from critical industrial processes. As highlighted in this report, Alberta provides a compelling case study for navigating the complex regulatory, financial, and technical landscapes required to advance these projects to an FID. The urgency of reaching FID is underscored by the global need to scale up CCS deployment rapidly to meet climate targets. By addressing foundational questions and leveraging the Alberta government's established frameworks and geological capacity, stakeholders can accelerate the transition from project conception to successful implementation, ultimately contributing to global efforts to combat climate change.

Understanding the key drivers and differentiators of CCS projects is critical for making informed decisions that lead to successful outcomes. Corporate emission reduction strategies for emission-intensive industries incorporate CCS as a tool to maintain production while achieving significant emissions reductions. Before embarking on CCS projects, it is essential to conduct thorough pre-capture activities, including facility emissions analysis, stakeholder engagement, and market opportunity assessments. Additionally, considerations related to $CO_2$ storage options, transportation infrastructure, and the selection of appropriate capture technologies and EPC partners further differentiate CCS projects and determine their feasibility and success. By assessing these factors early, emitters can strategically plan and execute CCS initiatives to align with corporate goals and regulatory requirements, ensuring long-term sustainability and compliance.

Regulatory requirements for CCS projects are essential to ensuring initiatives are developed responsibly, safely, and in a manner that benefits the public and the environment. Despite CCS being a proven and safe technology, regulations are in place to mitigate risks and enhance project integrity. A regulatory landscape to provide public assurance on the safety of CCS projects and share long-term risks, as is the case in the Alberta government, plays a significant role in using CCS as a pathway for compliance with emission reduction mandates. Its permitting processes within the province, for instance, are designed to thoroughly evaluate site suitability, ensure environmental protection, and manage long-term liability. These requirements, including detailed MMV plans, are put in place to build confidence that CCS projects will be effective and secure, and support the goal of reducing carbon emissions while safeguarding the public interest. The presence of liability transfers shows the recognition of major industrial emission reductions as a shared benefit whereby governments can share in any risks, while ensuring appropriate mitigation actions have been taken.

When considering CCS as an emission reduction solution, the financial viability of the project must be clear and compelling. Large emitters must evaluate the total costs, potential revenues, and available incentives to determine the value of such an investment. CCS projects typically involve significant capital and operational expenditures. However, these projects can also offer less direct benefits, such as market access for low-emission products and enhanced environmental and social standing. The business case for CCS is driven by a combination of regulatory compliance, potential revenue from carbon credits, government incentives, and the strategic value of reducing emissions. To justify the investment, the returns must outweigh not only the real costs but also the opportunity costs of other investments, with each industry and corporation having different thresholds for what constitutes a sufficient return. Understanding these factors is essential for making informed decisions that align with both financial goals and sustainability commitments.

Understanding and mitigating risks is essential to the development and investment in CCS projects. Various risks, including policy and carbon pricing uncertainties, labour and supply chain challenges, long-term liabilities, and the need for public support, all play a role in determining whether a project can reach an FID. Policy instability, particularly regarding carbon pricing and government incentives, can impact project economics. Labour shortages and supply chain disruptions can lead to delays and increased costs, further complicating project execution. Long-term liabilities associated with $CO_2$ storage and the need for robust public and Indigenous community support add additional layers of complexity. Both CCS proponents and governments have roles in addressing these risks. Proactive management, strategic planning, and effective stakeholder engagement are part of ensuring the positive FIDs to proceed for CCS projects.

In conclusion, the successful deployment of large-scale CCS projects hinges on a comprehensive understanding of the various factors influencing their viability. The Alberta context provides a robust framework for navigating the intricate regulatory, financial, and technical landscapes essential for advancing CCS projects to an FID. Stakeholders must carefully assess the key drivers, from corporate emission reduction strategies to the regulatory requirements to ensure project safety and public benefit. Financial viability is paramount, with considerations ranging from capital expenditures to potential revenue streams, including government incentives and carbon credits. Additionally, understanding and mitigating risks—such as policy uncertainties, supply chain challenges, and long-term liabilities—are crucial to maintaining project momentum and achieving success. The approach taken by the governments of Alberta and Canada serves as a model that can be adapted and applied globally, offering valuable insights for other regions aiming to scale up CCS deployment. By addressing these elements holistically, stakeholders can strategically plan and execute CCS initiatives to align with corporate objectives and climate goals and meet the potential step-change emission reductions from implementing CCS, ultimately contributing to the global effort to mitigate the effects of climate change.

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