Final Report

COMPANY | FRACMOD

PROJECT | CARBON CAPTURE UTILIZATION & STORAGE

PREPARED BY: ASISH ANAGHAN, PARAG BALDHA, SANA FATIMA, AND SHWET KUKADIYA

FRACTURE MODELING INC. | Suite 3000, 888 – 3rd Street SW, Calgary, Alberta, Canada | https://fracmod.com/

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1. Introduction

As the world grapples with the escalating crisis of climate change, the need for effective strategies to mitigate its impact has never been more urgent. This report aims to serve as a comprehensive guide to understanding and addressing this global challenge through the lens of carbon sequestration and utilization.

The first section provides an in-depth look at the various sources of carbon emissions, from individual activities to large-scale industrial operations. It serves as a foundation for understanding the scale and complexity of the problem we face. Following this, the report delves into the environmental, economic, and societal ramifications of unchecked CO2 emissions, offering a sobering view of the potential consequences of inaction.

The heart of the report focuses on technological methods for carbon sequestration, exploring innovative solutions like Direct Air Capture, Carbon Capture and Storage, and Bioenergy with Carbon Capture and Storage. Each method is examined for its efficacy, challenges, and potential for real-world application. To provide a practical perspective, the report also highlights current projects in Canada that are leading the way in implementing these technologies.

In addition to sequestration methods, the report explores the concept of carbon utilization, discussing how captured CO2 can be economically leveraged. This section introduces the idea of carbon credits and offsets as policy tools to incentivize emission reductions.

The report concludes with a multi-faceted approach to mitigating the effects of rising atmospheric CO2 levels, emphasizing the need for technological innovation, policy intervention, and global cooperation. It serves as both a comprehensive overview and a call to action, urging immediate and collective efforts to safeguard our planet for future generations.

2. Carbon Sequestration

2.1 Overview

Carbon sequestration is the process of capturing and securely storing carbon dioxide (CO_2) emissions, primarily to mitigate the increasing concentrations of greenhouse gases in the atmosphere. The process is divided into two broad categories: natural and artificial (technological) methods. The primary objective is to provide a viable strategy for countries and industries to lower their carbon footprints, thereby mitigating the adverse impacts of climate change.

2.2 Natural Carbon Sequestration Methods

2.2.1 Forestry and Afforestation

Forestry, especially afforestation and reforestation, is one of the most straightforward methods of natural carbon sequestration. Trees absorb CO_2 from the atmosphere during photosynthesis and store the carbon in their biomass. Sustainable forest management practices are critical to ensure that the forest ecosystem retains its ability to sequester carbon over the long term. Deforestation and poor forest management can reverse the benefits, releasing stored carbon back into the atmosphere.

2.2.2 Soil Carbon Sequestration

Soil carbon sequestration is another natural method that focuses on agricultural lands. By using agricultural practices such as reduced tillage, cover cropping, and enhancing organic matter content, the soil's ability to store carbon can be improved. Through these practices, carbon is sequestered in the soil in a stable form that is less likely to be released back into the atmosphere, thereby serving as a long-term carbon sink.

2.2.3 Wetland Restoration

Wetlands like marshes and peatlands serve as significant carbon sinks. They are highly effective at capturing and storing CO_2 due to their slow decomposition rates and anaerobic conditions. Wetland restoration and protection efforts are therefore essential strategies in natural carbon sequestration. Properly managed, these wetlands can act as long-term reservoirs of stored carbon.

2.2.4 Ocean Carbon Sequestration

Oceans play a vital role in regulating the Earth's climate, absorbing approximately 25% of atmospheric CO_2. While this method is a natural part of the Earth's carbon cycle, it leads to ocean acidification, which poses severe risks to marine ecosystems, particularly coral reefs and shellfish.

2.3 Technological Carbon Sequestration Methods

2.3.1 Direct Air Capture (DAC)

Direct Air Capture technology aims to extract CO_2 directly from the atmosphere using chemical processes. These systems are usually powered by renewable energy sources to minimize their carbon footprint. However, the technology is still in its nascent stages and faces challenges such as high operating costs and energy requirements.

2.3.2 Carbon Capture and Storage (CCS)

Carbon Capture and Storage is a technological method that captures CO_2 emissions at their source, typically power plants and industrial processes, and transports them to geological formations for long-term storage. The captured CO_2 is injected deep underground into rock formations that have been deemed secure for millennia, thus providing a long-term sequestration solution.

2.3.3 Bioenergy with Carbon Capture and Storage (BECCS)

BECCS combines bioenergy production with carbon capture and storage. In this method, biomass like wood and agricultural residues is burned to produce energy. The CO_2 generated during combustion is captured and stored using CCS technology, making it a potentially carbon-negative energy source.

2.3.4 Enhanced Weathering

Enhanced weathering involves accelerating natural geological processes to capture CO_2. Minerals rich in calcium or magnesium are exposed to CO_2 in the atmosphere or in industrial settings, converting the gas into stable carbonates that can be stored safely.

2.3.5 Ocean Fertilization

Ocean fertilization is a controversial technological method that involves adding nutrients such as iron or phosphorus to ocean waters to stimulate phytoplankton growth. These microorganisms absorb CO_2 but can also have unforeseen ecological impacts, making this method a subject of ongoing debate.

2.3.6 Mineral Carbonation

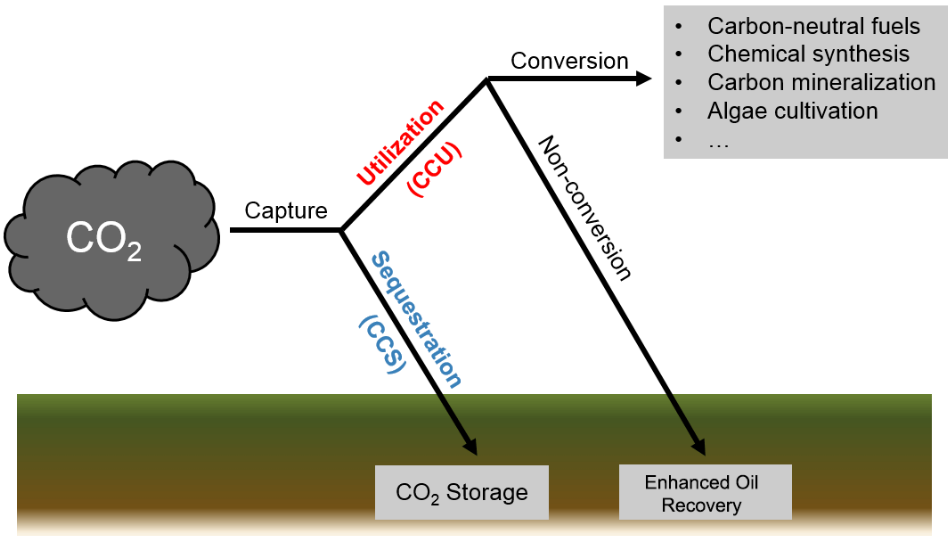
Mineral carbonation is an emerging technique where CO_2 reacts with abundant minerals like magnesium and calcium silicates under controlled conditions. The reaction produces stable carbonates, effectively immobilizing the CO_2 in a solid form that poses no threat to the environment.

2.4 Current Projects in Canada

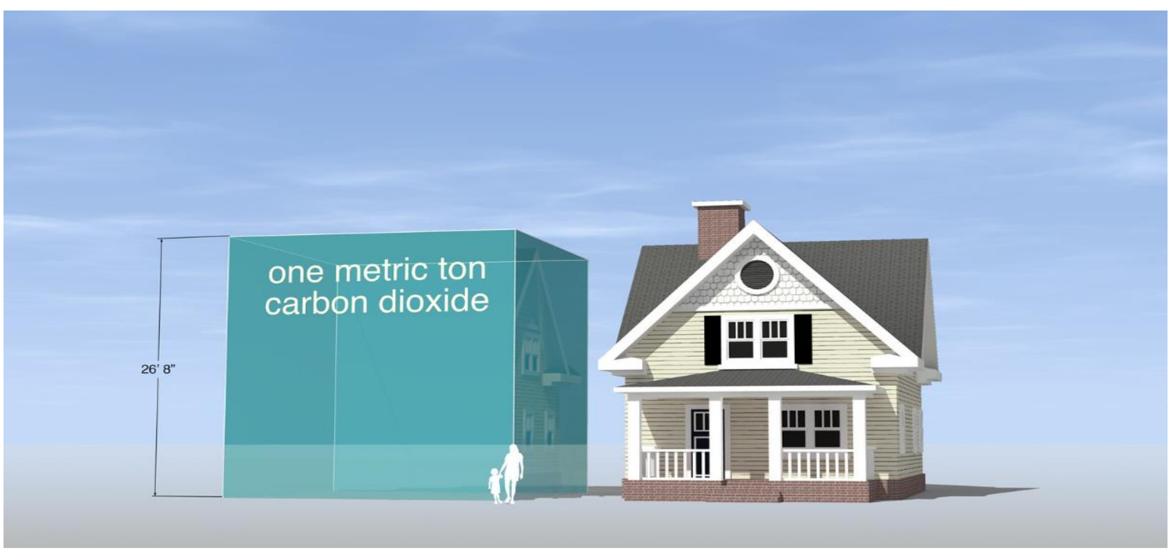
Canada is actively participating in several artificial carbon sequestration projects to combat climate change. Notable projects include the Boundary Dam Carbon Capture Project in Saskatchewan, which aims to capture about one million tonnes of CO_2 annually from a coal-fired power plant. Another significant project is the Quest CCS Facility in Alberta, which focuses on capturing and storing CO_2 from oil sands operations. CarbonCure Technologies, based in Nova Scotia, has developed a unique approach to utilize captured CO_2 in the production of concrete, thereby creating a market for captured CO_2 and encouraging further capture initiatives.

3. Carbon Utilization

CO2 utilization" is an industrial process that makes an economically valuable product using CO2 at concentrations above atmospheric levels. CO2 is either transformed using chemical reactions into materials, chemicals, and fuels, or directly in processes like enhanced oil recovery.



Below Figure (Source: Flicker) displays a comprehensive visual representation of one metric ton of carbon dioxide. The illustration emphasizes the volume that this quantity of CO2 occupies in its gaseous state. The visualization serves as a tangible reference point, enabling individuals to conceptualize the extent of CO2 emissions more effectively.

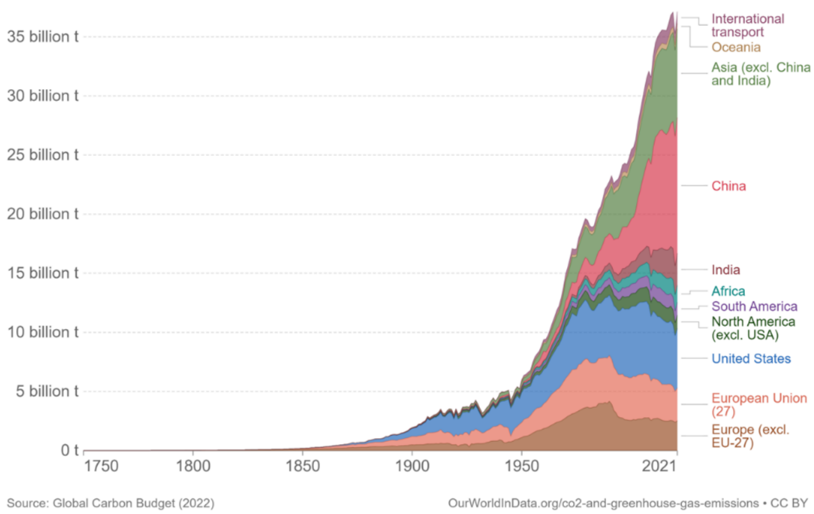


3.1 The Source of Emissions

The sources of carbon dioxide emissions are diverse, ranging from individual to industrial scales. Humans emit approximately 4.79 metric tons of CO2 equivalent (CO2e) per year, primarily through activities like energy consumption, transportation, and food production. Cars contribute a significant amount as well, with an estimated 1.19 metric tons of CO2e per year. Household energy use, specifically natural gas consumption, accounts for 5 to 10 metric tons annually, varying based on geographical location and usage patterns. In the industrial sector, oil rigs are significant contributors, emitting between 10,000 and 50,000 metric tons of CO2e per year. Natural mechanisms offer some relief; a single mature tree can absorb about 0.006 metric tons of CO2e annually, and microalgae can absorb around 2 tons per year per square meter of cultivation area.

Source of Emission	Amount of emission of CO2e per Unit
A Human	350 tones per life cycle/380Kg per year
Car	1.19 metric tons per year
Average CO2 emissions from natural gas consumption in household	5 to 10 metric tons per year
Volcanoes	0.3 billion metric tons
Oil rig	10,000 to 50,000 metric tons of per year
A single mature tree	- 0.006 metric tons per year
Amazon rainforest	-2200000000 metric tons (2.2 billion tons)
Microalgae	-2 ton per year per square meter of cultivation area

3.2 Annual CO_2 Emissions by World Region

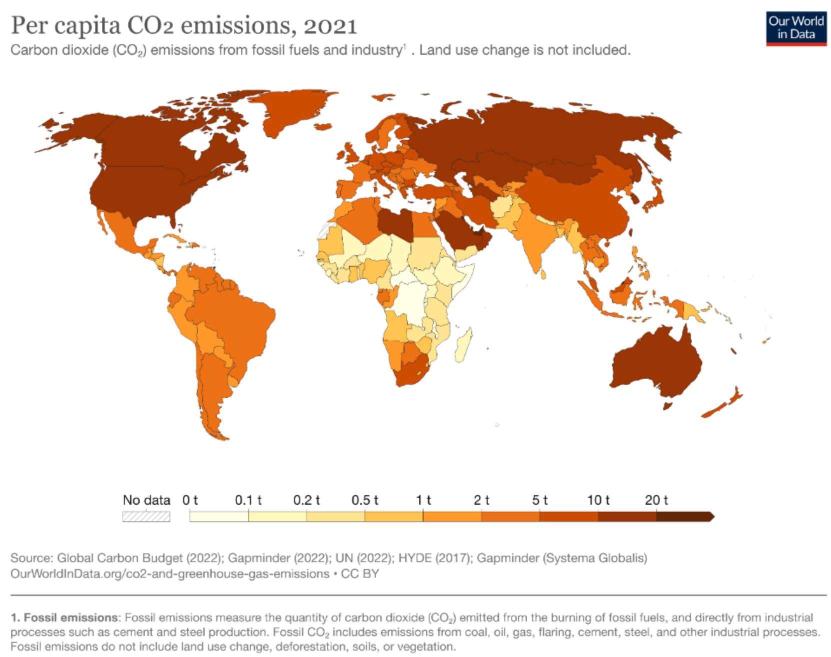


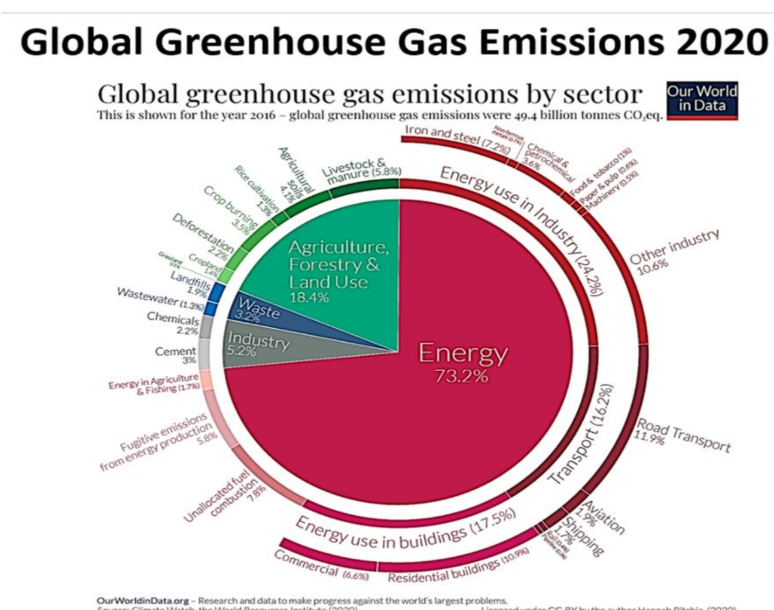
1. Fossil emissions: Fossil emissions measure the quantity of carbon dioxide (CO_2) emitted from the burning of fossil fuels, and directly from industrial processes such as cement and steel production. Fossil CO_2 includes emissions from coal, oil, gas, flaring, cement, steel, and other industrial processes. Fossil emissions do not include land use change, deforestation, soils, or vegetation.

Although not provided in the preliminary data, the geography of CO2 emissions is critical for understanding where intervention efforts should be focused. Developed nations traditionally emit more per capita, but emerging economies are increasing their share. This regional data can inform targeted policies, international collaborations, and technological deployments aimed at reducing emissions.

3.2.1 CO2 Emission Per Capita

Analyze CO2 emissions on a country basis, China would emerge as the leading contributor with 11.47 billion tons annually. However, if we shift our focus to per capita emissions, the situation takes a distinct turn. In this scenario, China falls behind both Europe and the USA. Here, provided a visual representation depicting the per capita CO2 emissions.





3.2.2 Greenhouse gas emissions by Sector

Energy Sector consider to be highest carbon emitter sector with 73.2% stack in total emissions in total global emissions.

3.3 Effects on Environment

Environmental impacts of CO_2 emissions are extensive. According to National Geographic, these include but are not limited to accelerated polar ice melt, contributing to rising sea levels that threaten coastal communities. Additionally, there is an increase in extreme weather events like hurricanes, floods, and droughts that disrupt ecosystems and human societies alike. The loss of biodiversity is another crucial concern, affecting not just wildlife but also human livelihoods that depend on stable ecosystems.

3.4 Effects on Economy

Economic ramifications of CO_2 emissions are often underappreciated but significant. They manifest in various forms like damage to infrastructure due to extreme weather events, increased healthcare costs due to pollution-related illnesses, and decreased agricultural yields due to changing weather patterns. These impacts can create a vicious cycle, draining resources that could otherwise be used for sustainable development and climate action.

3.5 Effects on Human Society

Rising CO_2 levels affect human society in several ways, often exacerbating existing inequalities. Poor air quality leads to health issues, particularly respiratory conditions. Extreme weather events often disproportionately affect vulnerable populations, leading to displacement and potentially even conflict over scarce resources. Moreover, water scarcity is becoming increasingly common, affecting both rural and urban communities.

3.6 Global Efforts to Control Carbon Emissions and Mitigate Climate Change

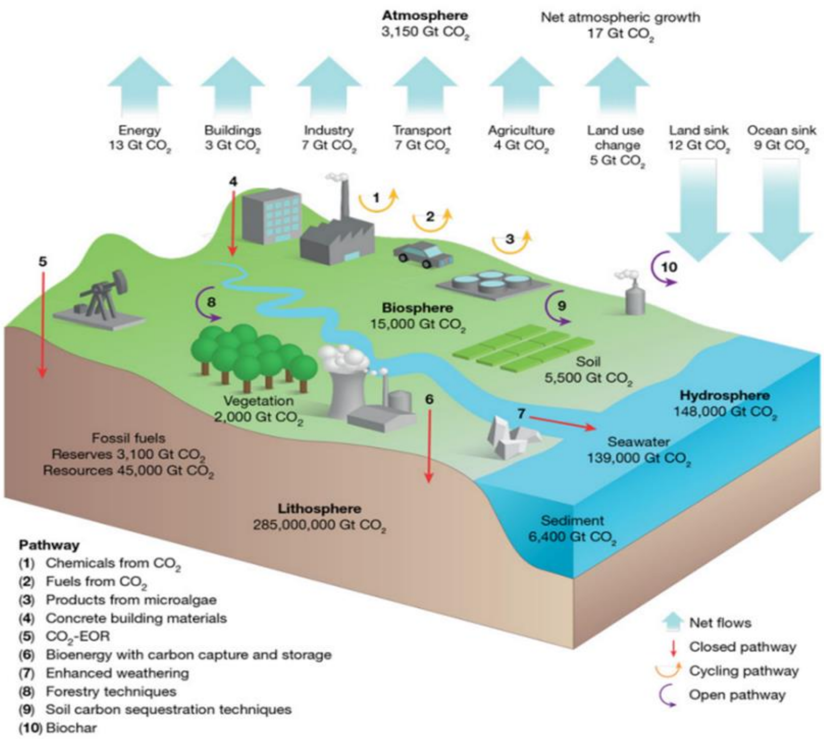
Global initiatives such as the Paris Agreement aim to limit global warming by reducing CO_2 emissions. Many countries have adopted carbon pricing, either through taxes or cap-and-trade systems, to incentivize emission reductions. Efforts are also underway to promote climate-friendly transportation, like electric vehicles and public transit, as well as encouraging businesses to adopt sustainable practices. Public awareness campaigns and educational initiatives are crucial in shaping public opinion and encouraging responsible behavior.

3.7 Carbon Utilization Techniques

Carbon utilization seeks to turn CO_2 emissions from a waste product into an economic asset. Techniques include using CO_2 for enhanced oil recovery or transforming it into building materials, chemicals, or fuels. The goal is to capture carbon at the source and either store it or use it, thereby reducing atmospheric concentrations.

3.8 10 Methods of Carbon Capture and Utilization

Based on a study by Nature, both conventional and non-conventional methods show promise in capturing and utilizing CO2. For example, enhanced oil recovery could potentially utilize up to 1,800 Mt of CO2 by 2050 at a net economic benefit, given its negative breakeven cost. Bioenergy with Carbon Capture and Storage (BECCS) is another non-conventional method with significant potential, capable of handling up to 5,000 Mt CO2 by 2050 at a breakeven cost between $60 to $160 per tons of CO2 utilized.



3.9 Scale and economics of CO_2 utilization

A study conducted by Nature calculates breakeven costs in 2015 US dollars per tons of CO_2 for each pathway (hereafter, all costs stated are in US dollars). The breakeven CO_2 cost represents the incentive per ton of CO_2 utilized that would be necessary to make the pathway economic. This can be thought of as the breakeven (theoretical) subsidy per ton of CO_2 utilization, although we are not recommending such a subsidy.

Pathway	Pathway potential in 2050 (Mt CO_2 removed per year)	Utilization potential in 2050 (Mt CO_2 utilized per year)	Breakeven cost of CO_2 utilization (2015 US$ per tons CO_2 utilized)
Conventional utilization			
Chemicals	Around 10 to 30	300 to 600	−$80 to $320
Fuels	0	1,000 to 4,200	$0 to $670
Microalgae	0	200 to 900	$230 to $920
Concrete building materials	100 to 1,400	100 to 1,400	−$30 to $70
Enhanced oil recovery	100 to 1,800	100 to 1,800	−$60 to −$45
Non-conventional utilization			
BECCS	500 to 5,000	500 to 5,000	$60 to $160
Enhanced weathering	2,000 to 4,000	No Data	Less than $200
Forestry techniques	500 to 3,600	70 to 1,100	−$40 to $10
Land management	2,300 to 5,300	900 to 1,900	−$90 to −$20
Biochar	300 to 2,000	170 to 1,000	−$70 to −$60

4. Carbon Credits & Offset

4.1 Introduction to Carbon Offsets

In Alberta, carbon offsets represent a mechanism whereby emissions can be offset by investing in projects that either reduce or capture greenhouse gases. These projects are quantified through Alberta-approved methodologies known as quantification protocols and are verified by a third party according to specific standards for validation, verification, and audit.

4.2 Types of Eligible Projects

The Alberta government provides a framework for project types eligible for generating carbon offsets. These types include various activities ranging from Aerobic Composting and Agricultural Nitrous Oxide Emission Reductions to Wind Powered Electricity Generation and Waste Heat Recovery. Each of these activities is outlined in a detailed quantification protocol that specifies monitoring, measuring, and quantification procedures to calculate net emission or sequestration reductions.

4.3 Process of Emission Offset Project Lifecycle

Step 1: Initiation

In this initial phase, project developers assess the eligibility of their proposed activities based on the approved quantification protocols. They then complete an Offset Project Plan form and submit it to the Alberta Emission Offset Registry. This submission leads to a public listing of the project plan, thereby establishing the offset start date and the crediting period.

Step 2: Implementation and Emissions Reductions

During this step, developers execute the project according to the plan, collect relevant data, and report emission reduction claims. These reports must be verified at least biennially, following the guidelines outlined in the Offset Project Report Form.

Step 3: Verification

A third-party verifier conducts an independent review of both the emission reduction project and the offset claim. The verification process must adhere to the stringent criteria laid out in the Standard for Validation, Verification, and Audit.

Step 4: Registration

Following successful verification, developers upload the necessary documents to the Alberta Emission Offset Registry for a completeness review. Once approved, these documents are posted publicly to support the project's registration.

Step 5: Serialization

The Registry then assigns unique serial numbers to verified emission reduction claims. These serial numbers are listed publicly, adding another layer of transparency and accountability.

Step 6: Transfer and Compliance

The last step involves the sale and transfer of emission offset credits. All transactions are tracked and updated on the Registry. Owners of these credits can either use them to meet annual emission targets or voluntarily retire them for other purposes.

4.4 Offset Eligibility Criteria

To be eligible for generating offset credits, a project must meet certain criteria outlined by the Specified Gas Emitters Regulation. These criteria include the geographical location (must occur in Alberta), timing (actions and effects must occur on or after January 1, 2002), and the nature of the emissions reduction (must be real, demonstrable, and quantifiable). Additionally, the project must be verified by qualified personnel and registered on the Alberta Emission Offset Registry.

4.5 Carbon Credits

Carbon credits are a financial construct designed to quantify reductions or avoidance of greenhouse gas emissions. Essentially, one carbon credit is equal to one metric ton of carbon dioxide or a similar quantity of other greenhouse gases. The concept of carbon credits introduces a market mechanism that allows companies, governments, and individuals to buy and sell the "right to emit" a certain amount of carbon. This not only generates revenue for low-emitting technologies but also places a financial penalty on high-emitting activities, thus offering a financial incentive to reduce emissions.

4.6 Carbon Credit program in Alberta:

The Technology Innovation and Emissions Reduction Regulation (TIER) requires regulated facilities to reduce greenhouse gas emissions and implements an emissions trading system. The regulation applies emissions reduction requirements to facilities which emit more than 100,000 tonnes of carbon dioxide per year Facilities which emit less than the threshold may voluntarily opt-in to the regulation, including conventional oil and gas facilities. Voluntarily opting in may allow facilities to receive an exemption from Canada's federal carbon fuel charge. Emissions reduction requirements are set using two benchmarking approaches: high-performance benchmarks that recognize and reward the most efficient facilities in an industry or facility-specific product benchmarks which set a reduction target relative to a facility's own historic performance.

To meet the emissions reduction requirement. Facilities can reduce their emissions or use emission performance credits, emission offsets or pay into a compliance fund (TIER fund). This ties-in to Alberta's Emission Offset System which enables compliance flexibility for facilities regulated under TIER. Regulated facilities must provide annual compliance reports and facilities that emit more than 1 million tonnes of carbon dioxide must also provide a yearly emissions forecasting report.

Regulation covers three kinds of facilities :
Large emitters –facilities with emissions over 100,000 tonnes (mandatory inclusion).

Opted-in facilities – facilities under 100,000 tonnes which have applied to enter the regulation as an individual facility. Regulatory approach the same as large emitters (voluntary inclusion).
Facilities may opt back out of the regulation in a subsequent year.

Aggregate facilities – made up of 2 or more small "conventional oil and gas" facilities. Different regulatory approach than large emitters or opted-in facilities (voluntary inclusion).

Regulation uses two main kinds of benchmarks to set emissions requirements:
Facility specific benchmarks – based on the historic emissions performance and production of a facility over three years.
Emissions intensity target starts at 90% in 2020 (requiring 10% reduction). Stringency increases by 1% annually starting in 2021.
High performance benchmarks – based on best performing facility or facilities in the sector.

Individual conventional oil and gas facilities with emissions less than 100,000 tonnes have three options:

1. Do not enter TIER and pay the fuel charge – this may be best for facilities with very little fuel consumption.

2. Opt-in to TIER as a single facility – this may be a preferred option for sites with CO2 enhanced oil recovery projects.

3. Apply to enter along with other conventional oil and gas facilities as an aggregate – this is the general approach designed for conventional oil and gas to minimize costs.

Emission offsets from 2017 and onwards have a Nine-year expiry starting from the year in which the reduction was made.

Facilities that are regulated under TIER are required to reduce their emission intensity from their Historical performance using facility-specific benchmarks (FSB), or from the performance of the top. Facility in a sector using an approved high-performance benchmark (HPB). Facilities that Outperform. The higher of their FSB or HPB can generate emission performance credits. Facilities that do not meet their emission intensity target can meet compliance obligations through:

- Use of emissions performance credits that are generated by other regulated facilities.
- Use Alberta-based emission offsets that are generated by projects that have voluntarily,
- Reduced their greenhouse gas.

Pay into the TIER fund, which is priced at $50 per tonne of carbon dioxide equivalent (CO2e) as of January 1, 2022. The TIER fund is invested in measures to support emission reductions or enhance, resilience to a changing climate.

The maximum allowable emission offsets, emission performance credits or sequestration credits that can be used by a given facility in a year to comply with its total regulated emissions amount will, continue to be 60% in 2023, but will increase thereafter to 70% in 2024, 80% in 2025 and 90% in 2026. and any subsequent year.

Emission offsets are generated by facilities that undertake a project or activity in Alberta that results in the reduction or sequestration of GHG emissions. The facility must also meet the standards set out for the quantification of offsets in an approved quantification protocol, verify its offsets through a qualified third party, and submit project information required by Alberta's Standard for Greenhouse Gas Emission Offset Project Developers for its offsets to be registered in the Alberta Emissions Offset Registry.

Each properly registered offset represents one tonne of CO2e that a TIER-regulated facility, can purchase and use to effectively offset the number of excess tonnes of CO2e it produces in a given year, relative to the applicable benchmark.

The carbon is $65/tonne currently, rising by $15 each year until it reaches $170/tonne in 2030.

4.7 Regulatory threshold:

TIER applies to any facility that has emitted 100,000 tonnes or more of carbon dioxide equivalent, (CO2e) greenhouse gases (GHGs) in 2016, or any subsequent year.

4.8 Facility opt in:

Facility with fewer than 100,000 tonnes of carbon dioxide equivalent GHG emissions per year may be eligible to opt-in to the TIER system if it competes against a facility regulated under TIER, or has greater than 10,000 tonnes of annual emissions and is in an emissions-intensive, trade-exposed sector.

Multiple small conventional oil and gas facilities with a common person responsible can also enter into TIER by applying to be regulated as an aggregate facility.

4.9 Benefits of being regulated:

The Government of Canada applied the federal carbon tax in Alberta on January 1, 2020, under the Greenhouse Gas Pollution Pricing Act (GGPPA). The tax applies to all fossil fuels used in Alberta, Including those in the conventional oil and gas sector. Alberta has challenged the constitutionality of This legislation in court and is awaiting the ruling from the Supreme Court. The GGPPA includes Provisions to exempt facilities subject to provincial policies that meet the federal benchmark criteria.

4.10 Eligibility Criteria:

Pathway 1 - Direct Competition

Facilities can opt-in to the Regulation to address situations where they compete directly with larger facilities that are automatically subject to the Regulation. Without opting-in, these smaller facilities could face higher per unit carbon cost, impacting competitiveness. If the facility produces a product listed in Table 1, it is eligible to opt-in through these eligibility criteria.

Pathway 2 - EITE Facilities

Facilities that belong to an EITE sector as defined in Section 4(1)(a) of TIER and had total regulated emissions of 10,000 tonnes in any year since 2018 or is expected to exceed 10,000 tonnes in its third year of commercial operation are eligible to opt-in. Table 2 provides a list of EITE sectors that include at least one facility that met or exceeded the 10,000- tonne CO2e threshold.

4.11 Third party Verification:

There is no third-party verification required for the opt-in application. The opt-in application must Include a Statement of Certification signed by a certified official who has the authority to bind the Company.

4.12 True up options:

Facilities are required to meet their true-up obligation through various avenues of compliance which, can include Fund payment at $30 per tonne of CO2e Use of emission offsets of emissions performance credits (up to 60 per cent of obligation) Submission of a third party verified facility specific benchmark application, if desired, by September of the year the benchmark would first apply.

4.13 Benchmarking methodology:

Emissions reduction obligations are determined according to a facility-specific benchmark approach, And high-performance benchmark approach. In most cases, a regulated facility is subject to the less stringent of the two approaches for that facility.

Facility specific vs. high performance benchmark:

Facility-specific benchmarks are not applicable to facilities in the electricity sector, which is subject to a “good-as-best gas” benchmark. Where a facility produces a product that has not received a high-performance benchmark the facility-specific benchmark approach applies under the facility-specific benchmark methodology, a facility is required to reduce emissions intensity by 10 per cent relative to the facility’s historical production-weighted average emissions intensity.

High performance benchmarks are set to the average emissions intensity of the most emissions-efficient facilities (performers in the top 10 per cent) producing each benchmarked product over reference years. If there are fewer than ten facilities producing a product, the high-performance Benchmark for a product is then set based on the emissions intensity of the best-performing facility.

4.14 Regulated Emission sources:

Regulated emission sources for aggregate facilities are different than for large emitters or opted-in facilities. Further information about emissions sources for aggregate facilities can be found in the regulation, applicable standards and the Conventional Oil and Gas TIER Fact Sheet.
For large emitter and opted-in facilities, regulated emissions under TIER include direct onsite, emissions of greenhouse gases (see Schedule 1 of the TIER Regulation for a complete list of specified gases). Though not part of regulated emissions, indirect emissions are accounted for under the allowable emissions calculation.

Direct Emissions: Direct emissions are greenhouse gases released from sources located at the facility, expressed in tonnes CO2e. It does not include biomass CO2 emissions nor the emissions from federally levied fuel at a time when an exemption certificate had been issued.

Indirect Emissions: Indirect emissions are emissions associated with electricity, industrial heat, and Hydrogen that are imported by a facility. The allowable emission for each regulated facility is adjusted For these imports. For example, the allowable emissions of a facility importing electricity will be adjusted to receive fewer allowable emissions.

4.15 Tightening Rate:

The stringency of facility-specific benchmarks will increase by 1 per cent annually beginning in 2021 so, a facility with a 90 per cent free emissions allocation (or a 10 per cent emissions intensity reduction requirement) in 2020 would receive 89 per cent free allocation in 2021, 88 per cent in 2022, And so on.

The tightening rate will not apply to IP emissions, emissions from electricity generation, high-performance benchmarks or benchmarks for aggregate facilities. The high performance benchmarks will act as the tightening rate end point for the facility-specific benchmark

Section 5: Pore Space for Carbon Sequestration in Alberta

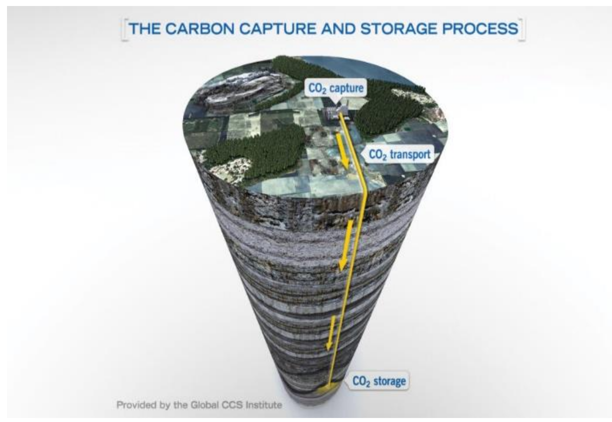
Overview

Alberta is playing a significant role in Canada's efforts to meet its climate goals by 2030, particularly in carbon capture, utilization, and storage (CCUS). This section elaborates on the different types of hubs, pipeline networks, main emitters of CO2, the companies that have won pore space in bidding rounds, and the regulatory landscape.

Pore Space for Carbon Sequestration

Introduction

- Carbon dioxide is stored in the pore space, minute gaps between sand and sediment particles.
- Alberta has vast geological formations located over two kilometers beneath the surface ideal for large-scale carbon sequestration.



Different Types of Hubs and Their Locations

Alberta has launched initiatives to set up several carbon storage hubs, primarily located near Edmonton in the Alberta Industrial Heartland (AIH) zone:

- **Meadowbrook Hub Project**: North of Edmonton
- **Open Access Wabamun Carbon Hub**: West of Edmonton
- **The Origins Project**: South of Edmonton
- **Alberta Carbon Grid™**: North and northeast of Edmonton
- **Atlas Carbon Sequestration Hub**: East of Edmonton
- **Wolf Midstream and partners**: East of Edmonton

In a second competition, more hubs were selected in other regions:

- **Athabasca Banks Carbon Hub**: North of Whitecourt
- **Battle River Carbon Hub**: East of Red Deer
- **Brazeau Carbon Sequestration Hub**: West of Edmonton
- **Central Alberta Hub**: East of Red Deer
- **Greenview Region CCS Project**: Southeast of Grande Prairie
- **Maskwa Project**: Around Swan Hills

- **Pincher Creek Carbon Sequestration Hub**: Southeast of Pincher Creek
- **Tourmaline Clearwater CCUS**: South of Edson

Carbon Capture Pipelines in Alberta

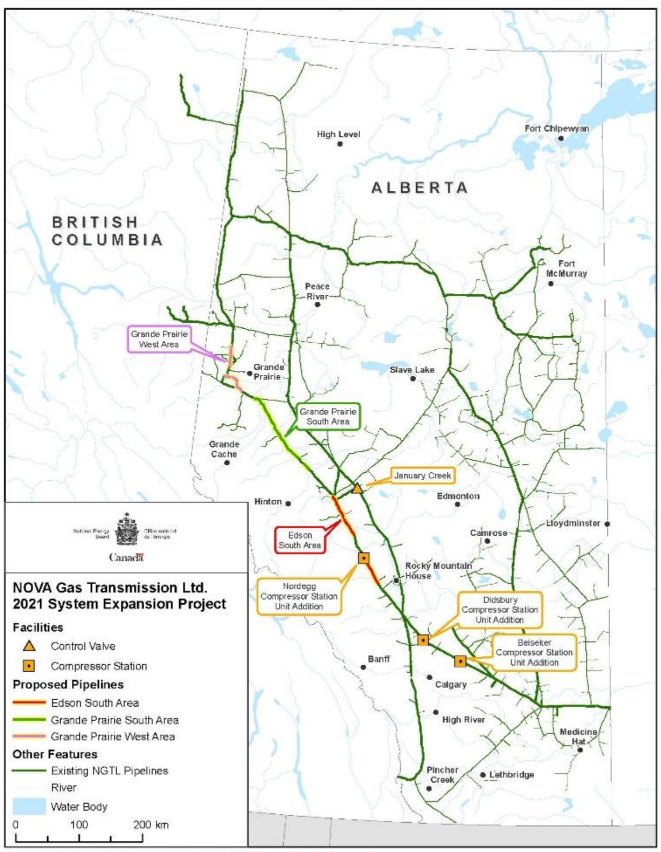
1. **Alberta Carbon Trunk Line (ACTL) Project**: A 240 km pipeline with a capacity of up to 14.6 million tonnes of CO_2 per year, focusing on transporting CO_2 for enhanced oil recovery projects.

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023
Injection amounts	0.371	1.11	1.138	1.066	1.128	0.941	1.055		

Alberta government: $745 million until 2025

Knowledge sharing injection amounts reported (in million tones)

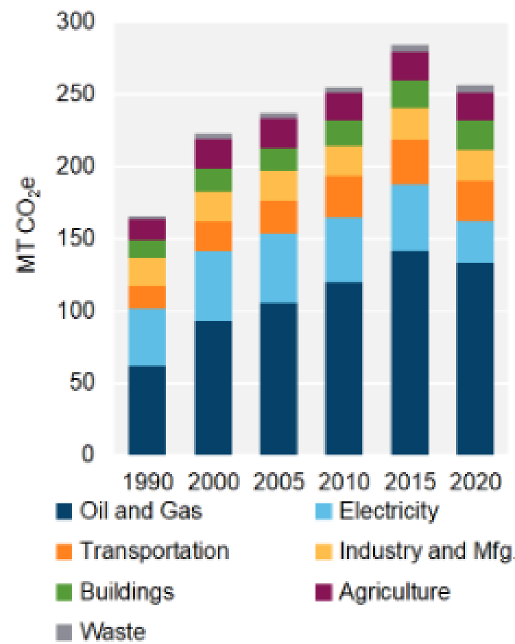
2. **NOVA Gas Transmission Limited (NGTL)**: A 40.1 km natural gas pipeline expansion, but its infrastructure could be adapted for future CCUS projects.



Main Emitters of CO2 in Alberta

The largest emitting sectors are oil and gas production (52%), electricity generation (11%), and transportation (11%). Significant companies include:

- **Syncrude Canada Ltd.**
- **Suncor Energy Inc.**
- **Canadian Natural Resources Limited (CNRL)**



Companies Granted Pore Space

- **First Bidding Round**: Bison Low Carbon Ventures Inc., Enhance Energy Inc., Enbridge Inc., Pembina Pipeline Corporation and TC Energy, Shell Canada Limited, ATCO Energy Solutions Ltd., Suncor Energy Inc., and Wolf Midstream.
- **Second Bidding Round**: Vault 44.01 Ltd., Moraine Initiatives Ltd., Heartland Generation Ltd., Tidewater Midstream & Infrastructure Ltd., Wolf Carbon Solutions Inc., Whitecap Resources Inc., ARC Resources Ltd., Kiwetinohk Energy Corp., West Lake Energy Corp., and Tourmaline Oil Corp.

Regulatory Aspects

1. **Application Process for Scheme Approval by AER**: Companies must submit detailed geological interpretations, plans for monitoring, and post-closure stewardship funds.
2. **Granting Carbon Sequestration Tenure**: Tenure is granted to companies that meet AER's stringent requirements.
3. **Carbon Sequestration Tenure Regulations**: Strict regulations govern the tenure, ensuring the integrity and safety of the carbon storage sites.

Application Process for Scheme Approval by AER

Companies wishing to operate carbon sequestration projects in Alberta must go through an intensive application process with the Alberta Energy Regulator (AER). The application for Underground Gas Storage requires applicants to submit a set of geological data, such as net pay isopach maps, structure contour maps, and annotated log cross-sections. A failure to provide a thorough geological interpretation could lead to processing delays. Additionally, estimates of initial gas and oil volumes, recovery factors, and the methods for these estimates are required. Details on bounding formations, such as the integrity of base and caprock, evidence of fracturing, and caprock threshold pressure must also be provided. If an active aquifer system exists, measured changes in gas and water contact and its impact are necessary.

For disposal activities classified under Classes I-IV, applicants must produce a timeline chart that specifies planned and issued dates for evaluation permits, sequestration leases, and renewal periods. An annual progress report is also mandatory. The general requirements section should outline the proposed disposal scheme, mentioning unique well identifiers, disposal zones, and projected daily disposal volumes. Additionally, a statement justifying the well's suitability for disposal is essential.

Granting Carbon Sequestration Tenure

The application process also includes a general overview that provides a high-level snapshot of the project, encompassing details like location, scope, schedule, cost estimates, and financing plans. The business model section is crucial and must include a rigorous economic analysis. This should cover capital and operating costs, financing arrangements, and also summarize the project's socio-economic benefits, particularly those impacting Indigenous communities.

Project Configuration and Execution requirements demand a comprehensive project execution plan, along with specific design details. Risk factors involving the geosphere, hydrosphere, atmosphere, and biosphere must be outlined, along with their mitigation strategies. Detailed plans about the project's annual injection volumes, secured volumes, and the project's geographical extent are also required. Any sub-surface conflicts that may arise with existing and potential resource development must be identified, along with mitigation options. Information on the proponent's operational capacity, public and Aboriginal consultation plans, emissions policy, and expected community benefits must also be submitted.

Carbon Sequestration Tenure Regulations

The regulations start by defining key terms like "carbon sequestration lease," "deep subsurface reservoir," "evaluation permit," and "Regulator," and specify the scope of the regulation's applicability. Evaluation permits, their term lengths, and area limitations are described in detail. The regulation also outlines the requirements for a Monitoring, Measurement, and Verification (MMV) plan, including its likely impact on mineral recovery. Carbon Sequestration Leases are detailed and post-closure requirements are provided, which include vital data like geological interpretations, well conditions, and decommissioning activities. The regulation also introduces a Post-closure Stewardship Fund, where a fee per tonne of captured carbon dioxide must be paid.

Hub Locations in Alberta

The Government of Alberta has recently outlined CO2 evaluation permit zones for the first round of applicants. Three primary zones have been identified for carbon storage: the Winterburn Group, the Woodbend Group, and the Basal Sandstone Unit. Several key players have secured permits in these zones:

- **Pembina Pipeline Corporation (Alberta Carbon Grid)**: Basal Sandstone Unit
- **Bison Low Carbon Ventures**: Woodbend
- **Enbridge Wabamun Hub**: Winterburn & Basal Sandstone Unit
- **Wolf Carbon Hub**: Basal Sandstone Unit
- **Shell Canada (Atlas/Polaris)**: Basal Sandstone Unit

- **Enhance Energy (Origin)**: Woodbend

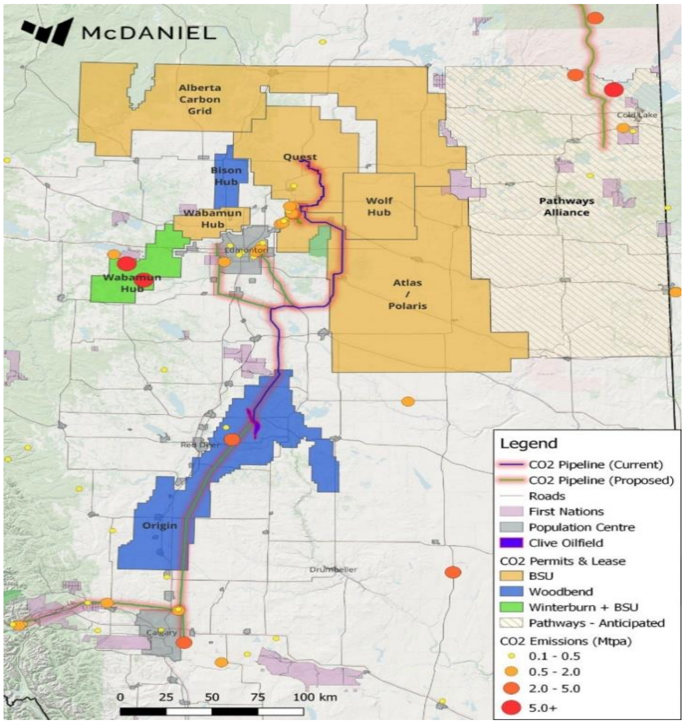


Figure shows different Hub location.

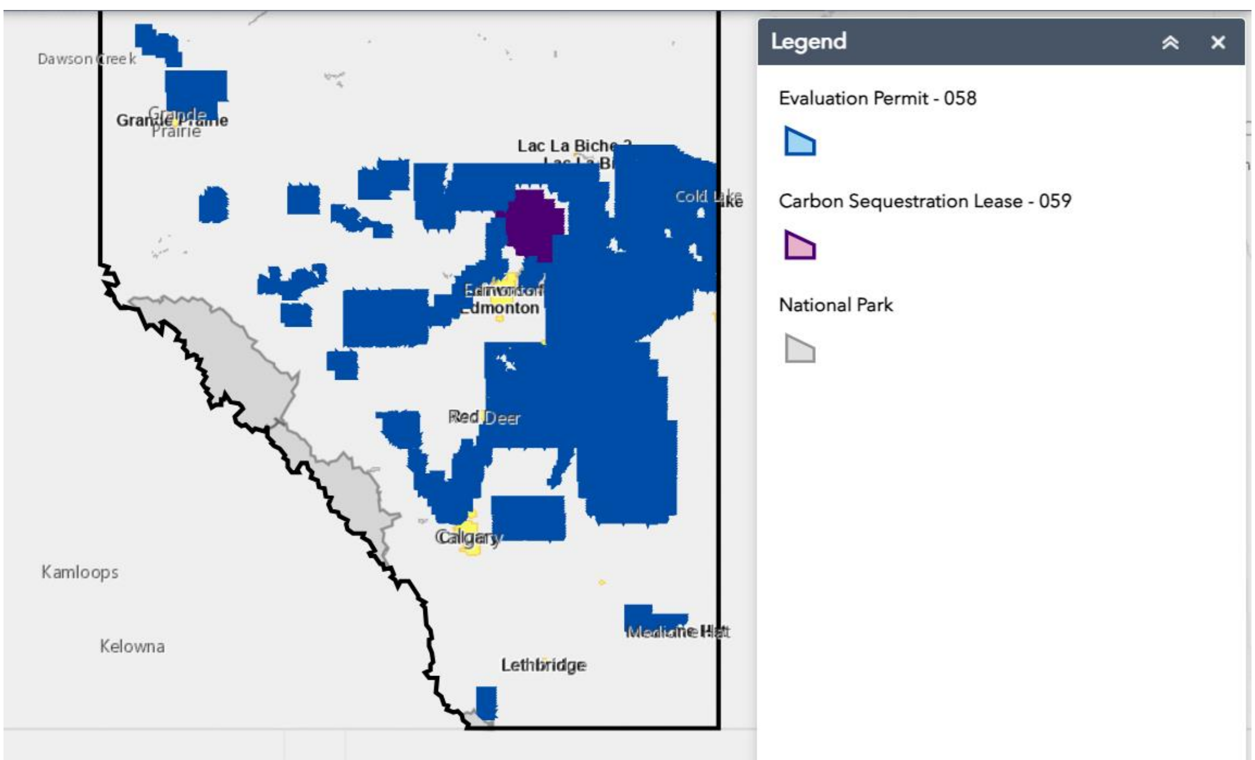


Figure shows the Alberta Carbon Sequestration Map

Alberta Carbon Sequestration Projects

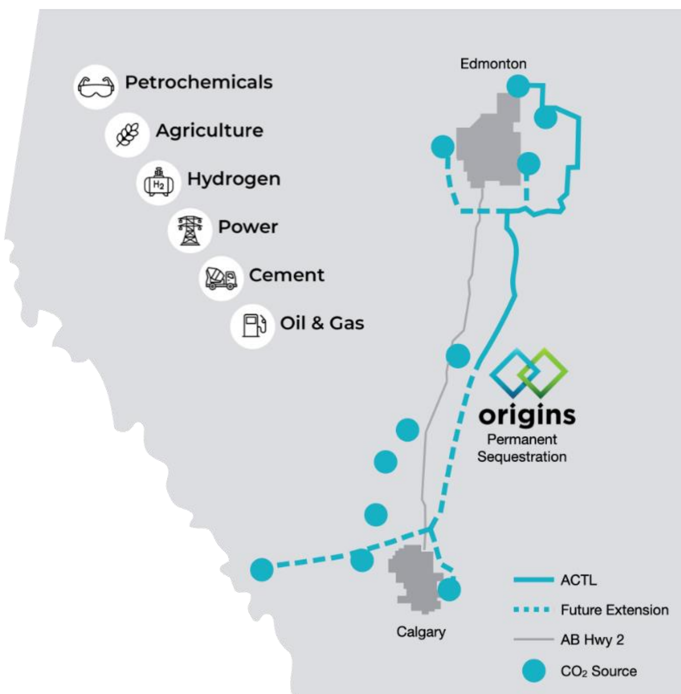
Various carbon capture and sequestration projects are underway in Alberta, exemplifying how this technology can be used to mitigate carbon emissions.

Quest Carbon Capture and Storage (CCS)

The Quest CCS facility, operated by Shell Canada, is located at the Scotford upgrader near Edmonton. It aims to achieve net-zero emissions by 2050. Shell's threefold strategy includes avoiding emissions, reducing through technologies like CCS, and compensating with carbon credits. Quest CCS is part of the Athabasca Oil Sands Project (AOSP) and demonstrates the real-world applications of CCS.

Enhance Energy (Origin)

Enhance Energy is developing the "Origins" project to capture up to 20 million tonnes of CO_2 per year. The company aligns with government goals, focusing on hard-to-abate industries and targeting net-zero by 2050. Enhance Energy aims to offer long-term sequestration capacity for both new and existing CO_2 streams.



Pembina Pipeline Corporation (Alberta Carbon Grid)

Pembina and TC Energy plan to develop the Alberta Carbon Grid (ACG), aimed at transporting over 20 million tonnes of CO_2 annually. The project is supported by federal and provincial ministers and is essential for meeting Canada's climate targets. ACG's design involves retrofitting existing pipelines and creating new ones.

Bison Low Carbon Ventures

Bison has developed two significant CO_2 storage projects, one of which is the Meadowbrook Carbon Storage Project. These projects aim for a full project timeline of under 36 months and are open to partnerships with emitters seeking CO_2 storage solutions.

Wolf Carbon Hub

The Government of Alberta has selected a consortium led by Wolf Midstream to develop a potential carbon sequestration hub. The hub will be an open-access system with initial volumes expected to be between two to three million tonnes per annum

6. Conclusion

In closing, this report serves as an all-encompassing exploration into the critical subject of carbon sequestration and utilization, a topic that has never been more urgent as we face the existential threat of climate change. Beginning with an overview of the diverse sources of carbon emissions, ranging from individual activities to industrial operations, the report highlights the scale and complexity of the challenge ahead. It delves into the environmental, economic, and societal ramifications of unchecked CO_2 emissions, painting a sobering picture of a world in crisis—from melting polar ice caps to widening social inequalities.

The report then transitions into a detailed analysis of various technological methods for carbon sequestration, such as Direct Air Capture, Carbon Capture and Storage, and Bioenergy with Carbon Capture and Storage. Each method comes with its own set of advantages and challenges, but the underlying message is clear: innovation is key to turning the tide. The report also sheds light on current projects in Canada, showcasing real-world applications of these technologies and offering a glimmer of hope in the fight against climate change.

Furthermore, the report discusses the importance of carbon utilization, touching on innovative ways to create a market for captured CO_2, thereby making carbon capture initiatives more economically viable. It also explores the concept of carbon credits and offsets, providing a policy framework that could incentivize emission reductions.

As we navigate the complexities of a changing climate, this report underscores the need for a multi-faceted approach that combines technological innovation, policy intervention, and global cooperation. It is a clarion call for immediate action, urging each one of us to take responsibility and contribute to mitigating the devastating effects of rising atmospheric CO_2 levels. The time for debate is over; the time for action is now. Our collective future depends on the choices we make today, and this report serves as both a guide and a catalyst for sustainable change.

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