Carbon Capture, Utilization and Storage in British Columbia: A Literacy and Information Report for First Nations in British Columbia

"*Indigenous peoples have the right to the lands, territories, and resources which they have traditionally owned, occupied or otherwise used or acquired. Indigenous peoples have the right to own, use, develop and control the lands, territories, and resources that they possess by reason of traditional ownership or other traditional occupation or use, as well as those which they have otherwise acquired.*

States shall give legal recognition and protection to these lands, territories, and resources. Such recognition shall be conducted with due respect to the customs, traditions and land tenure systems of the Indigenous peoples concerned."

(Article 26 of United Nations Declaration on the Rights of Indigenous Peoples)

November 2025

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Executive Summary

Global climate change, driven by the increasing concentration of greenhouse gases (or GHG), poses a significant and immediate threat to the planet. The primary sources of emissions — carbon dioxide, methane, nitrous oxide and fluorinated gases — stem from industrial activities, deforestation and fossil fuel combustion. These emissions have resulted in global warming at an unprecedented scale, leading to more frequent extreme weather events, ecosystem disruptions, and socio-economic challenges. Urgent measures are required to mitigate these impacts and transition to a sustainable, low-carbon economy.

Carbon capture, utilization and storage (CCUS) technologies have emerged as essential tools in the fight against climate change. These technologies capture carbon dioxide from industrial processes and the atmosphere, repurposing it into useful products or securely storing it in geological formations. Innovative methods, such as enhanced oil recovery, deep geothermal carbon storage and integration with renewable energy systems, are driving transformative change in emissions management. By incorporating advanced techniques like membrane-based capture systems and modular units, CCUS technologies continue to improve in efficiency and cost-effectiveness.

One notable example of large-scale CCUS deployment is the Alberta Carbon Trunk Line, one of Canada's largest operational carbon capture and storage systems[1]. This project features a 240-kilometre pipeline capable of gathering, compressing, and transporting carbon dioxide for permanent storage of up to approximately 14.6 million tonnes of CO_2 per year, subject to operational conditions, in depleted oil reservoirs. The Alberta Carbon Trunk Line demonstrates the feasibility and potential of large-scale carbon storage systems to reduce emissions while supporting industrial decarbonization and long-term emissions management.

Prominent projects like the Alberta Carbon Trunk Line and CO_2-Plume Geothermal (CPG) systems[2] demonstrate the technical scalability and innovation potential of CCUS-related technologies. These projects also underscore the potential for CCUS to generate economic value in specific applications, including where captured carbon is utilized or supports co-production of energy, contributing to circular economy pathways while reducing greenhouse gas emissions. However, challenges persist, particularly in the economic feasibility of certain technologies, such as direct air capture, which currently remain capital- and energy-intensive and require continued

[1] Government of Alberta, Alberta Carbon Trunk Line Project Overview. https://majorprojects.alberta.ca/details/Alberta-Carbon-Trunk-Line/622

[2] Randolph, J.B. and Saar, M.O., *Coupling carbon dioxide sequestration with geothermal energy capture (CO_2-Plume Geothermal)*, Energy Procedia, 2011. https://www.sciencedirect.com/science/article/pii/S1876610214026125

investment, technological advancement, and supportive policy frameworks to achieve cost reductions.

The province of British Columbia (or Province) is uniquely positioned to advance carbon management initiatives due to its abundant natural resources and progressive climate policies. Geological assessments indicate that the province's Peace Region alone offers multi-billion-tonne CO_2 storage potential in deep saline aquifers and depleted oil and gas reservoirs. This potential aligns with BC's CleanBC Roadmap to 2030, which recognizes CCUS as part of the province's emissions-reduction approach. Additionally, the prospective integration of CCUS with geothermal energy production presents opportunities for dual-purpose systems that combine emissions reduction with renewable energy generation. Through strategic investments in carbon management, BC can serve as a model for other jurisdictions by demonstrating the economic and environmental benefits of a low-carbon transition.

BC's carbon pricing framework has evolved in recent years and remains an important component of the province's climate strategy. While British Columbia's broad-based consumer carbon tax was eliminated effective April 1, 2025, the province continues to apply industrial emissions pricing mechanisms to incentivize emissions reductions from large emitters. These industrial systems, including baseline-and-credit–style approaches aligned with federal minimum stringency requirements, provide flexibility and economic incentives for emissions reductions across covered sectors. These systems depend on robust regulatory frameworks and transparent governance to ensure their effectiveness and equity.

The development of a robust carbon economy in BC creates significant opportunities for industries to align with low-carbon pathways. By integrating CO_2 storage solutions into industrial processes, sectors such as cement, natural gas processing, and renewable energy can achieve emissions reductions while maintaining competitiveness. BC's extensive geothermal resources present additional opportunities to generate clean energy while supporting CO_2 storage–related initiatives.

Strategic partnerships, particularly with First Nations and industry leaders, are key to responsibly advancing carbon storage projects. These collaborations foster job creation, promote sustainable growth, and position BC as a jurisdiction with the potential to contribute meaningfully to the global transition to a low-carbon economy.

British Columbia is home to 204 First Nations, representing a remarkable diversity of cultures, languages, governance systems, and relationships with the land. This diversity calls for tailored and respectful engagement strategies, especially for projects involving land use and carbon storage. Recognizing First Nations as stewards of their territories and ensuring their meaningful participation in decision-making processes is not only a legal obligation but also an opportunity to leverage their leadership in addressing climate change.

First Nations are integral to addressing climate change, with carbon storage emerging as a potential tool in reducing greenhouse gas emissions. Their participation spans land use planning, carbon capture, and transport, underscoring the importance of their stewardship, knowledge, and rights. Federal initiatives, including the Indigenous Climate Leadership Agenda[3], support Indigenous-led and self-determined climate actions, enabling First Nations to pursue sustainable futures and strengthen economic participation in climate solutions.

Engagement must be established in partnerships built on collaboration and mutual respect, structured around political, legal, economic and socio-environmental dimensions. Policies should uphold the principles of the United Nations Declaration on the Rights of Indigenous Peoples and recognize First Nations' inherent and constitutional aboriginal and treaty rights.

Economic engagement should include transparent benefit-sharing agreements that recognize the inherent and constitutional rights of First Nations and provide them with substantial revenue generated by carbon storage projects. Such agreements strengthen economic opportunities while ensuring alignment with First Nations' roles as environmental stewards and owners of their lands. Socio-environmental partnerships must embed traditional knowledge and sustainable practices into project design, fostering shared governance and co-development in climate initiatives.

A robust legal framework for carbon storage is necessary to support these efforts. This includes creating permitting systems modeled on existing frameworks, such as BC's Petroleum and Natural Gas Act, and establishing strict monitoring protocols to protect the environment. Co-development of permitting systems with First Nations, supported by a steering committee of First Nations representatives, legal experts and government officials will ensure a carbon storage framework includes First Nations' inherent and constitutional rights and priorities.

Canada has established itself as a global leader in CCUS, leveraging robust regulatory frameworks, international collaboration and targeted financial incentives. Key initiatives like BC's Output-Based Pricing System (OBPS) drive emissions reductions while supporting economic competitiveness. The OBPS sets emissions intensity benchmarks for industrial facilities, offering flexible compliance options such as paying a carbon price, purchasing offsets or investing in emissions reduction projects. This approach promotes decarbonization, minimizes the risk of "carbon leakage" and reinvests revenues into climate action and low-carbon technology development.

National standards from organizations like CSA Group and ISO/TC 265 ensure CCUS projects adhere to stringent safety and efficiency guidelines, bolstering consistent and effective deployment. International partnerships with the International Energy Agency and the Global

[3] Government of Canada, *Indigenous Climate Leadership Agenda*. https://www.canada.ca/en/environment-climate-change/services/climate-change/indigenous-partnership.html

CCS Institute further enhance Canada's leadership by fostering innovation and global collaboration.

Canada's integrated approach to CCUS combines environmental responsibility with industrial resilience, advancing the country's climate goals while positioning it as a pioneer in sustainable economic development. The integration of CCUS technologies, carbon pricing mechanisms, and First Nations leadership positions BC as a global leader in climate action. By leveraging its geological resources, innovative technologies and collaborative frameworks, BC is well-equipped to achieve its emissions reduction targets.

First Nations' active participation ensures that CCUS projects are inclusive, equitable, and sustainable, contributing to both economic self-sufficiency and environmental stewardship. Together, these initiatives forge a path toward a sustainable, low-carbon future, demonstrating BC's commitment to addressing global climate challenges while fostering innovation and collaboration.

1.0 Introduction

The emissions of **CO_2 from human activities are** the primary driver of global climate change. This finding is scientifically supported by the clear correlation between the average global temperature and the concentration of CO_2 in the atmosphere (Figure 1a and Figure 1b).

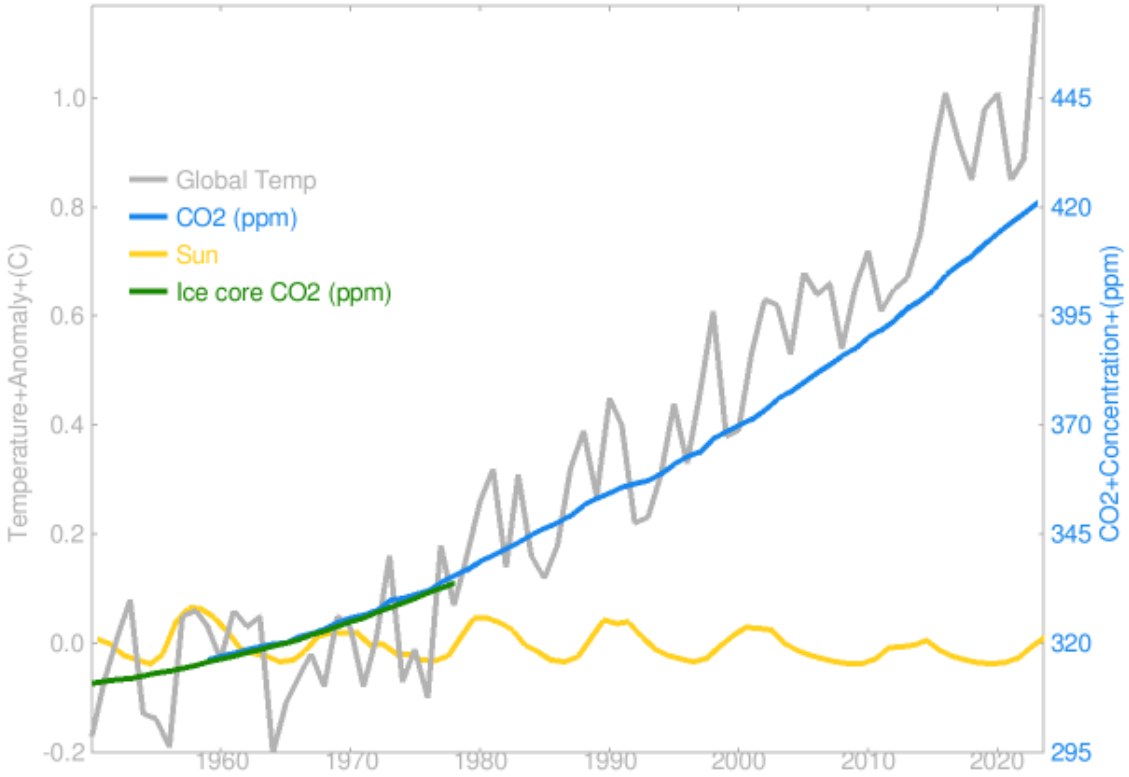

Figure 1a: Global Warming Trend: This graph illustrates the rapid rise in global temperatures over the past 50 years, based on NASA data. Source: NB Data Points. Global Temperature Trend: The Land-Sea Temperature Anomaly. Retrieved from https://nbdatapoints.ca/climate-data/global-temperature-trend-the-land-sea-temperature-anomaly/

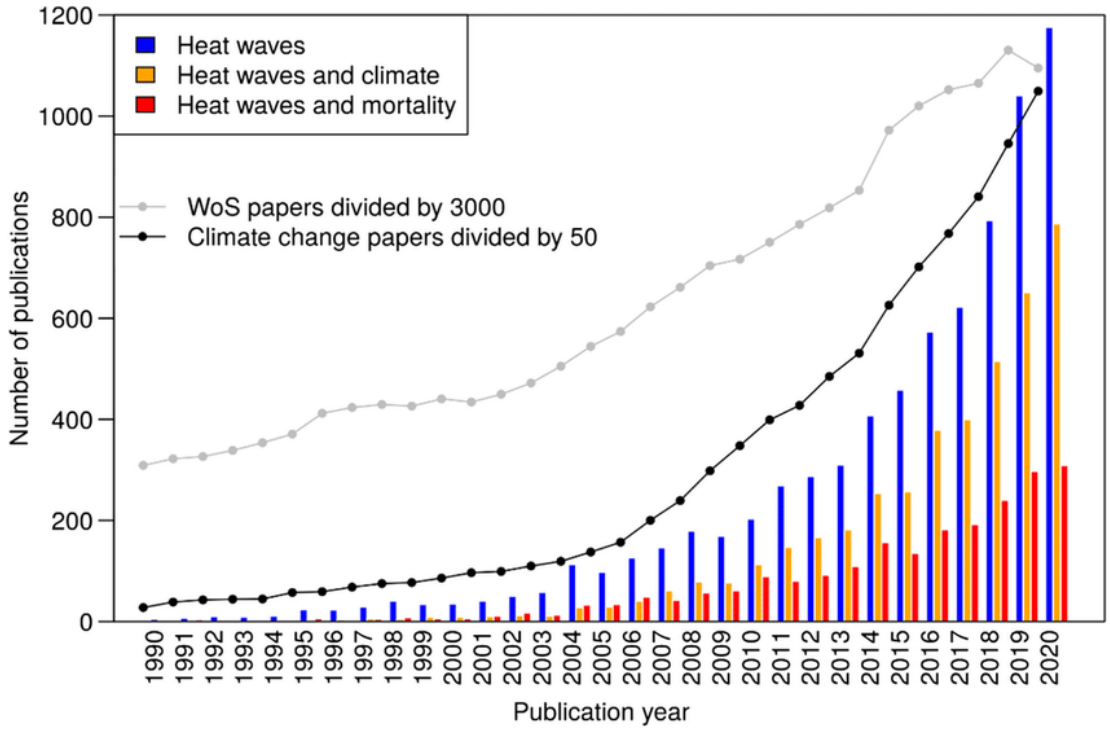

Figure 1b: Steady Increase in the Number of Heat Waves Over Three Decades (1990–2020). This figure illustrates the steady rise in the number of heat waves described in publications between 1990 and 2020, based on data from Marx et al. (2022).

The concentration of CO_2 in the atmosphere has been steadily increasing, with a particularly concerning acceleration in recent decades. Over the past 80 years, atmospheric CO_2 levels have risen from 300 ppm (parts per million) to 420 ppm, marking a 40% increase. During this same period, global temperatures have followed a similar trend, rising by approximately 1 degree Celsius (Figure 1a).

As atmospheric CO_2 levels have risen, the number of heat waves (and associated mortality rates) have also steadily increased over the past three decades (Figure 1b).

The positive correlation between average global temperature and atmospheric CO_2 levels (Figures 1a and 1b) highlights a clear cause-and-effect relationship between global warming and the emissions of greenhouse gases into the atmosphere.

Increased CO_2 concentration acts like a glass cover in a greenhouse: it allows solar light to enter but traps part of the heat energy, preventing it from fully escaping back into space. This phenomenon, known as the greenhouse effect, results in a rise in temperature beneath the "glass." Similarly, the CO_2 layer in the upper atmosphere functions like the greenhouse glass cover, contributing to an increase in global temperatures (Figure 2 and Figure 3).

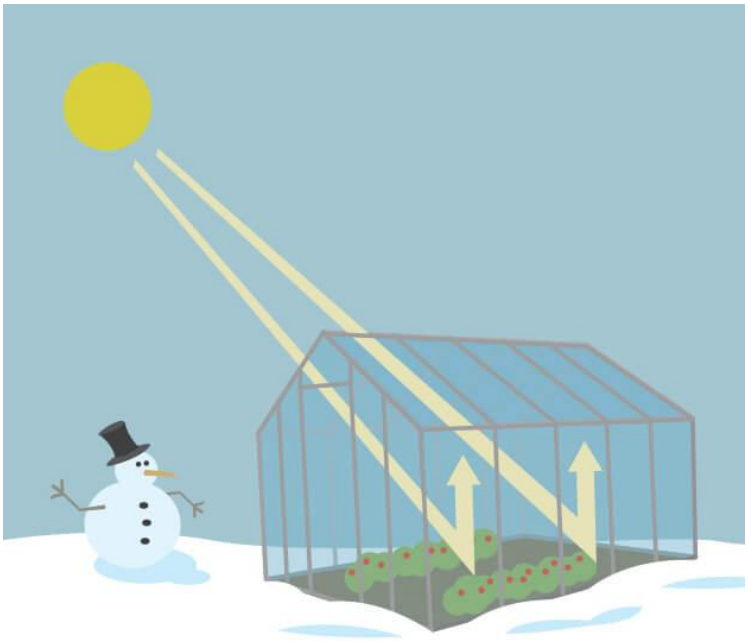

Figure 2: The Greenhouse Effect: A greenhouse traps heat from the Sun with its glass walls, which prevent heat from escaping and keep the plants inside warm.
Credit: NASA/JPL-Caltech. Source: NASA, https://climatekids.nasa.gov/greenhouse-effect/

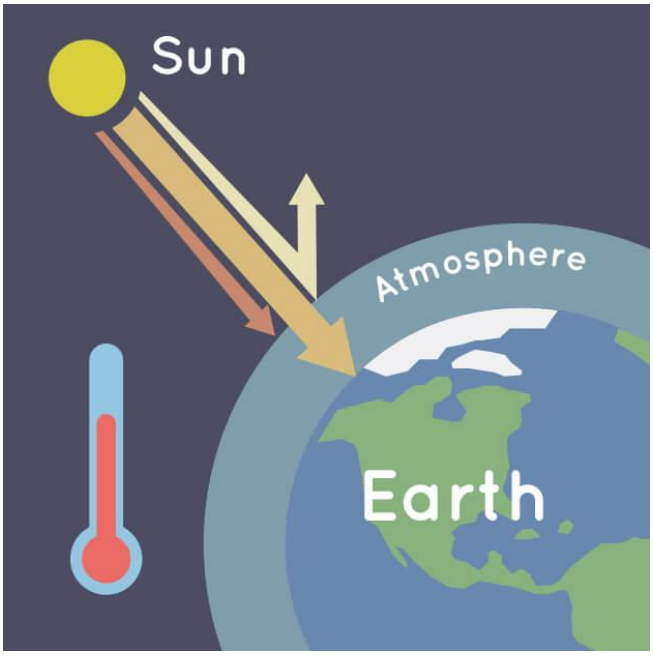

Figure 3: Earth's Atmosphere and Heat Trapping. Earth's atmosphere traps some of the Sun's heat, preventing it from escaping back into space. This heat-trapping effect intensifies as the concentration of carbon dioxide in the atmosphere increases.
Credit: NASA/JPL-Caltech. Source: NASA, https://climatekids.nasa.gov/greenhouse-effect/

2.0 Types of Greenhouse Gases

In addition to CO_2, several other greenhouse gases are emitted into the atmosphere as a result of human activities (Figure 4 and Table 1). The second most significant GHG after CO_2 is methane (or CH_4), commonly referred to as natural gas. Methane's greenhouse effect is 28 times greater than that of CO_2, meaning one ton of methane in the atmosphere has the equivalent effect of 28 tons of CO_2. However, due to its relatively lower emission levels compared to CO_2 , the overall greenhouse impact of methane is significantly smaller.

As the second most abundant GHG after CO_2, methane accounts for approximately 16% of total global emissions when measured in CO_2 equivalents (Figure 4).

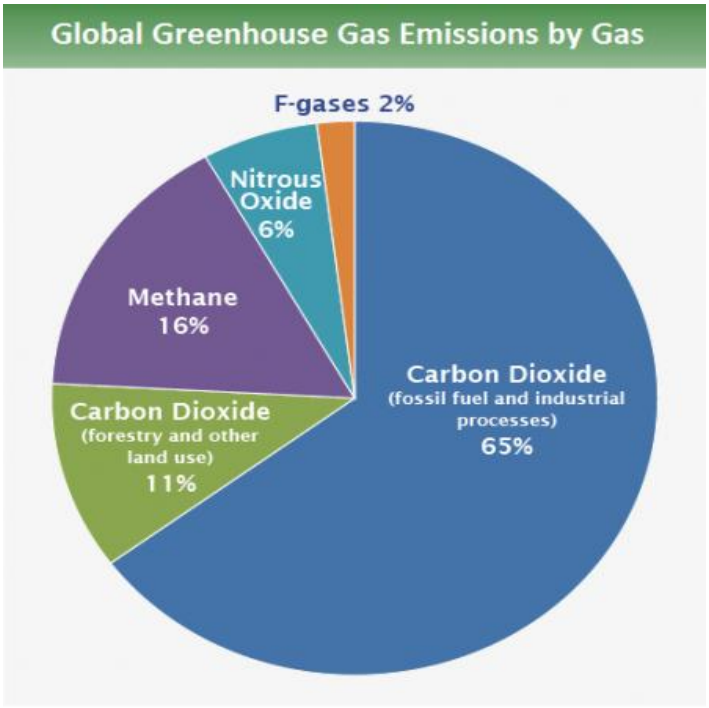

Figure 4: Contribution of Greenhouse Gases to Climate Change
The figure illustrates the contribution of greenhouse gases to climate change, measured in carbon dioxide equivalents. *Source: IPCC (2014), based on 2010 global emissions data. Further details are in the Fifth Assessment Report, Working Group III.*

At a global scale, the key greenhouse gases emitted by human activities are summarized in Table 1 and include the following:

Carbon Dioxide: Fossil fuel use is the primary source of CO_2 emissions. Land use changes, such as deforestation, agricultural expansion and soil degradation also contribute significantly. Conversely, land can act as a carbon "sink" or sponge by removing CO_2 from the atmosphere through activities like reforestation, soil restoration and sustainable land management.

Methane: Major sources of methane include coal mining, and natural gas and oil production. Methane is also released in large quantities from livestock, agricultural activities and the decay of organic waste in municipal landfills. Emissions from these sources have increased rapidly over the past two centuries, particularly in the last 50 years (Figures 5a and 5b). The most significant contributors to methane emissions are in the production of oil and gas and livestock agriculture.

Nitrous Oxide: Human activities that emit nitrous oxide include fossil fuel combustion (especially from vehicles), nitric acid production, welding, explosives use and petroleum refining. Agricultural practices, particularly fertilizer application, also contribute significantly to N_2O emissions. Biomass burning, such as from wood waste, is another source.

Fluorinated Gases: These gases are primarily generated through industrial processes, refrigeration, and the use of certain consumer products. Common types include hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Fluorinated gases have very high global warming potentials relative to CO_2, in some cases thousands of times greater on a per-unit basis, but are typically emitted in much smaller quantities compared to other greenhouse gases.

Greenhouse gas	Chemical formula	Global Warming Potential, 100-year time horizon	Atmospheric Lifetime (years)
Carbon Dioxide	CO_2	1	100*
Methane	CH_4	25	12
Nitrous Oxide	N_2O	265	121
Chlorofluorocarbon-12 (CFC-12)	CCl_2F_2	10,200	100
Hydrofluorocarbon-23 (HFC-23)	CHF_3	12,400	222
Sulfur Hexafluoride	SF_6	23,500	3,200
Nitrogen Trifluoride	NF_3	16,100	500

SOURCE

Fifth Assessment Report (Intergovernmental Panel on Climate Change, 2014).

Table 1: Greenhouse Gases Emitted to the Atmosphere. *Note:* The asterisk (*) indicates that "no single lifetime can be assigned to carbon dioxide because it moves through the Earth's system at varying rates. Some CO_2 is absorbed quickly, while some remains in the atmosphere for thousands of years". Source: Center for Climate and Energy Solutions (C2ES). Retrieved from https://www.c2es.org/content/main-greenhouse-gases/

The total CO_2 emissions from human activities are staggering. According to the U.S. Energy Information Administration (EIA), the United States alone emitted 5,130 million tonnes of energy-related CO_2 in 2019, while global energy-related carbon CO_2 reached 33,621.5 million tonnes.

In Canada, total emissions were estimated at 702 megatons of carbon dioxide equivalent (Mt) in 2023, a decrease of 5.6 Mt from 2022. Similarly, methane concentrations have been steadily increasing (Figures 5a and 5b), rising by approximately 20% over the past 50 years.

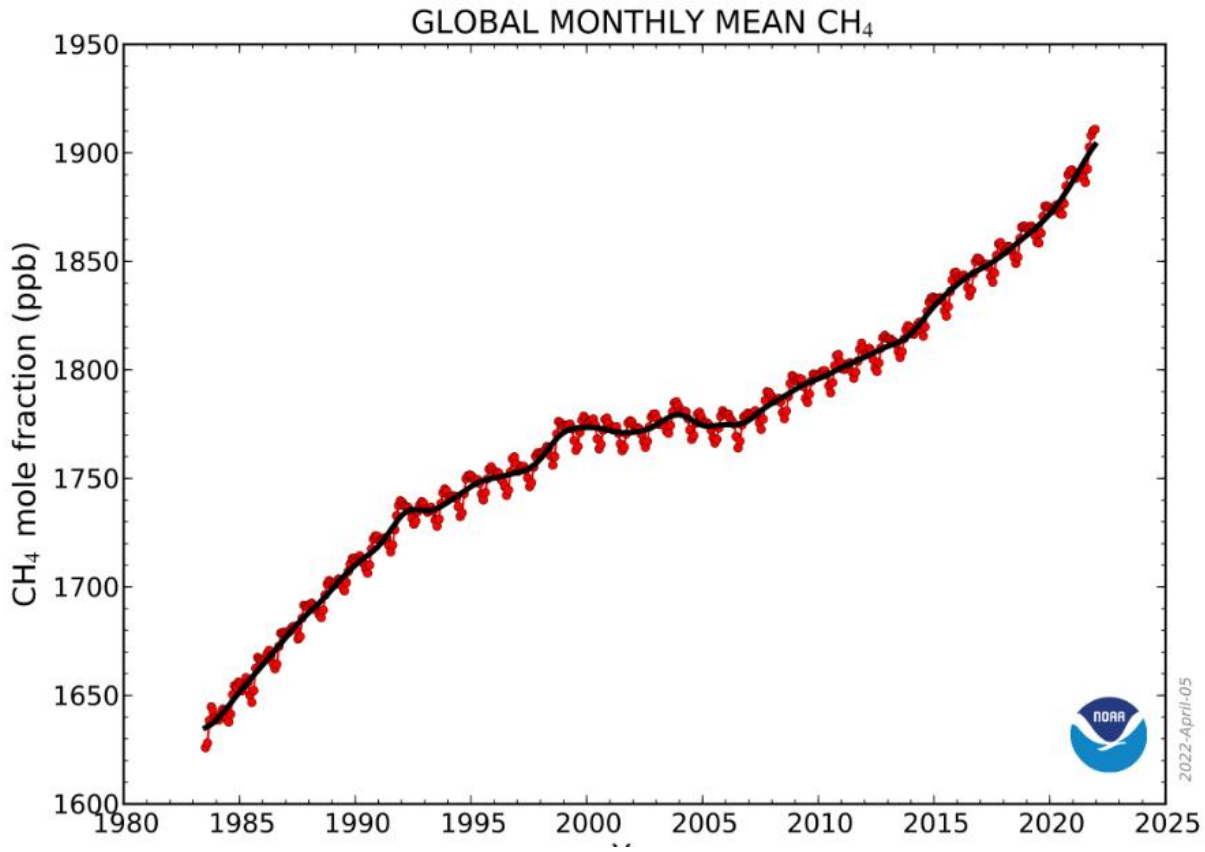

Figure 5a**:** Rapid Increase in Atmospheric Methane Concentration Over the Past 60 Years. This graph illustrates the globally averaged, monthly mean atmospheric methane levels, determined from marine surface sites since 1983. Values for the most recent year are preliminary (NOAA Global Monitoring Laboratory). Source: National Oceanic and Atmospheric Administration (NOAA), *Increase in Atmospheric Methane Set Another Record During 2021.* Retrieved from https://www.noaa.gov/news-release/increase-in-atmospheric-methane-set-another-record-during-2021.

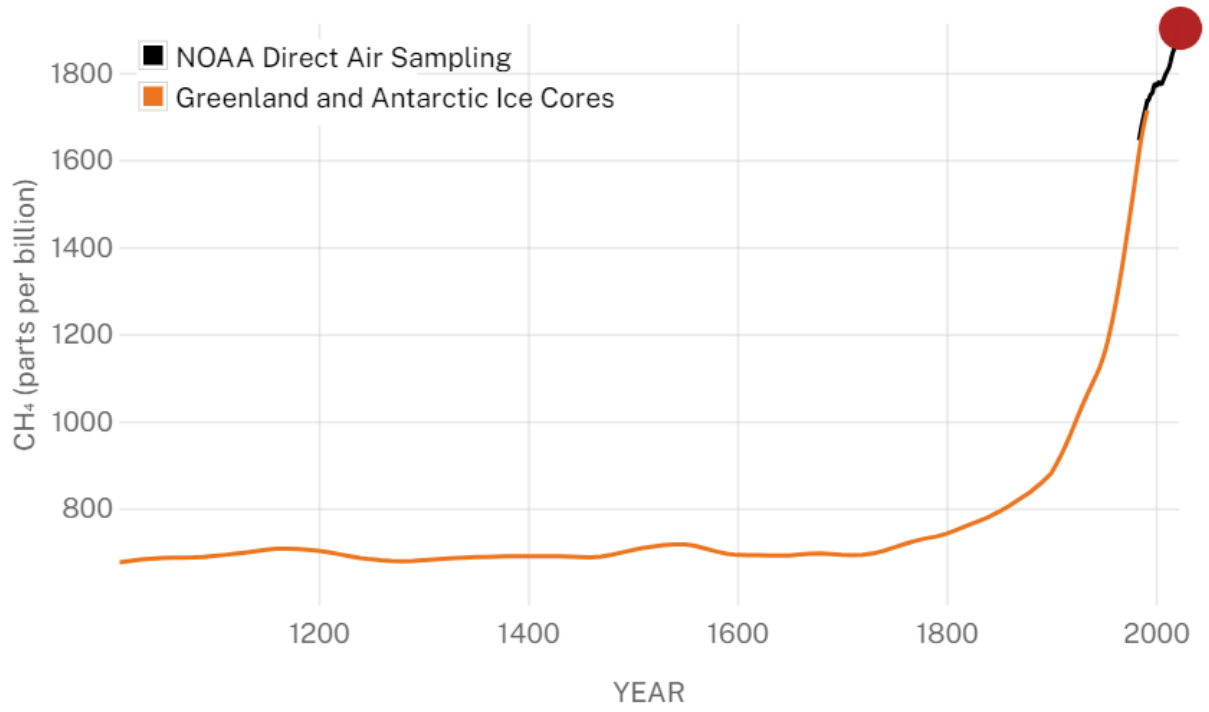

Figure 5b: Atmospheric Methane Concentrations Over the Past 1,000 Years. This graph shows atmospheric methane concentrations since the year 1010, spanning a period of 1,000 years. Data Sources: Etheridge et al. (1998) and NOAA Global Monitoring Laboratory. Source: NASA, *Vital Signs of the Planet: Methane.* Retrieved from https://climate.nasa.gov/vital-signs/methane/?intent=121#:~:text=The%20concentration%20of%20methane%20in,(which%20began%20in%201750).

According to NASA (2024), "aircraft and satellite instruments have been finding methane rising from oil and gas production, pipelines, refineries, landfills, and animal agriculture. In some cases, these measurements have led to finding leaks such as suburban gas leaks and faulty equipment to be fixed."

The concentration of methane in the atmosphere has more than doubled over the past 200 years. Scientists estimate that this increase is responsible for 20% to 30% of climate warming since the Industrial Revolution. In Canada, methane accounts for approximately 13% of the country's total greenhouse gas emissions, with the oil and gas sector contributing around 40% of these emissions. In 2016, the Government of Canada committed to reducing methane emissions from the oil and gas sector—the nation's largest emitter—by 40% to 45% below 2012 levels by 2025.

As global warming progresses, the impact of methane is expected to intensify due to positive feedback mechanisms, including the release of methane from oceans as water temperatures rise. Human activities in modern societies have significantly contributed to the emission of greenhouse gases, primarily carbon dioxide and methane, into the Earth's atmosphere. While there are natural sources of greenhouse gas emissions, scientific consensus confirms that

anthropogenic emissions are the primary driver of global warming. The concentration of these gases in the atmosphere began to rise with the onset of industrial activities, resulting in a 1.1°C increase in surface temperature above 1850–1900 levels during the period 2011–2020.

Global GHG emissions have continued to rise with increasing industrial activities, with the rate of increase accelerating significantly over the past 50 years. If this trend continues, it is expected to cause irreversible damage to human and animal habitats.

Global warming has already caused significant harm to the environment. Some of these impacts include more frequent heat waves (Figure 1b), forest fires, floods, storms and rising sea levels. To control global warming and mitigate its disastrous effects, a collective effort is required from all nations at both governmental and community levels. CO_2 capture and storage is one of the key tools available to reduce harmful emissions into the atmosphere.

3.0 Carbon Emission Trends

While the overall trend between 1990 and 2022 shows an increase in GHG emissions (Figure 6), emissions from some sectors have decreased. Canada's overall GHG emission growth during this 32-year period (1990 to 2022) was driven primarily by increased emissions from three sectors:

1. Oil and gas.
2. Agriculture.
3. Transportation.

The 7.1% decrease in GHG emissions between 2005 and 2023 was primarily due to reductions in emissions from the electricity and heavy industry sectors. It is important to note that the COVID-19 pandemic caused an industrial slowdown, leading to significant reductions in trade and travel by air and land. These slowdowns contributed to a 16% reduction in transport sector emissions between 2019 and the end of 2020.

A rebound in emissions was observed shortly after the partial recovery of economic activities in 2021, resulting in an increase of 12 Mt CO_2 equivalent (CO_2 eq) compared to 2020. Emissions continued to rise in 2022, with a further increase of 9 Mt CO_2 eq, although they remained below the pre-pandemic levels of 2019.

Recent data indicate that Canada’s emissions profile continues to evolve beyond 2022. Preliminary federal assessments and international energy reviews suggest that total Canadian GHG emissions in 2023 and 2024 remained broadly stable relative to 2022, with modest year-to-year variation driven primarily by energy demand, weather conditions, and economic activity. Continued reductions in emissions from electricity generation, reflecting the phase-out of coal-fired power and increased deployment of renewables, have been partially offset by sustained emissions from the oil and gas and transportation sectors.

More recent analyses also indicate that emissions intensity across several industrial sectors has continued to decline, even where absolute emissions have remained stable or increased modestly. This reflects the growing role of efficiency improvements, fuel switching, methane mitigation measures, and emerging emissions-reduction technologies, including carbon capture, utilization, and storage (CCUS). As a result, Canada's near-term emissions trajectory increasingly reflects the interaction between structural decarbonization efforts and broader economic conditions, rather than uniform growth or decline across all sectors.

According to the Greenhouse Gas Equivalencies Calculator developed by Natural Resources Canada[4], the 54 Mt CO_2 eq emission reduction between 2005 and 2023 is equivalent to:

- removing approximately 16.5 million gas-powered passenger vehicles from the roads for one year, or
- the annual energy-based emissions from approximately 12,600,000 homes.

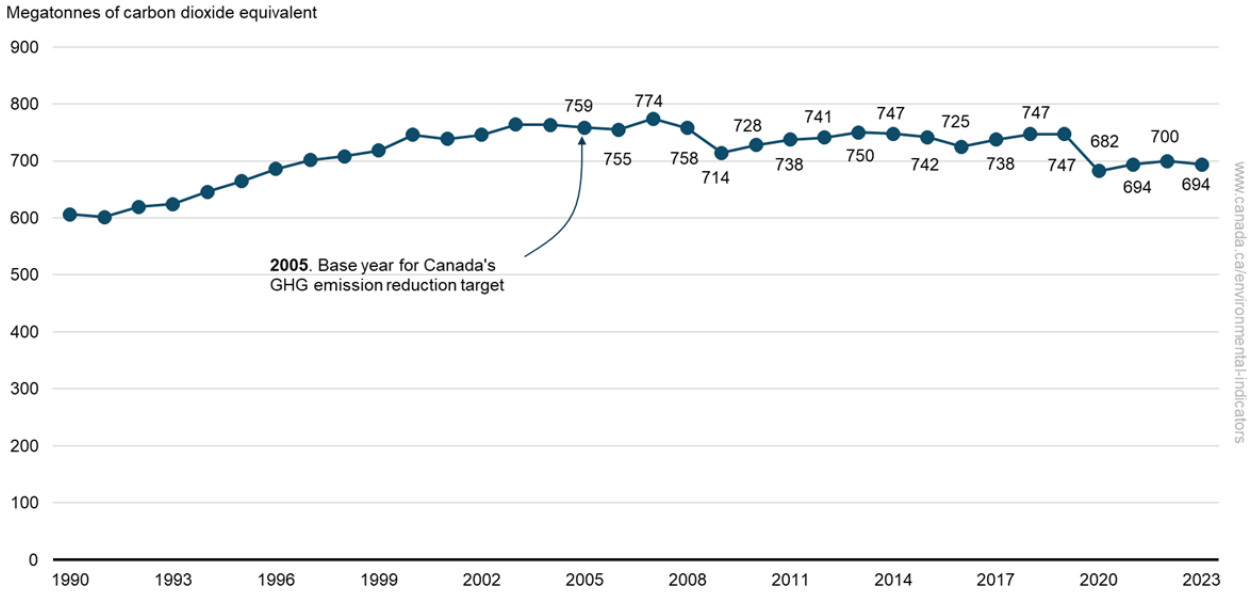

Figure 6: Canada's Carbon Dioxide Emissions History Since 1990
Source: Government of Canada, *Environment and Climate Change Canada (2024), National Inventory Report 1990–2023: Greenhouse Gas Sources and Sinks in Canada.* Retrieved from https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions.html.

[4] Natural Resources Canada, *Greenhouse Gas Equivalencies Calculator*. https://natural-resources.canada.ca/energy-efficiency/greenhouse-gas-equivalencies-calculator/21104

4.0 Brief History of International CCUS Efforts

The first international convention on environmental preservation was held in Stockholm, Sweden, in 1972. This convention, part of a UN Scientific Conference, was also known as the First Earth Summit. The objective of the Earth Summits was to establish principles for preserving and enhancing the human environment, followed by actionable plans. However, the output of these conventions was limited to recommendations for the international community to reduce harmful environmental pollution. The 1972 Stockholm Conference was the first environmental convention to raise the issue of global climate change. However, regarding the identification and control of environmental pollutants of broad international significance, the conference was not sufficiently vocal and only expressed concerns about climate change in its final declaration. Nonetheless, it served as the first international warning to governments to monitor activities that could lead to climate change.

The Stockholm Declaration also recommended that governments evaluate the likelihood and magnitude of climate effects associated with pollution. These warnings eventually led to the organization of regular international meetings and summits on climate change.

Every year, countries participating in the United Nations Framework Convention on Climate Change (UNFCCC) meet to assess the progress of their actions against climate change. These gatherings also provide an opportunity to negotiate multilateral responses to the issue.

The UNFCCC, adopted in 1992, shortly after the first assessment report by the Intergovernmental Panel on Climate Change (IPCC) in 1990, aims to stabilize greenhouse gas concentrations "at a level that would prevent dangerous anthropogenic (human-induced) interference with the climate system."

Since entering into force in 1994, the UNFCCC has provided the foundation for regular international climate negotiations, including the Conference of the Parties (COP) meetings and landmark agreements such as the Kyoto Protocol (1997) and the Paris Agreement (2015).

The COP is the supreme international decision-making body under the UNFCCC. All Parties to the Convention are represented at COP meetings, where they review implementation, adopt legal instruments, and make decisions to promote effective action, including institutional and administrative arrangements. To address climate change and its negative impacts seriously, world leaders reached a breakthrough at the UN Climate Change Conference (COP21) in Paris in 2015. This historic Paris Agreement, signed by all members, was considered legally binding and entered into force in November 2016.

The goal of the Paris Agreement is to strengthen the global response to climate change by limiting global temperature increases to below 2 degrees Celsius. In recent years, however, most world leaders have emphasized the need to limit global warming to 1.5°C by the end of this

century. The IPCC warns that crossing the 1.5°C threshold risks causing extreme climate change impacts, including more frequent and severe droughts, heatwaves and floods.

5.0 Fundamentals of Carbon Capture, Utilization and Storage

There are two primary approaches to reducing the concentration of GHGs in the atmosphere:

- reducing emissions into the atmosphere
- sequestering emitted gases from the atmosphere

The capture of CO_2 can occur naturally or through specialized technologies. The most natural and significant form of carbon capture is photosynthesis, where plants use solar energy to absorb CO_2.

Carbon sequestration refers to the process of capturing and storing atmospheric CO_2. It is a critical strategy for reducing atmospheric carbon dioxide levels and mitigating global climate change. The U.S. Geological Survey (USGS) is currently conducting assessments on two major types of carbon sequestration: geologic and biologic.

The USGS has completed an assessment of technically accessible storage resources (TASR) for CO_2)in geologic formations in onshore and offshore areas of the United States. Similar assessments are being conducted in British Columbia by Geoscience BC.

In the U.S. assessment, the evaluated geological formations are located at depths of greater than approximately 900 metres below the surface. TASR assessments estimate the technically accessible and sustainable CO_2 storage capacity available for injection into specific geological formations under defined geologic and technical conditions.

The accessible storage capacity is determined using geologic and hydrologic data about subsurface formations. The USGS has identified 36 storage basins (subsurface areas containing multiple carbon storage locations) with accessible storage values. The mean TASR assessed by the USGS is approximately 3,000 gigatons (Gt).

In British Columbia, similar studies should be conducted, with priority given to regions where there is a viable market for carbon storage. These assessments would provide critical insights into the province's geological storage capacity and support the development of targeted carbon sequestration initiatives.

Before storing carbon dioxide in geological formations, the gas must first be captured. Carbon dioxide can be separated from other gases produced at industrial facilities such as coal and natural gas-fired power plants, refineries, steel mills, cement factories and fertilizer plants before it is emitted into the atmosphere. Several technologies and chemical processes are currently available and in use for CO_2 capture.

One critical issue associated with carbon capture from heat or power generation facilities is the efficiency loss caused by interference with the facility's stack or exhaust system. This efficiency loss must be factored into the overall carbon capture process.

CO_2 can be captured from a point source facility or directly from the atmosphere using direct air capture (DAC). Capturing carbon dioxide directly from the atmosphere is extremely expensive and requires a large operational footprint (Figure 7).

DAC technology is relatively new but is expected to become more efficient in the future. Some companies are already manufacturing modular DAC units. One of the first U.S. DAC systems designed for mass production, the Leo Series DAC module, is the size of a standard shipping container and can capture 500 tons of CO_2 annually. These modules can be combined into arrays to capture much larger volumes of CO_2.

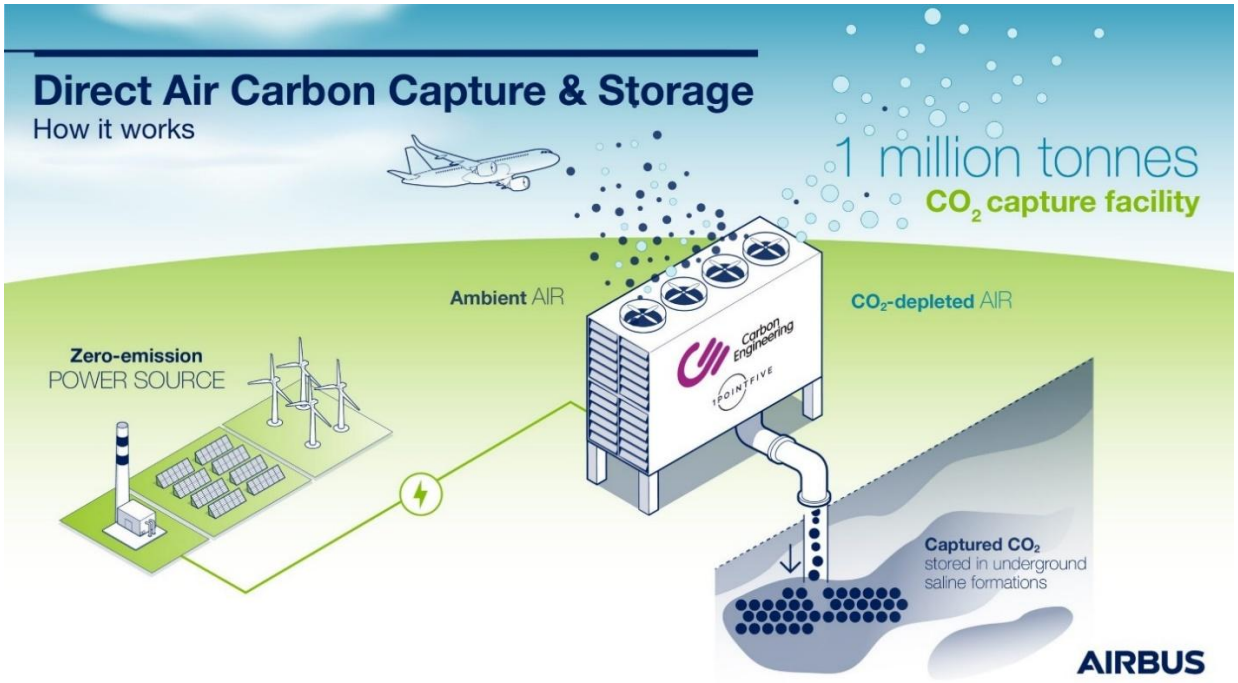

Figure 7: Illustration of DAC Technology. This figure shows how captured carbon can be stored underground through geological storage. Source: Air Insight Group, *Airbus and Air Canada Invest in Canadian Carbon Capture Plant.* Retrieved from https://airinsight.com/airbus-and-air-canada-invest-in-canadian-carbon-capture-plant/.

DAC is one of the tools available to the air industry to reduce its carbon emissions. Airlines such as Air Canada, Air France, KLM, and Lufthansa, are now committed to reducing their carbon footprint. Since air transportation currently cannot rely on clean fuels, the options for reducing emissions are limited to either purchasing carbon credits or utilizing DAC technology.

DAC technology was originally designed by Airbus and the European Space Agency to remove carbon dioxide from the air aboard the International Space Station (ISS). Following its success in space, DAC technology is now widely applied to address climate change, with applications such as converting CO_2 into fertilizers, fuels and carbon-negative materials (materials capable of absorbing carbon dioxide).

Currently, the capacities of DAC modules are limited, and costs remain high. Despite ongoing technological advancements, prices are expected to stay elevated. It is estimated that the cost of removing 1 tonne of CO_2 from the air in 2050 will range between US$230 and US$540.

Researchers have compared the potential costs of three established carbon capture approaches and found no consistent cost advantage among them across all applications. As a result, each of these technologies—post-combustion capture, pre-combustion capture, and oxy-fuel combustion (which uses oxygen and a fuel gas)—requires further technological development and cost reduction to achieve broader economic viability. The World Economic Forum (2023b) states, "for the carbon capture technology to be widely adopted, the end-to-end cost of carbon dioxide removal, including final storage, will need to fall to below $200 per ton and ideally closer to $100 per ton. This must happen by 2050, but preferably earlier."

By 2050, achieving net-zero emissions is expected to require the removal of several billion tonnes of CO_2 annually, with some scenarios estimating requirements of up to approximately 10 billion tonnes per year. At current DAC cost levels, achieving removal at this scale could imply annual expenditures on the order of several trillion U.S. dollars, highlighting the economic challenges associated with large-scale deployment without significant cost reductions.

According to studies by the International Energy Agency (IEA, 2021), "Carbon Capture, Utilization, and Storage (CCUS) applications do not all have the same cost." Carbon capture costs vary significantly depending on the CO_2 source, ranging from US$15-25 per ton for industrial processes that produce highly concentrated CO_2 streams (such as ethanol production or natural gas processing) to US$40-120per ton for processes with dilute gas streams, such as cement production and power generation.

The IEA's analysis highlights the importance of a diverse portfolio of technologies to achieve significant emissions reductions. While energy efficiency and renewable energy remain central to climate strategies, CCUS is also recognized as a critical tool in combating climate change. In a recent report, the IEA identified four essential contributions of CCUS to the clean energy transition:

- CCUS can be retrofitted to power and industrial plants that might otherwise emit 8 billion tons of CO_2 annually by 2050—around one-quarter of today’s energy-sector emissions.
- CCUS addresses emissions in sectors with few alternatives, such as cement, steel, and chemicals manufacturing, as well as in synthetic fuel production for long-distance transport.
- CCUS enables low-carbon hydrogen production from fossil fuels, which is a cost-effective option in several regions worldwide.
- CCUS can remove CO_2 from the atmosphere by combining it with bioenergy or direct air capture, balancing emissions that are technically difficult to eliminate.

5.1 Carbon Utilization and Transport

Captured CO_2 can be utilized in various industrial and agricultural applications. In greenhouse agriculture, carbon dioxide is often used to enhance the process of photosynthesis. Greenhouse operators frequently purchase carbon dioxide at high prices, particularly during warm seasons. The purchased CO_2 is released inside the greenhouse, where it is absorbed by plants through photosynthesis.

Carbon dioxide is also employed in enhanced oil recovery, where it serves as a solvent to stimulate additional oil production. After its use, the CO_2 is permanently stored in depleted underground oil reservoirs.

There are also emerging and innovative applications for CO_2, particularly in low-carbon and clean-energy industries. For example, in enhanced geothermal power and heat generation, CO_2 can be used as an alternative working fluid or within integrated system designs to improve geothermal energy recovery under specific geological conditions[5].

This process involves injecting CO_2 into deep geothermal reservoirs, where it can enhance heat transfer between the reservoir rock and the circulating fluid used for electricity or heat generation. Under certain reservoir conditions, the use of CO_2 may improve pressure management and fluid mobility compared to conventional water-based systems, which can contribute to improved heat extraction efficiency, without implying permanent or universal increases in reservoir permeability.

These geothermal systems can also serve as permanent storage sites for carbon dioxide. Such synergistic applications are particularly valuable because they combine carbon storage with the generation of renewable energy.

Once captured and separated, carbon dioxide must be compressed to a dense, liquid-like state for transportation. This is typically done using large, metallic high-pressure cylinders. Alternatively, CO_2 can be transported via specialized pipelines to a suitable site for geological storage. Carbon dioxide can also be transported by trucks, trains, or ships, depending on the specific requirements of the region where carbon capture and storage projects are implemented.

6.0 Carbon Value Chain

To address global climate change and ensure global temperature rise remains within 2°C above pre-industrial levels, substantial carbon dioxide removal from the atmosphere is essential.

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[5] International Energy Agency Greenhouse Gas Programme (IEA-GHG), *Prospective Integration of Geothermal Energy with Carbon Capture and Storage*, Technical Report 2023-02. https://publications.ieaghg.org/technicalreports/2023-02%20Prospective%20Integration%20of%20Geothermal%20Energy%20with%20Carbon%20Capture%20and%20Storage.pdf

Achieving this goal requires a thorough cost analysis of each stage in the carbon management process.

The price of carbon depends on its journey—from emission at the source to its capture, and ultimately to storage, utilization, or conversion. Carbon holds a negative value when released into the atmosphere but becomes a positive asset when captured and stored. Consequently, its value fluctuates depending on its position along this journey (Figure 8 and Figure 9).

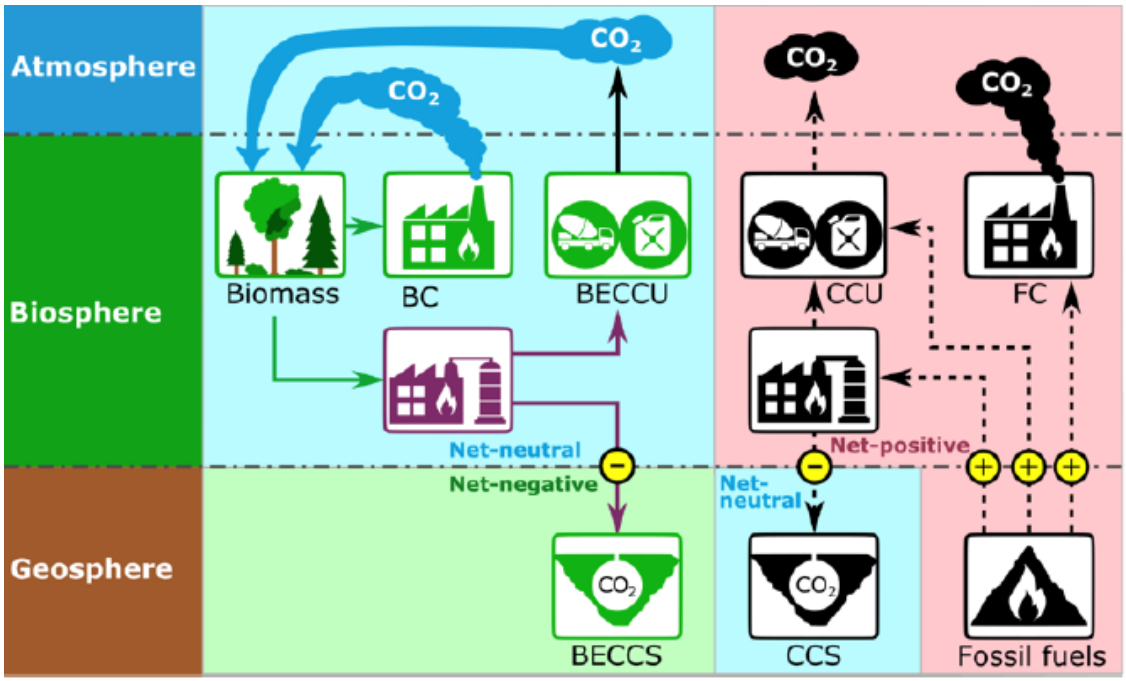

Figure 8: Schematic Diagram of Carbon Dioxide Cycles in Various Bioenergy Utilization Routes
Source: International Energy Agency (IEA), *Bioenergy with Carbon Capture and Utilization (BECCU),* 2020. Retrieved from https://www.iea.org/reports/bioenergy-with-carbon-capture-and-utilisation

The term "carbon value chain" was introduced to evaluate the economic cost of carbon emissions and has since evolved into a key concept for driving net-zero emissions and emission reduction strategies. It is particularly effective in quantifying the economic benefits of carbon reduction for high carbon-intensity industries, such as thermal power plants, by providing strong financial incentives for decarbonization.

The carbon value chain refers to the changes in the value or cost of carbon as it progresses through its journey from emission to capture and, ultimately, to storage or utilization (Foresight Canada, 2024). This journey is underpinned by various technologies collectively known as "carbon tech."

Carbon tech is a rapidly expanding sector in Canada and internationally. It encompasses technologies focused on controlling carbon emissions and reducing atmospheric carbon dioxide levels through a range of innovative methods and applications (Figure 8 and Figure 9).

From a policy perspective, carbon tech efforts have primarily concentrated on conversion and point-source capture technologies. In contrast, carbon storage, a critical component for the permanent removal of carbon dioxide, has received comparatively less political attention and investment. As a result, there are fewer companies developing carbon storage solutions compared to those focused on capture technologies.

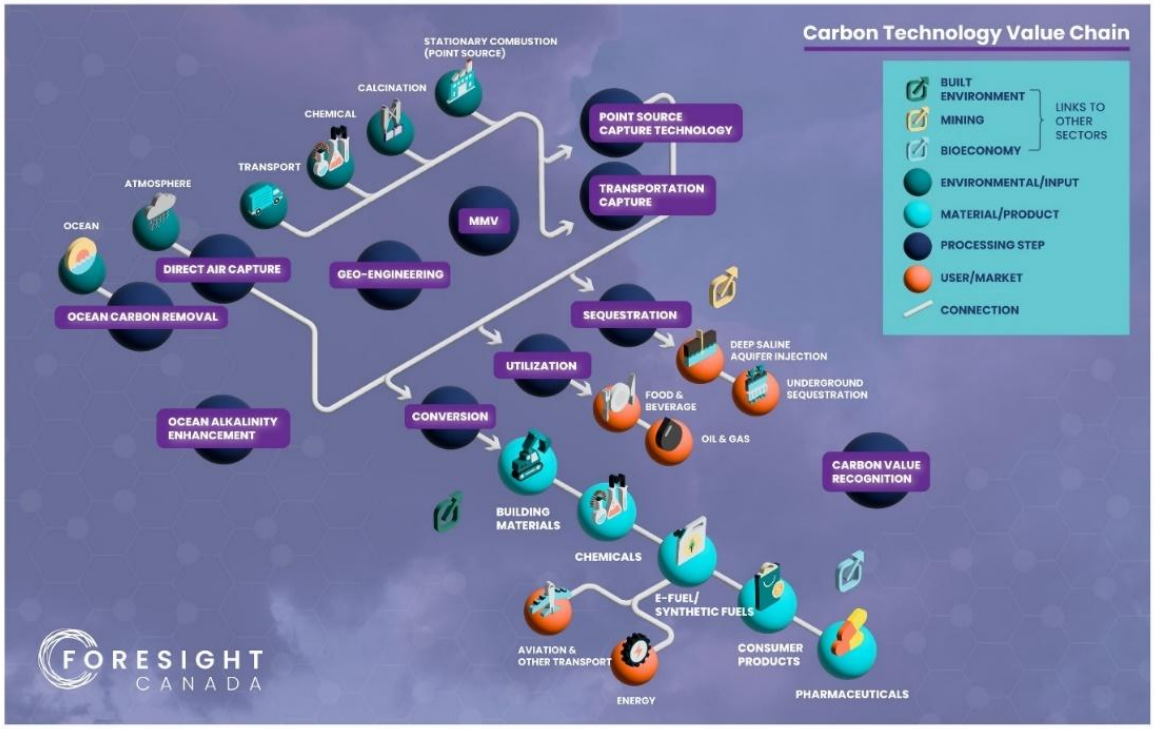

Figure 9: Carbon Tech - The Journey of Carbon Dioxide from Emission Source to Capture, Storage, Utilization, and Conversion. Source: Foresight Canada (2024). Retrieved from https://spectra.mhi.com/what-is-the-co2-value-chain-and-why-is-it-key-for-net-zero.

Carbon capture technology has made remarkable progress over the past two decades. Despite this global advancement, the key challenge is finding effective ways to manage captured carbon dioxide and ensure it does not return to the atmosphere.

Captured greenhouse gases must be stored or altered to ensure they cannot re-enter the atmosphere. Storing carbon dioxide in geological formations deep underground has proven to be the most effective and secure method for permanently containing carbon, preventing its release back into the atmosphere.

To provide economic incentives for permanent storage, it is essential to assign a value to captured CO_2 and an even higher value to its permanent storage, which represents the final step in eliminating its environmental liability.

Captured CO_2 can also be utilized in various industrial applications, ranging from carbonated beverages to cement production, and greenhouse agriculture. These uses transform carbon dioxide into a tradable commodity with its own market value, independent of the value associated with reducing its environmental liability.

Similar to other tradable goods, usable CO_2 should be evaluated through a comprehensive value chain analysis—a cycle encompassing all technologies and industries involved in its capture, temporary storage, transportation, utilization, and eventual permanent storage underground. Carbon dioxide capture, therefore, represents only one part of the broader carbon tech value chain.

For most industrial applications, captured CO_2 must first undergo temporary storage and transportation from the capture site to the end user. This transportation can be carried out via pipelines or by hauling pressure vessels containing the gas.

Transporting CO_2 by truck or ship requires the gas to be converted into liquefied carbon dioxide (LCO_2). The pressurized (or liquefied) gas is then transferred to an LCO_2 carrier and prepared for transport. Upon reaching its destination — such as a greenhouse facility — a gasification system is required to safely convert the LCO_2 back into a usable gaseous form for various applications.

Several processes are used for CO_2 capture and storage, as illustrated in Figure 9. Following separation, the CO_2 is transported to a processing site where it is compressed into a supercritical state. The critical point of CO_2 occurs at 31°C and 73.77 bar, where its density is approximately 500 times that of its gaseous state. Pipelines are another well-established method for transporting CO_2.

Some compressed CO_2 — free of carbon monoxide and other toxic gases — can be sold to greenhouse growers at a premium price, offsetting the costs of capture, pressurization, and transportation. Currently, greenhouse operators pay approximately $200 per ton of delivered carbon dioxide. The carbon capture and storage value chain depends on the supply chain, technologies, and resources employed for emission reduction across various stages, including both upstream and downstream activities.

The emission reduction value begins with the capture of carbon dioxide, either from the atmosphere or directly at the point of emission. This value increases at each subsequent stage, culminating in its utilization or permanent storage in geological formations. The final value, therefore, reflects the cumulative added value across all stages of CCUS.

6.1 Examples of the CO_2 Value Chain in Action

Carbon dioxide capture technologies are still in their early stages of development. Most current carbon capture and storage projects focus on controlling emissions from large-scale power plants and industrial clusters.

Carbon dioxide emitted by medium and small-scale sources cannot be easily captured before entering the atmosphere, meaning these emissions are currently unavoidable. Once carbon dioxide enters the atmosphere, it becomes extremely costly to remove. However, direct air capture technology is steadily improving and is believed to play a significant role in net-zero pathways, despite its high costs.

In the IEA Net Zero Emissions by 2050 Scenario, "DAC technologies capture more than 85 Mt of CO_2 in 2030 and around 980 $MtCO_2$ in 2050, requiring a large and accelerated scale-up from almost 0.01 $MtCO_2$ today" (IEA, 2022).

One critical application of CCUS is in reducing emissions from thermal power plants, which account for over 40% of energy-related carbon dioxide (CO_2) emissions. These plants rely on carbon-intensive fossil fuels such as coal, for energy generation.

The application of CCUS in carbon-intensive industries typically involves three main stages:

1. Separation of CO_2 from exhaust gases (carbon capture),
2. Transportation of the captured CO_2, and
3. Utilization or permanent geological storage (sequestration) of the CO_2.

The CCUS value chain corresponds to these stages and represents the end-to-end process of managing CO_2 from emission sources to its final destination. This process includes capture, transport (for example, via pipelines or shipping), storage (injection into deep geological formations), and utilization (conversion of CO_2 into products such as fuels, construction materials, or chemicals). The overall value associated with CCUS is distributed across these stages.

In many cases, storage represents a significant component of total system cost, while transport costs vary depending on the distance between capture sites and storage locations. The utilization stage may add additional economic value, depending on the end use. For example, in controlled-environment agriculture, CO_2 used for plant growth in greenhouses can command values on the order of US$200–300 per tonne, which is higher than typical estimates for the cost of CO_2 sequestration, often reported in the range of approximately US$60–120 per tonne across different jurisdictions.

The application of CCUS in most carbon-intensive industries (such as thermal power plants) involves three main stages:

1. Separation of CO_2 from exhaust gases, commonly referred to as carbon capture (CC),
2. Transportation of the captured CO_2,
3. Utilization or permanent geological storage (sequestration) of the CO_2.

The value chain of CCUS is therefore defined by these stages and represents the end-to-end process of managing CO_2 from emission sources to its final destination. This process includes capture (separating CO_2 from industrial gas streams), transport (for example, via pipelines or ships), storage (injecting CO_2 into deep geological formations), and utilization (converting CO_2 into products such as fuels, construction materials, or chemicals).

The total economic value associated with CCUS is distributed across these stages, with storage typically representing a significant component of overall system cost, while transaction margins are often lowest at the storage stage. Transportation costs vary primarily with distance, infrastructure availability, and mode of transport between the point of capture and the storage location.

The utilization phase can add additional economic value to sequestered CO_2, depending on the application. In controlled-environment agriculture, such as greenhouse operations, CO_2 used to enhance plant growth can command values in the range of approximately US$200–300 per tonne, which is higher than typical estimates for the cost of CO_2 sequestration, often reported in the range of approximately US$60–120 per tonne across different jurisdictions.

7.0 Sustainability of Carbon Capture and Storage Technologies

Estimating the costs of carbon management and associated technologies is often a complex and challenging task. Most CCUS technologies are costly and energy-intensive, posing a significant challenge to their advancement. To make CCUS sustainable, it is critical to select the most appropriate technologies based on the socio-economic conditions of the project's location and the needs of the community.

One commonly used CCUS technology relies on physicochemical methods to enhance the adsorption of CO_2 using zeolites or lignite. However, this approach requires minerals that are extracted and processed through energy-intensive operations. Some CCUS technologies, such as geothermal carbon storage, can generate clean energy as a by-product. This dual-purpose technology may support the sustainability of the mining and smelting industries by supplying clean baseload energy while storing carbon dioxide.

Integrating carbon capture systems with pipeline networks and storage sites, along with digital connections to track and facilitate end-to-end transactions, can enhance the sustainability of CCUS by reducing costs and creating jobs. Studies in the United States show that CCUS has the potential to generate significant employment opportunities. For example, a Colorado School of

Mines study (2024) estimates that over 130,000 jobs could be created in the U.S. within a decade through capital investment in CCUS.

It is important to note that CCUS is not standalone solutions to climate change and will not eliminate the need to transition from fossil fuels to cleaner renewable energy sources. However, as part of a broader CO_2 value chain, CCUS can help decarbonize hard-to-abate industries and significantly reduce their carbon footprints.

CCUS solutions and infrastructure can be tailored to the specific site and operational requirements of industries such as thermal power plants, cement manufacturing, steelmaking, aluminum production, waste-to-energy plants, and LNG liquefaction facilities.

One notable application of CCUS is in the oil and gas industry. Currently, CO_2 is extensively used in enhanced oil recovery (EOR), where it helps extract additional oil while also being stored underground. CO_2 is also utilized in producing synthetic fuels, construction materials like cement and aggregates, and in the manufacture of fertilizers, plastics, and chemicals. An example of CCUS in action is capturing and storing CO_2 for the oil and gas sector in northeast British Columbia.

The sustainability of carbon technologies depends on their combined socio-economic and environmental impacts. While the environmental benefits of carbon storage are linked to reductions in greenhouse gas emissions, these benefits should not come at the expense of community well-being or local economic outcomes.

When selecting CCUS technologies, it is essential to consider operational characteristics, by-products, and potential secondary impacts. For example, while direct air capture (DAC) technologies are capital-intensive and highly automated, they generally generate limited long-term employment opportunities at the local level. In contrast, geological carbon storage and associated infrastructure development can support skilled employment, supply-chain activity, and longer-term regional economic participation, particularly in areas with suitable subsurface geology.

Governments should evaluate CCUS technologies holistically and design incentives that reflect environmental performance, socio-economic outcomes, and long-term sustainability considerations. Integrating carbon storage with clean energy production is one approach to improving overall system performance. British Columbia has demonstrated potential to integrate carbon storage with geothermal power and heat generation, which can simultaneously reduce emissions and support local energy production. In addition, the BC Hydrogen Strategy[6] highlights opportunities to combine hydrogen production with carbon storage, thereby

[6] Government of British Columbia, *BC Hydrogen Strategy* (2021). https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/electricity-alternative-energy/electricity/bc-hydro-review/bc_hydrogen_strategy_final.pdf

supporting emissions reduction while enabling industrial development and energy system diversification.

Another important factor in improving the sustainability of CCUS processes is the development of dedicated CO_2 transportation infrastructure. Alberta has advanced earlier than most jurisdictions in this area, including the development of large-scale CO_2 pipeline infrastructure to support carbon transportation and storage.

The Alberta Carbon Trunk Line is one of the world's largest CCUS infrastructure projects, with a designed capacity of up to approximately 14.6 million tonnes of CO_2 per year. Like British Columbia, Alberta has extensive sedimentary basins and geological formations suitable for long-term CO_2 storage. Alberta's progress in advancing carbon storage projects can be partly attributed to early regulatory clarity, supportive policy frameworks, and targeted public investment. The province has established one of the earliest comprehensive legislative and regulatory regimes for CCUS in Canada and has committed on the order of approximately CA$2 billion to CCUS-related funding programs, incentives, and infrastructure support. Comparable policy clarity and infrastructure planning would be required to support large-scale CCUS deployment in British Columbia.

8.0 Importance of CCUS to British Columbia's Emissions Goals

The BC Clean Roadmap to 2030[7] identifies CCUS as a strategic pathway to reduce emissions in the industrial sector. By capturing CO_2 and either utilizing it or storing it permanently, CCUS has the potential to substantially lower emissions across critical industries in British Columbia, including oil and gas, cement production, pulp and paper, smelting and steel manufacturing.

For industries facing significant challenges in meeting mandated emissions reduction targets, CCUS offers a critical and practical solution. The technology provides a viable solution for these sectors to reduce their carbon footprints effectively. For example, the BC smelting industry is actively investigating CCUS options to meet its 2030 target of a 50% reduction in emissions and its 2050 goal of achieving net-zero emissions.

As part of British Columbia's broader approach to managing industrial emissions, CCUS is reflected within the objectives of the BC Hydrogen Strategy, which examines pathways for producing low-carbon hydrogen while managing associated CO_2 emissions. In particular, the strategy recognizes the role of carbon capture and permanent geological storage in reducing emissions from hydrogen production pathways that rely on natural gas, leveraging British Columbia's sedimentary basins and geological formations.

[7] Government of British Columbia, *CleanBC Roadmap to 2030*. https://www.britishcolumbia.ca/news-stories/cleanbc-roadmap-to-2030/

CCUS is also being considered within the context of the provincial emissions offset framework. Under this framework, emissions reductions achieved through eligible CCUS activities may be considered for inclusion in BC's offsets program, subject to approved protocols and regulatory requirements. The program establishes methodologies for quantifying, verifying, and reporting greenhouse gas emissions reductions, which are essential for ensuring environmental integrity.

In September 2023, the Province released a draft CCUS offset protocol for public consultation, representing an important step toward integrating carbon capture and storage into the BC offsets system. The consultation process supports regulatory clarity and stakeholder input and signals the province's intent to further develop a policy framework for CCUS-based emissions reductions, subject to final approval and implementation.

9.0 Technological Innovations in Carbon Capture

Emerging climate change and carbon cycle models highlight the transformative potential of CCUS technologies in mitigating climate change. These innovations are particularly effective in advancing the decarbonization of industrial sectors, addressing a critical area of global emissions.

Governments worldwide are responding to these findings by implementing policies to encourage investments in CCUS technologies. Canada has positioned itself as a global leader in both policy development and technological implementation in this field. This leadership has catalyzed increased interest and investment in CCUS initiatives over recent years.

In Canada, the United States and the European Union, recent research has focused on strengthening CCUS technologies, particularly through the conversion of captured carbon into valuable commercial products. This emerging field introduces a new paradigm for evaluating the economic potential of carbon capture and storage. With strategic policy support and resource allocation, Canada — especially British Columbia — has an opportunity to solidify and expand its leadership in carbon technology, building on its successes in CCUS innovation.

Despite these advancements, economic barriers remain a significant challenge for carbon capture programs. Direct air capture technologies are still prohibitively expensive, while point-source carbon capture from industrial emitters has become increasingly cost-effective. However, the transportation and storage of captured CO_2 remain costly. Promising technological innovations are under development to address these challenges, particularly in the power generation sector, where pilot projects and testing are underway.

Several noteworthy projects illustrate the potential of advanced CCUS technologies, as reported by the International Energy Agency (IEA, 2024):

- NET Power's 50 MW clean energy plant (2018): This pioneering natural gas-fired power plant employs an oxyfuel supercritical CO_2 power cycle, using CO_2 as a working fluid. The technology offers significant potential for reducing carbon capture costs.

- Net Zero Teesside Power (United Kingdom): Scheduled to commence operations in 2027, this project aims to become one of the first commercial-scale gas-fired power stations with integrated CCUS capabilities. It was designated as a priority investment by the UK government in March 2023.

- Taizhou Coal Power Plant (China): This large-scale demonstration project features a carbon capture unit capable of sequestering 0.5 million tons of CO_2 annually.

Currently, chemical absorption and physical separation technologies dominate the CCUS landscape. Emerging innovations, such as membrane-based systems and looping cycles, are pushing the boundaries of what is possible.

Membrane-based CO_2 capture technology utilizes permeable materials to selectively separate CO_2 from mixed gas streams. This approach leverages differences in gas diffusion rates and surface absorption properties, enabling more efficient carbon separation (NETL, 2024).

Calcium looping (CaL-CLC) is another promising technology, involving the use of calcium oxide (CaO) sorbents to capture CO_2 from industrial flue gases, such as those generated by cement plants. A key advantage of this method is its ability to utilize the heat produced during the chemical reaction, reducing the energy demands typically associated with air separation processes in conventional calcium looping.

Innovations in carbon capture and transport are also progressing. Mitsubishi Heavy Industries Group (MHI) has developed cost-effective solutions for transporting liquid CO_2 (LCO_2) to end users or storage sites overseas (Figure 10). A recently launched test vessel in Japan demonstrates the practicality of this approach. Additionally, MHI has introduced modular CO_2 capture systems designed for small- and medium-scale emitters, significantly reducing costs and streamlining delivery and installation processes.

Figure 10: Specialist ships for carbon dioxide transportation – a critical component of the CO_2 value chain, facilitating the efficient and reliable movement of liquefied CO_2 (LCO_2) to storage sites and end users. *(Source: SPECTRA, Mitsubishi Heavy Industries Group, 2022. "The Specialist Ships at the Heart of the CO_2 Value Chain." Available at: https://spectra.mhi.com/the-specialist-ships-at-the-heart-of-the-co2-value-chain)*

One more innovative idea in CCUS involves using CO_2 captured from power plants and industry to produce fish feed, a critical resource for aquaculture.

The UK-based energy company Drax is currently working on converting up to 70% of the CO_2 captured from its biomass power plant into single-cell proteins, which can be used to produce fish feed and other animal feeds (Figure 11). Innovative advancements in the carbon value chain offer significant potential to drive cost efficiency within the emerging circular economy.

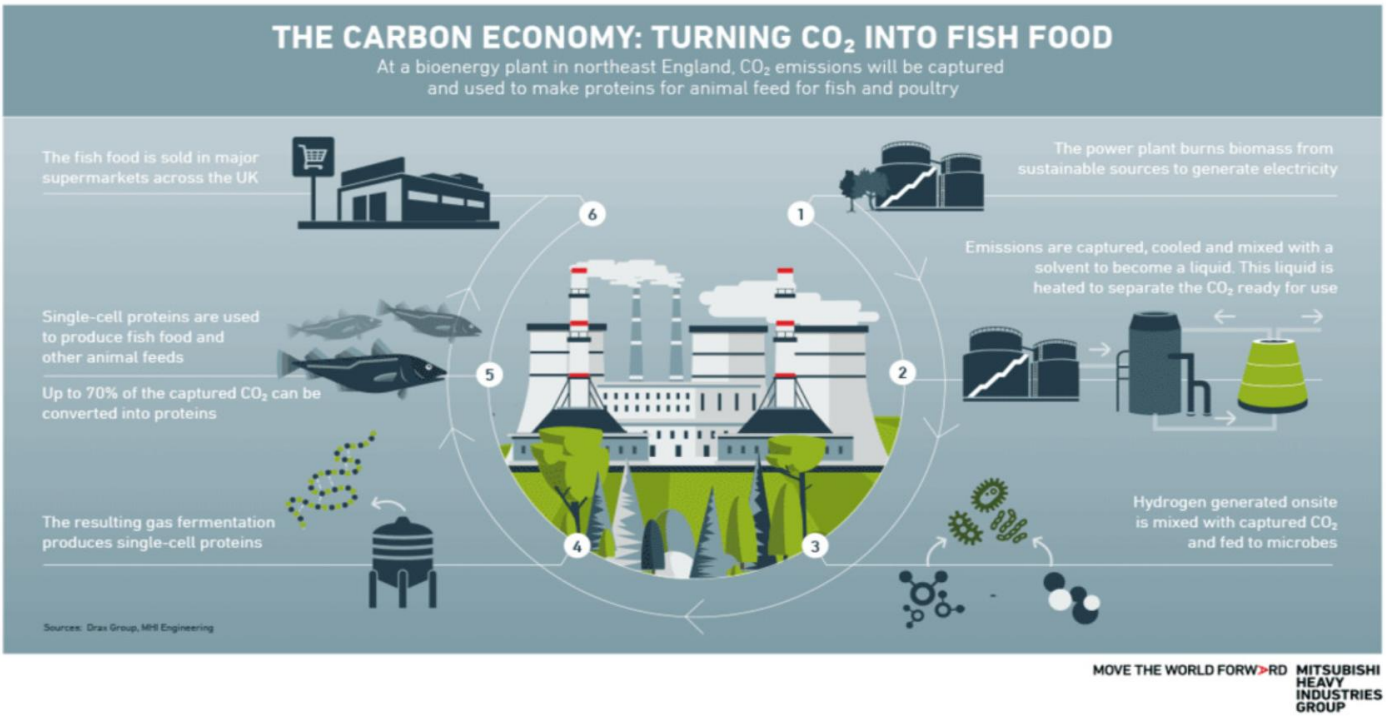

Figure 11: UK initiative leveraging captured carbon dioxide to produce sustainable fish feed, exemplifying innovation in the CO_2 value chain. *(Source: SPECTRA, Mitsubishi Heavy Industries Group. "What is the CO_2 Value Chain and Why is it Key for Net Zero?" Available at: https://spectra.mhi.com/what-is-the-co2-value-chain-and-why-is-it-key-for-net-zero*

9.1 Deep Geothermal Carbon Storage and Its Value

Deep geothermal carbon storage presents an innovative solution for decarbonizing carbon-intensive processes, such as smelting. This approach involves capturing the carbon dioxide generated during industrial processes and injecting it into geological formations for secure, long-term storage.

The effectiveness of this technology is location-dependent, requiring geological conditions suitable for carbon storage. A notable advantage of this method is the potential to generate geothermal power as a by-product of the carbon sequestration process, adding economic and energy benefits to the decarbonization effort (Figure 12).

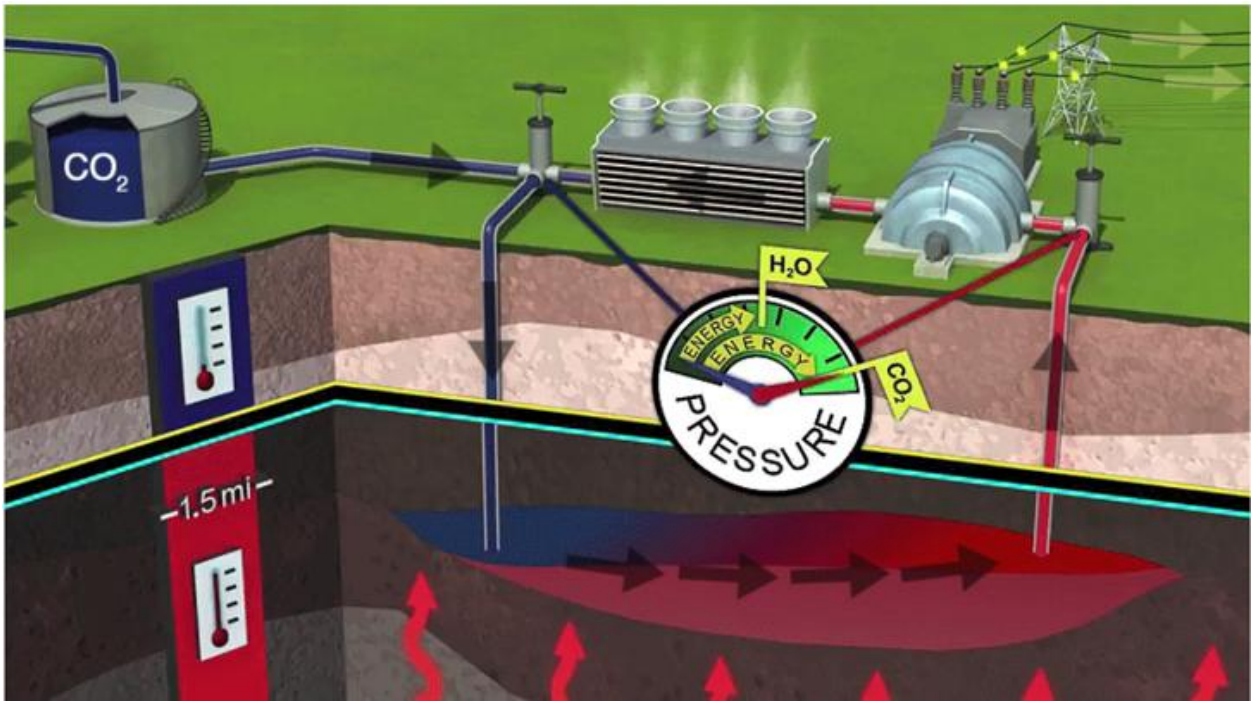

Figure 12: CO_2 Plume Geothermal (CPG) systems – combining carbon dioxide storage with geothermal energy production for sustainable energy and carbon management. *(Image courtesy of TerraCOH, Inc., showcasing the Carbon Dioxide Plume Geothermal (CPG™) technology.) Retrieved from* https://www.terracoh-age.com

The so-called CO_2 Plume Geothermal (CPG) technology enables the dual benefits of storing CO_2 and producing green energy. Developed by the TerraCOH, this innovative approach combines CO_2 storage with geothermal energy production. The technology utilizes geothermal reservoirs for two key purposes:

1. Producing clean geothermal energy.
2. Deep storage of CO_2.

The CPG technology offers a unique solution that transforms the challenge of CO_2 emissions into an asset. By storing CO_2, the method enhances the geothermal productivity of the reservoir, providing both environmental and economic advantages (Figure 13).

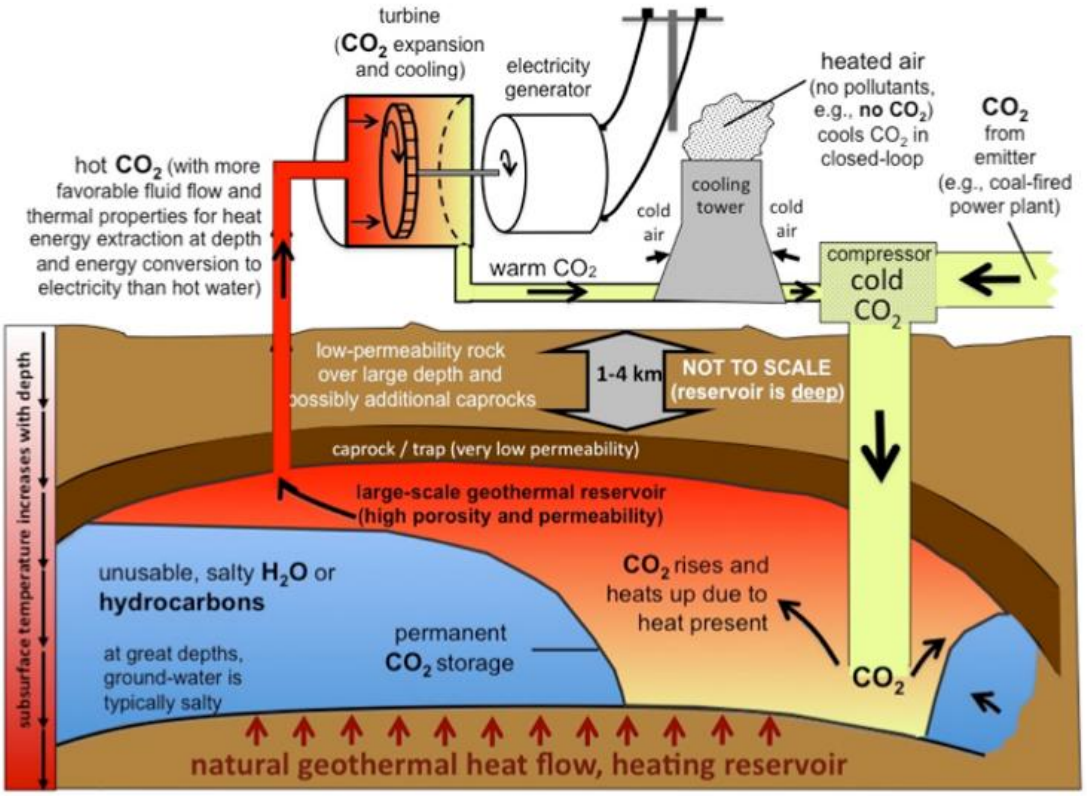

Figure 13: CO_2 Plume Geothermal (CPG) System – conceptual model illustrating the integration of CO_2 storage and geothermal energy production. *(Source: geg.ethz.ch)*

In CPG technology, part of the CO_2 is used as the working fluid to drive a turbine-generator before being returned to the deep ground for permanent storage (Figure 13). The CO_2 is injected into saline aquifers deep underground, where its temperature rises due to geothermal heat in the rocks. The extracted hot CO_2 powers a turbine to produce electricity.

Injected CO_2 is captured from industrial emissions (e.g., cement manufacturing, biofuel refineries, fossil-fueled power plants). The captured gas acts as a working fluid, transferring energy between the geothermal reservoir and the power plant. The subsurface CO_2 absorbs energy from the reservoir rocks and delivers it to the turbine.

After transferring its energy to the plant, CO_2 is cooled, condensed, and reinjected into the deep reservoir, closing the loop and ensuring that all the originally injected CO_2 remains permanently sequestered (Randolph and Saar, 2011a; Saar et al., 2012; Adams et al., 2014, 2015).

The potential of this technology for effective implementation, requires adequate government policies. In British Columbia, amendments to the Geothermal Resources Act are necessary to support the dual use of geothermal reservoirs for energy production and carbon storage.

One advantage of CPG systems is their ability to utilize low-temperature geothermal resources, which are currently underdeveloped for geothermal energy. This feature gives CPG significant potential to expand the geographic regions where geothermal energy can be harnessed, while also enabling CO_2 storage.

Moreover, First Nations have an exceptional opportunity to collaborate with the metallurgical sector, particularly in advancing green smelting initiatives. First Nations communities in BC can:

1. Provide land for the development of zero-emission smelters.
2. Form strategic partnerships with industry stakeholders to establish green smelting facilities on their traditional territories.
3. Engage in joint ventures to offer carbon sequestration solutions as integral components of smelting operations.

It is essential to identify and evaluate resources suitable for deep-underground CO_2 storage in BC to support new smelting facilities. This evaluation should include an assessment of their potential for emissions sequestration from industrial activities. Furthermore, First Nations, in partnership with the metallurgical industry, should actively explore other emerging green smelting technologies to enhance the sustainability and environmental stewardship of industrial operations.

9.2 The Role of Government in Advancing CCUS

Based on the British Columbia Government's CleanBC Roadmap to 2030, CCUS is identified as an important pathway for reducing emissions in hard-to-abate industrial sectors. Capturing CO_2 and subsequently utilizing it or storing it permanently has the potential to contribute to emissions reductions across several industrial activities in British Columbia, including oil and gas processing, cement production, pulp and paper, and metals manufacturing. The Roadmap recognizes that CCUS may be particularly relevant for industrial sectors where alternative emissions-reduction options are limited or not yet technically feasible, and that expanded utilization pathways may further enhance its role over time.

In recent years, both the federal and provincial governments have strengthened policy and regulatory frameworks intended to support CCUS development, including targeted financial incentives for research, development, and early deployment. The Province has signalled support for private-sector investment by advancing regulatory clarity, funding geological characterization studies, and aligning CCUS with broader climate and industrial strategies. Geological assessments undertaken in British Columbia have helped identify sedimentary basins with potential for long-term CO_2 storage, supporting future project planning and risk assessment.

Federal and provincial governments have also increasingly focused on understanding the value of CO_2 across its full lifecycle, from capture through transport, utilization, and permanent storage. While governments establish the overall price signal for carbon through carbon pricing

mechanisms, additional policy tools are required to address how value is distributed along the CCUS value chain. The valuation of capture and transport activities is relatively well understood, whereas assigning value to long-term geological storage remains more complex, particularly where subsurface pore space and long-term stewardship considerations are involved. The valuation of storage services may therefore need to account for domestic demand as well as potential international markets, including jurisdictions such as Japan that lack sufficient domestic geological storage capacity.

British Columbia's Clean Transportation Action Plan (2023) prioritizes emissions reductions through efficiency-first and electrification-focused transportation strategies, and does not currently position CCUS as a primary mitigation option for mobile sources, given the technical challenges associated with capturing emissions from vehicles. Mobile Carbon Capture (MCC) technologies do exist at an early stage of development, particularly for heavy-duty and off-road applications, where exhaust CO_2 may be captured using sorbents or solvents and temporarily stored onboard. While not yet commercially mature, MCC technologies could warrant further evaluation for specialized applications such as large mining trucks, subject to performance, safety, and cost considerations.

Government directives on value chain assessment are necessary to enable the transport of captured CO_2 from domestic and international industries to geological storage sites in BC. Metrics for valuing carbon dioxide should be based on three key pricing components:

1. Local carbon taxes.
2. International carbon trading prices.
3. The market price of carbon dioxide for industrial users (e.g., greenhouse growers).

A robust business case for CCUS remains to be developed. To facilitate this, the government should fund a demonstration project for carbon storage in BC, serving as a model for future cost-effective CCUS initiatives. Additionally, the increasing stringency of climate targets and the rising international carbon prices (calculated as a per-tonne cost of CO_2 emissions) should be incorporated into a dynamic valuation model for carbon storage.

10.0 Emission Sources in British Columbia

In 2022, Canada's total greenhouse gas (GHG) emissions were 708 megatonnes (Mt CO_2e), marking a 1.3% increase from 698 Mt CO_2e in 2021. Between 1990 and 2022, Canada's GHG emissions increased by approximately 16.5% (about 100 Mt CO_2e), averaging an annual increase of approximately 0.5%. Preliminary national estimates indicate that total Canadian GHG emissions declined slightly after 2022, with 2024 emissions estimated at approximately 694 Mt CO_2e, essentially unchanged from 2023 levels and modestly below the 2022 total.

According to the 2022 Climate Change Accountability Report, British Columbia's total GHG emissions in 2020 were 61.7 Mt CO_2e, equating to approximately 12.0 tonnes per capita, which is lower than the national average of approximately 18.1 tonnes per capita. While BC has largely stabilized emissions in recent years, the province's total emissions remain approximately 26% higher than 1990 levels and about 3% higher than 2005 levels, as reported under CleanBC.

Provincial policy mandates that all facilities emitting 10,000 tonnes or more of CO_2e annually—or those that exceeded this threshold in any of the previous three reporting years—must report their GHG emissions. Facilities emitting 25,000 tonnes or more of CO_2e in the current or any of the previous three reporting periods are required to have their emissions independently verified by an accredited third party. In addition, all regulated liquefied natural gas (LNG) operations are subject to mandatory emissions reporting and third-party verification requirements.

Emission data from large emitters is published in the BC Industrial GHG Public Report, ensuring transparency and accountability. In 2021, oil and gas production accounted for 48% of BC's industrial GHG emissions. The remaining contributions from other sectors were as follows (Figures 14a and 14b):

- 48% oil and gas
- 16% manufacturing industries
- 14% industrial processes and product use
- 11% other industries
- 7% mining
- 4% public electricity and heat production

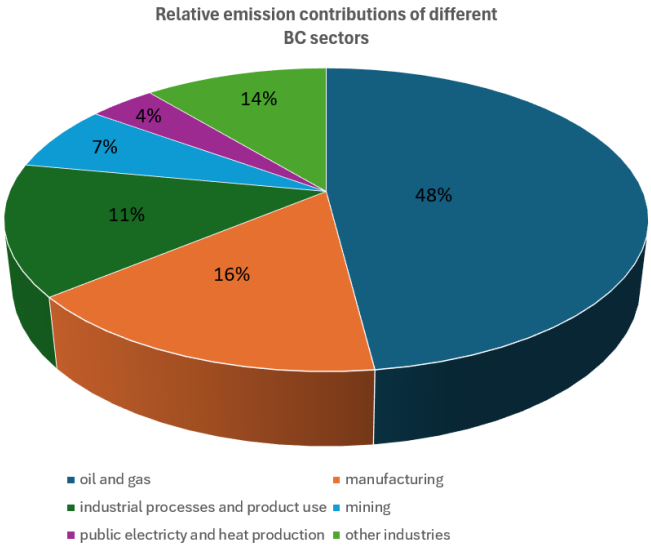

Figure 14a: Relative contributions of various industrial sectors to BC's greenhouse gas emissions. *Source: Provincial Inventory of Greenhouse Gas Emissions 1990-2021 Methodology Report. Source: Government of British Columbia. Provincial Greenhouse Gas Inventory and*

Climate Change Accountability Report. Ministry of Environment and Climate Change Strategy. *https://www2.gov.bc.ca/gov/content/environment/climate-change/data/provincial-inventory*

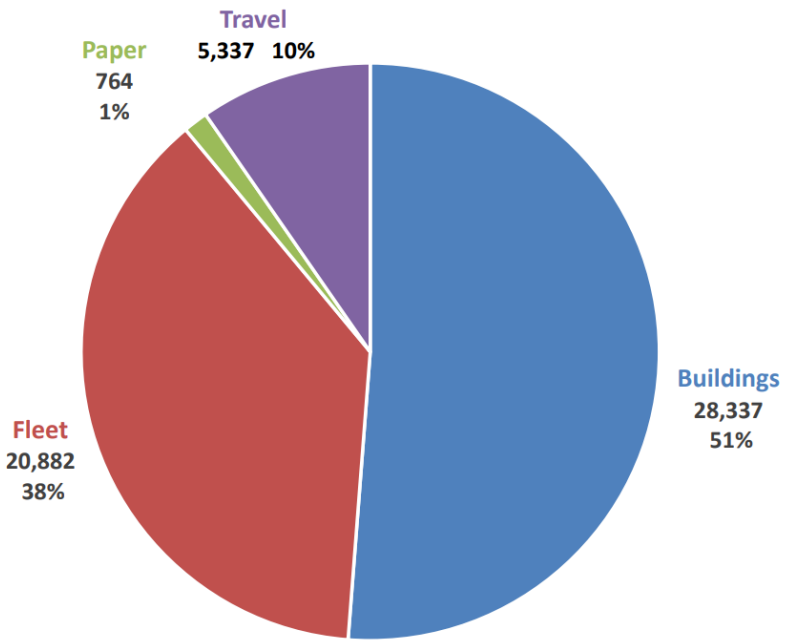

Figure 14b: Greenhouse gas emissions from British Columbia government operations by source category (tCO_2e). Source: Government of British Columbia, *Corporate GHG Inventory Report (2024)*. https://www2.gov.bc.ca/assets/gov/environment/climate-change/cnar/2024/2024_bc_government_climate_progress_report.pdf

It is important to note that industrial activities in BC account for 40% of the province's GHG emissions. The breakdown of these industrial emissions, normalized to represent 100% of BC's industrial sector emissions, is as follows:

- 19% from oil and gas operations
- 21% from other industries

The remaining 60% of BC's total GHG emissions are attributed to the following sectors:

- Transportation: This includes emissions from on-road vehicles and off-road vehicles such as mining trucks and tractors, which are included in BC's transportation emissions totals.

- Buildings: Energy consumption for heating and other uses in residential, commercial, and industrial buildings contributes to BC's building emissions totals.

- Agriculture: Farming and food production are significant sources of greenhouse gases, with energy usage on farms included in BC's agricultural emissions totals.

By 2030, all newly constructed buildings in BC will be required to meet zero-emission standards, marking a significant step toward reducing emissions in the building sector.

11.0 Regulated Price on Emissions

Pricing emissions is widely recognized as one of the most effective and economical strategies to reduce GHG emissions and stimulate innovation. In BC, this principle is applied through the BC Output-Based Pricing System (OBPS), a framework that aligns with the federal carbon pollution pricing model.

The OBPS is specifically tailored to encourage large industrial emitters to reduce their emissions while maintaining economic competitiveness. Under this system, each industrial facility is assigned an emissions intensity benchmark or limit, which is determined based on the output of the facility and the average emissions intensity of similar operations. Facilities are allowed to emit up to this limit without penalty, creating a clear incentive to adopt cleaner technologies and improve efficiency.

For emissions exceeding the set benchmark, facilities must pay a compliance cost, which can be fulfilled in one of three ways:

1. Direct payment of a carbon price for emissions above the limit.
2. Purchasing compliance units, such as offsets or credits generated by other facilities or projects that reduce emissions.
3. Investing in approved emissions reduction projects to lower their own emissions.

This flexibility ensures that facilities can choose the most cost-effective way to meet their obligations, thereby reducing the overall economic burden while still achieving significant emissions reductions.

One of the advantages of the OBPS is that it does not apply a flat carbon tax directly to the fuels purchased by large industrial facilities. Instead, it targets emissions performance, encouraging facilities to reduce emissions intensity while maintaining economic competitiveness. This approach is particularly important for energy-intensive and trade-exposed industries, as it reduces the risk of "carbon leakage," whereby production shifts to jurisdictions with weaker climate regulations.

In British Columbia, the carbon tax applies directly to fossil fuels, including gasoline, at a rate of approximately 17.61 cents per litre as of April 2024, which is equivalent to a carbon price of $80 per metric tonne of CO_2e. For large industrial emitters, BC applies an Output-OBPS rather than the standard fuel-based carbon tax. Under the OBPS, regulated facilities are required to pay the carbon price on emissions that exceed sector-specific performance benchmarks, while emissions below the benchmark generate compliance credits. In 2024, the carbon price under the OBPS is $80 per tonne of CO_2e and is scheduled to rise annually to $170 per tonne by 2030, in alignment

with the federal carbon pricing trajectory. Credits generated by efficient facilities may be banked for future compliance or sold to other regulated emitters, while less efficient facilities incur compliance costs, thereby creating a financial incentive for emissions reductions across the industrial sector.

Revenue generated through OBPS compliance mechanisms may be reinvested into climate action initiatives, supporting innovation, emissions-reduction projects, and the development and deployment of low-carbon technologies. By creating incentives for industrial facilities to improve emissions performance and adopt cleaner production practices, the OBPS contributes to British Columbia's emissions-reduction objectives while supporting industrial competitiveness. This approach helps position the province as a jurisdiction that aligns climate policy with sustainable industrial development, rather than relying solely on prescriptive regulation.

11.1 The Energy Action Framework

The BC Energy Action Framework (2023) builds on British Columbia's commitment to clean energy initiatives, aiming to support sustainable economic growth while advancing emissions reductions across the energy sector. The key components of the framework are as follows:

- All proposed liquefied natural gas (LNG) facilities undergoing new or in-process environmental assessments must meet stringent emissions standards. These facilities are required to develop plans to achieve net zero emissions by 2030.

- A regulatory emissions cap will be implemented for the oil and gas sector, ensuring that the industry adheres to its 2030 emissions reduction targets. This measure seeks to align industrial operations with provincial and federal climate goals.

- A newly established office will focus on expediting investment in clean energy technologies and fostering the creation of sustainable jobs. This initiative supports BC's transition to a cleaner, more resilient economy.

- A dedicated task force within BC Hydro will accelerate electrification efforts across the province. This will enable more homes, businesses, transportation systems, and industries to transition to renewable electricity, reducing dependence on fossil fuels.

According to David Eby, Premier of British Columbia, BC's Energy Action Framework is intended to support the province's climate objectives while strengthening a clean-energy economy. The framework recognizes that emissions-intensive sectors, including oil and gas, are expected to contribute to emissions reductions, and that emerging technologies, including CCUS, may play a supporting role where appropriate. In parallel, the framework promotes the development of clean-energy projects that could incorporate CCUS as part of broader decarbonization strategies.

The framework aligns with the federal government's commitment to implement a national emissions cap for large industrial emitters, particularly within the oil and gas sector. By coordinating provincial and federal policy approaches, the Energy Action Framework supports regulatory consistency and reinforces British Columbia's role in advancing clean-energy innovation and climate action.

12. Geological Carbon Storage – BC Potential

The United States Geological Survey (USGS, 2024) is currently assessing two primary methods of carbon sequestration:

- geologic sequestration
- biologic sequestration

Geologic carbon sequestration involves storing carbon dioxide in underground geological formations. CO_2 is pressurized until it transitions to a liquid state, after which it is injected into porous rock formations within geologic basins (Figure 15). This method is often associated with enhanced oil recovery, where the injected CO_2 is used to release trapped oil and gas while being permanently sequestered in the subsurface.

Geological formations are well-suited for carbon storage because they naturally trap oil and gas over long periods, often tens of millions of years. Similarly, CO_2, as a naturally occurring molecule, can be safely and permanently stored in many geological environments, demonstrating stability and immobility under proper conditions.

The potential for geologic carbon sequestration depends significantly on the geological characteristics of a region. While it is challenging to identify a single "ideal" formation for carbon storage due to variations in geology, certain regions exhibit higher storage potential.

In BC, significant potential exists in the northeastern part of the province, known as the Peace region. This region, part of the prairies, features geological formations favourable to carbon sequestration.

The USGS estimates a storage potential of 3,000 gigatons of CO_2 across the United States. A similar nation-wide study should be undertaken by the Geological Survey of Canada, with a specific focus on BC geology, to assess the province's storage potential. Such an initiative would provide valuable insights into the feasibility of utilizing BC's subsurface resources for long-term carbon storage and contribute to broader climate change mitigation efforts.

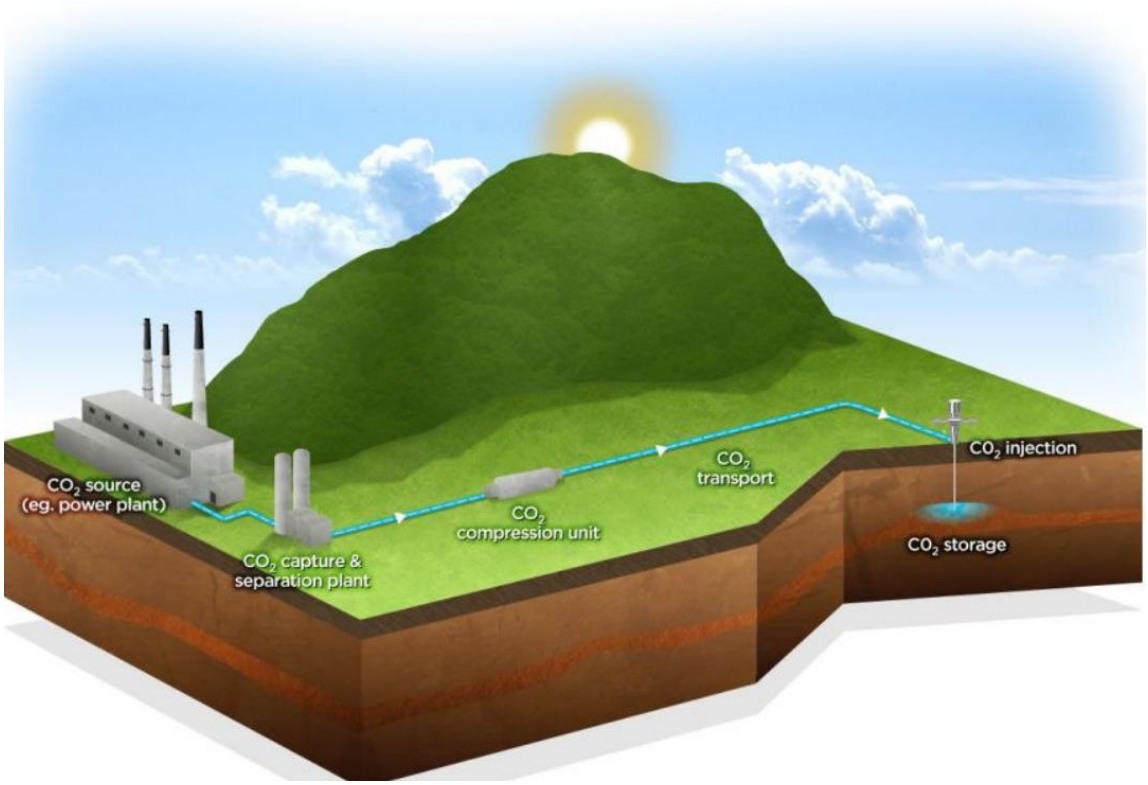

Figure 15: Carbon Capture, Transportation, and Deep Storage. *Source: U.S. Department of Energy, Office of Fossil Energy and Carbon Management. "Carbon Capture, Transport, and Storage Supply Chain Review: Deep Dive Assessment." February 2022. Available at: https://www.energy.gov/fecm/carbon-capture-transport-and-storage-supply-chain-review-deep-dive-assessment*

12.1 Technical and Economic Viability of Deep Carbon Storage

A recent modeling study by Schmelz (2022) conducted in the United States highlights the complexities and constraints associated with the effective storage of CO_2 in geological formations. According to the study, "the available pore space for CO_2 storage may be constrained by the pressure increases caused during injection" (Schmelz, 2022). These pressure limitations directly influence both the total storage capacity and the injectivity rate of the formation.

Injectivity is a critical factor in determining the feasibility of carbon storage. "The injection rate must be low enough to allow pressure dissipation while remaining below the fracture threshold of the caprock" (Schmelz, 2022). For instance, in the Mt. Simon Formation in Illinois, the injection of CO_2 is carefully managed to avoid exceeding a pressure increase of 25%, with wells spaced 30 km apart over a 50-year timeframe. Actual injection rates for this formation are typically around 1 Mt CO_2 per year to ensure safe long-term storage conditions.

Sophisticated carbon reservoir modeling is therefore required before initiating injection. These models must be dynamically updated based on real-time pressure monitoring data collected during the injection process.

Factors Influencing the Cost of Deep CO_2 Injection

The cost of deep carbon injection is influenced by several geological and operational factors, including:

- depth of the geologic formation used for storage
- extent of the underground basin in which the formation is located
- reservoir life span
- sustainable injection rate of CO_2
- costs of surface injection infrastructure and monitoring systems

External Factors Affecting Economic Viability

Economic viability depends not only on geological conditions but also on external factors such as:

- proximity to carbon-generating facilities, affecting transportation costs
- local carbon pricing, including taxes or trading prices

Cost Categorization in Carbon Storage

The total cost of carbon storage is typically expressed in dollars per tonne of CO_2 stored. As a standard practice, the cost is categorized into three main components (Schmelz, 2022):

1. Capture costs for a given facility type, such as a power plant.
2. Transportation costs to the nearest suitable geological storage site.
3. Storage costs at the site, determined by the geological reservoir's characteristics.

By accounting for these factors, decision-makers can assess the economic feasibility of carbon storage projects and design strategies to optimize costs while meeting environmental and sustainability objectives.

Independent of specific technologies, a key economic advantage of CCUS is its potential to deliver emissions reductions at lower cost compared to some alternative mitigation options. However, capture, transport, utilization, and storage costs must be evaluated on a project-specific and site-specific basis.

From an economic perspective, capital expenditures (CAPEX) and operating expenditures (OPEX) represent the primary cost components when assessing the viability of CCUS assets. Major CAPEX items include carbon capture equipment, storage site development (including drilling), surface facilities, and monitoring infrastructure. For CO_2 transport, pipeline

construction typically represents the dominant capital cost, which is most economically justified for large, high-emitting facilities, such as smelters or major industrial plants.

Surface infrastructure for carbon storage includes compression and injection facilities, while subsurface infrastructure consists primarily of injection and monitoring wells.

Site development represents a significant investment; however, these costs may be partially reduced when utilizing existing oil and gas fields, where some infrastructure is already in place. In cases where CO_2 storage is integrated with geothermal systems, a portion of storage-related costs may be offset by revenue from geothermal heat or power generation, thereby improving overall project economics.

13. Standards

Standards organizations such as the CSA Group, in collaboration with the International Organization for Standardization Technical Committee (ISO/TC 265), have been pivotal in developing protocols for carbon dioxide capture, transportation, and geological storage. These efforts have positioned Canada as a leader in international standardization for CCUS technologies.

ISO/TC 265: Comprehensive Framework for CCUS

The ISO/TC 265 technical committee focuses on creating international standards that address all aspects of CCUS, including:

- design and construction of capture and storage infrastructure
- operational guidelines for CO_2 capture and transportation systems
- environmental planning and management to mitigate impacts
- risk management to ensure the safety of injection and storage operations
- monitoring, quantification, and verification to validate CO_2 sequestration

By standardizing these components, ISO/TC 265 ensures that CCUS technologies are implemented safely, effectively, and sustainably across global projects.

CSA Group's Contributions

The CSA Group has led the development of more than 12 international standards for CCUS, addressing critical areas of the CCUS value chain. These include protocols for:

1. Carbon Capture: Methods and systems for capturing CO_2 from industrial sources.
2. Transportation: Standards for pipelines and infrastructure to transport high-pressure CO_2 to storage sites.

3. Geological Storage: Requirements for injecting and permanently storing CO_2 in deep geological formations, including protocols for enhanced oil recovery (CO_2-EOR).

CSA standards like CSA Z741 (Geological Storage of Carbon Dioxide) and ISO 27914 provide detailed guidelines for secure CO_2 sequestration, ensuring minimal environmental and operational risks.

Emerging Standards and New Developments

The CSA is actively developing standards for Measurement, Monitoring, and Verification (MMV) under CSA TS-226. This forthcoming standard will establish protocols for monitoring CO_2 storage sites, ensuring that geological sequestration is both effective and secure.

Additionally, CSA standards such as CSA Z624 and Z625 address well integrity and design in CCUS projects, safeguarding the infrastructure used for CO_2 injection. Standards like ISO 27916, which focuses on CO_2-EOR, highlight opportunities to integrate carbon storage with resource recovery operations.

Examples of Existing Standards

CSA and ISO have compiled a comprehensive list of standards relevant to CCUS. These include:

1. ISO/TR 27912: Carbon dioxide capture systems, technologies, and processes.
2. ISO 27919-1: Performance evaluation methods for post-combustion CO_2 capture.
3. CSA Z662: Oil and gas pipeline systems for CO_2 transportation.
4. ISO 27913: Pipeline transportation systems for captured CO_2.
5. CSA Z741: Geological storage of carbon dioxide.
6. ISO/TR 27918: Lifecycle risk management for integrated CCS projects.
7. ISO/TR 27923: Injection operations, infrastructure, and monitoring.

The full list of standards can be found in the CSA publication titled "Infographic: Carbon Capture Standards".[8]

Global Collaboration and Canada's Leadership

Canada's leadership in CCUS standardization is strengthened through active collaboration with international organizations, including the International CCS Knowledge Centre and multilateral climate bodies operating under the United Nations Framework Convention on Climate Change.

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[8] CSA Group – Infographic: Carbon Capture Standards
https://www.csagroup.org/article/infographic-carbon-capture-standards/

These collaborations support alignment between Canadian standards developed by CSA Group and international ISO standards, helping ensure consistency with global best practices and supporting the responsible deployment of CCUS technologies worldwide.

CCUS is a core component of broader carbon management strategies, an area in which Canada is recognized as an international leader, supported by early project deployment, regulatory frameworks, and standards development. Carbon management encompasses a range of approaches to capture CO_2 from point sources or directly from the atmosphere, followed by durable geological storage or utilization. CCUS is widely recognized as an important element of global climate mitigation efforts.

According to assessments by the Intergovernmental Panel on Climate Change and the International Energy Agency, achieving global net-zero emissions would be significantly more challenging without the deployment of carbon management technologies, including CCUS. Both organizations indicate that large-scale expansion of carbon capture and storage will be required over the coming decades, with deployment levels increasing by one to two orders of magnitude by mid-century to align with net-zero pathways.

Relevance of Standards

Standards play a crucial role in enabling the scalability and economic viability of CCUS projects by:

1. Providing consistency across projects and jurisdictions.
2. Enhancing risk management with robust monitoring and verification protocols.
3. Optimizing costs by defining efficient practices for capture, transportation, and storage.
4. Fostering environmental stewardship by aligning with global emissions reduction targets, such as the Paris Agreement goals.

By addressing the entire CCUS value chain and aligning with international efforts, standards developed by the CSA Group and ISO/TC 265 provide a comprehensive framework for the safe and effective deployment of CCUS technologies. These standards not only support Canada's climate action goals but also enhance its position as a global leader in carbon management innovation.

14. Carbon Pricing and Market Mechanisms for Emissions Reduction

There are two primary policy approaches for reducing GHG emissions: carbon taxing and carbon cap-and-trade systems.

Carbon taxing is a policy implemented in many countries, including British Columbia, that discourages GHG emissions by imposing a financial penalty proportional to the amount of emissions generated. This penalty applies not only to industrial operations but also to the

consumption of emission-producing products like gasoline and natural gas. British Columbia's carbon tax is recognized as one of the most comprehensive in North America, covering 75% of the province's total reported emissions in 2022, which amounted to 14.11 Mt CO_2e out of 18.74 Mt CO_2e. The tax applies to various sources of emissions, including stationary combustion, mobile equipment, natural gas flaring and venting, and waste incineration.

The carbon tax and carbon management policies have contributed to measurable emissions reductions in British Columbia across several regulated sectors and performance indicators. According to the 2024 Government of British Columbia Climate Progress Report, emissions reductions of up to approximately 34% relative to a 2010 benchmark have been achieved for specific policy-driven metrics, reflecting the impact of carbon pricing, fuel standards, and complementary climate policies.[9]

Carbon trading, also referred to as carbon emissions trading, addresses the global nature of climate change by leveraging the shared atmospheric resource. Since greenhouse gases affect the global climate regardless of where they are released, carbon trading allows entities to collectively benefit from emissions reductions. In a carbon trading system, entities are permitted to emit a certain amount of carbon dioxide, provided they pay for it. Those that reduce their emissions below their allocated amount earn credits, which can then be sold in the carbon market. This market-driven mechanism incentivizes reductions and creates a global platform for emissions management.

Governments worldwide have established carbon markets, enabling the trade of emissions or emissions reductions between entities at national or international levels. However, despite its theoretical simplicity, implementing such markets can be complex and challenging due to the need for robust regulatory structures, effective monitoring, and market dynamics.

One widely used system is cap-and-trade, where governments set a cap on allowable emissions for specific industries or operations. Entities under this system are allocated emission allowances, which correspond to the cap. These allowances act as permits for emitting a specified amount of CO_2e. If an entity emits less than its allocated amount, it can sell surplus allowances to others. Conversely, entities exceeding their cap must purchase additional allowances on the market. This system introduces flexibility and economic incentives for emissions reductions but also presents challenges, including potential loopholes and complexities in distinguishing between different types of carbon markets.

Carbon markets generally operate under two major frameworks. The first is the cap-and-trade model, where pollution permits, often referred to as allowances, are traded. In this model, entities are required to surrender an allowance to the regulator for every tonne of CO_2e emitted. The

[9] Government of British Columbia, *2024 Climate Progress Report*. https://www2.gov.bc.ca/assets/gov/environment/climate-change/cnar/2024/2024_bc_government_climate_progress_report.pdf

second framework is the baseline-and-credit mechanism, also known as offsetting. This system allows entities to purchase credits generated by activities or projects that reduce emissions beyond baseline levels. For example, an oil and gas company might fund the protection of rainforests in the Amazon to offset its emissions, thereby claiming a reduction without directly reducing its operational emissions.

While both systems aim to reduce emissions, they operate differently. Cap-and-trade focuses on limiting total emissions through regulated caps, while offsetting allows entities to balance their emissions by funding reductions elsewhere. Both approaches are vital tools in combating climate change, but their effectiveness depends on strong governance, transparency, and enforcement to ensure environmental integrity and equity.

By combining financial penalties with market-driven incentives, carbon taxing and trading mechanisms create diverse pathways to address the pressing challenge of global GHG emissions. Their success lies in balancing economic feasibility with environmental accountability, fostering collective progress toward a sustainable future.

Carbon trading in Canada includes provincially led compliance markets for large industrial emitters, implemented through OBPS, as well as a federal Greenhouse Gas (GHG) Offset Credit System. Together, these instruments create compliance markets in which regulated facilities can generate, trade, or purchase emissions credits to meet performance standards, thereby incentivizing emissions reductions and investment in low-carbon technologies. These systems operate alongside a consumer-facing fuel charge (commonly referred to as a carbon tax), which applies to fossil fuels used by households and smaller emitters.

In British Columbia, in parallel with the carbon tax, a compliance-based carbon pricing and crediting framework applies to large industrial emitters. British Columbia's OBPS regulates facilities with significant emissions by setting emissions-intensity benchmarks and requiring compliance for emissions above those benchmarks. British Columbia also operates an offset credit system that enables the generation and trading of credits from verified emissions-reduction projects, which are registered and tracked through the B.C. Carbon Registry. These mechanisms are established under provincial climate legislation, including the Greenhouse Gas Industrial Reporting and Control Act and related regulations, and support flexible, market-based compliance while maintaining environmental integrity.

15. Geological Favorability for Carbon Storage

The Western Canada Sedimentary Basin (Figure 16) has significant potential for carbon dioxide storage. This vast basin also possesses considerable geothermal resources (Jessop et al., 1991, Akto, et al., 2023) highlighting its potential for dual applications in carbon storage and clean energy production.

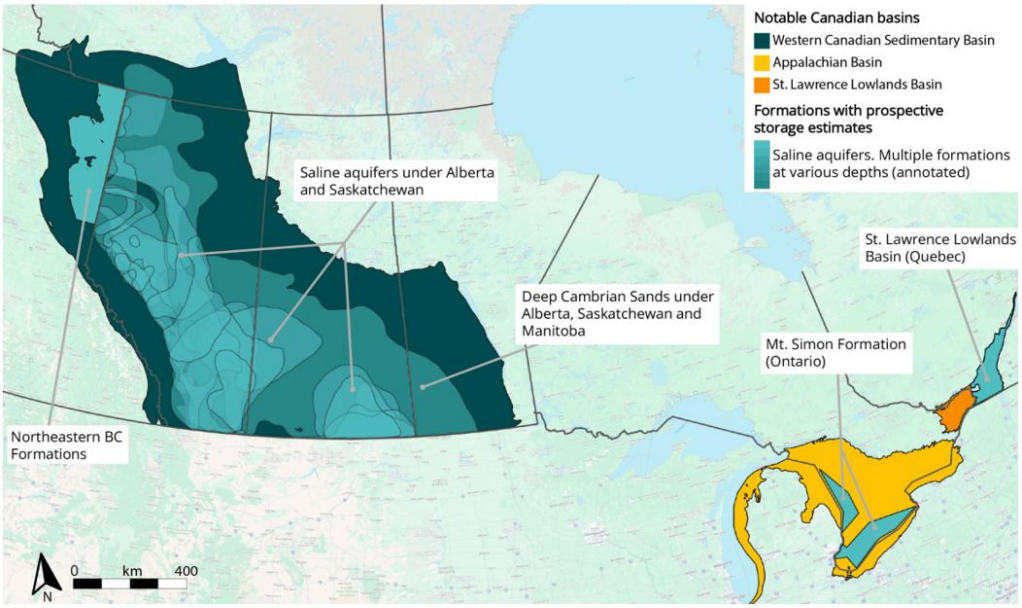

Figure 16: Canadian basins with potential reservoirs for carbon dioxide storage. Formations highlighted in blue represent deep saline aquifers evaluated for prospective storage capacity. *Source: Felder, M., Smith, J., & Zhang, L. (2024). Evaluating Carbon Storage Potential in Canadian Sedimentary Basins. Journal of Geological Studies, 58(3), 245-268.*

The national study by Felder et al. (Fig. 16) highlights that the Peace region of BC, with significant potential for carbon dioxide storage. In British Columbia, CCUS has been identified as an important strategy for reducing GHG emissions, aligning with federal policies on climate mitigation. To advance this approach, it is essential to thoroughly evaluate and characterize geological formations across the province for CO_2 storage potential.

Favourable geological conditions for CO_2 storage in BC are primarily associated with deep sedimentary basins, particularly in the Peace region. In addition, several geothermal anomaly zones—linked to sedimentary basins, volcanic systems, and fault-controlled fracture networks—may also offer carbon storage potential.

Figure 17 illustrates key regions in BC where geological conditions are considered favourable for CO_2 storage, based on surface indicators of deep-circulating thermal waters and regional geothermal anomalies (Ghomshei, 2010; Jessop et al., 1991). The Peace region in northeastern BC represents the most near-term opportunity for industrial CCUS deployment, given its extensive oil and gas activity, existing infrastructure, and subsurface data availability.

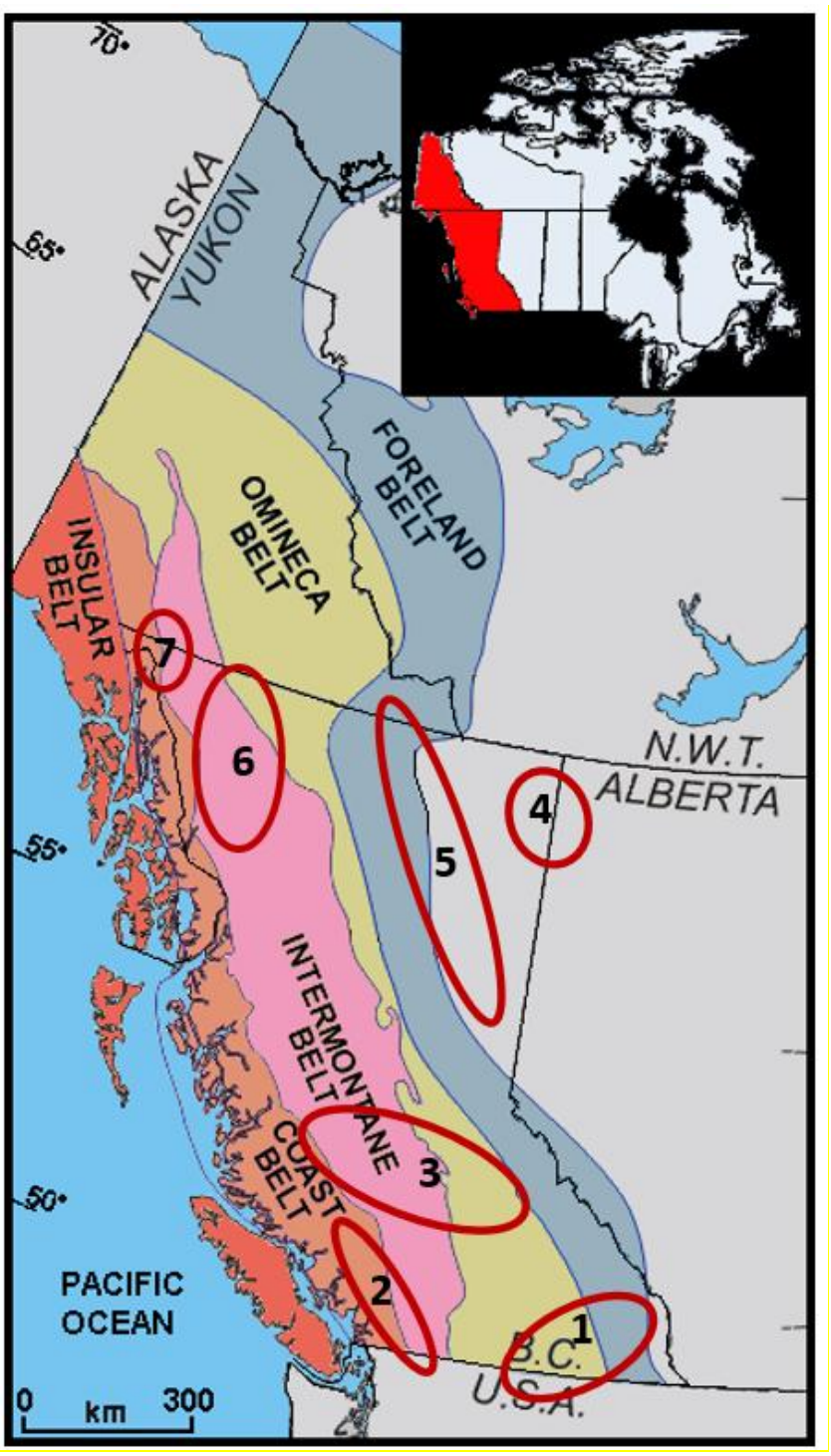

Figure 17: Prospective regions with elevated potential for geological CO_2 storage in BC. Prospective areas are overlaid on a base geological map adapted from the Northeast British Columbia Geological Carbon Capture and Storage Atlas (Canadian Discovery Ltd., 2023), prepared for Geoscience BC. Source: Canadian Discovery Ltd. (2023). *Northeast British Columbia Geological Carbon Capture and Storage Atlas*. Geoscience BC.

Seven regions in BC exhibit geological characteristics indicative of potential carbon storage capacity (Figure 17):

1. Okanagan to Kootenay Sedimentary Basins
2. Fraser Valley and Garibaldi Volcanic Belt
3. Anaheim Volcanic Belt and Interior Sedimentary Basins
4. Northeastern BC and the Western Canada Sedimentary Basin
5. Liard Basin and Northern Western Canada Sedimentary Basin
6. Stikine Volcanic Complex and Mount Edziza Volcanic Complex
7. Coast Plutonic Complex and Batholiths in Northwestern BC

As geothermal reservoirs are known to offer potential for the deep storage of CO_2, it is essential to explore all geothermal prospects in BC (Figure 18) as potential carbon storage sites. Injecting CO_2 into geothermal reservoirs can also enhance their energy productivity — a well-documented effect in oil and gas reservoirs but with the advantage that geothermal fields produce clean energy.

However, harnessing renewable electricity from geothermal sources requires the development of dedicated green power corridors to transport this energy to the main grid. These corridors could be integrated with CO_2 pipeline infrastructure, creating a dual-purpose system.

A First Nations-owned utility is recommended to facilitate carbon storage in geothermal fields across BC. Such a utility could trade CO_2 with industrial partners and green power (generated or stored) with the main grid, supporting both emissions reduction and clean energy initiatives. BC's high geothermal potential areas (Fig. 18) offer dual benefits for emissions reduction:

- Carbon-free energy production (heat and power)
- Permanent storage of CO_2

Deep geological basins, such as those in the Peace region, could be utilized primarily for CO_2 storage, with geothermal energy as a secondary byproduct. Conversely, high-grade geothermal sites could prioritize green energy production, using carbon storage as a complementary function.

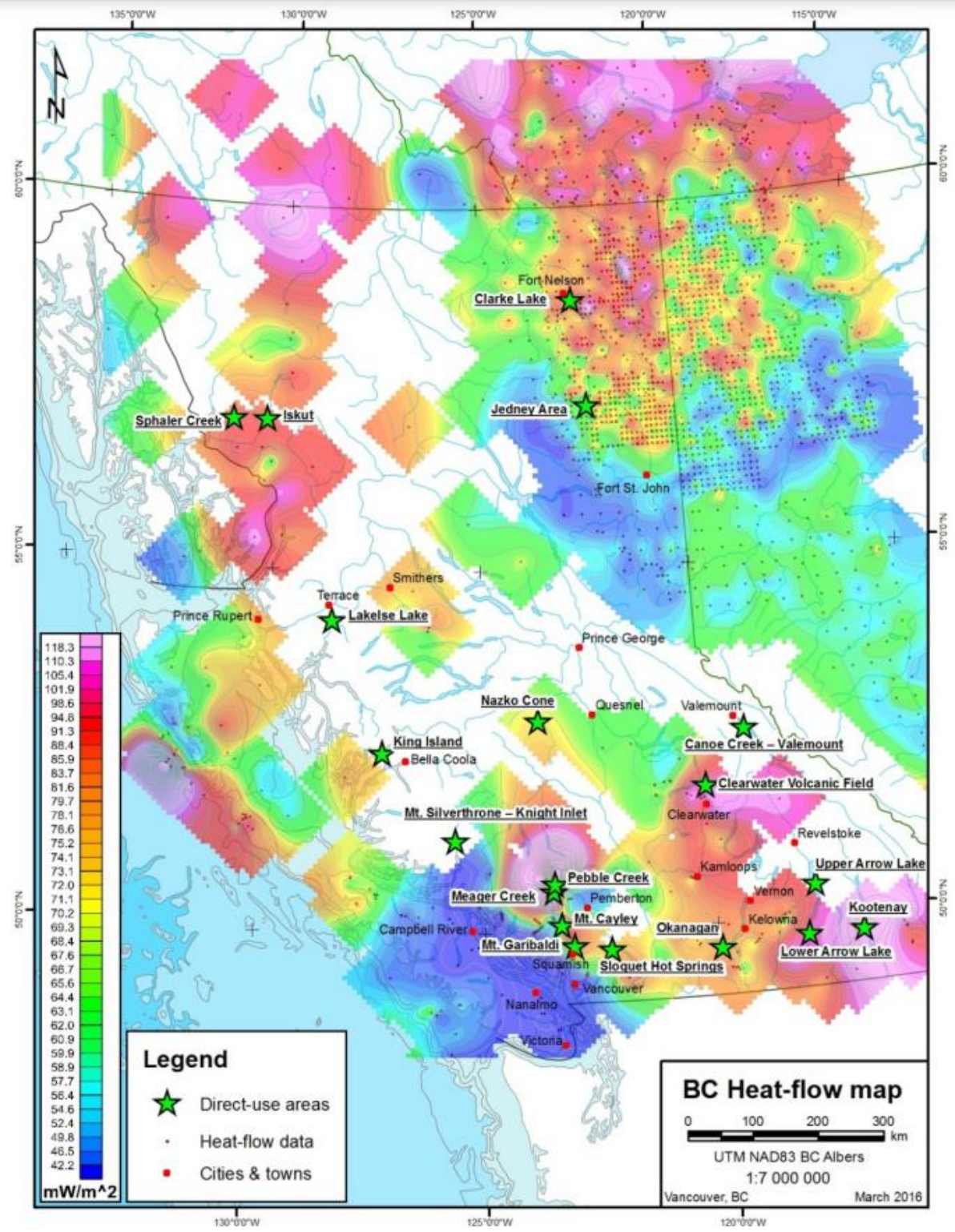

Figure 18: Areas in British Columbia with high geothermal potential. Detailed studies are recommended to identify optimal locations for carbon dioxide storage within these regions. *Source: Ghomshei, M., 2010. Geothermal Energy Resources in British Columbia. Journal of Renewable Energy Studies, 22(4), pp. 451–470.*

Northeast BC has a long-standing history of geological research and extensive subsurface data collection associated with oil and gas exploration and production. The Northeast BC Geological Carbon Capture and Storage Atlas, released in January 2023, leveraged existing oil and gas exploration datasets and well information to estimate a significant CO_2 storage capacity of approximately 4.2 billion metric tonnes within depleted oil and gas reservoirs and deep saline aquifers in the region.

At current industrial emission rates across BC, this storage capacity equates to over 300 years' worth of provincial industrial CO_2 emissions.

According to Felder et al. (2024), "of British Columbia's prospective geological storage capacity, 3,000 megatons (Mt) are located in the sparsely populated, mountainous northeast region of the province. Only about 1.2 Mt, or 20%, of provincial point-source facility emissions are situated near known prospective storage sites."

This disparity between storability and market proximity suggests that the practical application of CCUS in BC is currently limited unless additional basins are discovered and developed. Remote basins could still be used for carbon storage, but this would require the construction of long CO_2 pipelines, similar to Alberta's carbon dioxide pipeline project.

16.0 Government Support for Advancing Geoscience Research

The geological potential for carbon storage across British Columbia is not yet fully understood. To address this, the BC government is actively supporting geoscience research to close knowledge gaps and evaluate storage opportunities in basins throughout the province.

The research initiatives include three principal categories of sedimentary basins:

- Northeastern BC basins
- Interior basins
- Southwestern BC basins

The Ministry of Mining and Critical Minerals, in collaboration with the Government of Canada, First Nations, geoscience organizations, industry leaders, and academic institutions, is funding the following key projects:

1. Northeast BC Granite Wash Carbon Storage Assessment – Lead Agency: Geoscience BC
2. Central Interior BC Carbon Storage Assessment – Lead Agency: Geoscience BC
3. NEBC Geothermal- CO_2 Project – Lead Agency: Tu Deh Kah Geothermal
4. the Carbon Capture and Storage Assessment for the Lower Mainland is a collaborative research initiative led by Simon Fraser University (SFU), with funding from the Natural

Sciences and Engineering Research Council of Canada (NSERC) and the B.C. Ministry of Energy, Mines and Low Carbon Innovation.

The findings of these studies are disseminated by the respective lead agencies as the research progresses.

The outcomes of this initiative include:

1. A detailed report accompanied by high-resolution maps identifying key CO_2 sequestration candidates within NEBC.
2. A systematic classification of saline aquifers and nearly depleted natural gas pools with strong potential for CCUS.
3. The development of reservoir metrics and geological parameters essential for precise CO_2 storage capacity estimations.
4. Quantification of an estimated 4,230 megatonnes (Mt)of CO_2 storage potential within NEBC's geological formations.

Two areas of significant importance identified in the study are:

- Depleted reservoirs situated north and northeast of Fort St. John, as well as in the far northeast of the province.
- Deep saline aquifers located within the Dawson Creek–Fort St. John corridor and areas south of Fort Nelson.

The study distinguishes between storage capacity — reservoirs that are fully characterized and commercially viable — and storage potential, where geological conditions meet threshold criteria for suitability

A cornerstone of this project is the development of the Carbon Storability Atlas, which provides a detailed inventory of high-capacity areas, identifies sites with promising storage attributes, and offers preliminary quantification of CO_2 storage volumes at each site.

The overarching objective of this initiative is to integrate existing datasets—predominantly derived from natural gas exploration and production—into a comprehensive Northeast BC Geological Carbon Capture Map. This foundational resource will eventually support the creation of a province-wide geological CCUS map, aligning storage opportunities with high-emission point sources and contributing to BC's low-carbon transition strategy (Figures 19, 20, 21a, 21b,).

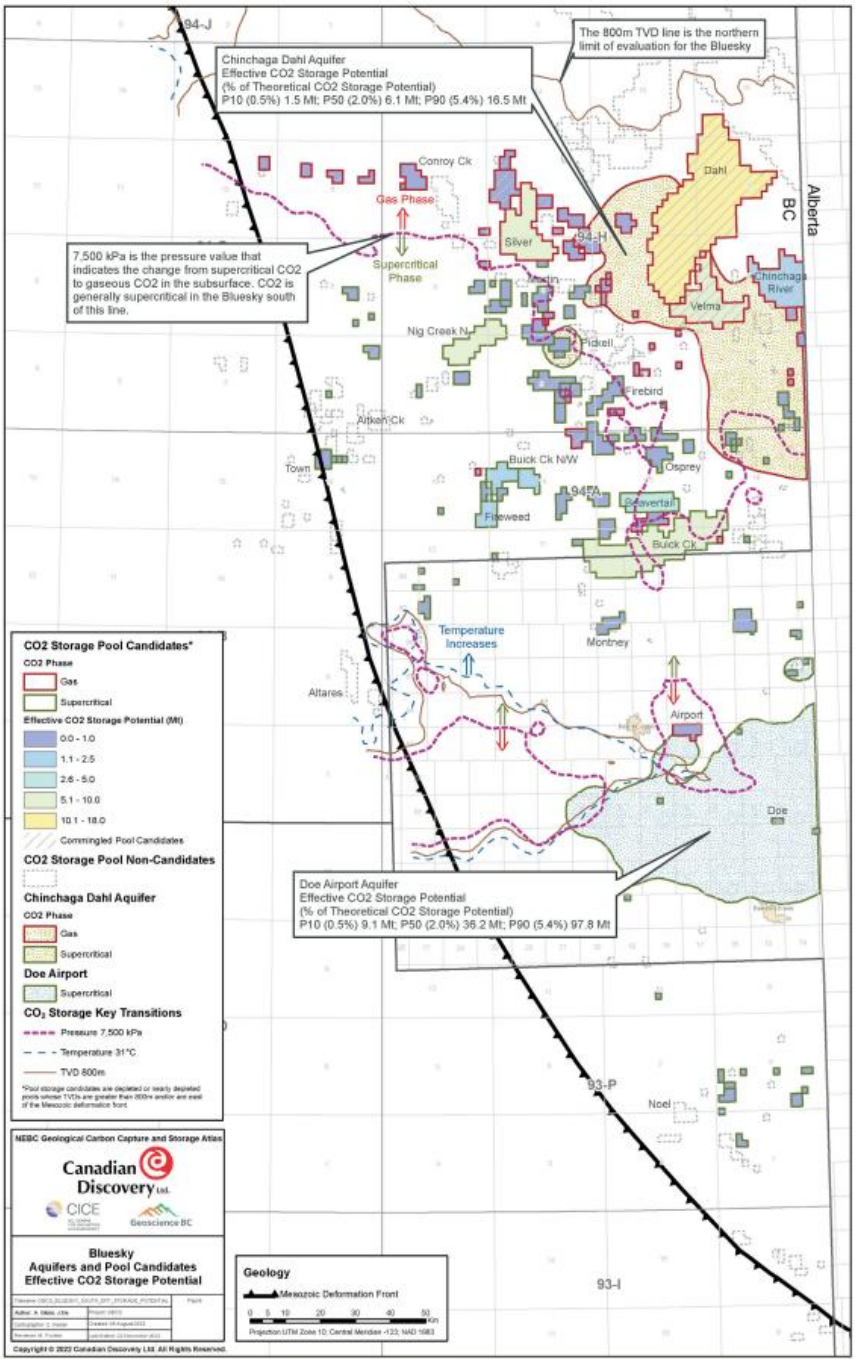

Figure. 19: Example map of candidate aquifers and depleted pools in Northeast British Columbia. The figure illustrates effective carbon dioxide (CO_2) storage potential mapped for selected geological formations, based on probability ranges (P10, P50, P90), pressure and temperature constraints, and reservoir characteristics. Source: *Northeast BC Geological Carbon Capture and Storage Atlas* (Canadian Discovery Ltd., 2023), prepared for Geoscience BC. After: Hughes, J. (2023). *Energy and Water State of Activity 2022*. https://cdn.geosciencebc.com/project_data/GBCReport2023-02/P2022-001_Hughes_EnergyWaterSoA2022.pdf

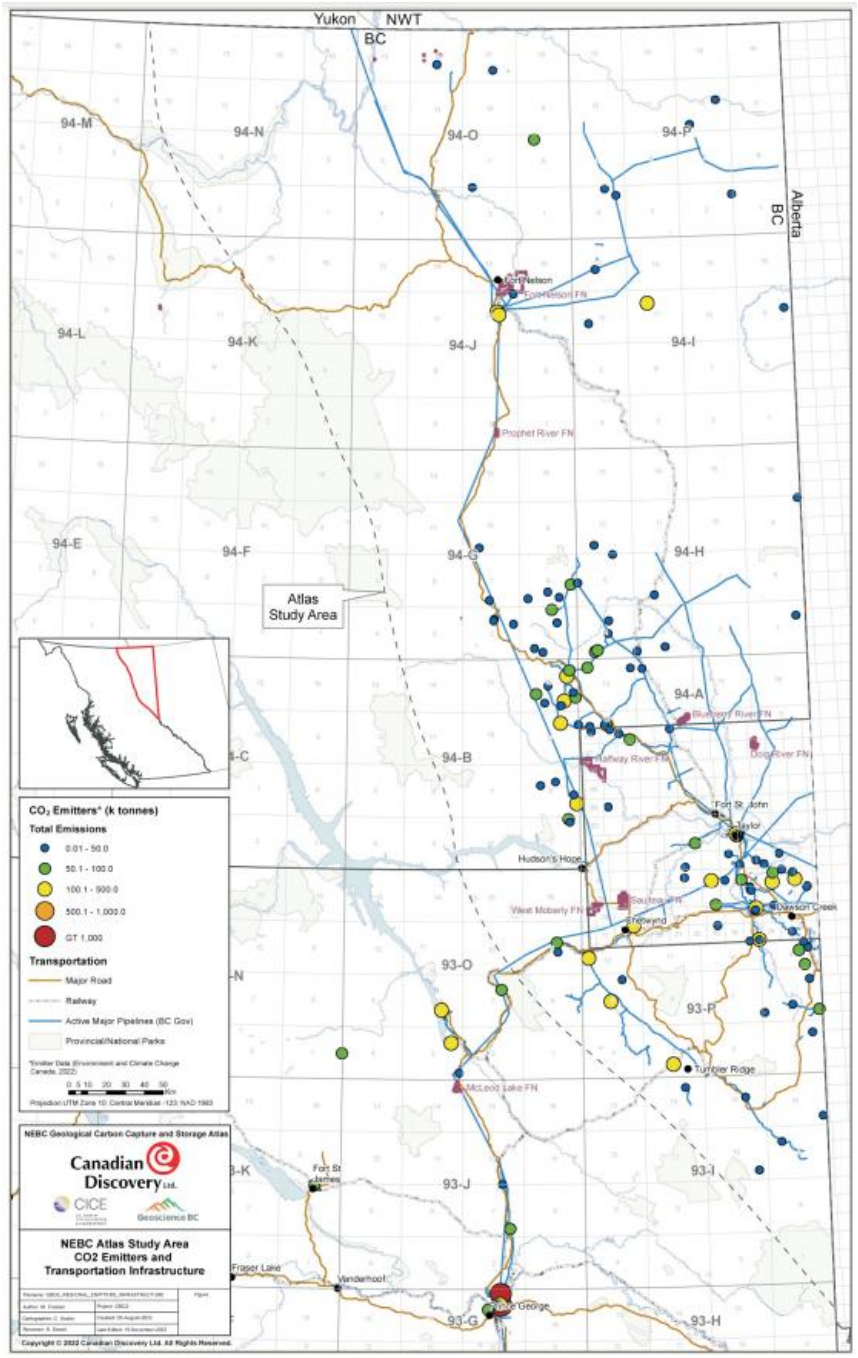

Figure 20: Map of Carbon Storage Opportunities in Northeast BC Geological Formations Adapted from Geoscience BC (Hughes, 2023), this map illustrates the study area for the Carbon Capture and Storage Atlas project. Carbon dioxide emitters are represented by colored circles, with the size and color of each circle corresponding to annual CO_2 emission volumes. Source: *Geoscience BC Report 2023-02, Hughes, J. (2023). Energy and Water State of Activity 2022*. Available at: https://cdn.geosciencebc.com/project_data/GBCReport2023-02/P2022-001_Hughes_EnergyWaterSoA2022.pdf

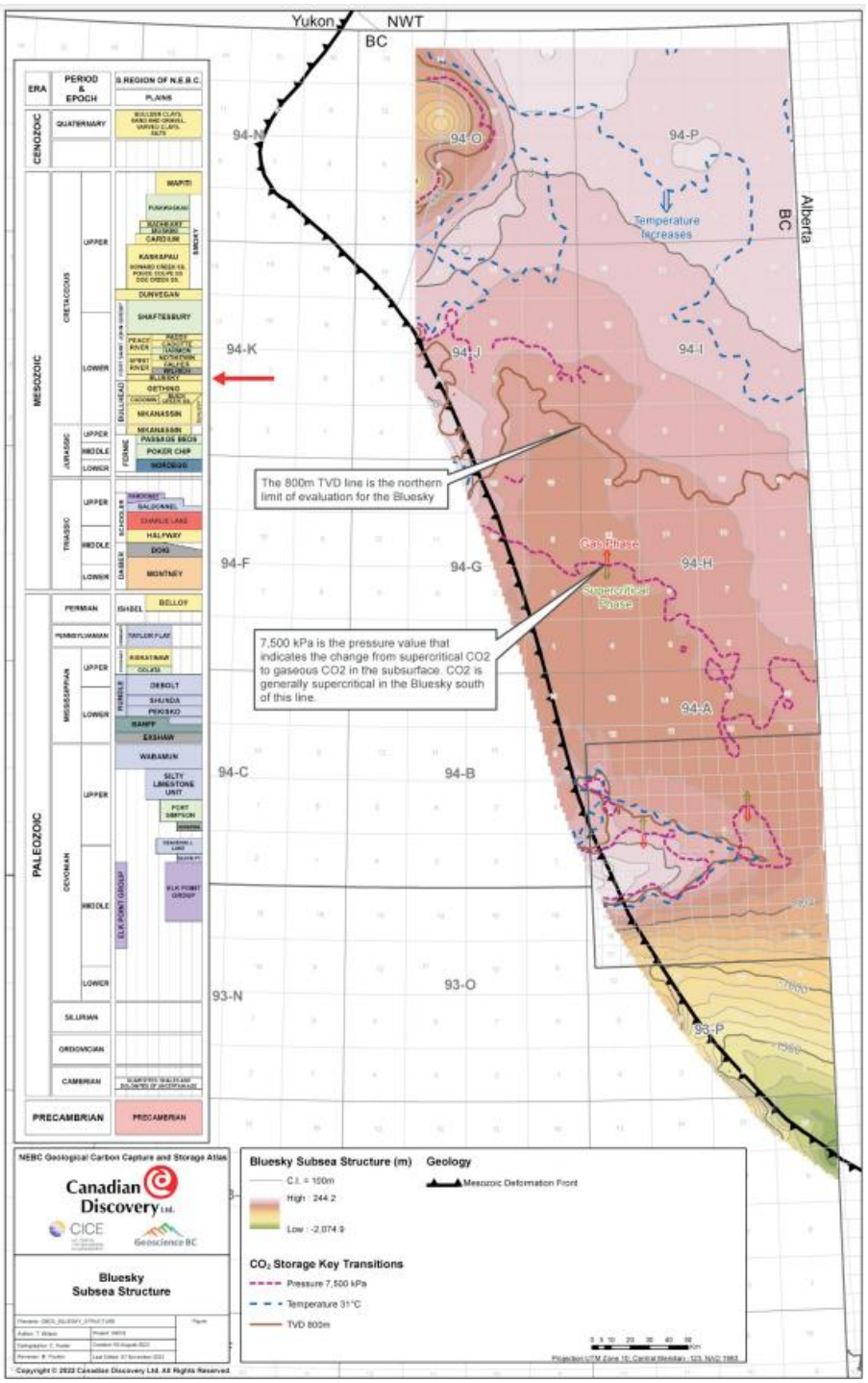

Figure 21a: Carbon Dioxide Storage Potential in BC's Peace Region
This map from the Northeast BC Geological Carbon Capture and Storage Atlas (Canadian Discovery Ltd., 2023) highlights CO_2 storage features, including 800 m depth, 31°C temperature, and supercritical conditions boundaries. Source**:** *Hughes, J. (2023). Energy and Water State of Activity 2022. Geoscience BC Report 2023-02.* Available at: https://cdn.geosciencebc.com/project_data/GBCReport2023-02/P2022-001_Hughes_EnergyWaterSoA2022.pdf

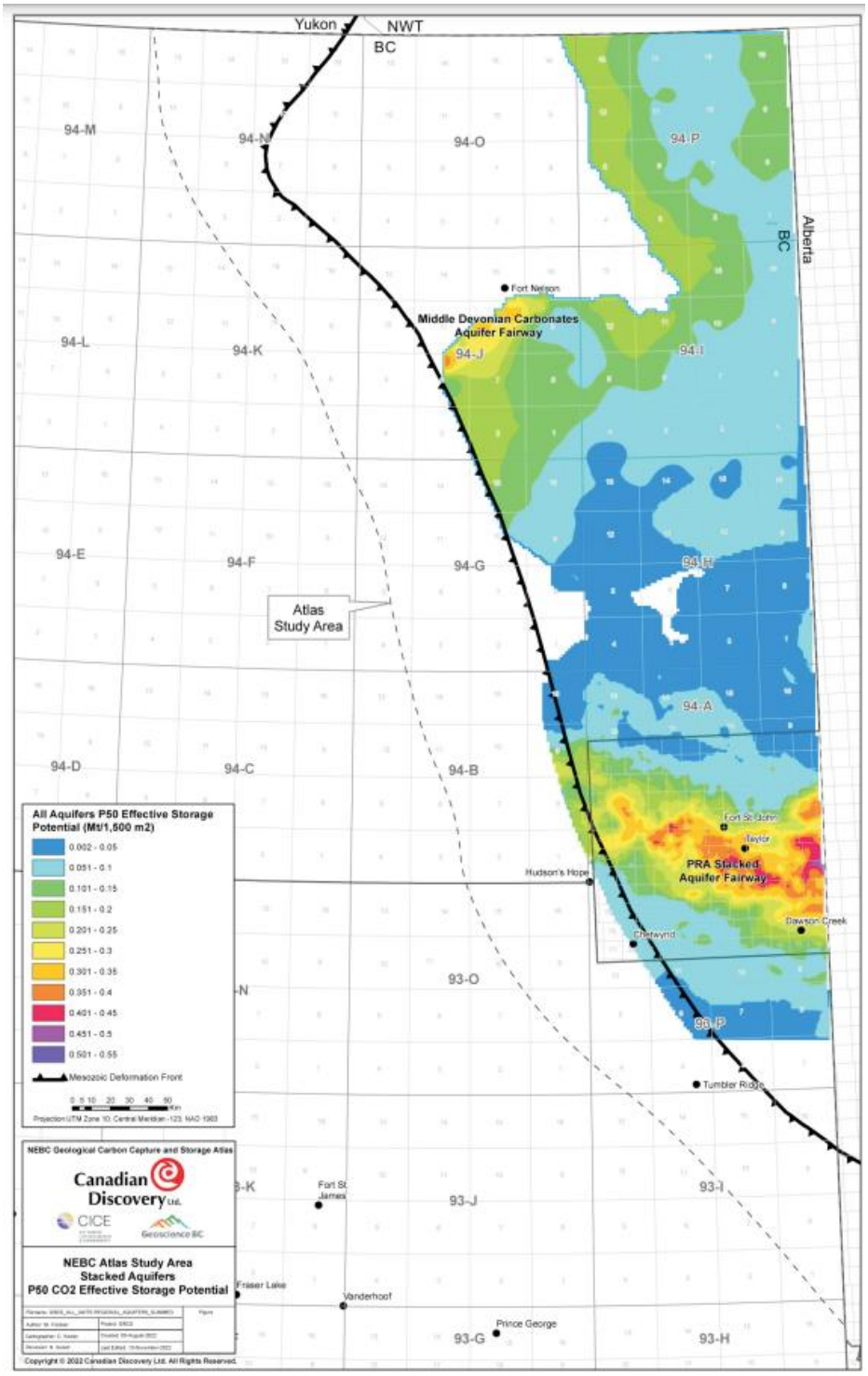

Figure 21b: Total Estimated CO_2 Storage Potential in Stacked Aquifers of Northeastern BC Adapted from Hughes (2023), this summary map illustrates the total effective CO_2 storage potential (P50 percentile) across 12 mapped formations in NEBC. Source**:** Hughes, J. (2023). *Energy and Water State of Activity 2022.* Geoscience BC Report 2023-02. Available at: https://cdn.geosciencebc.com/project_data/GBCReport2023-02/P2022-001_Hughes_EnergyWaterSoA2022.pdf

17.0 Carbon Economy

In a world driven by capital, environmental challenges must be reframed as economic liabilities to ensure they receive appropriate attention. By recognizing these issues as financial risks, they can be prioritized within economic decision-making frameworks.

Climate change significantly impacts the global economy. Its effects — such as heat waves, forest fires, and storms — undermine economic growth by damaging infrastructure, reducing labor supply, and decreasing productivity. These disruptions contribute to rising costs in critical sectors, including food, energy, and insurance. This phenomenon can be described as a unique type of inflation linked directly to global warming.

Evaluations of the economic consequences of rising temperatures suggest that climate change could exacerbate inflationary pressures through 2035. According to research by leading climate institutions, global warming uncertainties may contribute an additional 1–3% in inflation by 2035, with annual impacts estimated at 0.32–1.18 percentage points on average. These findings underscore the substantial role of climate change in exacerbating inflationary trends in the coming years.

The economic toll of extreme weather events has escalated dramatically. According to a report by the World Meteorological Organization and the World Economic Forum (2023), extreme weather is projected to cause economic losses amounting to several trillion dollars within the next decade. Over the past two decades, hurricanes, floods, heat waves, and other extreme weather events have already inflicted an estimated US$3 trillion in damages globally.

The World Economic Forum's Global Risks Report 2023 highlights the international economic system's struggle to effectively address climate change, particularly in monetizing the risks associated with its effects. Key insights from the report include:

- The global cost of climate change damages is estimated to range between US$1.7 trillion and $3.1 trillion annually by 2050.
- These costs encompass damages to infrastructure, property, agriculture, and human health.
- The financial burden is expected to grow as climate impacts become more severe over time.
- The world's poorest countries face the greatest economic risks from the impacts of climate change.

The World Economic Forum's *Global Risks Report 2025* identifies climate change as a dominant long-term global risk, with extreme weather events, biodiversity loss, and ecosystem collapse ranked among the highest-impact risks over the coming decade. Recent assessments cited by the WEF indicate that global economic losses from climate-related disasters regularly exceed US$100 billion annually, underscoring the scale and persistence of climate-related financial risk.

To mitigate these escalating costs, CCUS offers potential economic benefits, including job creation across engineering, construction, and operational phases, support for technological innovation, continued decarbonization pathways for hard-to-abate industries (such as steel and cement), the development of markets for CO_2-derived products, and the attraction of private and institutional investment aligned with long-term climate objectives.

For a realistic cost-benefit analysis, carbon-reduction initiatives should be evaluated within a circular-economy framework. The Circular Carbon Economy (CCE) is a holistic approach to greenhouse gas management that builds on the traditional circular-economy principles of Reduce, Reuse, and Recycle, with a fourth principle—Remove—explicitly applied to carbon. The CCE framework emphasizes retaining carbon within productive economic systems rather than releasing it as unmanaged waste, and explicitly incorporates technologies such as CCUS.

The circular carbon economy focuses on minimizing the volume of carbon requiring management, reusing carbon as a feedstock for fuels and materials, recycling carbon through biological and industrial processes, and—distinctively—removing and durably storing excess CO_2.

Achieving a circular carbon economy through CCUS depends on continued cost reductions, supportive policy frameworks, and coordinated infrastructure development. As international collaboration accelerates the deployment of carbon-management technologies and clean-energy systems, the CCE provides a practical framework to guide policy development, investment decisions, and long-term climate action.

17.1 Corporate Carbon Emissions: Costs and Opportunities

According to climate scientists, global carbon dioxide emissions must be significantly reduced to mitigate the effects of climate change. The Intergovernmental Panel on Climate Change estimates that limiting global warming to 1.5°C requires net anthropogenic CO_2 emissions to decline by 45% from 2010 levels by 2030, reaching net zero around 2050. For a 2°C limit, emissions need to drop by 25% by 2030 and reach net zero by 2070. Any temperature increase beyond these thresholds could result in increasingly unpredictable and hazardous consequences for ecosystems, societies, and the global economy. The urgency to intensify efforts against climate change is widely recognized, with the reduction of anthropogenic greenhouse gas emissions being the central focus.

Existing government policies alone are insufficient to tackle this challenge. Economic investment and innovative business models are critical to addressing the global climate crisis. Effective business models should not only support climate change mitigation but also deliver tangible economic benefits. Investments in clean energy technologies and climate innovation must be economically rewarding to ensure their sustainability over the long term.

The International Energy Agency projects that annual global investment in clean energy must rise to nearly $4 trillion by 2030 to achieve net-zero emissions by mid-century. A significant portion of this funding must come from the private sector. Viable economic models should incorporate the value of carbon as a resource, aligning emission reductions with business growth.

Many corporations are beginning to recognize that emission-reduction initiatives are not just ethical or regulatory obligations but also smart business strategies. Reducing GHG emissions offers companies opportunities to lower costs, enhance brand reputation, and gain a competitive edge in the market. These incentives, whether financial or reputational, are increasingly driving corporate actions to address climate change.

As the impacts of climate change become more frequent and severe, governments are introducing new policies and regulations to curb national emissions. These policies often employ a carrot-and-stick approach, combining penalties with incentives to motivate compliance. New regulations are designed to create both regulatory and economic motivations for transitioning to zero emissions through economically sustainable planning.

The United States and Canada are among the leading nations to set ambitious net-zero targets by 2050. The U.S. Department of Energy's 2022 report, Pathways to Net-Zero Greenhouse Gas Emissions by 2050, outlines the strategies required to achieve this goal (Figure 22). The report emphasizes the critical role of technologies such as CCUS in reducing emissions from industrial sources and power generation, making CCUS a cornerstone of the USA's net-zero strategy.

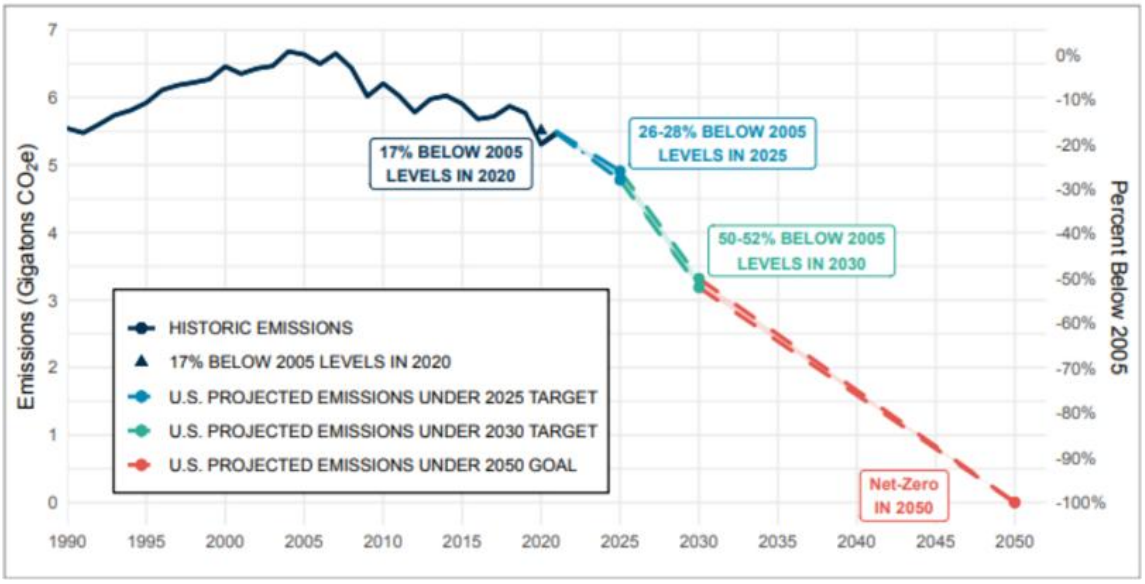

Figure 22: U.S. Pathway to Net-Zero Emissions by 2050. This graph shows the U.S. greenhouse gas emission reduction targets: 17% below 2005 levels by 2020, 26–28% by 2025, 50–52% by 2030, and net-zero by 2050. *Source: U.S. Department of Energy). Pathways to Net-Zero Greenhouse Gas Emissions by 2050. Published in 2022. Available at: The Long-Term Strategy of the United States: Pathways to Net-Zero Greenhouse Gas Emissions by 2050.*

Canada's commitment to significant carbon emission reductions began in 2020 and culminated in the release of the 2022 report, which outlined ambitious targets for 2030 and 2050 (Figure 23).

In March 2022, Canada unveiled its 2030 Emissions Reduction Plan, a comprehensive framework designed to guide the country toward its climate goals. Independent evaluations have identified key priority areas that require swift policy development and implementation to meet these targets effectively (Figure 23).

While the 2030 Plan is widely regarded as comprehensive and credible, its success hinges on the timely development and execution of supporting economic policies to ensure efficient implementation. Five policy areas are critical to achieving nearly two-thirds of the emissions reductions needed to meet Canada's 2030 milestone:

- Strengthening Canada's carbon pricing system
- implementing an oil and gas sector emissions cap
- adopting a Clean Electricity Standard
- developing policies to reduce land-use emissions
- enhancing the Clean Fuel Standard

Among these, the carbon pricing policy plays a pivotal role. By directly impacting the financial performance of large emitters, it creates a strong incentive for companies to adopt innovative solutions such as CCUS.

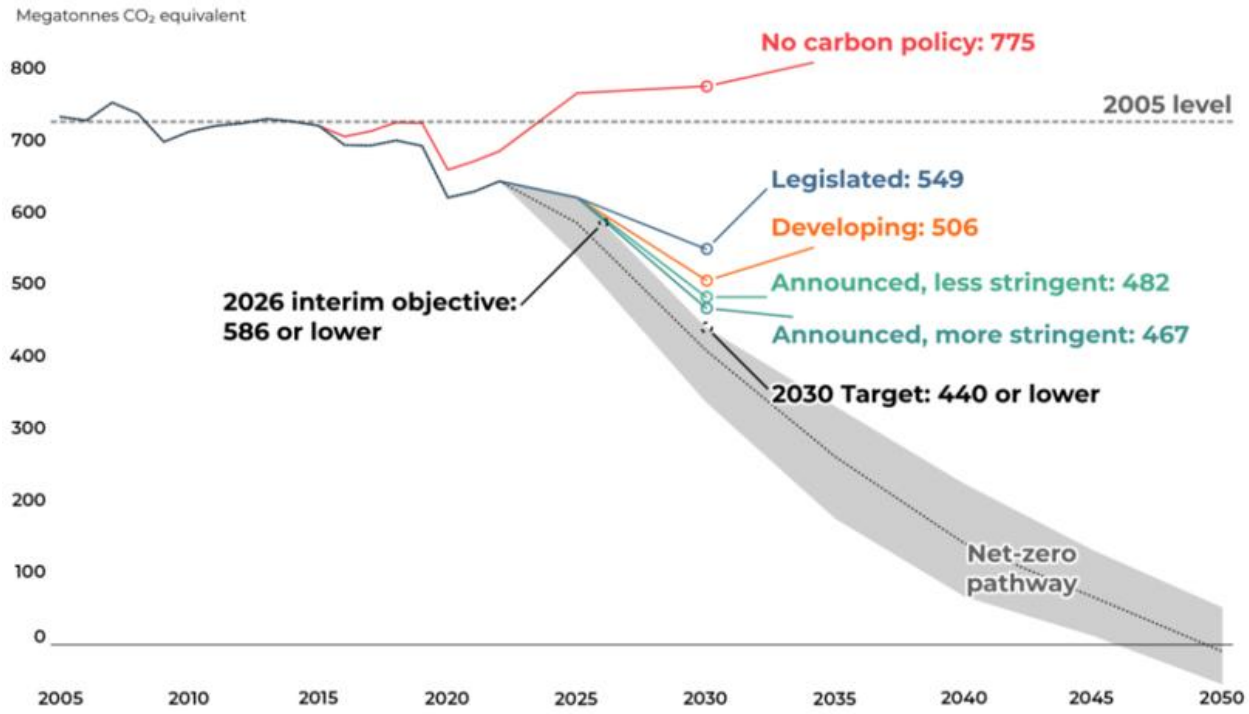

Figure. 23: Canada's Emissions Pathway to Net-Zero. Based on Canada Climate Institute's 2023 modeling, this graph outlines Canada's emissions reduction plan, highlighting interim objectives for 2026, the 2030 target, and the projected trajectory to achieve net-zero emissions by 2050. *Source: Canada Climate Institute, 2023. 2030 Emissions Reduction Plan. Available at: https://climateinstitute.ca/reports/2030-emissions-reduction-plan/*

Certain aspects of Canada's climate policies hold particular importance from an economic perspective, as they incentivize corporations to invest in emission reduction measures. According to the Canadian Climate Institute (2022), key policy areas include:

- "To make carbon pricing work better by increasing policy certainty, the government will explore approaches to de-risk private sector low-carbon investments through mechanisms such as carbon contracts."
- "Expanding on the contribution from the transportation sector, Canada will aim to reach 35 percent of medium- and heavy-duty vehicle (MHDV) sales being ZEVs by 2030."
- "A significant expansion in funding to support technology deployment and innovation necessary for achieving longer-term reductions."

These policies are vital as they provide direct economic incentives that benefit both corporations and society at large.

Canada's approach to fighting climate change involves a sector-by-sector framework, setting clear expectations for each sector's contribution to national emission reduction milestones. This

framework enables industries to align their business models and financial strategies with climate goals, facilitating proactive planning for medium- and long-term emissions reductions.

For instance, Canada's oil and gas sector — the largest contributor to national emissions — is tasked with delivering a 31% reduction in emissions by 2030. To meet this target, companies in the sector can develop plans in advance, adopting economic models and leveraging government incentives and carbon markets to achieve the desired reductions efficiently.

A successful corporate climate strategy relies on the value chain of carbon management. By assigning an economic price to emissions and providing incentives for reduction, corporations can incorporate emissions costs into their cash flows while benefiting from the positive financial impact of emission reduction activities. This approach enables companies to balance costs and gains over the lifecycle of their projects.

Robust accounting and reporting standards — particularly for Scope 3 emissions— are essential to provide companies with clear guidelines for calculating their GHG inventories, including indirect emissions throughout their value chains. The supply chain for CCUS represents a series of interconnected technologies aimed at achieving deep decarbonization, especially for high-emission industries like steel production, smelting, fertilizer manufacturing, and cement production.

Robust accounting and reporting standards — particularly for Scope 3 emissions — are essential to provide companies with clear guidelines for calculating their GHG inventories, including indirect emissions throughout their value chains. Scope 3 emissions refer to indirect emissions that occur as a result of activities from assets not owned or directly controlled by the company. These emissions are part of the company's broader value chain and often represent the largest share of a company's total emissions. Scope 3 includes emissions from sources such as:

- Purchased goods and services: Emissions from the production of materials and products bought by the company.
- Transportation and distribution: Emissions from the transportation of goods, both within and outside the company's operations.
- Waste disposal: Emissions from waste generated during company operations.
- Employee commuting: Emissions from employees traveling to and from work.
- Business travel: Emissions from travel undertaken for business purposes.
- Use of sold products: Emissions generated when a product is used by the customer.

The supply chain for CCUS represents a series of interconnected technologies aimed at achieving deep decarbonization, especially for high-emission industries like steel production, smelting, fertilizer manufacturing, and cement production.

Emerging decarbonization technologies are becoming increasingly economically viable in sectors like power generation and industrial heat production. These innovations enable carbon- and heat-intensive industries to transition toward net-zero operations without compromising efficiency or competitiveness. Beyond reducing emissions, CCUS offers significant economic benefits at the national level, including job creation in sectors most affected by emissions reductions, such as oil and gas, cement, and agriculture.

At a time when automation and artificial intelligence are reducing traditional job opportunities, emerging CCUS technologies may create well-paying roles, offering a vital economic boost to transitioning industries while supporting Canada's broader climate goals.

18. Economic Assessment of CCUS: Value and Opportunities for BC First Nations

The benefits of CCUS should particularly be directed to the communities most impacted by climate change. In British Columbia, First Nations communities have been heavily affected by the effects of climate change and should therefore stand to benefit from the growing CCUS economy.

By making their lands available for carbon storage, First Nations can play a critical role in the CCUS value chain. However, a comprehensive value chain analysis is essential to fairly assess and assign the value of First Nations' resources utilized for carbon storage. The CCUS value chain includes several stages and processes that require proper valuation. The key components are:

- Carbon capture
    - From the atmosphere
    - At the point of emission (e.g., industrial stacks)
- Carbon transportation
- Carbon injection into the ground for permanent storage
- Land value
- Monitoring value

The valuation of land for CCUS projects is complex and requires negotiation with landowners on a case-by-case basis. Unlike technology, the value of land (Lv) cannot be accurately estimated through simple economic costing models, as it depends on non-technical factors such as the relationship between landowners and their land.

While valuing CCUS technology is relatively straightforward, assessing land value is more intricate and requires a detailed value chain analysis to account for its significance as a carbon storage resource. A thorough economic assessment should allocate the overall carbon value across all processes within the value chain. The following equation provides a framework for this evaluation:

$$Ev = Cv + Tv + Iv + Lv + Mv$$

Where:

- **Ev:** Emission value (determined by government regulations or international carbon markets)
- **Cv:** Value attributed to capturing greenhouse gases
- **Tv:** Value attributed to transporting greenhouse gases
- **Iv:** Value attributed to injecting greenhouse gases into storage
- **Lv:** Land value (negotiated with landowners)
- **Mv:** Value attributed to monitoring the storage reservoir and associated lands

The emission value (Ev) is typically set by local governments. In BC, carbon tax policies and federal trading metrics can provide a benchmark for assigning a dollar value to Ev. This value is dynamic and changes over time. For accurate projections, the initial Ev should be estimated by forecasting the carbon price at the time the project begins operation.

Given the emission reduction targets for 2030 and 2050, the value of emissions is expected to increase over time. This anticipated rise should be integrated into the overall carbon value chain analysis.

While technological advancements may reduce the cost of CCUS processes, land value is unaffected by such improvements. Instead, land value is determined by factors independent of technology, such as the relationship between landowners and their land and alternative uses.

These factors must be carefully evaluated at the outset of every CCUS project, with an appropriate escalation rate negotiated to reflect long-term considerations. The escalation rate for land should account for two critical factors:

1. Potential land degradation
2. Alternative uses of the land

Any cash flow analysis for CCUS projects must incorporate a negotiated escalation rate for land value. This rate should reflect both the above factors and forecasted inflation (CPI), and it should be integrated into the project's overall financial modeling.

18.1 Basis for a Cash Flow Model for First Nations' CCUS Projects

A life-cycle cash flow model for CCUS projects should be customized to each specific project, incorporating validated economic parameters and site-specific conditions.

The costs of CCUS vary significantly based on the type of capture process. Capture technologies can be expensive, particularly depending on the characteristics of the facility capturing the gas. For example, Direct Air Capture is the most expensive method and is typically not used by

carbon-intensive plants due to its high costs. Most emission-intensive facilities capture carbon directly from their stacks at a relatively low cost, often less than $50 per tonne.

Capital costs for CCUS projects depend heavily on geographical and geological factors as well as the required infrastructure for transport and storage. One of the most critical components is the transportation of carbon dioxide to a deep storage site, which often necessitates constructing pipelines between the capture facility and the designated storage location.

The selection of a deep storage site is determined by geological and hydrogeological characteristics, which may result in a significant distance from the emission source. Consequently, the length and flow capacity of the pipeline play a substantial role in determining transportation costs.

Pipeline and Compression Costs

To maximize storage efficiency, carbon dioxide must be compressed into a dense phase (>74 bar) for transportation and storage. Compression into the dense phase reduces transportation costs compared to gas-phase transport by maximizing the use of available storage capacity. CO_2 compression costs include two main components:

- Capital costs for compressors and associated equipment
- Energy costs to power the compression process

Energy costs scale proportionally with the flow volume, meaning that doubling the flow doubles the energy consumption. This creates a trade-off between the capital costs of pipeline construction and the energy costs associated with compression.

To align with sustainability goals, clean energy sources should be used for gas compression, whether for transportation or injection. This creates a synergy between renewable energy generation and carbon storage. In British Columbia, geothermal energy offers a natural complement to CCUS projects, as many carbon storage sites overlap with medium- or high-grade geothermal resources. A cash flow model is essential to optimize project costs, particularly for compression. BC's clean and cost-effective electricity allows for higher levels of compression, reducing overall transportation costs.

Additionally, economies of scale can reduce the capital costs of compression equipment. For example, commercial CO_2 compression systems are available with maximum power ratings of approximately 40 MW. For larger volumes of CO_2 (e.g., over 3 Mtpa), multiple compression trains may be required (Kearns et al., 2021).

A cash flow model serves as a framework for evaluating the costs and benefits of CCUS projects involving First Nations, particularly for future initiatives. This framework provides an economic basis to support negotiations between First Nations and industry stakeholders. The following

parameters are suggested for the cash flow model to provide an economic framework for First Nations CCUS projects:

Parameter	Value (Range)
Project Life	20 to 40 years
Carbon Injection Rate	1 to 10 Megaton per year (metric ton)
Carbon Storage Value	60 to $100 per tonne
Carbon Value Escalation	3% - 5% per year
Initial Land Value	To be negotiated as CAPEX item
Inflation (CPI)	1% - 3% per year
Total CAPEX	To be assessed for each project
Royalty for Landowner	10% - 20 % of carbon transfer and storage value (to be negotiated)

These parameters provide a framework for assessing the economic potential of CCUS projects and supporting negotiations between First Nations and industry stakeholders. The value ranges presented are indicative and should be adjusted on a case-by-case basis to reflect the specific economic and geological conditions of each project.

First Nations can leverage the initial value of their land as an investment in the project, enabling them to secure a return on investment (ROI). Alternatively, the initial land value may be compensated by the industry proponent to First Nations in the form of royalties. In both scenarios, the land value is considered part of the capital expenses (CAPEX) within the cash flow model.

In addition to land value and gas transportation, two major capital cost items are:

1. Drilling Costs:
    - Estimated at $1 million to $4 million per well, depending on reservoir characteristics.
    - The number of wells required should be determined through project-specific modeling.
    - For deep or directional wells, costs could be double or triple the baseline estimates.
2. Gas Injection and Monitoring Facilities:
    - Costs typically align with drilling expenses.

- These costs vary based on the injection rate and specific project requirements.

Note that the cost of drilling is controlled by three factors:

1. The type of rocks (lithology).
2. The depth of the carbon storage reservoir.
3. Well completion and wellhead equipment.

Harder rock formations result in higher drilling costs. For soft sedimentary rocks, such as those in the Western Canadian Sedimentary Basin, the drill rate is higher compared to drilling in formations elsewhere in British Columbia. The depth of the reservoir also strongly influences drilling costs. Deep and long wells require heavy-duty drilling rigs, significantly increasing costs. Shallower reservoirs, on the other hand, can be accessed at much lower costs.

Well completion, which includes the casing and wellhead equipment, is another critical cost factor. The completion and monitoring system can add substantially to capital costs. Currently, there are no regulations in BC governing the completion and monitoring of carbon dioxide injection wells, although underground storage is regulated under the Petroleum and Natural Gas Act.

Given the site-specific geological and engineering complexity of carbon storage projects, generic cost assessments have limited applicability. Early-stage cost estimates, however, often reference oil and gas drilling costs as a baseline, given the similarity in drilling depth, casing requirements, and pressure conditions.

In the Canadian onshore oil and gas sector, drilling costs vary depending on geology, well depth, trajectory, and logistical complexity. For wells drilled to approximately 3,000 metres vertically with an additional 3,000 metres of horizontal section, total drilling costs commonly range from approximately $3–5 million, depending on formation characteristics and operational conditions.

While hydraulic fracturing can add an additional $2 – 4 million to oil and gas well costs, it is generally not required for dedicated geological carbon storage reservoirs, which can reduce overall project capital costs relative to unconventional oil and gas developments.

For carbon dioxide storage wells, drilling costs may be lower than those for oil and gas wells, as fracking is unnecessary. However, well completion costs, including specialized casing to prevent gas leakage into aquifers, can add significantly to overall costs. Heavy-duty wellhead equipment, capable of handling very high pressures, can cost $1 million or more per well.

Another significant cost is the rig mobilization and demobilization (mob/demob). This one-time expense depends on the distance from the nearest rig to the site and can exceed $1 million per rig. Mobilization costs double if two rigs are required to develop the well field.

Carbon value escalation should be assessed using historical carbon tax data specific to each jurisdiction. In British Columbia, escalation rates have historically ranged between 3% and 5%, based on data from the past decade.

Royalties for First Nations should be negotiated on a project-by-project basis. A baseline value can be derived from royalty rates applied to oil and gas projects, typically ranging from 10% to 20%. However, the royalty for carbon storage should be higher than that of oil and gas, given that carbon storage reservoirs do not generate wealth but instead mitigate liabilities.

In the oil and gas sector, the BC government announced a new royalty system in May 2022, which balances economic development, fair resource returns, and environmental protection. This system will take effect on January 1, 2027. Similarly, royalties for carbon storage should reflect a balance between emission reduction goals, environmental safeguards, and a fair return on CCUS investments.

The project life for cash flow analysis is proposed to range between 20 and 40 years. While 20 years represents the minimum duration needed to justify investments in drilling and infrastructure, the actual project life may extend much longer, allowing for the renewal of agreements after 20 years.

The actual life of the project (LoP) is determined by factors such as land storability and the sustainable rate of carbon injection, which is proposed to range between 1 and 10 megatons per year. The lifespan of carbon storage reservoirs should be evaluated on a case-by-case basis using advanced geological and hydrological models.

For reservoirs with limited storage capacity, the injection rate must align with the reservoir's ability to sustain a project life of 20 years or more. It is important to note that increasing the injection rate typically shortens the lifespan of the reservoir. To maximize the project life and justify high drilling costs, the injection rate should be maintained at a sustainable level.

It is also critical to distinguish between the life of the project and the life of the injection wells. The injectivity of wells typically decreases over time due to rising reservoir pressure. While a single gas injection well may have a useful life of approximately 10 years, the overall project life can span 30 years or more. In such cases, wells need to be replaced (or renewed) every 10 years.

The cost of replacement wells (referred to as make-up wells) should be treated as part of the operating costs. These costs, including drilling and completion, should be amortized over the well's lifespan and incorporated into the operating expense line items. The value of CCUS is shaped by the supply chain, technologies, and resources utilized at each stage of the emission reduction process, including both upstream and downstream activities. The engagement of First Nations adds value across all stages of CCUS, enhancing project outcomes.

The total value of CCUS is the sum of the added value at each stage of being capture, transport, utilization and storage. A cash flow model for each CCUS project should incorporate the contributions made by First Nations and translate these into a tangible ROI.

19.0 Engagement Policies for First Nations – Approaches to Participation in Projects

BC is home to 204 First Nations, representing the most culturally and linguistically diverse aboriginal population in Canada. Each First Nation has a distinct history, heritage, and way of life. This diversity is reflected in their social organization, governance systems, approaches to business, relationships with resources, and socio-economic priorities.

Engagement with First Nations in industrial or environmental projects must respect these unique conditions and interests. When partnering with First Nations, industries should base their engagement plans on shared interests and active participation in decision-making processes regarding land use. This principle is especially relevant for projects involving land use for carbon storage.

First Nations of BC should play a leading role in efforts to address climate change. Carbon storage, as one of the most effective tools for mitigating climate change, demands meaningful engagement with First Nations to ensure these projects are efficient, sustainable, and impactful in significantly reducing the province's carbon dioxide emissions. As landowners, First Nations in British Columbia should actively participate in carbon storage projects. Their engagement can extend beyond land use to include carbon transport (via pipelines) and carbon capture at emission sources.

Under the federal government's 2030 emissions reduction plan, $29.6 million has been allocated starting in 2022-2023 over three years to advance an Indigenous Climate Leadership Agenda. This funding supports self-determined action on First Nations' climate priorities, including phased implementation of projects (Environment and Climate Change Canada, 2024).

As guardians and stewards of ecosystems, First Nations in BC have already taken significant steps to reduce greenhouse gas emissions. Building on these efforts, their leadership and knowledge are critical in carbon storage, where land is a key resource. First Nations in BC are already owning and managing numerous renewable energy projects across the province. It is equally important to support their leadership in the carbon sequestration sector, which is vital to achieving BC's legislative goal of reducing GHG emissions by 40% below 2007 levels by 2030.

Supporting remote First Nations communities in developing carbon storage projects is also essential to fostering economic self-sufficiency by enabling them to benefit from these initiatives. The Governments of Canada and BC are committed to strengthening Nation-to-Nation and Government-to-Government relationships with First Nations, in alignment with the

United Nations Declaration on the Rights of Indigenous Peoples. This commitment emphasizes the principle of free, prior, and informed consent.

Engagement with First Nations should, therefore, be framed within partnerships built on collaboration and mutual respect. Such partnerships must be constructed at three interconnected levels:

- Political/legal
- Economic/financial
- Socio-environmental

At the political and legal level, engagement policies must align with the principles of United Nations on the Declaration of the Rights of Indigenous Peoples and Canadian constitutional aboriginal and treaty rights. Court rulings affirm that aboriginal rights encompass practices, customs, or traditions integral to the unique cultures of First Nations, often tied to specific lands. This connection to the land reflects both economic rights and environmental stewardship, highlighting the importance of meaningful engagement.

Engagement strategies at the political level should be guided by the evolving relationship between provincial and federal governments and First Nations. This relationship must include shared decision-making authority on land rights and permitting processes. BC should adopt an inclusive and collaborative approach to land and resource management, integrating First Nations' sustainability priorities and traditional knowledge.

The Province's engagement with First Nations should be supported by both treaty and non-treaty agreements, which can serve as templates for similar arrangements in carbon storage projects. Industry proponents must proactively understand existing agreements or arrangements between First Nations and governments at the earliest stages of project development. These agreements significantly influence project factors such as permitting timelines, land use, and revenue-sharing mechanisms.

Revenue-sharing agreements should ensure that First Nations receive a substantial share of revenues generated from carbon credit sales, acknowledging their inherent rights over their lands. These agreements should be designed to reflect First Nations' legal and cultural connection to their territories.

At the economic level, First Nations' engagement strategies should establish a foundation for benefit-sharing agreements that create a robust economic framework for their participation in project development and related industries. First Nations' land rights include permitting authority for land uses, such as carbon storage, which must respect their role as environmental stewards.

Given the critical role of First Nations in environmental stewardship, new regulations, guidelines, and standards for carbon storage must be developed in partnership with First Nations.

Benefit sharing agreements should reflect their unique legal rights and emerge from open, transparent negotiations.

At the legal level, it is vital to define specific rights for land use in carbon dioxide storage. While BC currently has rights frameworks for minerals, oil and gas, and geothermal resources, a distinct legal framework for carbon storage is required, founded on respect for First Nations' land rights.

Since deep carbon storage projects typically begin with exploration for suitable geological formations, industry proponents must obtain exploration permits through a specialized process directed by First Nations. Existing permitting frameworks, such as BC's Petroleum and Natural Gas Act, can serve as models for creating a permitting system tailored to carbon storage projects.

A steering committee composed of First Nations representatives, legal experts, and government officials should be established to develop a comprehensive legal framework for carbon storage. The committee's primary responsibilities should include:

1. Recognition and protection of First Nations' land rights.
2. Development of a permitting process for deep carbon storage.
3. Regulations for well completion to ensure safety and environmental integrity.
4. Establishing rigorous monitoring systems for wells and well fields.

Strict monitoring protocols are essential to prevent potential groundwater contamination from gas injection. These protocols should be developed collaboratively with First Nations, the BC Energy Regulator, and the Ministry of Water, Land, and Resource Stewardship.

Canada's climate plan, "A Healthy Environment and a Healthy Economy" (Government of Canada, 2020), underscores the foundational role of First Nations climate leadership. Its principles include:

- Recognizing the unique realities, needs, and priorities of First Nations.
- Respecting and advancing self-determination.
- Ensuring early and meaningful engagement.
- Embedding inclusiveness and co-development in all climate actions.
- Creating space for First Nations' voices in governance and decision-making.

- Incorporating traditional knowledge, local expertise, and First Nations' science equally in policy and program development.

Carbon Capture and Sequestration Protocol: Regulatory Alignment with First Nations Engagement Principles

In August 2025, the Province of British Columbia approved the Carbon Capture and Sequestration (CCS) Protocol under the *Greenhouse Gas Industrial Reporting and Control Act*

(GGIRCA).[10] The CCS Protocol establishes a standardized framework for quantifying greenhouse gas emission reductions and removal enhancements associated with carbon capture and sequestration projects in the province.

The CCS Protocol applies to projects that permanently sequester captured carbon through either injection and long-term storage within a geological storage complex or through chemical transformation into stable compounds capable of durable carbon storage. By defining eligibility criteria, accounting methodologies, and permanence requirements, the Protocol provides regulatory clarity for proponents seeking to implement carbon sequestration projects in British Columbia.

A key function of the CCS Protocol is to enable direct financial incentives through British Columbia's carbon offset and compliance system, particularly in cases where existing regulatory mechanisms or incentive programs do not fully recognize emission reductions or removals. In this context, the Protocol supports the integration of carbon sequestration into the province's broader carbon management framework, including industrial emissions regulation and offset market development.

Importantly, the CCS Protocol was developed through multiple consultation periods and in partnership with the First Nations Leadership Council Technical Working Group on Climate Change**,** in collaboration with the B.C. Assembly of First Nations. The finalized Protocol explicitly affirms the Province's obligations under section 35 of the Constitution Act, 1982, the Declaration on the Rights of Indigenous Peoples Act, and a distinctions-based approach that recognizes the diverse governance systems, legal traditions, and territorial relationships of First Nations in British Columbia.

These provisions emphasize the importance of Indigenous rights, consultation, and co-development in the implementation of carbon sequestration projects. For First Nations and project proponents, the finalized CCS Protocol provides greater certainty regarding regulatory expectations, engagement processes, and the role of carbon sequestration within British Columbia's evolving climate policy framework.[11]

20.0 Carbon Storage Market for BC Deep Storage Sites

British Columbia is powered by clean and emission-free electricity. The province's power is primarily derived from hydro, which does not involve direct emissions. Yet, reservoir-based

[10] Government of British Columbia. *Carbon Capture and Sequestration Protocol* (approved August 6, 2025), established under the *Greenhouse Gas Industrial Reporting and Control Act*. https://www2.gov.bc.ca/gov/content/environment/climate-change/industry/offset-projects/offset-protocols

[11] Government of British Columbia. *Carbon Capture and Sequestration Protocol: What We Heard Report (2025).* https://www2.gov.bc.ca/assets/gov/environment/climate-change/offsets/offsets-portfolio/ccsp_what_we_heard_report_2025.pdf

hydro projects (such as Site C) emit significant amounts of carbon dioxide due to the cement used in dam construction.

For this reason, BC's emissions are mostly related to transportation and industries such as oil and gas, cement factories, and agriculture. Figures 24, 25, 26, and 27 illustrate the reported industrial sources of emissions in BC.

The GHG Reporting Program requires all facilities that emit the equivalent of 10,000 tonnes (10 kilotons) or more of GHGs (in carbon dioxide equivalent units) per year to submit a report to Environment and Climate Change Canada. Facilities with emissions below 10 kilotons per year may voluntarily report their GHG emissions. Based on the reported data, the market for carbon storage is expected to grow rapidly, considering the following facts:

- Total greenhouse gas (GHG) emissions in 2021 in BC were 62 million tonnes of carbon dioxide equivalent (Mt CO2e). This represents a 1% increase in gross emissions since 2020, a 4.9% decrease in gross emissions since 2019, and a 2.8% decrease in gross emissions since 2007—B.C.'s baseline year for assessing reductions in GHG emissions.

- B.C. has set targets for reducing GHG emissions over the next 26 years. The targets are a 40% reduction by 2030, a 60% reduction by 2040, and an 80% reduction by 2050, compared to 2007 levels. To keep BC on track, an interim target for reducing GHG emissions by 16% from 2007 levels has been set for 2025 (Fig. 26a).

- Different gases contribute to the total GHG emissions reported over time. The gases released in 2021 were carbon dioxide (84.3% of total emissions), methane (10.5%), nitrous oxide (2.6%), hydrofluorocarbons (2.5%), and perfluorocarbons (0.1%).

- Government emissions data from 2022 indicates that B.C.'s industrial reporting operations emitted 18.74 Mt CO_2e, excluding 12.36 Mt CO_2e from biomass as classified under Schedule C of the Greenhouse Gas Emission Reporting Regulation (BC Reg. 249/2015).

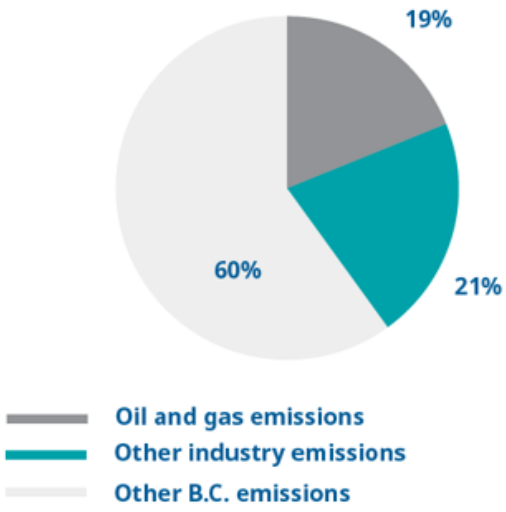

Figure 24: Greenhouse Gas Emissions by Sector in British Columbia. *Source: Government of British Columbia. "Greenhouse Gas Emissions by Sector." CleanBC - Industry Drivers, https://cleanbc.gov.bc.ca/about-climate-change/drivers/industry/.*

After carbon dioxide, methane is the second-largest contributor to GHG emissions in BC, originating from various sources.

In the oil and gas sector, methane emissions primarily result from intentional or unintentional releases into the atmosphere or combustion processes. While combustion emissions, such as flaring, are less harmful than direct methane releases, the greenhouse effect of one ton of methane is equivalent to 28 tons of carbon dioxide. To mitigate these impacts, burning methane when direct release is unavoidable is recommended, particularly when combined with carbon storage technology.

A highly effective solution for the oil and gas industry is converting flare gas into electricity and capturing the resulting carbon dioxide for underground storage. This approach can significantly reduce emissions. Similar strategies can be applied to landfills to minimize methane emissions. In BC, oil and gas emissions are concentrated in the northeastern region (the Peace region), where geological formations provide substantial potential for carbon dioxide storage.

The transportation and fossil fuel sectors are the largest sources of GHG emissions in BC. Key contributors include large passenger vehicles, trucks, heavy-duty trucks, and rail. However, transportation emissions do not offer a direct market for carbon storage. The most effective strategy for reducing these emissions is electrification. Electricity generation from renewable natural gas or methane from oil and gas — integrated with carbon storage systems — can indirectly support the energy needs for transportation electrification.

BC’s extensive geothermal resources present another opportunity to reduce transportation emissions. By leveraging these resources for dual purposes — carbon storage and power generation — green geothermal energy can be produced to support electrification. Industries, which account for 40% of BC's GHG emissions, represent a significant market for carbon capture and storage. Many industrial operations can adopt CCUS technology to achieve their emissions reduction targets, further supporting BC's climate goals.

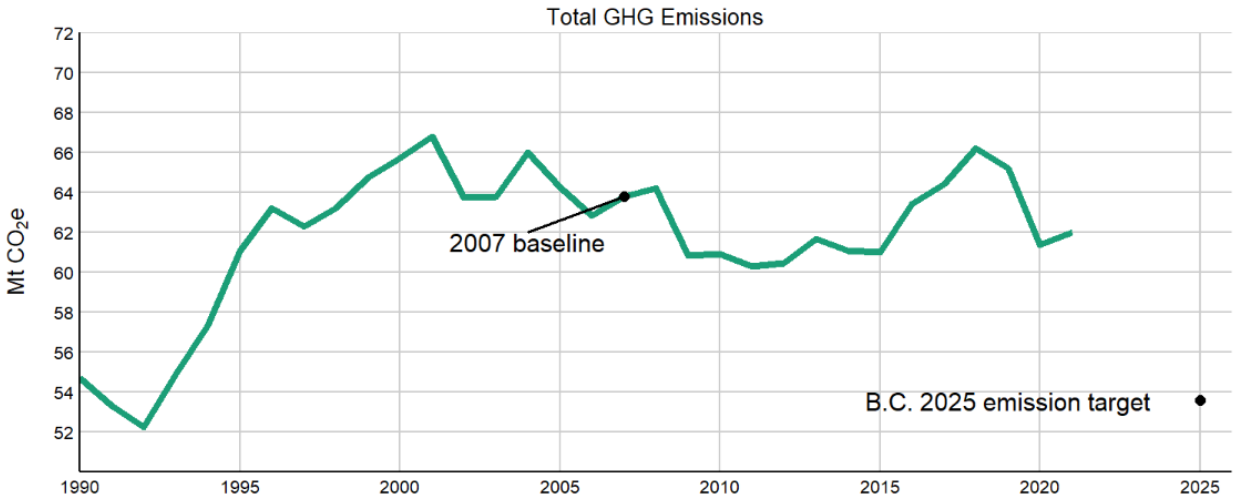

Figure 25: Total BC Emissions (1990–2021) with 2007 as the Benchmark for Emission Reduction. *Source: Provincial Inventory of Greenhouse Gas Emissions 1990–2021. Available at https://www2.gov.bc.ca/gov/content/environment/climate-change/data/provincial-inventory*

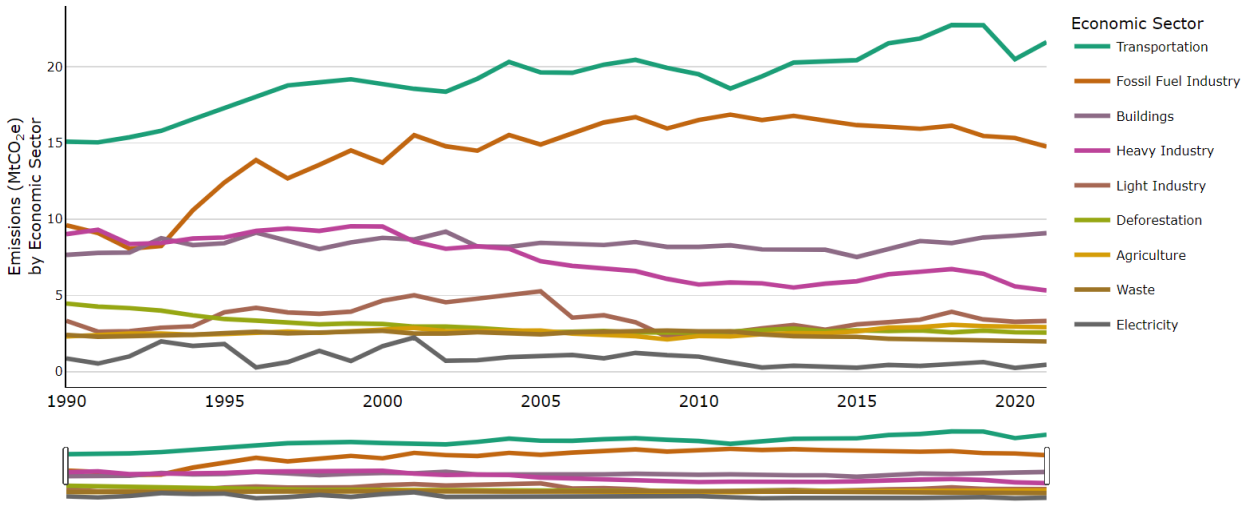

Figure 26: Greenhouse Gas Emissions by Source in BC (1990–2021)**.** *Source: Government of Canada, Environmental Reporting BC. Available at: https://www.env.gov.bc.ca/soe/indicators/sustainability/ghg-emissions.html.*

The carbon storage market for BC is not limited to the province itself. Significant industrial emissions across Canada (Fig. 27) create substantial opportunities for utilizing BC's carbon storage capacity. Alberta's oil and gas sector, in particular, represents a key market for future deep storage projects in BC.

The Peace region of BC, with its abundant deep carbon storage potential, is ideally located near Alberta's major emission sources, making it a strategic option for cross-provincial carbon management.

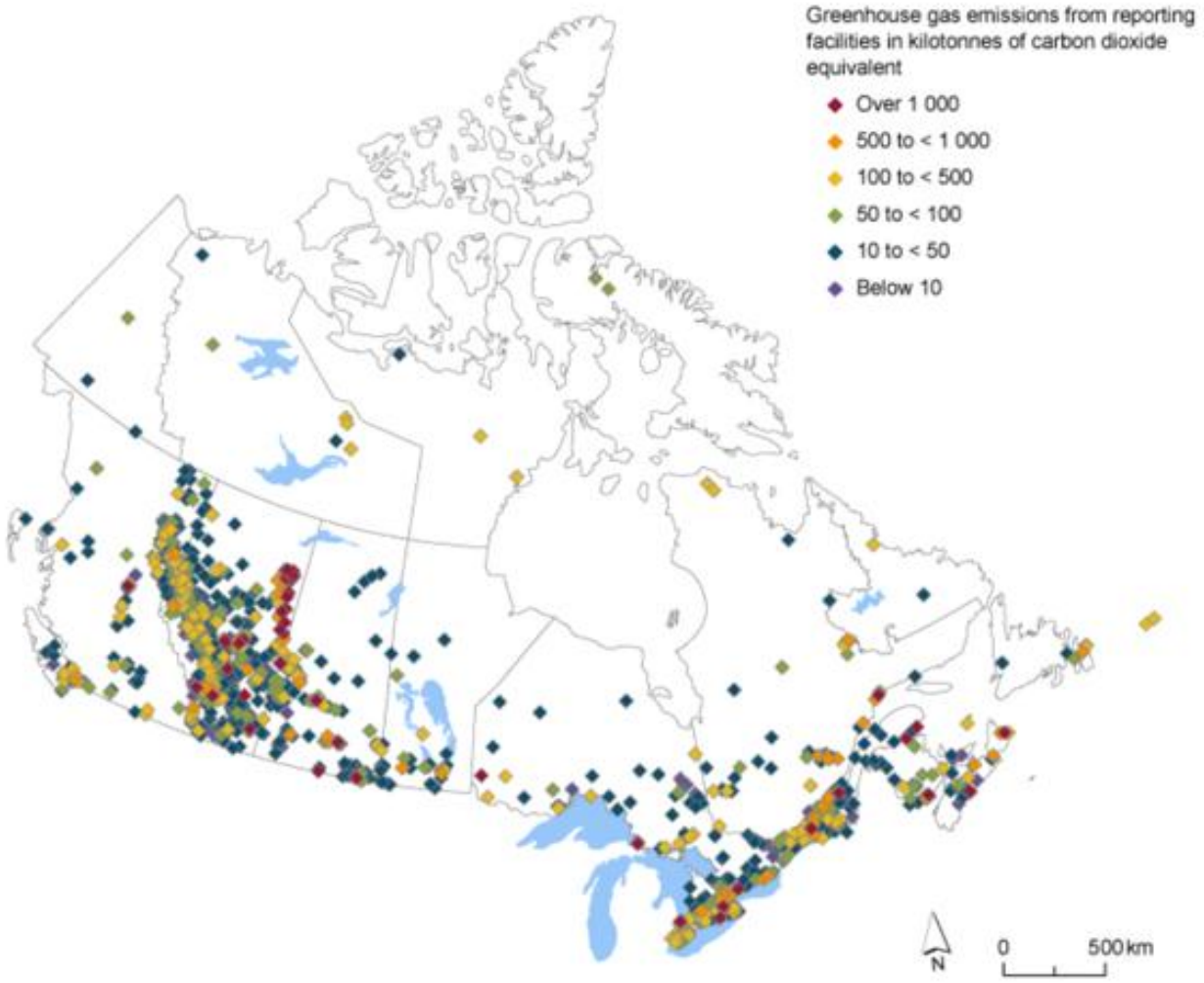

Figure27: Locations of Major Greenhouse Gas Emitting Facilities in British Columbia and Across Canada. Source: Environment and Climate Change Canada (2024), *Greenhouse Gas Reporting Program - Overview of 2022 Reported Emissions.* Available at: https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions/large-facilities.html.

The cement industry represents another significant market for deep carbon storage. Producing one ton of cement emits approximately 1.3 tons of carbon dioxide. This estimate excludes additional emissions from water used in the production process and the transportation of concrete. When these factors are considered, the total carbon footprint of cement can reach nearly 2 tons per ton of cement used, such as in dam construction.

Beyond production and transportation, concrete's carbon footprint is further influenced by its water usage, as water is essential for both mixing and curing the material. Concrete plants, being single-point emitters, offer substantial opportunities to reduce their carbon emissions. By

adopting carbon capture, transportation, and deep storage solutions, these facilities can significantly lower their environmental impact.

21.0 Concluding Highlights and Recommendations

Global climate change, driven by the increasing concentration of GHGs, poses a significant and immediate threat to the planet. The primary sources of emissions — carbon dioxide, methane, nitrous oxide, and fluorinated gases — stem from industrial activities, deforestation, and fossil fuel combustion. These emissions have resulted in global warming at an unprecedented scale, leading to more frequent extreme weather events, ecosystem disruptions, and socio-economic challenges. Urgent measures are required to mitigate these impacts and transition to a sustainable, low-carbon economy.

Carbon capture, utilization, and storage technologies have emerged as essential tools in the fight against climate change. These technologies capture carbon dioxide from industrial processes and the atmosphere, repurposing it into useful products or securely storing it in geological formations. Innovative methods, such as enhanced oil recovery, deep geothermal carbon storage, and integration with renewable energy systems, are driving transformative change in emissions management. By incorporating advanced techniques like membrane-based capture systems and modular units, CCUS continues to improve in efficiency and cost-effectiveness.

One notable example of large-scale CCUS deployment is the Alberta Carbon Trunk Line, one of the world's largest CCUS projects. This project highlights the feasibility and potential of large-scale CCUS systems to reduce emissions while supporting industrial sustainability.

Prominent projects like the Alberta Carbon Trunk Line and TerraCOH's CO_2 Plume Geothermal systems demonstrate the scalability of CCUS technologies. These projects also underscore the potential for CCUS to generate economic value by transforming emissions into tradable commodities, promoting a circular economy while reducing greenhouse gas emissions

British Columbia is uniquely positioned to lead in carbon management initiatives due to its abundant natural resources and progressive climate policies. The province's Peace region alone offers over 4 billion tonnes of carbon dioxide storage capacity in deep saline aquifers and depleted oil and gas reservoirs. This vast potential aligns seamlessly with BC's CleanBC Roadmap to 2030, which emphasizes carbon capture and storage as a critical strategy for achieving its emissions reduction targets.

Additionally, BC's integration of CCUS with geothermal energy production enables dual-purpose systems that combine emissions reduction with renewable energy generation. Through strategic investments in carbon management, BC can serve as a model for other jurisdictions by demonstrating the economic and environmental benefits of a low-carbon transition.

BC's carbon pricing policies, including its comprehensive carbon tax and market-driven cap-and-trade systems, are foundational to its climate strategy. Covering 75% of the province's emissions, BC's carbon tax incentivizes reductions across industrial and consumer sectors. Carbon trading mechanisms, such as baseline-and-credit systems, provide additional flexibility and economic incentives for emissions reductions. These systems depend on robust regulatory frameworks and transparent governance to ensure their effectiveness and equity.

The development of a robust carbon economy in BC creates significant opportunities for industries to align with low-carbon pathways. By integrating carbon storage solutions into industrial processes, sectors such as cement, oil and gas, and renewable energy can achieve emissions reductions while maintaining competitiveness. BC's extensive geothermal resources present additional opportunities to generate clean energy while supporting carbon storage initiatives.

Strategic partnerships, particularly with First Nations and industry leaders, are key to scaling up carbon storage projects. These collaborations foster job creation, promote sustainable growth, and position BC as a leader in the global transition to a low-carbon economy.

British Columbia is home to 204 First Nations, representing a remarkable diversity of cultures, languages, governance systems, and relationships with the land. This diversity calls for tailored and respectful engagement strategies, especially for projects involving land use and carbon storage. Recognizing First Nations as stewards of their territories and ensuring their meaningful participation in decision-making processes is not only a legal obligation but also an opportunity to leverage their leadership in addressing climate change.

First Nations are integral to addressing climate change, with carbon storage emerging as a key tool in reducing greenhouse gas emissions. Their participation spans land use, carbon capture, and transport, underscoring the importance of their stewardship, knowledge, and rights. Federal initiatives, including the Indigenous Climate Leadership Agenda, provide critical funding and support for self-determined climate actions, enabling First Nations to build sustainable futures and advance economic self-reliance through participation in climate solutions.

Engagement must be established in partnerships built on collaboration and mutual respect, structured around political, legal, economic, and socio-environmental dimensions. Policies should uphold the principles of the United Nations Declaration on the Rights of Indigenous Peoples and recognize First Nations' constitutional aboriginal and treaty rights.

Economic engagement should include transparent benefit-sharing agreements that recognize the inherent and constitutional rights of First Nations and provide substantial participation in revenue generated by carbon storage projects. Such agreements strengthen economic opportunities while ensuring alignment with First Nations' roles as environmental stewards. Socio-environmental partnerships must embed traditional knowledge and sustainable practices into project design, fostering shared governance and co-development in climate initiatives.

A robust legal framework for carbon storage is necessary to support these efforts. This includes creating permitting systems modeled on existing frameworks, such as BC's Petroleum and Natural Gas Act, and establishing strict monitoring protocols to protect environmental integrity. Co-development of these regulations with First Nations, supported by a steering committee of First Nations representatives, legal experts, and government officials, will ensure the framework respects their rights and priorities.

Canada has established itself as a global leader in carbon capture, utilization, and storage leveraging robust regulatory frameworks, international collaboration, and targeted financial incentives. Key initiatives like British Columbia's Output-Based Pricing System drive emissions reductions while supporting economic competitiveness.

National standards from organizations like CSA Group and ISO/TC 265 ensure CCUS projects adhere to stringent safety and efficiency guidelines, bolstering consistent and effective deployment. International partnerships with the International Energy Agency and the Global CCS Institute further enhance Canada's leadership by fostering innovation and global collaboration.

The integration of CCUS technologies, carbon pricing mechanisms, and First Nations leadership positions BC as a global leader in climate action. By leveraging its geological resources, innovative technologies, and collaborative frameworks, BC is well-equipped to achieve its emissions reduction targets. First Nations' active participation ensures that CCUS projects are inclusive, equitable, and sustainable, contributing to both economic self-sufficiency and environmental stewardship. Together, these initiatives forge a path toward a sustainable, low-carbon future, demonstrating BC's commitment to addressing global climate challenges while fostering innovation and collaboration.

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