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Engineered Carbon Dioxide Removal in a Net-Zero Canada

Policy brief

by Carson Fong and Scott MacDougall | April 13, 2023

Summary

- Carbon dioxide removal (CDR) is a necessary tool to achieve net-zero emissions by 2050, but only as a complement to emissions reductions.
- Biological CDR methods like afforestation and reforestation are already well known and deployed at large scales.
- Engineered, non-biological methods are technologically immature, so more work is needed to address their current high costs and possible environmental impacts. However, they have the potential to provide highly durable and measurable CDR.
- Research, development and rapid testing of non-biological CDR now is needed to ensure it is ready for large-scale deployment in the future. Rapid "learning by doing" can reduce costs and improve commercial viability of CDR.
- Canada has favorable geography and expertise that provide good potential for CDR development. The western provinces and territories are conducive to direct air capture with geologic storage development, because their geologic storage potential is near access to renewable energy.
- The potential of CDR cannot be a reason to slow down emissions reduction efforts. This would not only limit climate change mitigation, but also likely negatively impact public perception towards CDR.

Recommendations

- Regulations relevant to CDR are inconsistent and ambiguous across Canada. Pore space ownership — a key issue for carbon dioxide storage — is unclear in some jurisdictions, and there is no clear path to license new offshore projects, particularly involving sub-oceanic storage. Addressing these regulatory gaps can help remove a barrier to development while promoting safe deployment.

- Early, rapid deployment and testing can quickly generate learning that improves operational efficiency and technological advancement. This research and development, as well as pilot and demonstration projects, will require capital support. These projects should have knowledge sharing requirements to better enable a learning curve to significantly reduce the high capital and operating costs and environmental risks associated with many non-biological CDR solutions.
- Non-biological CDR methods are currently excluded from federal and provincial carbon pricing and offset programs, resulting in a lack of predictable operating revenue making project financing difficult. Including non-biological CDR as an eligible pathway in decarbonization policies can create a business case for deployment and remove a significant barrier to CDR growth in Canada.

The need for carbon dioxide removal

Canada is one of many nations committed to keeping the global temperature rise below 1.5°C relative to pre-industrial levels. To contribute to this, Canada's goal is to reduce emissions by 40-45% from 2005 levels by 2030, and then achieve net-zero in 2050. A state of net-zero emissions means the amount of greenhouse gases going into the atmosphere must be balanced by removal out of the atmosphere. Net-zero can be achieved with early, deep and sustained reductions of direct emissions, and then tackling the remaining hard-to-reduce emissions with additional tools like carbon dioxide removal (CDR). No less an authority than the United Nations Intergovernmental Panel on Climate Change (IPCC) has noted the need for CDR, saying: "The deployment of CDR to counterbalance hard-to-abate residual emissions is unavoidable if net-zero CO_2 or GHG emissions are to be achieved."[1]

CDR processes extract carbon dioxide from the atmosphere and durably store it so that it does not re-enter the atmosphere. It can be an indirect solution for hard-to-reduce emissions by removing the equivalent amount of carbon dioxide emitted. CDR can also counteract emissions if Canada overshoots its carbon budget and can even help achieve negative net emissions after net-zero is reached. In this way, it can extract some of the legacy carbon that humanity has released into the atmosphere over the last few centuries.

[1] Intergovernmental Panel on Climate Change, *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (2022), "Summary for Policymakers," 36. https://www.ipcc.ch/report/ar6/wg3/

Some studies estimate CDR could reduce the cost of tackling these remaining emissions by 40% compared to alternatives.[2] The cost of not doing enough to prevent climate change, meanwhile, could cause economic damage in Canada totaling $391 billion to $865 billion annually by 2100, not to mention the human toll of climate-related disasters.[3]

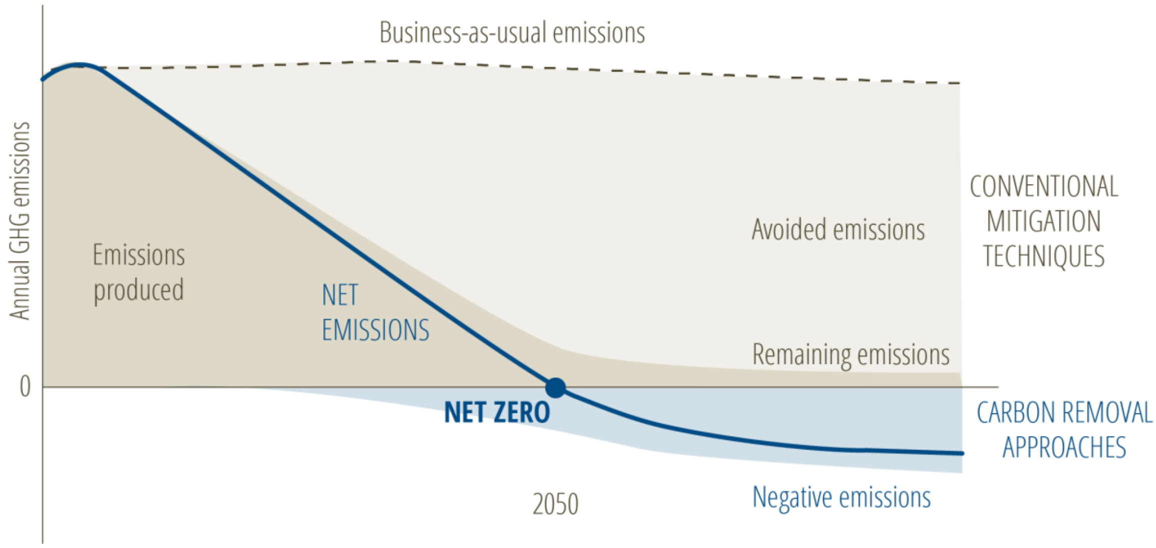

Figure 1: Stylized timeline of net CO_2 emissions in a path towards net-zero in 2050 and net negative emissions afterwards.

Source: Adapted from IPCC[4]

Types of CDR

Many biological CDR approaches (afforestation, reforestation, soil sequestration) are well known, heavily discussed and available for deployment now. They make up the majority of currently implemented CDR and are expected to continue to play a significant role in carbon removal in the following decades.

By contrast, engineered non-biological CDR solutions, such as direct air capture (DAC) with geologic storage, carbon dioxide mineralization, and many types of carbon use, are technologically immature and more expensive, but have the potential to offer verifiable

[2] International Energy Agency, *Exploring Clean Energy Pathways* (2019), 3. https://iea.blob.core.windows.net/assets/fc698d6d-1f9d-4c46-9293-e67a600d01c6/Exploring_Clean_Energy_Pathways.pdf

[3] Canadian Climate Institute, *Damage Control: Reducing the costs of climate impacts* (2022), 6. https://climateinstitute.ca/wp-content/uploads/2022/09/Damage-Control_-EN_0927.pdf

[4] IPCC, *Climate Change 2022: Mitigation of Climate Change*, 1263.

and durable CDR in the medium-to-long term. Development and testing now can help ensure technological readiness and economic feasibility when deployed at full scale around mid-century, when cheaper emissions reduction opportunities have been fully implemented. However, the potential of CDR should not be a rationale for delaying short-term emissions reductions.

- **DAC** is the process of removing carbon dioxide from the air using liquid or solid materials that bind specifically to carbon dioxide as air passes through them.
- **Ocean alkalinity enhancement** is lowering the acidity of oceanwater by dissolving alkaline material into it. This increases the water's natural ability to capture and dissolve atmospheric carbon dioxide.
- **Mineralization** is the creation of solid carbonate material by reacting carbon dioxide with alkaline rock like basalt, and is a secure way of storing carbon. This can happen underground (*in situ*), in industrial facilities (*ex situ*), or along the ground in the open environment (surficial, including enhanced weathering).
- **Geologic storage** is storing carbon dioxide in deep underground saline aquifers. An impermeable caprock prevents the carbon dioxide from rising back to the surface.
- **Carbon use** is taking carbon dioxide as an input to create products that generate revenue. One notable example is concrete, in which carbon dioxide can be securely stored and also reduce the amount of cement required in concrete production.

An overview of the costs, readiness and potential challenges that need to be addressed are shown in Table 1.

Table 1: Summary of economic and environmental considerations for engineered, non-biological CDR technologies in Canada

Technology	Type	Estimated costs at scale ($/tCO2)	Technology readiness level (TRL)	Potential environmental positives (likelihood)[5]	Potential environmental challenges (likelihood)[5]	Difficulty of measuring CO_2 removed/ stored
Direct air capture	Removal	130-390 [6]	6 [7]	Lower land-usage (high) Can be on non-arable land (high) Solid DAC produces water as byproduct (high)	High energy use (high)	Low
Ocean alkalinity enhancement	Removal and Storage	52-338[8]	1-2 [9]	Slow-down of ocean acidification (high)	Increased mining activity (high) Eutrophication (unknown) Ecosystem damage (unknown)	High

[5] In comparison to afforestation unless otherwise stated.

[6] David W. Keith, Geoffrey Holmes, David St. Angelo, Kenton Heidel, "A Process for Capturing CO2 from the Atmosphere," *Joule* 2, issue 8 (2018), 1573. https://doi.org/10.1016/j.joule.2018.05.006

[7] IPCC, *Climate Change 2022: Mitigation of Climate Change*, 1275.

[8] IPCC, *Climate Change 2022: Mitigation of Climate Change*, 1275.

[9] IPCC, *Climate Change 2022: Mitigation of Climate Change,* 1275.

Surficial mineralization	Can be removal and storage	65-260[10]	1-5 [11, 12]	Improved plant growth on farmland (high)	Increased mining activity (high) Toxic metals contamination (unknown)	High
In situ mineralization	Storage	26-39 [13] Seafloor basalt: 260-520[14]	2-6 [15]	Increased permanence (high) Lower risk of leakage than geologic storage (high)	Higher water usage (medium) Risks related to well bore connectivity (low) Drinking water contamination due to leakage (low) Induced geological or seismic activity (unknown)	Medium
Ex situ mineralization	Storage	68-300 [16]	Wide range, some as high as 9[17]		Increased mining activity (high)	Low

[10] IPCC, *Climate Change 2022: Mitigation of Climate Change*, 1275.

[11] Cara N. Maesano, James S. Campbell, Spyros Foteinis et al. "Geochemical Negative Emissions Technologies: Part II. Roadmap," *Frontiers in* Climate 4 (2022). https://doi.org/10.3389/fclim.2022.945332

[12] Mission Innovation, *Carbon Dioxide Removal Technology Roadmap: Innovation Gaps and Landscape Analysis* (2022), 2. https://explore.mission-innovation.net/wp-content/uploads/2022/09/Carbon-Dioxide-Removal-Mission-Roadmap-Sept-22.pdf

[13] Peter Kelemen, Sally M. Benson, Hélène Pilorgé, Peter Psarras, Jennifer Wilcox. "An Overview of the Status and Challenges of CO2 Storage in Minerals and Geological Formations," *Frontiers in Climate* 1 (2019). https://doi.org/10.3389/fclim.2019.00009

[14] Kelemen et al., "An Overview of the Status and Challenges of CO2 Storage in Minerals and Geological Formations."

[15] Cara N. Maesano et al., "Geochemical Negative Emissions Technologies: Part II. Roadmap."

[16] Fei Wang and David Dreisinger, "Status of CO2 mineralization and its utilization prospects," *Minerals and Mineral Materials* 1, no. 1 (2022), 4. http://dx.doi.org/10.20517/mmm.2022.02

[17] Colin D. Hills, Nimisha Tripathi, Paula J. Carey. "Mineralization Technology for Carbon Capture, Utilization, and Storage," *Frontiers in Energy Research* 8 (2020). https://doi.org/10.3389/fenrg.2020.00142

Geologic storage	Storage	9-23 [18]	9 [19]	Increased permanence (high)	Risks related to well bore connectivity (low) Drinking water contamination due to leakage (low) Induced geological or seismic activity (unknown)	Low
Carbon use	Storage	Net revenue generator	Wide range, some as high as 9 [20, 21]	Varies	Varies	Low

[18] Susan Hovorka and Peter Kelemen, "Geological Sequestration: Current costs and estimated costs" in *CDR Primer* (2021). https://cdrprimer.org/read/chapter-2#sec-2-9-5

[19] David Kearns, Harry Liu and Chris Consoli, *Technology Readiness and Costs of CCS* (Global CCS Institute, 2021), 23. https://www.globalccsinstitute.com/wp-content/uploads/2021/03/Technology-Readiness-and-Costs-for-CCS-2021-1.pdf

[20] John Zhou, David Van Den Assem, Rick Chalaturnyk, et al. *Carbon Capture, Utilization, and Storage (CCUS): Technology Innovation to Accelerate Broad Deployment in Alberta* (Alberta Innovates, 2022), 14. https://albertainnovates.ca/app/uploads/2022/06/AI-CCUS-WHITE-PAPER_2022_WEB.pdf

[21] Hills et al., "Mineralization Technology for Carbon Capture, Utilization, and Storage."

Current costs are high with non-biological CDR approaches. Accelerating learning-by-doing will help lower costs and improve the viability of these options at scale. Figure 2 shows the estimated range of levelized costs of options that include carbon removal, storage or both.

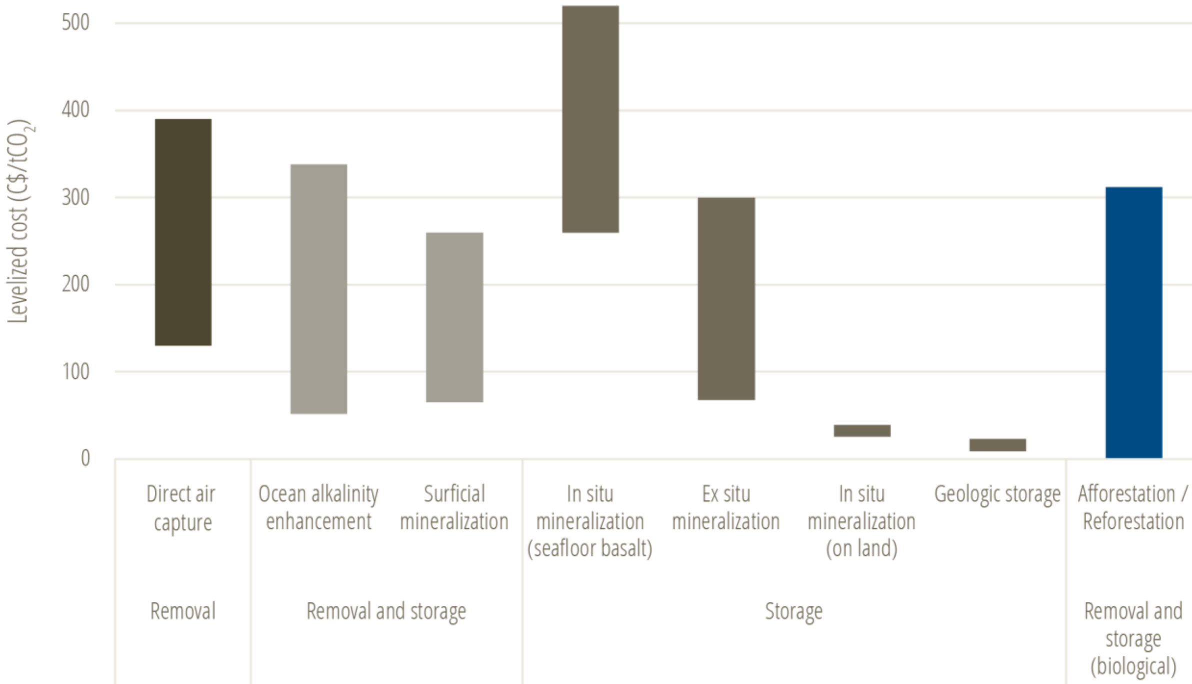

Figure 2. Range of estimated levelized costs of removal and storage for non-biological engineered CDR solutions, alongside afforestation/reforestation for comparison

Note that costs may not encompass a complete CDR system if both removal and storage are not included.

Data sources: various, see Table 1; afforestation/reforestation data from IPCC[22]

Recommendations to capture Canada's CDR opportunity

Emerging engineered non-biological technologies show promise of durable and measurable carbon dioxide removal. Timely investment and rapid deployment can advance the technology and address questions around environmental impacts and high current costs of deployment. However, it cannot delay direct emissions reduction efforts. Framing CDR as an alternative to short-term emissions reductions opportunities will likely negatively impact public acceptance and hinder progress.

B.C., Alberta, Saskatchewan, Manitoba, the Northwest Territories and the Yukon all feature overlapping underground storage potential and access to renewable energy, either through

[22] IPCC, *Climate Change 2022: Mitigation of Climate Change*, 1276.

low-carbon grids or location-specific generation potential. This makes them prime locations for DAC with geologic storage development. Existing expertise and infrastructure in Alberta and Saskatchewan relevant for geologic storage can be leveraged.

Canada's strategy towards CDR development has potential to impact the rights and interests of Indigenous communities, and thus needs to involve them as decision-makers and to provide consent for any actions. Continued education and engagement with other communities will help build public support.

Current areas requiring attention include:

- Measurement and verification standards for each type of CDR will ensure credible accounting and help scale procurement.
- Support is critical for research and development aimed at addressing risks, uncertainties and high costs of CDR.
- Investment in progressively larger implementations can advance CDR technologies down their learning curves, improving their costs and lowering their risks.
- Unambiguous regulation that keeps pace with CDR development can improve investment certainty, while also ensuring safe deployment. Pore space ownership is a key issue for geologic storage and needs to be clarified in certain jurisdictions. Licensing for offshore projects including sub-oceanic storage requires clarity.
- Supporting the business case for CDR through credit market deployment, including recognizing CDR within federal and provincial carbon offset systems, can provide reliable revenue to justify investment.