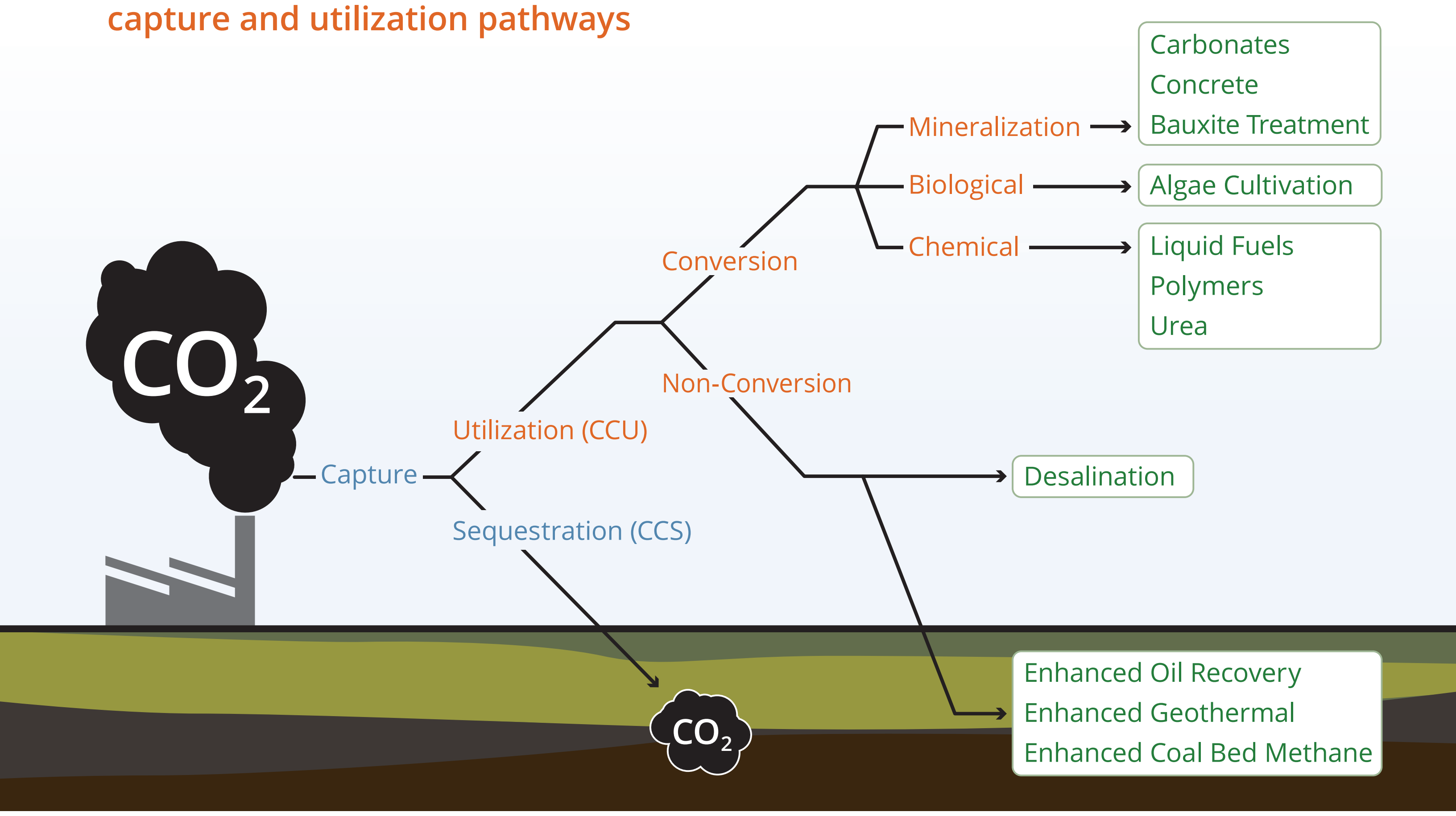
Carbon Capture and Utilization

In the innovative field of carbon capture and utilization (CCU[1]), CO_2 waste emissions from large emitters is captured and used to produce new products and economic opportunities.

Figure 1. Paving the way — A selection of today's carbon capture and utilization pathways



CO_2 can be used in its original form or converted to new forms, such as chemical feedstocks or energy.

Carbon emissions and climate change

In North America, carbon dioxide is the main greenhouse gas (GHG) emitted into the atmosphere, accounting for 79% of Canada's total GHGs. In 2012 Canada emitted 699 million tonnes (Mt) of gases equivalent to carbon dioxide (CO_2e), 551 Mt of which were CO_2. While a variety of activities account for Canada's overall carbon emissions, the consumption of energy through the burning of fossil fuels — coal, petroleum products and natural gas — is by far the largest contributor. These greenhouse gases trap heat on the earth's surface. The recent rapid increase in GHGs is leading to global climate change.

Role of sequestration and utilization

One technique that could be a significant tool to drastically reduce CO_2 emissions is carbon capture and storage (CCS), which would permanently store carbon in the ground. In Canada we have four large-scale industrial CCS projects (Shell's Quest, SaskPower's Boundary Dam, Cenovus Apache's Weyburn-Midale and Enhance Energy's Alberta Carbon Trunk Line). Further deployment of CCS has been hampered by a variety of factors, including high costs, need for further technological progress, limited resources and a lack of strong regulatory signals. Carbon utilization technologies can generate revenue that can offset some of the costs of capture and sequestration. For example, enhanced oil recovery (EOR), a proven technology where carbon dioxide is injected into depleted oil fields to boost their overall production, has supported the business case for several permanent sequestration operations in Canada (Weyburn-Midale, Boundary Dam and the Alberta Carbon Trunk Line). As capture technologies improve and utilization pathways develop and multiply, advances in technology will benefit all aspects of carbon management and in some cases provide permanent sequestration of CO_2.

[1] CCU may also be referred to as carbon capture and reuse or carbon capture and recycling (CCR).

Overview of technological pathways[2]

		Technology	Description	Potential and permanence	Time to commercialization	Opportunities	Barriers
CONVERSION	MINERALISATION	Carbon mineralization	CO_2 reacted with a mineral or industrial waste products. Resulting new compound can be used in construction, as a consumer product or an alternative to CCS.	>300 Mt/yr permanent	1-5 years	• abundant materials (minerals or industrial waste) • alternative to CCS	• high energy use to accelerate the reaction • high material needs • cost of minerals and processing
CONVERSION	MINERALISATION	Concrete curing	Waste CO_2 flue gas stream used to cure precast concrete. CO_2 is stored as an un-reactive limestone within the concrete.	30-300 Mt/yr permanent	already operating on commercial scale	• low cost vs traditional curing • cement industry can use flue gases directly • carbon offset opportunity for the highly emissions intensive cement industry • low carbon consumer product with the potential to grow beyond a niche market	• product must meet quality standards • cost to modify curing process
CONVERSION	MINERALISATION	Bauxite residue carbonation	CO_2 reduces alkalinity of slurry from aluminum mining.	5-30 Mt/yr permanent	already operating on commercial scale	• mature technology • can reduce closure and reclamation costs at aluminum mines	• cost of concentrating CO_2 • need access to CO_2
CONVERSION	BIO-LOGICAL	Algae cultivation	Microalgae absorbs CO_2 and can then be converted into proteins, fertilizers and biomass for biofuels.	>300 Mt/yr non-permanent	1-5 years	• competitive source of biofuel • can use flue gas directly • can result in permanent storage • 1 tonne of micro algae can fix 1.8 tonnes of CO_2	• algae sensitive to impurities, pH • cost of controlling growth and drying conditions • large area and sunny climate needed for ponds • high energy need for photobioreactors
CONVERSION	CHEMICAL	Liquid fuels - methanol	CO_2 and hydrogen catalytically converted to methanol, which can be blended with gasoline.	>300 Mt/yr non-permanent	1-5 years	• energy carrier could replace fossil fuels, reducing dependence on conventional fuel for transport and other uses.	• inefficient process; requires renewable or low emissions energy to have net CO_2 abatement benefit • needs low cost renewable hydrogen • cost of purifying CO_2
CONVERSION	CHEMICAL	Liquid fuels - formic acid	CO_2 electro-reduced in water to produce formic acid	>300 Mt/yr non-permanent	5-10 years	• formic acid can be used as an energy carrier (with hydrogen being the primary fuel), or as a preservative and antibacterial agent	• inefficient process; requires renewable or low emissions energy to have net CO_2 abatement benefit • chemistry needs to be perfected • cost of purifying CO_2
CONVERSION	CHEMICAL	Polymers / chemical feedstock	CO_2 transformed into polycarbonates using zinc-based catalyst.	5-30 Mt/yr non-permanent	1-5 years pilot stage	• can use flue gas directly • large potential use of CO_2 • diversity of products possible (plastic bags, laminates, automobile, medical components, etc.) • existing infrastructure can be used	• non-permanent storage; some CO_2 re-emitted in as little as six months
CONVERSION	CHEMICAL	Urea yield boosting	Ammonia and CO_2 converted to urea fertilizer.	5-30 Mt/yr non-permanent	already operating on commercial scale	• mature technology • reduces emissions intensity of process	• non-permanent storage; CO_2 is re-emitted when urea breaks down as fertilizer

2 Potential, permanence and time to commercialization from: Global CCS Institute, *Accelerating the Uptake of CCS* (2011). http://cdn.globalccsinstitute.com/sites/default/files/publications/14026/accelerating-uptake-ccs-industrial-use-captured-carbon-dioxide.pdf

	Technology	Description	Potential and permanence	Time to commercialization	Opportunities	Barriers
NON CONVERSION	Desalination	CO_2 mixed with brine at high pressure and temperature to form hydrates that can be removed to leave clean water.	30-300 Mt/yr non-permanent	5-10 years	• produces potable water or treats process-affected water • provides a revenue stream or an opportunity to offset costs in a a system already commited to CCS	• electricity, equipment costs (but similar to existing water treatment alternatives)
	Enhanced oil recovery	CO_2 injected into an existing oil well to increase pressure and reduce the viscosity of the oil, increasing the amount of oil that can be recovered.	30-300 Mt/yr permanent	already operating on commercial scale	• mature technology • permanent storage • large potential use of CO_2 plus revenue stream that can offset the costs of carbon capture	• facilitates additional fossil fuel use, producing more CO_2
	Enhanced geothermal systems	Supercritical CO_2 transfers geothermal heat or generates power directly through a supercritical CO_2 turbine.	5-30 Mt/yr permanent	5-10 years	• improves efficiency of a clean energy resource • permanent storage	• long time to commercialization • cost of transporting supercritical CO_2 • grid connection needed for geothermal site
	Enhanced coal bed methane	CO_2 is injected into partially depleted coal seams, where it's adsorbed by coal, in turn displacing methane to the surface for it to be captured and consumed as fuel.	30-300 Mt/yr permanent	1-5 years	• methane could replace more carbon-intensive fuel sources • permanent storage	• adsorbed CO_2 can cause coal to expand and obstruct pathways; may disrupt methane recovery • low methane price • cost of transporting CO_2

Note: Utilization technologies depend on geography, availability, proximity and type of carbon sources, availability of other inputs and market potential.
The table above captures today's most promising technologies, but there are a lot of new ideas under development that may lead to breakthrough technologies of tomorrow.

Four companies working on carbon utilization in Canada.

The following companies are listed as examples only; their inclusion does not reflect an endorsement of either the companies or the publication.

MANTRA

Mantra Energy Alternatives Ltd.
• electro-reduction to formic acid
mantraenergy.com

quantiam technologies inc.

Quantiam Technologies Ltd.
• methanol production
quantiam.com

pond biofuels working green

Pond Biofuels
• algae cultivation
pondbiofuels.com

CARBONCURE SIMPLY BETTER CONCRETE

CarbonCure
• concrete curing
carboncure.com

If CCU technologies prove viable, we may find ourselves in a world where carbon is considered a valuable commodity instead of a waste stream in need of careful disposal.

Frequently asked questions

Does CCU result in net carbon reductions?

CCU technologies are so varied that each unique utilization process, in a specific context, will have a different carbon footprint. Factors to consider are the permanence of storage, the energy intensity of the process, the source of that energy and the end use of the product. Certain pathways are highly energy intensive, and depending on the source of the energy (for example coal-fired electricity vs renewables), the process itself might generate more CO_2 than it consumes. Finally, net carbon reductions may be achieved when the products of a given pathway replace a more carbon-intensive alternative. A full life cycle assessment would be required to assess the GHG abatement of a given technology in a specific context in order to answer the question "what is the net carbon benefit?"

Can CCU truly reach the scale needed to thwart climate change?

Current demand for CO_2 represents a fraction of our global net emissions (less than 1%). EOR is the largest consumer of CO_2 and two-thirds of that CO_2 still comes from naturally occurring reservoirs and not captured emissions.[3] The opportunity for growing CCU consumption of CO_2 lies in developing new market demand, driving down costs through innovation, and creating market incentives for low carbon products. Carbon utilization will not be a standalone solution to reducing CO_2 emissions but it can assist in developing demand for carbon reuse, carbon neutral or net negative products, and in advancing technologies to capture and store carbon.

Aren't the costs of CCU technologies as prohibitive as the costs for CCS?

EOR and urea boosting are cost-effective technologies with proven commercial viability. The remaining pathways are in various stages of development and have not established true commercial-scale costs. Based on laboratory and pilot scale work, the costs for many pathways are still hurdles to economic viability; however, as these technologies move from development to execution stages, costs are expected to decrease.

What is the benefit of CCU?

The broad range of CCU actions have the potential to shift the way we view carbon dioxide. If some or all of the technologies meet with economic success, a new industry will be born that values carbon dioxide emissions, invests in innovation that will drive down costs associated with capture and storage, and reduces CO_2 emitted to the atmosphere. In the absence of strong regulatory signals, venture capital, grants and other funding is stimulating interest in the field of CCU around the world. CCU can support further deployment of CCS by providing a revenue stream to offset the costs and additional research and development that will improve affordability of capture and storage technology.

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More information: ico2n.com

3 International Energy Agency, *CCS 2014: What lies in store for CCS?* (2014), 82. http://www.iea.org/publications/insights/insightpublications/Insight_CCS2014_FINAL.pdf