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Canadian Capabilities in Carbon Capture & Storage Technologies

Guide and Company Directory for the Oil and Gas Sector

June 2024

TRADE COMMISSIONER SERVICE (TCS)

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This document has been prepared by Petroleum Technology Alliance Canada (PTAC) for the Trade Commissioner Service, Global Affairs Canada.

Introduction

The Intergovernmental Panel on Climate Change (IPCC) and related international energy and climate change focused groups have indicated that, for the world to achieve greenhouse gas (GHG) targets for avoiding model-based predictions of global warming, the concentration of carbon dioxide (CO_2) in the atmosphere should be reduced, or at least held, at near current levels. The main focus is to move countries and companies towards achieving "net-zero" GHG emissions by 2050. To achieve this will be a major challenge requiring substantial changes in global energy use and energy systems. Carbon Capture and Storage (CCS) has been identified as a stop-gap measure to bridge the potential energy shortfalls expected, even with a relatively rapid build up in renewable power generation and conversion of transportation and heating fuels to low emission energy carriers. By developing CCS capacity, countries and companies will retain the capability and flexibility of continuing to use hydrocarbon fuels of various types by capturing the CO_2 in the flue gases from combustion sources or produced by the production of hydrogen from natural gas, biomass, or other fossil fuels.

Currently, most of the CO_2 injection into the subsurface globally is CO_2 that has been either intentionally produced to surface with natural gas to be sold for use in CO_2 Enhanced Oil Recovery (EOR)[1]; dilute formation CO_2 produced with raw natural gas along with other acid gases like hydrogen sulphide and other impurities; or produced to allow recovery of small but strategically very important and valuable volumes of helium, which is usually found in reservoirs containing large concentrations of CO_2[2]. Total CO_2 captured and injected to date globally from all projects is on the order of hundreds of megatonnes, mainly for CO_2 EOR, while to meet projected requirements will require potentially as much as 1,000 to 2,700 gigatonnes of cumulative injection by 2100[3], over 10,000 times the CO_2 injected to date for EOR. While rough estimates of potential pore space for CO_2 storage in underground aquifers are high, that pore space is already occupied by brine, which is usually more saline than seawater and must be displaced towards the surface, so the capacity for CCS is not unlimited and will have other impacts which are difficult to predict at this time. The CCS process itself also takes a considerable amount of energy, so not all of the CO_2 injected is CO_2 avoided or prevented from being emitted into the atmosphere. If renewable energy is used for CCS, then it is not available for other purposes so could increase emissions in other areas.

The main capital costs for CCS are in the capture portion of the process which is also the most energy intensive step so has the highest operating costs. A key reference for costs has been prepared by the Global Carbon Capture and Storage Institute[4], which illustrates ranges of costs for CCS over an assumed 30 year project life. This document estimates the CO_2 capture step will generally cost between a few U.S. dollars/tCO_2 from a pre-existing hydrogen plants (95+% CO_2) to US$300 to $400/t$CO_2$ for Direct Air Capture (0.04% CO_2) with costs mainly being a function of the concentration of CO_2 in the source stream. Other steps in the full CCS process are additive to the capture costs and range from approximately

[1] Institute for Energy Economics and Financial Analysis https://ieefa.org/articles/shute-creek-worlds-largest-carbon-capture-facility-sells-co2-oil-production-vents-unsold

[2] The ExxonMobil Shute Creek Plant the largest carbon capture facility in the world (~7MtCO_2 capture per year) treats gas containing 65% CO_2, 21% methane, 7% nitrogen, 5% hydrogen sulphide (H_2S) and 0.6% helium with most revenues coming from the sale of helium. Most of the CO_2 is used for EOR or is reinjected with the H2S with the remainder being vented to atmosphere.
https://www.sciencedirect.com/science/article/pii/S1876610211008101

[3] "Global geologic carbon storage requirements of climate change mitigation scenarios" – Royal Society of Chemistry, Energy and Environmental Science – Zahasky & Krevor – May 2020

[4] Circular Carbon Economy Section 6 Remove: Carbon Capture and Storage, August 2020, Figure 5, Global Capture and Storage Institute, https://www.globalccsinstitute.com/wp-content/uploads/2020/11/Remove-Carbon-Capture-and-Storage-6.pdf

US$15 to $25/t for compression and dehydration, dependent mainly on the pressures required for pipelining and storage; US$3 to $25/t for CO_2 pipelines depending on length and capacity; US$5 to $20/t for CO_2 injection and storage; and US$3 to $5/t for monitoring and verification of containment. Utilization of CO_2 for EOR, Enhanced Gas Recovery (EGR), or other purposes, where the use of CO_2 provides an economic return, can turn the injection and storage costs into revenues from product sales and may also reduce the monitoring and verification costs to some extent. Note that while the costs are only shown for a 30 year project life, the monitoring and verification may be required at some level for hundreds of years.

The objective of this guide and company directory is to share Canada's experience and expertise in CCS which is based on existing projects and using products or services in the oil and gas sector, since CCS as a separate business sector has not yet emerged and remains only a potential industry sector. The guide highlights Canadian capabilities with the purpose of assisting both Canadian producers and other oil and gas producing countries in assessing and implementing CCS projects, primarily associated with upstream and midstream oil and gas operations. Similar process equipment and services may be used for cement, smelting, and other CO_2 emissions intensive industries, however, currently those markets are only in their infancy and may require alternative technologies.

Carbon Capture and Storage in Canada

Canada has a global reputation for environmentally responsible development of its natural gas, oil and bitumen resources, and upstream production and midstream processing, which are the main sources of CO_2 emissions from fossil fuels. This production made Canada the fourth largest oil producer in 2022, producing about 5.6% of the world's oil, and sixth largest gas producer in the world. Resources in place greatly exceed its own, relatively small domestic demand for hydrocarbons, so much of the oil and gas use is to produce oil and gas for export. To allow production of this vast and valuable resource to continue, industries from oil and gas to cement and steel production are turning to CCS as a potentially preferred method of reducing GHG emissions for energy intensive resource industries which dominate the Canadian economy.

Canada and the Province of Alberta have been world leaders in "sweetening" – removing H_2S and CO_2 from – raw natural gas. Up to a third of the natural gas produced in Alberta has been "sour", requiring the extensive development and deployment of amine systems to remove the acid gas components from the raw natural gas streams. The acid gas is usually either processed further to recover sulphur from the H_2S; flared if the acid gas volumes and sulphur content is low; or increasingly the acid gases are injected back into underground formations, similar to what is planned for CCS. Various types of amine processes have been used as a key method of removing CO_2 from hydrogen production and combustion flue gases, making past Canadian experience with sour gas an advantage in the key step of carbon capture. Experience with injecting acid gas also has direct application to the other steps in the overall CCS process, even though the annual volumes of acid gas injected are much lower than what is being contemplated for CCS. This was recognized early on by an IEA Greenhouse Gas R&D Programme report in 2003[5] which documented 31 acid gas injection projects in Alberta at that time, and many subsequent reports on CO_2 capture and injection at various specific Canadian acid gas or CO_2 injection projects which have been produced over subsequent years. Most recently, in November 2023, a report[6] by Emissions Reduction Alberta documented the conversion of TAQA North Ltd.'s Crossfield Gas Plant from sulphur recovery to acid gas injection to reduce GHG and other emissions, improve energy efficiency, and implement Enhanced Gas Recovery (EGR) from nearby deep gas fields.

Canada hosts some major, world class, CCS projects including:

- **Whitecap Joffre CO_2 EOR Project**[7] – This smaller yet significant CO_2 EOR project in the Joffre Viking field started in 1984 with CO_2 delivered to the project by truck from nearby gas and petrochemical plants. It is recognized as Canada's first commercial CO_2 flood for EOR. It is still in operation and to date is estimated to have sequestered approximately 1.35 $MtCO_2$.

- **Whitecap Weyburn CO_2 EOR Project**[8] – This project came into operation in 2000, initially receiving approximately 1$MtCO_2$/yr from the Great Plains Synfuel coal gasification plant in North Dakota and later, starting in 2014, receiving an additional ~1 $MTCO_2$/yr from the Boundary Dam Carbon Capture Project (see

[5] "Acid Gas Injection: A Study of Existing Operations" January 2003 https://ieaghg.org/docs/General_Docs/Reports/Ph4_15%20Acid%20gas%20injection%20Phase%201%20interim%20report.pdf

[6] Emissions Reduction Alberta Report on Project by TAQA North Ltd. https://www.eralberta.ca/wp-content/uploads/2023/11/2023-11-20-Final-Outcomes-Report-E0160360-Ammended.pdf

[7] https://www.wcap.ca/sustainability/co2-sequestration

[8] https://www.wcap.ca/sustainability/co2-sequestration

below). This EOR project has greatly extended the life and recovery of oil from the Weyburn field, which is the second largest oilfield in Canada and the largest CO_2 EOR project in the world. Weyburn has been extensively studied through international collaborations coordinated through the Petroleum Technology Research Centre in Regina. Estimated total CO_2 sequestered to date in this project is about 36 $MtCO_2$.

- **SaskPower Boundary Dam Carbon Capture Project**[9] **-** This project, since 2014, has captured approximately 1$MtCO_2$/yr or 90% of the CO_2 produced from one unit in the Boundary Dam coal power plant, which produces over 120 MW of clean power for the province of Saskatchewan. This project was the first large scale Carbon Capture Project from a coal fired plant in the world. The unit continues to operate with most of the captured CO_2 going to the Weyburn EOR project. Any surplus CO_2 is injected into the **Aquistore Deep Saline CO_2 Storage Project** which is located about 3km from the Boundary Dam Site, is the world's largest industrial-scale CCS research project, and to date has injected over 500 $ktCO_2$.

- **Shell Quest Project**[10] - This project captures and injects roughly 1$MtCO_2$/yr from a hydrogen plant at the Scotford Upgrader and Refinery near Edmonton, Alberta, to avoid venting the gas. The Quest project receives a CO_2 rich stream from a hydrogen/CO_2 separation unit in the refinery, compresses and dries the CO_2, and pipelines it to a sequestration site where it is injected into a deep saline aquifer. This project started operation in 2015 as a commercial demonstration and, to the end of 2022, the project has injected approximately 7.7 $MtCO_2$ into 3 aquifer injection wells, avoiding roughly 6.1 $MtCO_2$ emissions based on the most recent annual report, published in 2022 and submitted to Alberta Energy[11].

- **Alberta Carbon Trunk Line (ACTL)**[12] – The world's largest carbon capture and storage project[13] was completed in 2020 and consists of a 240 km CO_2 pipeline which has a capacity to carry 14.6 $MtCO_2$/yr from the Industrial Heartland in Alberta to CCUS sites in the Red Deer area. Currently, the system carries approximately 1.6 $MtCO_2$/yr from the North-West Regional Upgrader (bitumen gasifier) and Nutrien Redwater Fertilizer Plant (ammonia production). It has carried roughly 4 $MtCO_2$ to date to EOR projects in the Clive oil field. In September 2023, it was announced that an ACTL Edmonton Connector will be built in the Edmonton area to collect up to 7 $MtCO_2$/yr from other concentrated CO_2 sources such as a new Air Products Hydrogen Plant which is being designed to be zero-emissions as well as the announced Dow Chemical plant Path2Zero Chemical Plant. The pipeline portion of the project is funded by the Canadian Pension Plan Investment Board.

- **Development of Carbon Hubs** – In addition to the above projects, Alberta has embarked on the development of regional Carbon Hubs to promote CCS in the province and has already gone through two rounds requesting proposals for the Industrial Heartland, where many industrial CO_2 emission sources are concentrated, and other areas of the province.

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9 https://ccsknowledge.com/bd3-ccs-facility

10 Shell Quest Website - https://www.shell.ca/en_ca/about-us/projects-and-sites/quest-carbon-capture-and-storage-project.html

11 Shell Quest Annual Report for 2022 issued March 2023 https://open.alberta.ca/dataset/356aeeda-134c-4779-971c-931573400ddf/resource/8a1b4350-9634-4e66-a983-8c16199fa2e7/download/quest-annual-summary-report-2022-alberta-department-of-energy.pdf

12 ACTL Pipeline https://wolfmidstream.com/carbon/

13 Government of Alberta https://majorprojects.alberta.ca/details/Alberta-Carbon-Trunk-Line/622

Policy and Regulation

CCS has been recognized both federally and provincially as a key process for meeting aggressive GHG reduction and net zero targets. The Federal focus is on aquifer CCS with no incremental hydrocarbon production while the Provinces of Alberta and Saskatchewan are more supportive of carbon capture, utilization, and storage (CCUS) through utilization of CO_2 for Enhanced Hydrocarbon Recovery (EOR or EGR) projects, which generally will require less government support to move ahead as these projects are usually economic. However, Alberta is also supporting CCS into aquifers through Carbon Hubs in the province[14]. The province has declared Crown ownership of all "pore spaces" in the province[15] which are openings in sedimentary rock which could store CO_2. Right to use the pores for storing CO_2 requires licensing and the province takes responsibility for any long term liability related to storage after sites are no longer active and declared to be secure. CCS volumes injected can generate offsets through Alberta's Carbon regulation, Technology Innovation and Emissions Reduction (TIER), which provides quantification protocols. In other jurisdictions, like the U.S., ownership of the subsurface pore space for aquifer CCS is not as clear cut and can vary by state for onshore CCS. Most international pure CCS projects (non-EOR) are generally being considered for offshore areas where Federal jurisdiction prevails, ownership of any subsurface resources is under Federal responsibility, and the Federal governments will assume responsibility for protection of these areas and long-term monitoring of any injected CO_2.

Access to Financing and Financial Incentives

Federal and Provincial governments in Canada have promised to invest in developing CCS options through a range of programs at various stages of the CCS development process from research into new capture technologies to support for commercial CCS projects. Supports being developed include guarantees for CO_2 value in the future to de-risk pure CCS activities which are mainly justified based on existing carbon pricing or tax policies, which could be altered with any change in government. The provincial Government of Alberta is also reinvesting money from carbon taxes into technology development for emissions reduction through the TIER regulations. Industry commitments are generally through collaborative targets and commitments to GHG reductions by 2050, which usually contain some components related to CCS or individual corporate commitments. The main industry focus, currently, is on the Oil Sands Pathway to Net Zero Alliance[16] which was formed in June 2021 and is a collaborative effort of six large oil sands producers responsible for ~95% of bitumen production in Alberta. The Pathways Alliance is projecting a potential CCS target of 40 $MtCO_2$/yr into aquifers in the Cold Lake, Alberta Region, but is also working on many other options to meet their net zero targets.

Investment in Research and Development

The Canadian petroleum industry is heavily involved in research and development of new ideas and technologies, with oil and gas producers providing substantial investment in clean technology development. This includes associations such as the Petroleum Technology Association of Canada (PTAC), Canada's Oil Sands Industry Alliance (COSIA), and the Clean Resource Innovation Network (CRIN) which provide a collaborative framework for developing appropriate

[14] Alberta CCS fact sheet issues August 17, 2023 - https://www.alberta.ca/system/files/custom_downloaded_images/energy-fact-sheet-storage-hub-development.pdf

[15] Changes in resource management acts to manage pore space. https://www.alberta.ca/carbon-capture-utilization-and-storage-leadership#:~:text=This%20act%20also%20clarifies%20that,Oil%20and%20Gas%20Conservation%20Act.

[16] Oil Sands Pathways to Net Zero Alliance website https://pathwaysalliance.ca/

technologies. These organizations assist entrepreneurs and companies at various stages of development, from start-up to testing and proving new technologies.

Industry Collaboration

One major attribute that Canadian industries possess and demonstrate is a spirit of collaboration to tackle and find solutions to shared environmental and security issues. There are many associations, such as the Canadian Association of Petroleum Producers (CAPP) and the Petroleum Services Association of Canada (PSAC), that enable employees and companies to easily associate with each other and develop solutions to address common issues. Federal and Provincial governments, as owners and regulators of the resource, are active in many of these associations and help to guide the discussions and suggest areas of research. Researchers are involved as well, providing the unique detailed perspective on the science that the industry relies on to improve their performance. Technology vendors and service providers, highlighted in this guide, collaborate to understand the needs of the industry, and develop appropriate solutions. Once solutions are created, the market is ready to accept them. In this spirit of sharing and collaboration, technologies and services can develop quickly, and risk is shared between industry producers and the supply chain.

Environmental, Social, and Corporate Governance

Canada has a long tradition of responsible development within its oil and gas fields, and it is expected that this will be extended into CCS operations. Companies are active in consulting with local communities and stakeholders as they propose Carbon Hubs. Their employees are well paid members of those communities who are active citizens, contributing to their communities through local volunteer and civil society organizations. Companies and their executives are continuously striving to improve their strong environmental, social and governance (ESG) performance and many individual companies have committed to net zero targets, with many companies proposing, planning, or carrying out projects to achieve those goals. Some companies, such as WhiteCap Energy are already net zero or even "net negative" as a result of their large CO_2 EOR projects, which result in net GHG injection for the company.

Availability of Capital and Operating Expenditures

Canada and the Provinces allow private corporations to lease and develop natural resources on Crown leases. These private and public companies are driven by their shareholders to invest capital and provide a rate of return while meeting ESG commitments. While oil and gas prices have improved since the last downturn in world prices in 2014, there continues to be a great deal of uncertainty related to future oil and gas demands due to the energy transition, and availability of secure energy supplies as a result of international conflicts, and on-going tensions in other parts of the world.

New technologies and services to facilitate and enable CCS provide opportunities for producers to work together to further improve their ESG performance. These technologies and services ensure that producers are supported by government regulations and with financial support, so that they are able to implement CCS projects without significantly impairing their ability to compete in global markets and meet shareholder expectations for positive returns.

Summary

The above regulatory and policy incentives, as well as growing support from investors, innovators, producers, and Indigenous communities to demonstrate and implement CCS and CCUS, have resulted in the development of many existing projects and a significant list of potential new project proposals which are moving toward Final Investment Decisions (FIDs). Existing technology and knowledge are ready to be exported while additional innovations develop.

Major Sources of CO_2 Emissions in the Oil and Gas Industry

Carbon dioxide emissions from upstream oil and gas have been classified into several types of facilities to create a better understanding of the issues involved in mitigating the emissions as well as the relative scale of the target operations. The following section provides the CO_2 emission source categories and amounts of CO_2 specific to oil and gas industry facilities based generally on the Environment Canada GHG Inventory Report and the gas emitted[17]. It should be noted that other industry sources such as electrical power generation and industrial chemicals may include emissions which may be co-located with major oil and gas facilities to provide power or hydrogen. These additional amounts would add to the CCS system duty. The values below only focus on CO_2 emissions which are the target of CCS, CO_{2e} emissions are usually larger as most sites have some methane emissions associated with them.

The emissions shown are based on the latest published Canada GHG Inventory Report by Gas for 2021. Information on Percentage of emissions from facilities over 100 kt/yr and the number of sites are taken from 2021 reporting facilities plus rough estimates of the number of smaller non-reporting facilities mainly for conventional oil and gas sites. It is assumed that sites emitting more than 100 kt/yr of CO_2 will be the primary targets for CCS, however, some operators of smaller sour gas plants may also be able to convert to CCS through converting operations to acid gas injection and potentially capture of flue gas emissions at some sites.

Total CO_2 Emissions $MtCO_2/yr$ (% from facilities over 100kt/yr)	Approximate Number of Sites	Emissions Sources and Characteristics
43 (99%)	~30 in-situ oilsands & ~20 heavy oil thermal	**In-Situ Oil Sands and Heavy Oil Thermal** The main CO_2 sources from these operations are from steam generation facilities which use either once-through steam generators (OTSGs) or heat recovery steam generators (HRSGs). Flue gases from OTSGs contain ~8-9% CO_2 while HRSGs produce steam and power and the exhaust stream is closer to 4% CO_2. Note that some HRSG generated power is exported to the Alberta grid while other in-situ or thermal sites receive power from the grid or adjacent co-generation facilities operated by third parties. Generators are usually located in clusters in each plant which facilitates collection. Less than 10% of the emissions will come from thermal heavy oil operations which are mainly located in the province of Saskatchewan.
25 (100%)	~5-6	**Bitumen/Heavy Oil Upgraders** These facilities have a wide range of CO_2 sources. The primary targets for CCS will be the relatively pure (95%+) CO_2 from hydrogen plants (2 of which are already captured at Scotford and North West Refinery), which may account for ~10-20% of upgrader CO_2 emissions depending on the process. Upgraders also require steam, heating and power for the hydrogen plants and other refinery processes so most of the remaining CO_2 emissions come from direct combustion of natural gas in steam plants and fired heaters each at ~8-9% CO_2 and co-generation units at ~4% CO_2. The exact percentages of CO_2 at various concentrations will vary widely by site and is dependent on how integrated the upgrader is with mining and extraction operations and how it is producing or acquiring the hydrogen required for upgrading.

[17] ECCC GHG Inventory for 2021 https://data-donnees.az.ec.gc.ca/data/substances/monitor/canada-s-official-greenhouse-gas-inventory/B-Economic-Sector/?lang=en

14 (100%)	~7	**Oil Sands Mining and Extraction** Mining emission sources are mainly from fossil fuel driven mining trucks and shovels, and from steam generation used for heating the extraction process. Most shovels are electrified, so it is assumed most of the mining emissions are from large haul trucks and, similarly to large mining vehicles in other sectors, would require fuel substitution to reduce CO_2 emissions, as there is likely no viable method of capturing the CO_2. Emissions from steam generation and power generation for shovels and extraction processes would likely be a similar mix to those found in-situ steam plants with some direct combustion heaters and co-generation (HRSG) units producing both heat and power, with some connection to the electrical grid to feed other sites or export to southern Alberta.
34 (~22%)	~600 reporting and >1000 non-reporting	**Natural Gas Production and Processing** Only 40 of these 1000s of sites emit more than 100ktCO_2/yr and therefore would be the obvious targets for CCS. The largest emitters are either sour gas plants, which already have amine systems for sour gas treating, or are large fractionation facilities located near industrial complexes. Most of these larger sites could be candidates for combustion and incinerator flue gas CO_2 capture or conversion to acid gas disposal. The vast majority of the sites are gas well treating, dehydration, or field compression sites where CCS is not likely to be practical. CO_2 emissions for small non-reporting sites are estimated based on fuel use values in provincial production reports.
11 (12%)	>1000 reporting and non-reporting	**Conventional Oil Production** The only sites in this category that are above 100 ktCO_2/yr are the four offshore (Frontier) oil production facilities. It is noted that in 2021 only 3 of 4 reported, as the Terra Nova FPSO was shutdown at the end of 2021, sent to Spain for life extension modifications, and restarted in 2022. However, CO_2 emissions for Terra Nova in 2019 were 491 kt CO_2/yr, indicating that it is a significant contributor. The offshore platform/FPSO emissions are mainly from power generation with produced natural gas, as the gas cannot be sold and is otherwise reinjected into the formations. Most conventional oil wells are electrified for pumping, so the main fuel use is usually at oil batteries for small power generation, flaring, enclosed combustion to reduce methane emissions, or building, process, or tank heating. Few of these small sites would normally be considered for CCS or fuel substitution. CO_2 emissions for small non-reporting sites are estimated based on fuel use values in provincial production reports.
8 (97%)	~20 pipeline systems	**Oil, Natural Gas and CO_2 Transmission** These emissions are from transmission systems, so cannot be related to individual sites which have varying sizes and types of compressor equipment, heaters, and potentially other equipment. The systems with the largest emissions are the most distributed and are generally the collection systems which require larger compression horsepower. The largest compressor sites have multiple gas turbine drives. Some sites for interprovincial gas transmission and exports may not be located in areas where CCS is possible such as the Canadian Shield or mountainous areas
Total 135	**All Upstream O&G Sources**	

Case Studies

These case studies provide examples of Canadian technologies and services applied in the field, along with the impacts on clients. In some examples, multiple technologies and services are used to provide the best solution to the client.

CO_2 Removals and Support for Project Developments

Carbon Alpha Group

Provides a wide range of services to manage CO_2 Removal Projects. Their current focus has been working with Heartland Generation since 2021 to progress the carbon sequestration hub component of their Battle River Carbon Hub (BRCH) through the various stages of development with the objective of becoming Canada's first large scale power generation project using hydrogen. Carbon Alpha is now working with Heartland on an appraisal well program to gather new information to increase understanding of injectivity and storage capacity of the subsurface storage reservoir and to confirm its hydraulic isolation from other formations.

Computer Modelling Group (CMG)

Provides software for modelling complex subsurface and surface processes. CCS is a new process which requires extensive modelling to allow proponents to de-risk their energy projects. The performance and distribution of CO_2 in the subsurface, especially in aquifers, is a relatively new field so may also require extensive research and analysis of initial injection trials to project ultimate performance.

Carbon Capture Processes

Delta Cleantech

Delivers practical engineering support and solutions for pre- or post-combustion capture of CO_2 from industrial sources. Services include modelling, scaling, and costing of CCS projects.

Entropy Inc.

A full-services CCS developer, with services extending from the subsurface to the sale of CO_2 credits. The Glacier Project in Alberta is a natural gas plant that commercially captures and sequesters carbon from post-combustion emissions. The initial Phase 1 CO_{2e} emissions avoided are estimated to be 63 $ktCO_{2e}/yr$. The Glacier Project has been in operation since 2022, at a cost of ~$45M; For more information visit Entropy Inc.'s website.

Ionada

Located in Calgary, Ionada supplies membrane technology combined with amine absorption for capturing CO_2 from flue gases in both marine and industrial operations. Their systems are capable of removing 99% of CO_2 from flue gas with a 33% percent higher energy efficiency and are designed for small to medium sources that emit less than 200 $ktCO_2/yr$.

Monitoring and Measurement of Emissions

Flux Lab

A not-for-profit research group located at St. Francis Xavier University in Nova Scotia, specializing in GHG measurement and data processing in both natural and industrial settings. Flux Lab provides a key service for CCS, which is to design monitoring systems for emissions measurement and reporting.

Research, Development and Demonstration

The Petroleum Technology Research Centre (PTRC)

A not-for-profit company located in Regina, Saskatchewan. PTRC manages the Aquistore Project which is the most comprehensive full-scale geological field laboratory for CO_2 storage in the world. This on-going project injects and stores CO_2 from SaskPower's Boundary Dam Coal Power Carbon Capture Facility near Estevan, Saskatchewan to demonstrate the sustainability of deep saline storage, and is providing the knowhow for other jurisdictions and companies interested in those processes. PTRC previously managed CO_2 monitoring and storage through the IEAGHG Weyburn-Midale CO_2 Monitoring and Storage Project (2000-2013) and through an extension of that research in a two-year program called SaskCO_2USER, which expanded upon the datasets created at Weyburn to further examine such things as wellbore integrity during CO_2 storage, and minimum datasets for assuring safe storage in depleted oilfields.

CO_2 Utilization

Carbon Upcycling

Facilitates the utilization of large volumes of CO_2 by combining it with by-product materials, such as fly ash, silicates, aggregate fines, and others, to chemically bind CO_2 to locally produce and create unique construction materials, avoiding importation of these materials.

Carbonova Corp

Combines CO_2 and methane in an efficient, low-cost process which permanently converts them into water and carbon nanofibers which can be used for composites, batteries, plastics, rubbers, and coatings. These processes replace energy-intensive and expensive processes with higher CO_2 emissions.

Canadian Capabilities to Enable or Implement CCS

The following table lists the Products and Services available from Canadian experts to assist in the global effort to reduce CO_2 emissions from upstream oil and gas operations through CCS. Product categories below describe the type of products available for the various stages of the CCS system. Service categories cover various studies and assessments needed to implement CCS systems. Note that many of the products and services listed may also be applied to midstream and downstream operations.

Category	Description
Products	
Capture Systems	Products could include amine or other absorption and regeneration-based processes, where CO_2 is absorbed from a source stream and recovered in a purer form after the absorbent is regenerated. Other capture systems may use abundant low cost solid or liquids (e.g. water) absorbents which are continually supplied and disposed of. May include corrosion resistant heat exchangers, vessels and/or energy recovery systems as enhancements to the capture process.
Compress and Dry CO_2	Equipment for compressing gaseous streams containing CO_2 and water to reach pressures suitable for equipment used to dehydrate the CO_2 or flue/acid gas to prevent acid formation in pipelines and injection wells which may lead to failures.
CO_2 Transport	Equipment for construction, safe operation, monitoring, and control of pipelines carrying CO_2/flue/acid gases as a gas, liquid, or supercritical fluid. Could also include equipment to carry CO_2 by truck or ship (normally as a cryogenic fluid or liquid) in batches, or to transport spent absorbent after it has captured CO_2.
Inject CO_2	Specialized equipment required to drill, complete, convert, condition, or provide blowout and flow back prevention in wells used for CO_2 injection into underground formations, such as aquifers or depleted oil or gas reservoirs.
Monitoring and Verification	Any in-well devices used to monitor wells being used for active injection or as observation wells in nearby zones. Also includes devices or technologies for measuring CO_2 being injected, seismic activity, plume dispersion, and CO_2 flux at the surface as required, to ensure that CO_2 is not being unexpectedly released and to verify the storage is permanent and not causing other issues.
Small Scale Utilization	Small scale, opportunistic methods of utilizing CO_2 in upstream oil and gas operations to gain some economic benefit, where the primary goal is to reduce GHG emissions and improve energy efficiency. These methods would not be viable as a stand alone, field wide EOR or other utilization method which would be implemented based solely on economics, without credit for GHG emissions reductions.
Services	
Geological Studies	Service providers who can study the subsurface conditions of potential storage sites to assess capacity for storage, expected injectivity rates, barriers to vertical or lateral flow, potential pressure build up, in-situ geochemical reactions for long-term sequestration, potential for seismicity as a result of injection, and other factors focused on well or formation stability and suitability for long-term storage or sequestration.

Research	Research providers for investigations and assessments of options in all stages (Capture to Monitoring or Utilization) of the CCS processes being proposed, including but not limited to assessments of life cycle net CO_2 emissions avoided, energy inputs, geology, well construction monitoring methods, materials selection and testing, or evaluation of new technologies which may arise.
Reporting	Companies with systems for collecting, collating, analyzing, and interpreting data from all stages of the CCS process to meet technical, economic, and regulatory needs of a wide range of stakeholders.
Management and Engineering	Service providers assessing CCS management options and priorities to achieve the greatest emissions reductions in the most sustainable fashion on a basis of life-cycle analysis and net benefit to society, balancing environment, economics, and security. Engineering of specific installations and facilities once higher-level options have been assessed.
New Technology/Redesign	Innovators developing new breakthrough technologies which are not yet commercially proven or validated through third party evaluations or field trials, that may eventually result in advanced in CCS technologies applications at any stage of the process. May be looking for international support for technology validation.

Canadian Company Directory

The Canadian companies listed here have identified a primary product/service category, and each company is listed under its respective primary category. Each company has also identified additional products and services that it offers. Click on a company name to skip to its listing. Listing includes companies who have submitted summaries specific to this **Directory (in Bold)** as well as companies listed in the Canadian Energy Export Guide (*).

		Product Categories							Service Categories				
Company	Page Number	Capture Systems	Compression & Transport	Monitoring Equipment	Inject CO_2	Enhanced Oil Recovery	CO_2 Utilization	Carbon Capture and Storage	Emissions Monitoring and Verification	Research and Development	CO_2 Removals Support for Development	Geological Studies	Management Engineering
Directory													
Canadian CCS System Products													
Carbon Alpha	17		■					■			■		
Carbonnova Corp.	18		■					■			■		
Carbon Upcycling	19						■	■					
Computer Modelling Group	20					■					■	■	
Delta CleanTech	21	■											
Entropy Inc.	22	■				■							
Ionada Inc.	23	■											
Petroleum Technology Research Centre	24					■		■		■			
Canadian CCS System Services													
Flux Lab	25					■		■		■			
Canada's Energy Export Guide													
Alco Gas and Oil Production Equipment		■	■										■
Big Guns Energy Services					■			■				■	■

Bighorn Energy Corp													
BMO Capital Markets													
Enbridge													
Equinox Engineering													
Gas Liquids Engineering													
Grey Owl Engineering													
Invert													
Petronim Projects													
Svante													
Thermo Design Engineering													
University of Alberta – Reservoir Geomechanics Research Group													
Vault 44.01													
Wolf Carbon Solutions													

Canadian CCS System Products

Carbon Alpha Corp.

https://www.carbonalpha.com/

LOCATION
Calgary, AB, CANADA

PRIMARY CATEGORY
Carbon Dioxide Removals (CDR)

CONTACT INFORMATION
info@carbonalpha.com
587-323-7250

SECONDARY CATEGORY
Carbon Capture and Storage (CCS)

COMPANY DESCRIPTION

Carbon Alpha is a Calgary-based company committed to creating a sustainable world for future generations by generating high-quality, scalable carbon solutions. Founded in 2021, Carbon Alpha's full-service approach develops carbon dioxide removal projects from concept to credit generation.

Carbon Alpha is Canada's largest team of fully integrated professionals dedicated to developing carbon dioxide removal (CDR) projects, carbon capture and storage (CCS) solutions and supplying the highest-quality carbon credits.

Carbon Alpha has a unique and comprehensive understanding of the challenges businesses, industries and governments face to reduce their emissions. Our experts are equipped to help organizations adopt CDR and other emissions avoidance solutions from concept to development and execution.

With decades of experience across every aspect of carbon storage and transport, operations, regulations and more — Carbon Alpha puts quality, safety and excellence first. Our commitment to decarbonization through high-quality CDR solutions and verifiable carbon credits makes us the trusted partner for investors and credit buyers who are looking to minimize risk while maximizing climate impact.

As CDR and CCS emerge as critical solutions to climate change, Carbon Alpha has the proficiency and ingenuity to provide and scale solutions that will make a difference. By bringing CDR technology to the private and public sectors, Carbon Alpha is equipped to deliver and scale high-quality carbon solutions and credits to create a sustainable world for future generations.

TECHNICAL CAPABILITIES

Our team of dedicated professionals possess all the necessary skills to completely develop a CDR or CCS project. We can work with companies on everything from subsurface evaluation, cost, and schedule analysis, MMV, financing, to fulfilling all the regulatory requirements. Our fully integrated team will do all of it and ensure that the project is developed within a consistent framework.

Carbon Alpha's carbon removal services offer measured and precise carbon accounting that can be verified with the highest standard methodology. Our data-driven operations platform monitors and optimizes carbon activity down to the particle, ensuring any investments you make with Carbon Alpha are truly reflective of their real-world environmental impact.

We oversee every step of carbon removal projects from start to finish — from site selection to development and operations. With built-in monitoring, reporting and verification (MRV) and site-specific risk assessments, Carbon Alpha is ensuring the highest quality CDR credits possible, storing carbon underground for enduring impact.

Our digital platform OMEGA can help rapidly identify optimal carbon storage options often closer to emissions sources, avoiding the intensive process of transporting carbon hundreds of miles away – ensuring a safe and sustainable process from start to finish.

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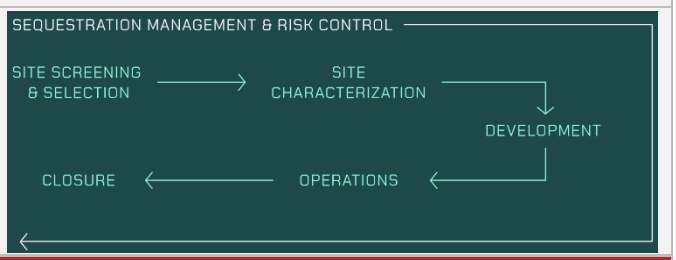


Carbonova Corp.

https://www.carbonova.com/

LOCATION
1-3200 14 Ave NE
Calgary, AB T2A 6J4
Canada

PRIMARY CATEGORY
CO_2 Utilization

CONTACT INFORMATION
Mina Zarabian, CEO & Co-Founder
mzarabian@carbonova.com
587-358-0927

SECONDARY CATEGORY
Carbon Capture and Storage (CCS)

COMPANY DESCRIPTION

Carbonova is developing and commercializing a technology that uses two main greenhouse gases (CO_2 and methane) and converts them "permanently" into essential materials that every human on earth can utilize: water and solid Carbon Nanofibers (CNF). The process is designed to be energy-efficient, and the product is one order-of-magnitude less expensive with a negative CO_2 footprint (competitive solutions have 30 t CO_2 / t carbon).

In a circular model, GHG emissions that are captured at our customer's facility are converted into solid CNFs and water, both intended to be utilized further downstream. CNFs are a material with nearly 40 sectors of applications including composites, batteries, plastics, rubbers, and coatings. Depending on the customer segment, CNFs may be used in the same location or transported to the nearest manufacturing facility - transportation can be done via truck or train with wide accessibility.

The unique value proposition of Carbonova's CNF is its low cost, negative carbon footprint. Competitors in the CNF industry typically use very energy-intensive processes that emit significant CO_2, at a much higher cost. The Carbonova process consumes CO_2 and Methane as a feedstock and is designed based on an exothermic reaction (produces energy). It operates at a medium range temperature and this energy requirement can be offset by using waste heat from the host facilities.

COUNTRIES EXPORTED TO

We have partners in South-East Asia and the USA, although we are currently at Stage 1 of our tech development (TRL Level 6/7): System prototype or minimum viable product (MVP) has been proven in an experimental environment. The next step is testing in an operational environment (pre-commercialization).

INTERNATIONAL APPLICATIONS AND EXPERIENCE

We are currently working with our international partners to develop CNF that compliments their respective applications.

TECHNICAL CAPABILITIES

The next steps in the development of our technology will be the pre-FEED and FEED work associated with a further 100x scale up to an approximately 100tpa facility (a commercial demonstration unit). This work, which is currently underway, will involve the conceptual design of the larger unit and the completion of a Techno-Economic Model (TEM) in order to optimize the sizing of key equipment, and site selection, followed by more detailed Pre-FEED and FEED work. The key risks and barriers associated with this work are expected to be related to acquiring/contracting the necessary subject matter experts (SMEs) to expedite the work. The process of acquiring these SMEs is ongoing.

Carbon Upcycling

https://carbonupcycling.com/

LOCATION
Calgary, Alberta, Canada

PRIMARY CATEGORY
CO_2 Utilization

CONTACT INFORMATION
Kristin Skelton
Kristin.Skelton@carbonupcycling.com
403-668-5869

SECONDARY CATEGORY
Carbon Capture and Storage (CCS)

COMPANY DESCRIPTION
Yearly, three billion tonnes of carbon emissions come from the concrete and cement industry, making it one of the world's largest emitters. Carbon Upcycling's (CUT) single-step low energy carbon utilization process combines low-purity industrial CO_2 with waste or low value materials creating cement replacements, known as CO_2-enhanced supplementary cementitious materials (SCMs). CUT's technology integrates into industrial plants, utilizing point source CO_2 and locally soured water materials like quarry fines, steel lag, fly ash, and industrial by-products. A Canadian company founded in 2014.

COUNTRIES EXPORTED TO
North America & Europe

INTERNATIONAL APPLICATIONS AND EXPERIENCE
CUT's technology and SCM production meets or exceeds the requirements for all regulatory jurisdictions in North America, Europe and beyond.

TECHNICAL CAPABILITIES
Our technology works by taking industrial byproducts or natural minerals and combining them with a CO_2 source (either from low or high-purity CO_2 sources) in our large catalytic reactors. Our patented reactor exfoliates the surface area of each particle of feedstock. Then we introduce CO_2 into the reactor. It binds to these particles in a chemical reaction that creates our unique materials and sequesters CO_2. The rougher the particles, the more surface area there is, allowing for greater CO_2 binding, improving CO_2 sequestration, product quality and reactivity all at the same time.

We've specifically designed our technology to work with a wide range of feedstocks, entire categories of materials from local industrial byproducts to naturally occurring minerals. Many of the feedstocks are locally (wherever you are) available in large volumes, and so far we have successfully demonstrated over 25 different ones, including fly ash, silicates, aggregate fines, and more.

By utilizing locally available materials, we remove the need to import foreign feedstocks and remove the strain on supply chains in cement production and plastics. This helps keep costs low.

Computer Modelling Group (CMG)

cmgl.ca

LOCATION
Headquarters: Calgary, AB
Offices: Houston, Oxford, Dubai, Bogota, Rio de Janeiro, Bengaluru, and Kuala Lumpur.

PRIMARY CATEGORY
Carbon Capture and Storage (CCS)

CONTACT INFORMATION
cmgl@cmgl.ca
1-403-531-1300

SECONDARY CATEGORY
Hydrogen, Geothermal

COMPANY DESCRIPTION
CMG is a global software and consulting company that combines science and technology with deep industry expertise to solve complex subsurface and surface challenges for the new energy industry around the world.
De-risk your energy projects – take off the blindfold with simulation software: Engineers in the energy sector work to design and develop methods to put carbon dioxide back into the Earth as part of energy transition projects. All without being able to see underground. The subsurface is a complex, geological puzzle that requires modelling to predict probable outcomes from actions — because we can't actually see what happens below the Earth's surface. So how do you ensure you manage all regulatory, financial, operational, and reputational risk? Simulation software.
The right simulation technology makes a difference: A nod to our research roots that go back as far as the 1970s, our technology is built on complex physics-based calculations to ensure accuracy with science-backed results. We are committed to ongoing innovation, research, and development to provide improved workflows for our customers and advance the new energy future.
A partner you can count on: Our commitment to our customers isn't limited to technology. We have a team dedicated to providing unparalleled customer service and expertise, training, and support to advance knowledge transfer to our customers and industry. Our expert technical sales and support team helps clients 24/7, no matter the time zone.

COUNTRIES EXPORTED TO
Globally

INTERNATIONAL APPLICATIONS AND EXPERIENCE
CMG plays a role in approximately three-quarters of energy transition projects in Europe, largely around hydrogen and geothermal energy, while actively contributing to the majority of active CO_2 sequestration projects globally. Our years of experience supporting the energy industry (100% of super majors, 75% of the top-25 largest oil companies, and 70% of the top unconventional producers) makes us the trusted software for energy projects, including energy transition projects, to optimize operations and mitigate risk. We also work with over 120 research and academic institutions globally.

TECHNICAL CAPABILITIES
As part of CMG's core software suite. Our carbon, hydrogen, and geothermal solutions allow organizations to assess and implement low-carbon energy technologies for a sustainable and secure energy future. With CMG's software you can:
Determine capacity and reliability.

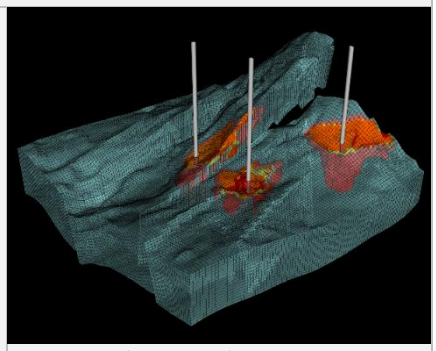
- Ensure contracting requirements are met by determining the storage capacity of the reservoir.
- Assess storage reliability by understanding the injection rate parameters of the reservoir for single or multi-well projects.

Mitigate risk.

- Model CO_2 trapping mechanisms to understand the extent of plume migration to mitigate project cost escalation.
- Reduce the risk of using saline aquifers for disposal or carbon sequestration through sensitivity analysis.

Achieve compliance and support regulatory approval.

- Ensure proper surface network design to meet production and injection requirements.
- Assess uncertainty and reduce environmental and safety concerns by assessing the potential for fault reactivation.



CCS 3D Plume Simulation – Computer Modelling Group (CMG) Ltd.

Delta CleanTech Inc.

https://deltacleantech.com/

LOCATION
2308 Palisade Dr. SW
Calgary, Alberta
T2V 3V1

PRIMARY CATEGORY
Carbon Capture and Storage (CCS)

CONTACT INFORMATION
Jeff Allison - President
jallison@deltacleantech.com
(306) 530-6025

SECONDARY CATEGORY
Methane Destruction

COMPANY DESCRIPTION
Delta CleanTech Inc. is a leading provider of technology for pre/post-combustion CO_2 capture from industrial sources, enabling significant and economical reduction of greenhouse gas emissions since 2004. Delta's goal is to deliver practical solutions to reduce greenhouse gas emissions, CO_2 utilization, and help solve the challenges of energy security and transition. Led by a team of experts in carbon capture, Delta's customers achieve their individual carbon capture goals through precise modeling, scaling, and costing. Delta CleanTech combines its own proprietary patented technologies with a global partnership network to meet aggressive 21st century carbon emission reduction targets.

COUNTRIES EXPORTED TO
World-Wide

INTERNATIONAL APPLICATIONS AND EXPERIENCE
Process design engineering for CO2 capture plants world-wide.

TECHNICAL CAPABILITIES
Process design of Pre and post combustion CO2 Capture plants, solvent reclaimers, low volume methane destruction units, Carbon credits.

Entropy Inc.

www.entropyinc.com

LOCATION
Calgary, AB, Canada

PRIMARY CATEGORY
Carbon Capture and Storage (CCS)

CONTACT INFORMATION
info@entropyinc.com

SECONDARY CATEGORY
N/A

COMPANY DESCRIPTION

Entropy Inc. is a leading global full-service carbon capture and storage (CCS) developer, specializing in innovative solutions to significantly reduce CO_2 emissions from pre and post combustion sources. Additionally, Entropy offers subsurface expertise in CO_2 sequestration.

Modular and integrated CCS technology, paired with the proprietary solvent Entropy23™, sets a new standard in efficiency and cost-effectiveness for both retrofit and new CCS installations.

Entropy entered a strategic investment agreement with Brookfield Renewable for $300 million in addition to a more recent investment agreement with the Canada Growth Fund (CGF) for $200 million, including a 15-year, $1-billion fixed-price carbon credit purchase agreement for up to 1 million tonnes per annum (tpa).

Entropy's CCS system, utilizing advanced solvent-based technology, is currently operational at the Glacier Gas Plant near Grand Prairie, AB, abating CO_2 from the exhaust of two natural gas reciprocating compressor engines.

EntropyIQ™ represents the digital innovation arm of Entropy's CCS technology and enables precise, real-time monitoring and optimization of carbon capture processes. This digital data gathering and processing engine plays a crucial role in achieving operational efficiencies.

Entropy has focused its carbon capture technology into three standardized designs to optimize post-combustion emissions capture across various industrial applications. The iCCS Thermal™ design targets boilers and steam generators, seamlessly integrating with these systems to curb emissions. For industrial engines, including compressors, the iCCS Recip™ design has been successfully deployed and is currently operating at the Glacier Gas Plant. Lastly, the iCCS Turbine™ design captures emissions from gas-fired turbines with low CO_2 concentrations, applicable worldwide for generating low emissions power generation and compression from turbines.

INTERNATIONAL APPLICATIONS AND EXPERIENCE

Entropy has initiated preliminary front-end engineering and design (pre-FEED) work on several large-scale projects across a broad range of emission sources, in both Canada and the United State. Both sets of projects target a diverse array of emission sources, including large industrial emitters, gas-fired boilers, steam generation, power generation, methanol production, and ethanol production.

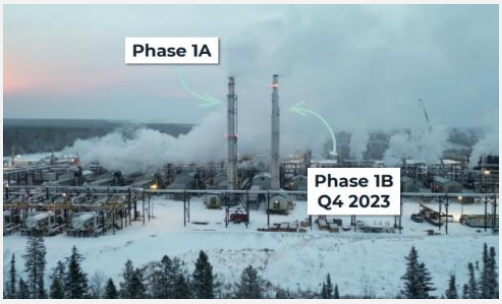
TECHNICAL CAPABILITIES

Proven: Operating since July 2022, Entropy is the world's first and only commercial natural gas post-combustion CCS facility, establishing itself as the provider of the lowest cost & most efficient technology in operation.

Energy Efficient: The use of waste heat recovery, heat integration, and a high-performance solvent significantly reduces the energy required for carbon capture, achieving high CO_2 recovery rates with lower electrical loads.

Advanced Solvent: The high-performance solvent Entropy23™ offers superior efficiency in CO_2 capture, resulting in lower energy and solvent requirements, enhancing the economic feasibility of CCS projects.

Scalable: Entropy's iCCS™ technology is designed for scalability, allowing for reduced capital costs, flexible maintenance, and efficient installation across various industrial applications and scales from <100ktpa to >1Mtpa



Ionada

https://ionada.com/

LOCATION
#106 – 7620 Elbow Dr. SW
Calgary, AB, Canada
T2V 1K2

PRIMARY CATEGORY
Carbon Capture and Storage (CCS)

CONTACT INFORMATION
Info@ionada.com
+1 888 561 7870

SECONDARY CATEGORY
N/A

COMPANY DESCRIPTION
Ionada develops, manufactures, and markets exhaust gas cleaning systems that reduce emissions from the marine and power generation industries. Our sustainable solutions keep our air and waters clean for future generations. Ionada's team includes international scientists, engineers and technicians that have developed breakthroughs in technologies to reduce emissions.

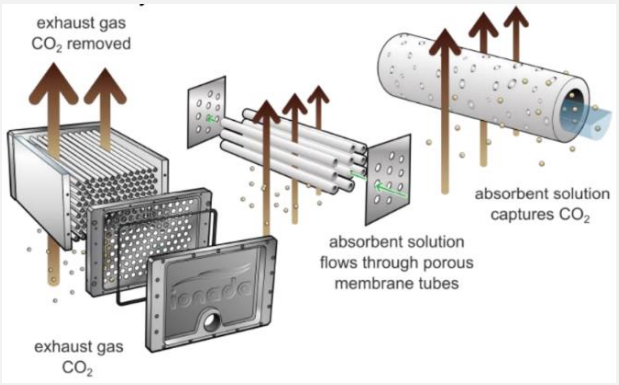
COUNTRIES EXPORTED TO
Ionada services the global market with operations in Germany, The Netherlands, United Kingdom and the Americas.

INTERNATIONAL APPLICATIONS AND EXPERIENCE
At Ionada, we uphold the highest standards, providing sustainable solutions in the ever-evolving maritime, energy, oil, and gas industries throughout the world.

TECHNICAL CAPABILITIES
Ionada's membrane technology offers an efficient solution for carbon capture in marine and power generation applications, capable of removing up to 99% of carbon dioxide from flue gas. This CO_2 decarbonization system is renowned for its sustainability and environmental benefits.
Key features include:
- Up to 99% CO_2 capture efficiency
- 30% higher energy efficiency
- Minimal carbon footprint
- Modular containerized design for easy retrofit installations
- Zero water consumption
- Reduced landfill costs with regenerable absorbent solutions
- Use of proven and reliable CO_2 absorbents

Ionada's Membrane Decarbonization system utilizes a combination of chemical absorption processes and porous ceramic tube membranes. This design effectively removes carbon dioxide from flue gas without generating sludge. The process involves separating carbon dioxide from exhaust gas and capturing it with an absorbent solution flowing through hollow ceramic membranes made of alumina. These membranes provide high absorption efficiency and durability in hot, corrosive environments, with a service life of at least 10 years.
Ionada's membrane CO_2 absorber uses proven amine absorbents to remove gases from exhaust gases. Cold amine solutions circulate in the membrane contactor to bind CO_2, with the binding reversed at higher temperatures.

$CO_2 + 2\ HOCH_2CH_2NH_2 \leftrightarrow HOCH_2CH_2NH_3^+ + HOCH^2CH_2NH(CO_2^-)$



Petroleum Technology Research Centre

https://ptrc.ca/

LOCATION
Regina, SK
T2V 1K2

PRIMARY CATEGORY
Carbon Capture and Storage (CCS)

CONTACT INFORMATION
Norm Sacuta
norm.sacuta@ptrc.ca
1-306-787-7497

SECONDARY CATEGORY
CO_2 storage MMV
Blue Hydrogen research
Geothermal Energy

COMPANY DESCRIPTION
The PTRC is a not-for-profit company that leverages public with private sector funding to conduct R&D and demonstration projects that increase the production of subsurface energy, while also lessening the environmental impacts of production. This includes CO_2 emissions reduction through carbon capture and storage (like the Aquistore project, which has 590,000 tonnes of CO_2 stored deep underground) and CO_2-enhanced oil recovery. PTRC's awareness of the deep subsurface has also led to new projects including geothermal heating (with both the cities of Regina and Estevan), a recent white paper on Compressed Air Energy Storage, and Blue Hydrogen R&D.

COUNTRIES EXPORTED TO
We do not produce products, but have managed CCS feasibility studies for Vietnam, and have provided CCUS instructional courses in the United States.

INTERNATIONAL APPLICATIONS AND EXPERIENCE
PTRC has recently conducted work for, or presented information from the Aquistore project, internationally to companies in UAE, Saudi Arabia, the United States and Japan and across Canada in Ontario, Quebec, Alberta and Saskatchewan. We recently managed a feasibility study for the Asian Development Bank on CCS in Vietnam.

TECHNICAL CAPABILITIES
The Aquistore CO_2 storage site, and affiliated field technologies that are being tested there, makes that location the largest industrial-scale field testing facility in the world for the measurement and monitoring of stored CO_2. Over 30 MMV technologies have been tested at the site, including innovative set point seismic sources, fibre optics of varying kinds, downhole pressure and temperature gauges, and other kinds of downhole and surface technologies. With close to 600,000 tonnes of CO_2 in the reservoir, stored from SaskPower's Boundary Dam CO_2 capture facility, the site offers the opportunity for new MMV technology developers to field test their devices in a fully operational, industrial-scale CCS site. The image provided is of the Aquistore injection well.

Canadian CCS System Services

FluxLab, St. Francis Xavier University

www.fluxlab.ca

LOCATION
Antigonish, Nova Scotia

PRIMARY CATEGORY
Environmental Protection and Management

CONTACT INFORMATION
Chelsie Hall: chall@stfx.ca / Dave Risk: drisk@stfx.ca

SECONDARY CATEGORY
Carbon Capture and Storage (CCS)

COMPANY DESCRIPTION

FluxLab is non-profit research group at St. Francis Xavier University, in Nova Scotia, which consists of over 30 students and professional researchers. The group's capabilities lie in gas emissions measurement and data processing to identify methane, and other gases, in natural and industrial settings.

We have been involved in ecological gas measurement projects from pole to pole; monitoring design for Carbon Capture and Storage sites, and for much of the past decade our focus has been reducing methane in Canadian oil and gas and solid waste sectors. Our research involves developing and improving gas measurement technology, inventory studies, computation, and providing data to support regulatory design and policy development. So far, our team has made gas emission measurements at over 10,000 oil and gas facilities across North America and at 130 landfills - onshore and offshore - to help industry and regulators better measure, understand, and manage greenhouse gas emissions.

This research group is a centre of excellence for greenhouse gas sensing, and many industries and government departments bring their questions here to be answered with specialized research, facilities, now-how, and proven ability to solve complex problems. We design our research to have impact outside traditional academic settings, and regularly collaborate and partner with companies, governments, non-government organizations, and international research initiatives to ensure our findings can be utilized in the real world.

COUNTRIES EXPORTED TO
United States, Turkmenistan, England, Antarctica

INTERNATIONAL APPLICATIONS AND EXPERIENCE
We FluxLab has worked with stakeholders and collaborators to help advance measurement technologies for monitoring, measurement, and validations, and executed large scale field measurement campaigns with third party vendors, NGOs and companies.

TECHNICAL CAPABILITIES

1. Measurement technology innovation and field application development
2. Field studies including large scale (national and international)
3. Emissions computational data science and plume modeling

(Image of our vehicle-based hardware used in mobile methane measurement campaigns)

Canadian Energy Export Guide

The Canadian Energy Export Guide is a searchable database that represents more than 1000 Canadian companies that export products and services in the area of oil & gas and related clean technologies, from grass roots exploration, pipeline construction and operation, to end of production decommissioning, reclamation, and remediation. The Canadian Energy Export Guide uses 12 primary categories and 60 sub-categories to identify Canadian companies that are exporting to international markets. The companies listed in this Canadian Capabilities in Carbon Capture and Utilization Directory can also be found online in the Canadian Energy Export Guide under the category of Clean Technology and Environmental Management/CCS.

Industry Partners

The following Canadian associations and organizations have members and/or are working in the area of Carbon Capture and Storage technologies and developments.

Canadian Association of Petroleum Producers (CAPP) is an industry association that advocates for economic competitiveness and safe, environmentally, and socially responsible performance from its members.

Canada's Oil Sands Innovation Alliance (COSIA) is an alliance of oil sands companies working with scientists, academics, and innovators to make Canadian energy part of a sustainable environment.

Canadian Emissions Reduction Innovation Consortium (CanERIC) was created by PTAC to respond to the oil and gas industry gap where there was a lack of streamlined support for critically needed, novel, high performance, and cost-effective technologies to address the global emissions reduction challenge.

Clean Resource Innovation Network (CRIN) was created to contribute to a future in which Canada is a global leader in producing clean hydrocarbon energy from source to end use.

Enserva is the national trade association representing the service, supply, and manufacturing sectors within the upstream petroleum industry. They also maintain the Canadian Energy Export Guide noted above.

Petroleum Technology Alliance Canada (PTAC) is an industry association with production, academia, government, regulator and technology vendor members. It leads the technology development of methane emission reduction devices, and research into many environmental areas. Of note is PTAC's Canadian Emission Reduction Innovation Consortium including 16 producers and 16 research organizations.