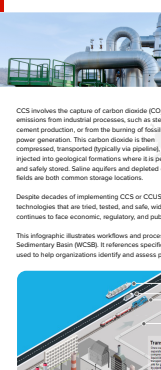
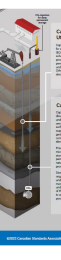
Carbon Capture, Utilization, and Storage (CCS/CCUS)

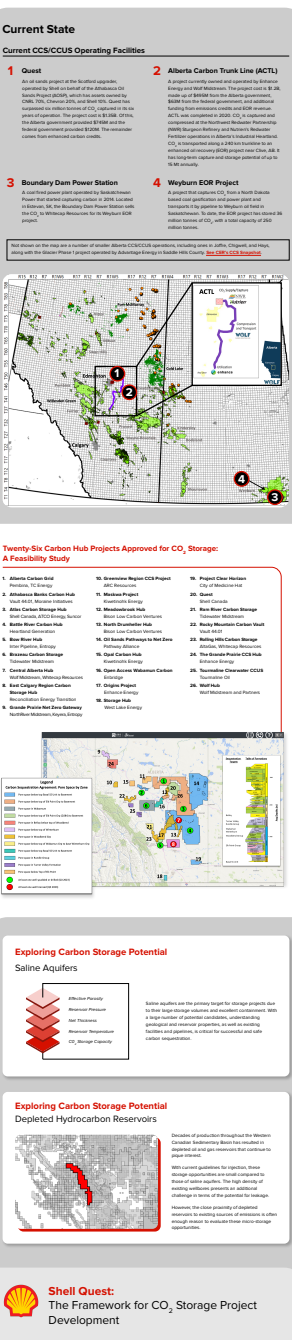


CCS involves the capture of carbon dioxide (CO_2) emissions from industrial processes, such as steel and cement production, or from the burning of fossil fuels in power generation. This carbon dioxide is then compressed, transported (typically via pipeline), and injected into geological formations where it is permanently and safely stored. Saline aquifers and depleted oil and gas fields are both common storage locations.



Despite decades of implementing CCS or CCUS, using technologies that are tried, tested, and safe, widespread adoption and deployment of CCS continues to face economic, regulatory, and public perception challenges.

This infographic illustrates workflows and processes related to CCS in the Western Canadian Sedimentary Basin (WCSB). It references specific **geoLOGIC data sets** and tools that can be used to help organizations identify and assess potential CSS solutions.



Current State

Current CCS/CCUS Operating Facilities

1 Quest

An oil sands project at the Scotford upgrader, operated by Shell on behalf of the Athabasca Oil Sands Project (AOSP), which has assets owned by CNRL 70%, Chevron 20%, and Shell 10%. Quest has surpassed six million tonnes of CO_2 captured in its six years of operation. The project cost is $1.35B. Of this, the Alberta government provided $745M and the federal government provided $120M. The remainder comes from enhanced carbon credits.

2 Alberta Carbon Trunk Line (ACTL)

A project currently owned and operated by Enhance Energy and Wolf Midstream. The project cost is $1.2B, made up of $414M from the Alberta government, $60M from the federal government, and additional funding from emissions credits and EOR revenue. ACTL was completed in 2020. CO_2 is captured and compressed at the Northwest Redwater Partnership (NWR) Sturgeon Refinery and Nutrien's Redwater Fertilizer operations in Alberta's Industrial Heartland. CO_2 is transported along a 240 km trunkline to an enhanced oil recovery (EOR) project near Clive, AB. It has long-term capture and storage potential of up to 15 Mt annually.

3 Boundary Dam Power Station

A coal-fired power plant operated by SaskatchewanPower that started capturing carbon in 2014. Located in Estevan, SK, the Boundary Dam Power Station sells the CO_2 to Whitecap Resources for its Weyburn EOR project.

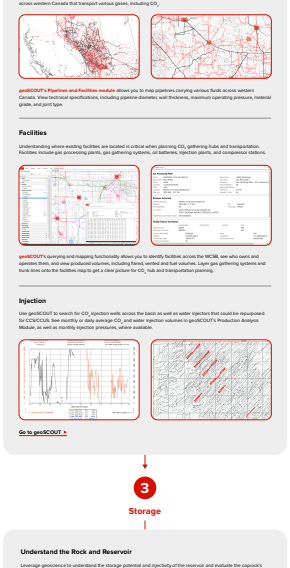
4 Weyburn EOR Project

A project that captures CO_2 from a North Dakota based coal gasification and power plant and transports it by pipeline to Weyburn oil field in Saskatchewan. To date, the EOR project has stored 36 million tonnes of CO_2, with a total capacity of 250 million tonnes.

Not shown on the map are a number of smaller Alberta CCS/CCUS operations, including ones in Joffre, Chigwell, and Hays, along with the Glacier Phase 1 project operated by Advantage Energy in Saddle Hills County. **See CER's CCS Snapshot.**

Twenty-Six Carbon Hub Projects Approved for CO_2 Storage: A Feasibility Study

1. **Alberta Carbon Grid** – Redwater, TC Energy
2. **Athabasca Basins Carbon Hub** – Vault 44.01, Mocanie Initiatives
3. **Atlas Carbon Storage Hub** – Shell Canada, ATCO Energy, Suncor
4. **Battle River Carbon Hub** – Heartland Generation
5. **Bow River Hub** – Inter Pipeline, Entropy
6. **Brazeau Carbon Storage** – Tidewater Midstream
7. **Central Alberta Hub** – Wolf Midstream, Whitecap Resources
8. **East Calgary Region Carbon Storage Hub** – Reconciliation Energy Townlator
9. **Grande Prairie Net Zero Gateway** – NorthRiver Midstream, Keyera, Entropy
10. **Greenview Region CCS Project** – ARC Resources
11. **Mistsiea Project** – Kiwetinohk Energy
12. **Meadowbrook Hub** – Bison Low Carbon Ventures
13. **North Drumheller Hub** – Bison Low Carbon Ventures
14. **Oil Sands Pathways to Net Zero** – Pathway Alliance
15. **Opal Carbon Hub** – Kiwetinohk Energy
16. **Open Access Wabamun Carbon** – Enbridge
17. **Origins Project** – Enhance Energy
18. **Storage Hub** – West Lake Energy
19. **Project Clear Horizon** – City of Medicine Hat
20. **Quest** – Shell Canada
21. **Rain River Carbon Storage** – Tidewater Midstream
22. **Rocky Mountain Carbon Vault** – Vault 44.01
23. **Rolling Hills Carbon Storage** – Altalink, Whitecap Resources
24. **The Grande Prairie CCS Hub** – Enhance Energy
25. **Tourmaline Clearwater CCUS** – Tourmaline Oil
26. **Wolf Hub** – Wolf Midstream and Partners



Exploring Carbon Storage Potential

Saline Aquifers

Saline aquifers are the primary target for storage projects due to their large storage volumes and excellent containment. With a large number of potential candidates, understanding geological and reservoir properties, as well as existing facilities and pipelines, is critical for successful and safe carbon sequestration.

Exploring Carbon Storage Potential

Depleted Hydrocarbon Reservoirs

Decades of production throughout the Western Canadian Sedimentary Basin has resulted in depleted oil and gas reservoirs that continue to pique interest.

With current guidelines for injection, these storage opportunities are small compared to those of saline aquifers. The high density of existing wellbores presents an additional challenge in terms of the potential for leakage.

However, the close proximity of depleted reservoirs to existing sources of emissions is often enough reason to evaluate these micro-storage opportunities.

Shell Quest: The Framework for CO_2 Storage Project Development

Considerations for Canadian CO_2 storage projects generally look to the Shell Quest Carbon Capture and Storage Project as a framework. It includes the Assessment of the BCS for Safety and Security of CO_2 Storage table, which provides a breakdown of critical, essential and desirable criteria.

Table 4.1 Assessment of the BCS for Safety and Security of CO_2 Storage

Quest ref.	No.	Criteria	Information	Subsurface Assessment	Risk Ranking
Critical	1	Reservoir-seal pair	Reservoir and seal lithology, extent and distribution	Presence of a reservoir-seal pair with regional extent and distribution	Critical
	2	Pressure regime	Overpressured, underpressured, hydrostatic	Pressure regime must be compatible with containment	Critical
	3	Fracturing regime	Fracturing intensity, orientation, and connectivity	Fracturing regime must be compatible with containment	Critical
Essential	4	Faulting and fracturing intensity	Faulting and fracturing intensity	Faulting and fracturing intensity must be compatible with containment	Essential
	5	Seismicity	Seismicity	Seismicity must be compatible with containment	Essential
	6	Caprock thickness	Thickness and lateral continuity of caprock	Caprock must be sufficiently thick and laterally continuous to ensure containment	Essential
Desirable	7	Depth	Depth	Depth must be sufficient to ensure containment	Desirable
	8	Thickness	Thickness	Thickness must be sufficient to ensure containment	Desirable
	9	Porosity	Porosity	Porosity must be sufficient to ensure containment	Desirable
	10	Permeability	Permeability	Permeability must be sufficient to ensure containment	Desirable
	11	Adverse diagenesis	Diagenesis	Diagenesis must be compatible with containment	Desirable
	12	Hydrogeology	Hydrogeology	Hydrogeology must be compatible with containment	Desirable
	13	Pressure	Pressure	Pressure must be compatible with containment	Desirable
	14	Temperature	Temperature	Temperature must be compatible with containment	Desirable
	15	Geothermal regime	Heat flow	Geothermal regime must be compatible with containment	Desirable
	16	Groundwater protection	Groundwater protection	Groundwater protection must be compatible with containment	Desirable
	17	Well density	Well density	Well density must be compatible with containment	Desirable
	18	Caprock thickness	Thickness and lateral continuity of caprock	Caprock must be sufficiently thick and laterally continuous to ensure containment	Desirable
	19	Faulting and fracturing intensity	Faulting and fracturing intensity	Faulting and fracturing intensity must be compatible with containment	Desirable
	20	Seismicity	Seismicity	Seismicity must be compatible with containment	Desirable

View Table

Ref: IPIECA / OGCI/SCCS (2011) Good Practice Carbon Capture and Storage Project CSP/11 Full Ed. APPLICATION TABLE No. 4.1 EL_0018 - QUEST CCS/SHELL Groundwater (2016)

** Note: Table 4.1 Assessment of the BCS for Safety and Security of CO_2 Storage *

It should be noted that this table is not up to date with recent rules and regulations. For example, the minimum depth is 1,000 vs. now 1,300 m.

Critical

Parameters focused on safety and security of a CO_2 storage scheme .

A CO_2 storage candidate requires a **reservoir-seal pair** – a porous reservoir zone with an impermeable seal above. The **pressure and depth regime** should be suitable for containing CO_2 in a super-critical state and **groundwater** must be protected from CO_2 invasion. There must be **monitoring potential** to ensure conditions are met and CO_2 is contained.

Essential

Parameters ensuring containment will be suitable once CO_2 injection begins.

Faulting and fracturing intensity can provide pathways for CO_2 to escape. Evaluating **seismicity** will indicate potential for future stability. **Hydrogeology** will indicate flow paths for CO_2 and mitigate the risk of groundwater contamination.

Desirable

Parameters that differentiate the quality of the storage scheme.

This includes factors that will affect the state of CO_2, such as **depth**, **pressure/temperature**, and **geothermal regime**, as well as factors that affect the volume of storage and ability to inject, including **porosity**, **permeability**, **thickness**, and **adverse diagenesis**. Other important factors to understand are a storage location's proximity to **fold and thrust belts** and the **well density** of existing development in the area.

Steps to Develop a CO_2 Storage Project

1

Quantify and Characterize Emissions

Some CO_2 storage projects are designed for a single source of emissions. Others are a collection hub for multiple sources.

In Canada, flaring emissions at the wellhead represent a small percentage of emissions in the oil and gas industry. These emissions include flaring and venting, as well as fugitive emissions (leaks and irregular releases). Facility emissions (e.g., emissions from gas plants) represent a much larger piece of the puzzle. The Canadian federal government releases greenhouse gas emissions data annually, collected from emitters through its greenhouse gas reporting program (GHGRP). Characterizing emissions is also very important. By understanding the compositional breakdown of the emissions, operators are able to understand whether it meets pipeline specifications.

Use **geoSCOUT** production data to monitor flared gas volumes at well and facility levels.

Evaluate Energy's Global Oil & Gas emissions data delivers vital insights into company greenhouse gas reduction measures and ESG performance. Enroll in our online **Evaluate Energy ESG Learning** courses to learn more about emissions.

Go to geoSCOUT ▸ **Go to Evaluate Energy ▸**

2

Transportation, Facilities, & Injection

Wellhead to gas plant/facility → **Emissions transport to CCS/CCUS facility** → **CCS/CCUS facility transport to injections site**

Transportation

Safely and reliably transporting CO_2 from where it is captured to a storage site is an important stage in the process. Pipelines can transport very large quantities of CO_2, involved in CSS. There are thousands of kilometres of pipelines across western Canada that transport various gases, including CO_2.

geoSCOUT's Pipelines and Facilities module allows you to map pipelines carrying various fluids across western Canada. View technical specifications, including pipeline diameter, wall thickness, maximum operating pressure, material grade, and joint type.

Facilities

Understanding where existing facilities are located is critical when planning CO_2 gathering hubs and transportation. Facilities include gas processing plants, gas gathering systems, oil batteries, injection plants, and compressor stations.

geoSCOUT's querying and mapping functionality allows you to identify facilities across the WCSB, see who owns and operates them, and view produced volumes, including flared, vented and fuel volumes. Layer gas gathering systems and truck lines onto the facilities map to get a clear picture for CO_2 hub and transportation planning.

Injection

Use geoSCOUT to search for CO_2 injection wells across the basin as well as water injectors that could be repurposed for CCS/CCUS. See monthly or daily average CO_2 and water injection volumes in geoSCOUT's Production Analysis Module, as well as monthly injection pressure, where available.

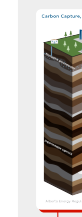
Go to geoSCOUT ▸

3

Storage

Understand the Rock and Reservoir

Leverage geoscience to understand the storage potential and injectivity of the reservoir and evaluate the caprock's ability to contain the carbon dioxide indefinitely.



Part 1: Subsurface – CCS/CCUS Environment

Determine the right location and depth for CO_2 storage. Understand the hydrogeology to protect the groundwater that lies above.

Part 2: Caprock – Ensure Sealing Integrity for Containment

Use stratigraphy and lithography to map the geology and ensure containment is continuous and competent. Evaluate possible routes of failure, including faults, fractures and potential for seismic activity.

Part 3: Reservoir – Determine Storage Potential

Understand the factors that impact the storage volume and injectivity of the reservoir: porosity, permeability, and thickness. Evaluate pressures and temperatures that impact the state of injected CO_2.

Part 1: Subsurface – CCS/CCUS Environment

Reservoir-Seal Pair

A CO_2 storage candidate has 2 primary components: a porous reservoir that is paired with an impermeable seal above it. Many storage formations are capped by thick shale deposits or evaporite deposits, which can form excellent seals for potential storage reservoirs. Reservoir and seal pairs are usually delineated with a high degree of confidence from logs and 3D seismic data.

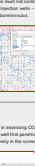
Use **geoROCK** to map the lithologies of the reservoir and seal to evaluate the competency of the barrier against vertical flow. Supplement this analysis by using **geoSCOUT's petrophysical workflows** to map lithology.

Go to geoROCK ▸

Go to geoSCOUT ▸

Depth

Ideally, a CO_2 storage zone is located at a sufficient depth and pressure that CO_2 can be injected as a supercritical fluid. Supercritical CO_2 is dense and behaves more like a liquid than a gas, allowing for storage of higher concentrations of CO_2 by volume.



Identify and map the depths of well completion events, formations tops, and pools across the entire WCSB using a variety of **geoLOGIC products**. Easily identify wells below a specified TVD, view their deviated surveys, and study the interval or more detail by analyzing a wide array of logs.

Go to geoLOGIC.com ▸

Location in relation to fold belts

Structural geology, including folds and thrusts belts, plays a critical role in assessing the integrity of the reservoir-seal pair used to store CO_2 and limit it from escaping to the surface.

Screen your candidate storage locations against **geoSCOUT's** built-in thrust belt map layer to ensure that they are sufficiently distant from any problem areas. You can also import your own fold belt shapefiles into **geoSCOUT's** powerful mapping interface, if you choose.

Shown on the map is geoSCOUT's Structures layer.

Go to geoSCOUT ▸

Groundwater protection

CO_2 from proposed storage schemes must not contact groundwater. Flow pathways from within the reservoir must not intersect with groundwater injection wells – and all wells within the reservoir – must have wellbore isolation to prevent flow up the wellbore/annulus.

Use **geoSCOUT's** base of groundwater elevation map layer to understand the depth of fresh groundwater for any current or proposed injection well.

Go to geoSCOUT ▸

Well density

Well density plays an important role in assessing CO_2 storage candidate formations, especially for prospective depleted oil or gas reservoirs. Each well that penetrates the storage formation, active or not, is considered a CO_2 escape risk and must be identified early in the screening process.

geoSCOUT's powerful query and mapping functionality allows you to easily identify well density for any field, pool, or producing formation across the WCSB. **geoLOGIC's Reserves** module provides producing and injecting well counts at a pool level for both oil and gas reservoirs.

Go to geoSCOUT ▸

Go to geoLOGIC Reserves module ▸

Part 2: Caprock – Ensure Sealing Integrity for Containment

Caprock thickness

CO_2 containment requires an impermeable caprock of adequate thickness that is continuous over the entirety of the storage area. Geomechanical properties of the caprock should be considered to determine if the increased pressure in the sequestered reservoir during CO_2 injection does not exceed the caprocks' fracture or stress gradient. Use Dipole Sonic (compressional and shear) and Density (Bulk) logs, available in geoSCOUT, to calculate the caprock's geomechanical fracture resilience in relation to the underlying sequestration reservoir.

geoSCOUT's LAS Module allows you to pull log data to perform batch LAS calculations. Determine the characteristics of the caprock and map that across the extent of the reservoir. Create a contour map in **geoSCOUT** to identify any thin spots that require further investigation.

Go to geoSCOUT ▸

Faulting and fracturing intensity

Faulting and fracturing within the caprock can threaten the seal integrity. For effective containment, faults must not penetrate the major seals and fracturing should be limited. Multiple layers of caprock can limit the growth of fractures.

View Micro Imager seismic logs in **geoSCOUT's Cross Section Module** to help identify fault and fracturing zones.

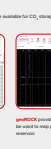
Go to geoSCOUT ▸

Seismicity

Seismicity is a measure of the current seismic or earthquake activity. Seismicity should be low at project initiation and monitored as CO_2 is pumped into the formation to ensure seismicity is not induced above an acceptable and regulated level.

Microseismic data from an offset monitoring well can provide baseline levels and be used for ongoing monitoring after injection.

Import shapefiles into **geoSCOUT** to map and visualize seismic occurrence data and incorporate it into your risk assessment.



Seismic Activity Events

Go to geoSCOUT ▸

Sources of data included are from: https://ags.aer.ca/arcgis/rest/services/Seismicity_search/mapserver

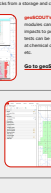
Part 3: Reservoir – Determine Storage Potential

Estimate the volume of rock within the reservoir that is available to accept injected CO_2 using the CO_2 Storage Volumetric tool in geoSCOUT. It will help you assess the carbon dioxide mass storage capacity for simple saline aquifers and residual oil reservoirs based on storage efficiency, CO_2 density, other rock and fluid parameters, and, optionally, the volume defined between contoured intervals.

The Depleted Gas Pool CCS/CCUS screening dashboard houses all of the GHGRP data, along with the AER's gas pool reserves data, allowing you to quickly screen gas pools for CO_2 storage. It identifies storage capacity that is available today as well as capacity that will come online over the next 30 years.

Thickness

The thickness of the reservoir directly correlates to the available storage volume and defines the extent of the reservoir.

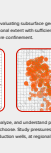


Apply cutoffs using geoSCOUT's LDS Analysis tools to calculate the thickness of key parameters like porosity and determine the extents of the reservoir. Contour numerical data from geoSCOUT, your User Database, or a .xls file, or draw contour lines yourself and let geoSCOUT colour fill them. Create structure maps to show net thickness. **geoROCK** can help identify various lithologies which will help determine reservoir area and thickness.

Go to geoROCK ▸

Porosity

The porosity within the reservoir informs the volume available for CO_2 storage. A CO_2 storage reservoir requires a continuous, thick layer of adequate porosity.



Plot porosity data from the most complete set of WCSB LAS data using **geoSCOUT Log and Core Analysis**. Perform batch LAS calculations and use cutoffs for porosity and thickness, along with core data, to map the storage reservoir.

geoROCK provides rock physics models which can be used to map porosity variations within the reservoir.

Go to geoSCOUT ▸ **Go to geoROCK ▸**

Permeability

Permeability is the ability for fluid to be transmitted through the storage layer. This transmissibility impacts access to the porosity within the rock, as well as the rate at which you can inject into the reservoir without incurring high pressures or inducing fractures.

geoSCOUT's Core Analysis module allows you to access core data and apply cutoffs for permeability, porosity, and thickness. You can filter, modify, calculate on, and plot core data across using the most complete dataset for the WCSB.

Go to geoSCOUT ▸

Adverse diagenesis

The process of sediment being converted to rock is called diagenesis. Any negative impacts to porosity, permeability, and flow paths are considered adverse diagenesis. This phenomenon can play a significant role in screening CO_2 storage target formations and caprocks from a storage and containment perspective.

geoSCOUT's Log Analysis and Core Analysis modules can be used to understand these impacts to porosity and permeability. Cornflow tests can be used as well-suitability tests to look at chemical composition, solubility, cementation, etc.

Go to geoSCOUT ▸

Hydrogeology

Hydrogeology describes the distribution and flow of water beneath the surface – typically a saline aquifer when talking about CO_2 storage. To be suitable for CO_2 storage, the potential system must be both large enough (interconnected/regional) and disconnected from fresh groundwater.

Pressure

Screening sites for CO_2 storage potential involves evaluating subsurface geologic data, including in-situ stress and formation fluid pressures. Formations have regional extent with sufficient pressure at depth to maintain injected CO_2 in a supercritical state in order to ensure confinement.

geoSCOUT's DST Pro module allows you to plot, analyze, and understand post-event pressure depletion versus time, elevation, or depth at any regional scope you choose. Study pressures spatially by creating bubble maps of post-event pressure data, for both injection and production wells, at regional scopes ranging from a section to many townships.

Go to geoSCOUT DST Pro ▸

Temperature

The temperature of the reservoir impacts the state of the CO_2 when injected. Higher temperatures are preferred so that the CO_2 is in a supercritical fluid phase, minimizing volume and facilitating the easiest transportation throughout the reservoir.

geoSCOUT's powerful contouring functionality allows you to easily build temperature-gradient maps that highlight regional differences in reservoir temperatures.

Go to geoSCOUT ▸

Geothermal regime

A geothermal regime with a low temperature gradient will have minimal variation over the height of the storage reservoir. Stable temperatures allow for predictable reservoir conditions and consistent phase.

CO_2 Storage Reserves Management System (SRMS) by SPE

The **SRMS** is a CO_2 storage resources management system (SRMS) that provides a consistent approach to estimating storable quantities, evaluating development projects, and presenting results within a comprehensive classification framework. This framework includes analytical procedures for estimating storage capacity by way of volumetric calculations. geoSCOUT's volumetric CO_2 Storage functionality, pool-level rock and fluid property data in the Reserves module, and a host of other tools and data will support you along the path of SRMS compliance.

Source for image: CO2 Storage Resources Management System (SPE) https://www.spe.org/media/filer_public/06/72/06726e64-f7c7-4ef6-8c8d-6a8be0da8f34/srms_sep2022_a_smaller.pdf

4

Monitoring

MMV – Measurement, Monitoring, & Verification

Monitor seismic stability and track the movement of CO_2 with measures in place to detect potential leaks.

Monitoring potential

Monitoring, measuring, and verification (MMV) is the critical component of tracking injected CO_2 movement in the reservoir or aquifer to verify that it is intact and permanently and safely stored after injection. MMV plans involve subsurface monitoring of the location of the plume traveling within the reservoir, as well as early-detection systems for leaks and seismic activity.

Use **geoROCK** with your 4D seismic data to help identify areas with increased gas saturation compared to pre-injection. This provides insights into migration of the CO_2 plume.

Ensure the integrity of existing wells by analyzing cement bond logs. Use **geoSCOUT's Area Hazard** module to identify areas with Surface Casing Vent Flows from monitoring and injection wells.

Go to geoSCOUT ▸ **Go to geoSCOUT ▸**

CCS Knowledge Centre

Carbon Capture and Storage (CCS) 101
https://www.globalccsinstitute.com/wp-content/uploads/2022/07/Factsheet_CCS-Explained_The-Basics.pdf

Carbon Capture and Storage at a Glance – Accelerated Emissions Reduction
https://cckcknowledge.com/pub/Factsheets/Poster_FullChain_CCS_Horizontal.pdf

What is Carbon Storage and Capture (CCS)
https://fluxtanos.com/wp-content/uploads/2022/08/HCCS-What-Is-CCS-Fact-Sheet-2022.pdf

Pathways Alliance CCS Project – Fact Sheets
https://pathwaysalliance.ca/news-resources/fact-sheets/

Enbridge Carbon Capture and Storage (CCS) – Fact Sheets
https://www.enbridge.com/about-us/how-energy-works/energy-technologies/carbon-capture-and-storage

Alberta Carbon Capture Incentive Program
https://www.alberta.ca/alberta-carbon-capture-incentive-program

geoLOGIC products support a deeper analysis of CCS/CCUS opportunities within the WCSB.

Tavaio Evaluate Energy ComboNet gluSCOUT gDC geoROCK tomINTEL DOF