Gas Turbine Carbon Capture Demonstration Project

Strathcona Lindbergh SAGD

STRATHCONA
RESOURCES LTD

PROJECT: Gas Turbine Carbon Capture Demonstration Project

HOST FACILITY: Strathcona Lindbergh SAGD

PREPARED FOR: Natural Resources Canada (NRCan) & the Office of Energy Research and Development (OERD)

PROJECT ID CODE	CCUS-21-5
PROGRAM NAME	Energy Innovation Program – Carbon Capture, Utilization and Storage (EIP-CCUS) FEED stream
PROPONENT	Strathcona Resources Limited
PROJECT TITLE	FGR on Gas Turbine with Mole Sieve CCS
PROJECT TYPE	Front-End Engineering Design (FEED)

TABLE OF CONTENTS

Project Description & Host Facility Context

Background and Objectives

The objective of this demonstration project was to develop and evaluate a first-of-its-kind Exhaust Gas Recirculation (EGR) technology coupled with a modular post-combustion Carbon Capture and Sequestration (CCS) facility. The system is designed to be integrated with a commercial cogeneration gas turbine at Strathcona's Lindbergh SAGD facility, with subsequent permanent storage into the Basal Sandstone Unit (BSU) formation in the Cold Lake region.

The scope of the project encompasses the demonstration design for capturing carbon on a single commercial-scale gas turbine. The project targets the capture of 44,000 tonnes of CO_2 per year at an approximate 95% capture rate on the demonstration train. This narrative report is submitted to Natural Resources Canada (NRCan) and the Office of Energy Research and Development (OERD) to summarize the findings, optimizations, and milestones achieved during the engineering phases.

Host Facility Context

The host site is Strathcona's Lindbergh SAGD facility, which began commercial operations in 2015. The facility currently produces approximately 20,000 barrels per day of heavy oil and consumes roughly 32 GJ/day of natural gas.

A critical aspect of the facility's design is that it generates 100% of the power it consumes. High-efficiency cogeneration is used to produce both electricity (~21 MW) and steam, utilizing gas turbines as the core technology. Future expansion phases could add significant cogeneration capacity (up to 74 MW total), making the decarbonization of gas turbine exhaust a critical priority for the facility's long-term emissions reduction strategy.

Figure 1 - Lindbergh SAGD CPF

Project Timeline & NRCan Engagement Milestones

2021: Genesis of the project following initial industry presentations on EGR feasibility.

2022: Project Expression of Interest (EOI) and Full Project Proposal (FPP) submitted to NRCan. Optimization efforts initiated with grant funding from Emissions Reduction Alberta (ERA) as part of a Carbon Capture Kickstart grant.

2023: Contribution Agreement executed between Strathcona and NRCan. Delivery of Rev. 0 Front-End Engineering Design (FEED) study.

2024: Original Equipment Manufacturer (OEM) testing of the EGR system; Delivery of Rev. 1 FEED study.

2025: Pre-FID preparation, commercial structuring, and project closeout reporting.

The Challenge: Capturing Gas Turbine Emissions

The Problem Statement

Gas turbine exhaust is a difficult point-source to abate due to its extremely low CO_2 concentration (~3% CO_2 mol fraction). Standard exhaust from a commercial gas turbine features large volumes of gas with low carbon density.

A typical baseline exhaust profile (modeled on a Solar T70 Gas Turbine) at the facility consists of:

- Mass Flow: ~2.2 Million kg/day
- Composition: ~75.4% to 78% Nitrogen (N_2), 14% to 21% Oxygen (O_2), and only ~3% to 4% Carbon Dioxide (CO_2).

To capture meaningful amounts of carbon using traditional methods, facilities must build extensive infrastructure (blowers, absorbers, and heat exchangers) to process these vast volumes of mostly nitrogen and oxygen. This leads to exceptionally high capital intensity and large physical footprint requirements.

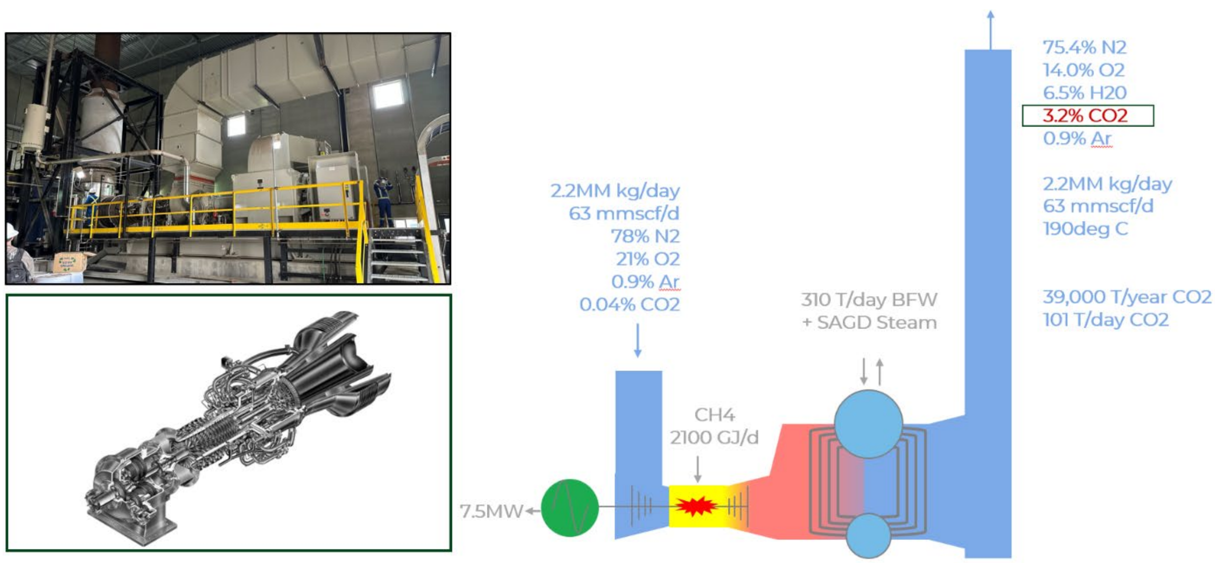

Figure 2 - Solar T70 typical flow composition

The Proposed Solution

This project introduces a novel solution by utilizing Exhaust Gas Recirculation (EGR). By recirculating a portion of the exhaust back into the turbine's intake, the system consumes the excess oxygen and dramatically increases the concentration of CO_2 fed into the downstream capture unit. This technology has the potential to significantly reduce the capital intensity, operating costs, and physical footprint of CCS across multiple heavy industries.

Technology Development: Exhaust Gas Recirculation (EGR)

The EGR Concept and Design

The core innovation relies on modifying the gas turbine's air intake and exhaust routing. Instead of venting standard exhaust to the atmosphere, a diverter valve redirects a portion of the exhaust through a Direct Contact Cooler and an EGR Blower, mixing it with ambient air in a dedicated mixer duct before it re-enters the turbine.

During the optimization phase, the system was designed to achieve 41% Exhaust Gas Recirculation. This recirculation yields two benefits for the downstream capture facility:

1. Reduced Mass Flow: The total volume of gas sent to the capture unit is reduced from 2.2 Million kg/day down to 1.4 Million kg/day.

2. Increased CO_2 Concentration: The CO_2 concentration in the exhaust stream increases to roughly 5.5% (a significant relative increase over the baseline).

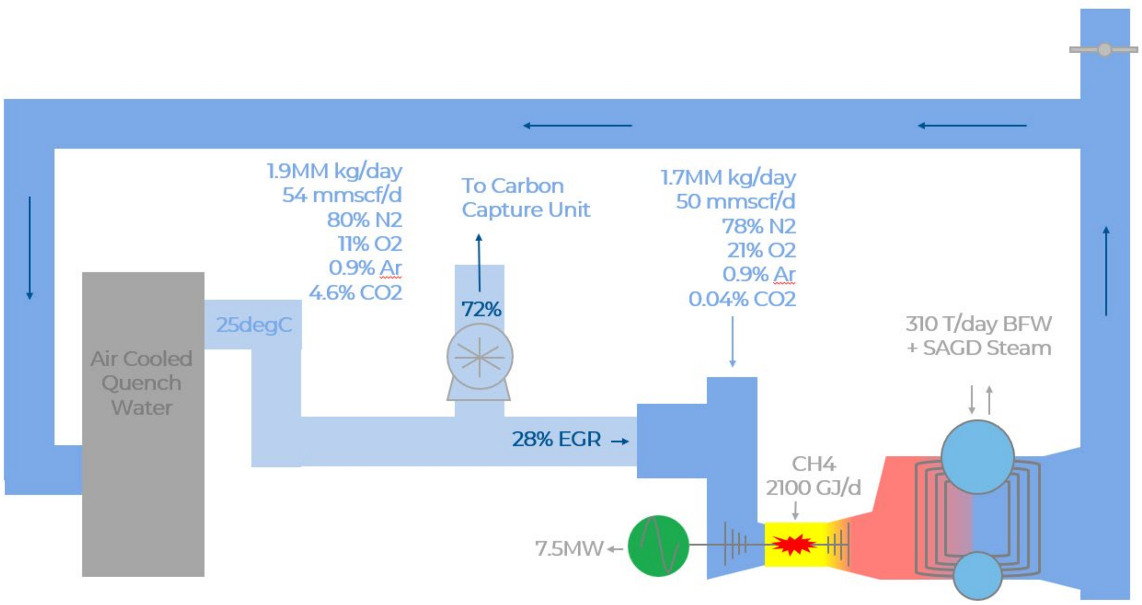

Figure 3 - EGR Initial Concept

OEM Testing and Validation

In mid-2024, physical testing of the EGR concept was conducted at an OEM test facility.

- Duration: Over 200 hours of continuous testing.

- Results: The testing successfully achieved a 2X increase in CO_2 concentration while maintaining robust combustion stability, managing emissions profiles, and preserving required turbine power output.

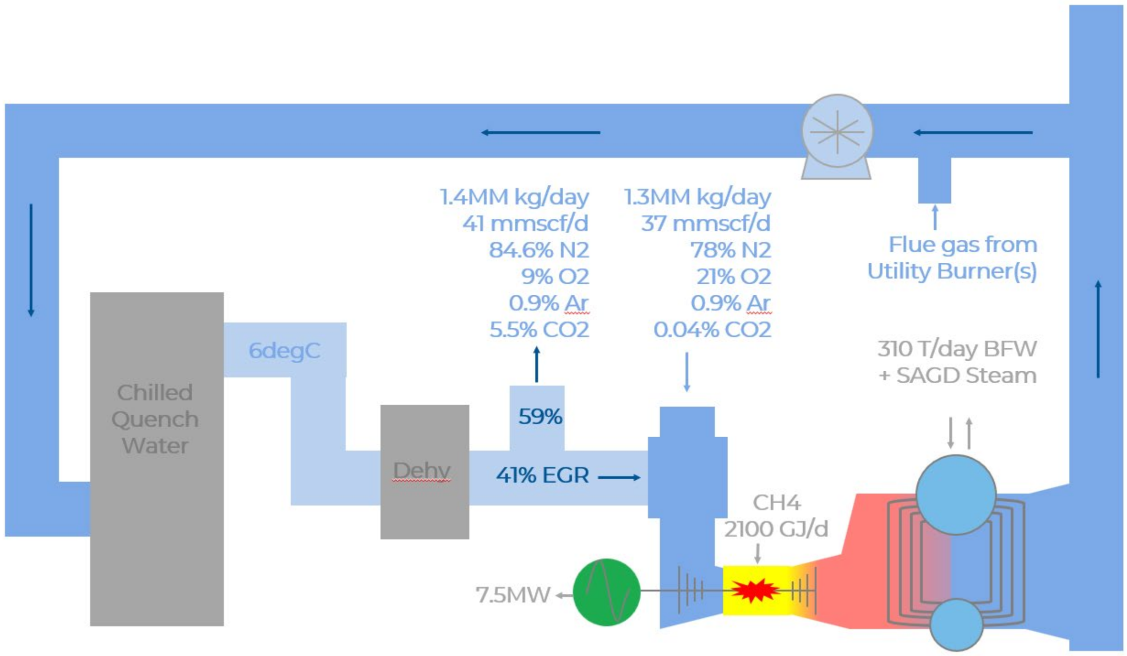

Figure 4 - Post-optimization EGR design

Capture Approach: Advanced Solvent vs. Solid Adsorption

With the CO_2 concentration increased by the EGR system, the project team evaluated two primary post-combustion capture concepts.

Concept A: Liquid Absorption (Advanced Solvent)

The initial baseline design (evaluated in Q4 2023) utilized a traditional liquid solvent system, specifically a 30% weight Piperazine solvent. In this process, CO_2 is absorbed into the liquid solvent at ~65°C and then heated to ~150°C for regeneration.

- Drawbacks: While commercially proven, the amine solvent is sensitive to sulphur (SOx) poisoning. Furthermore, amine degradation products build up over time, requiring continuous solvent maintenance.

- Economics: This system resulted in a high estimated capital cost (~$72 Million) and an unsubsidized Levelized Cost of Carbon Capture (LCOC) of approximately $265/tonne.

Concept B: Solid Adsorption (Zeolite 13X Molecular Sieve)

The team optimized the design by shifting to a Temperature Swing Adsorption (TSA) molecular sieve technology utilizing Zeolite 13X. Zeolite 13X is an aluminosilicate crystal with a unique pore structure (~1nm in diameter) that allows it to selectively adsorb specific molecules.

- The Process: CO_2 adheres to the surface of the solid material at lower temperatures and is then cleared off the surface by swinging the temperature up to 300°C.
- Advantage: This approach proved effective at purifying the concentrated EGR gas and bypassed the toxic degradation issues associated with liquid amines.
- Limitation: The molecular sieve is highly sensitive to water, requiring the flue gas to be strictly dehydrated prior to capture.

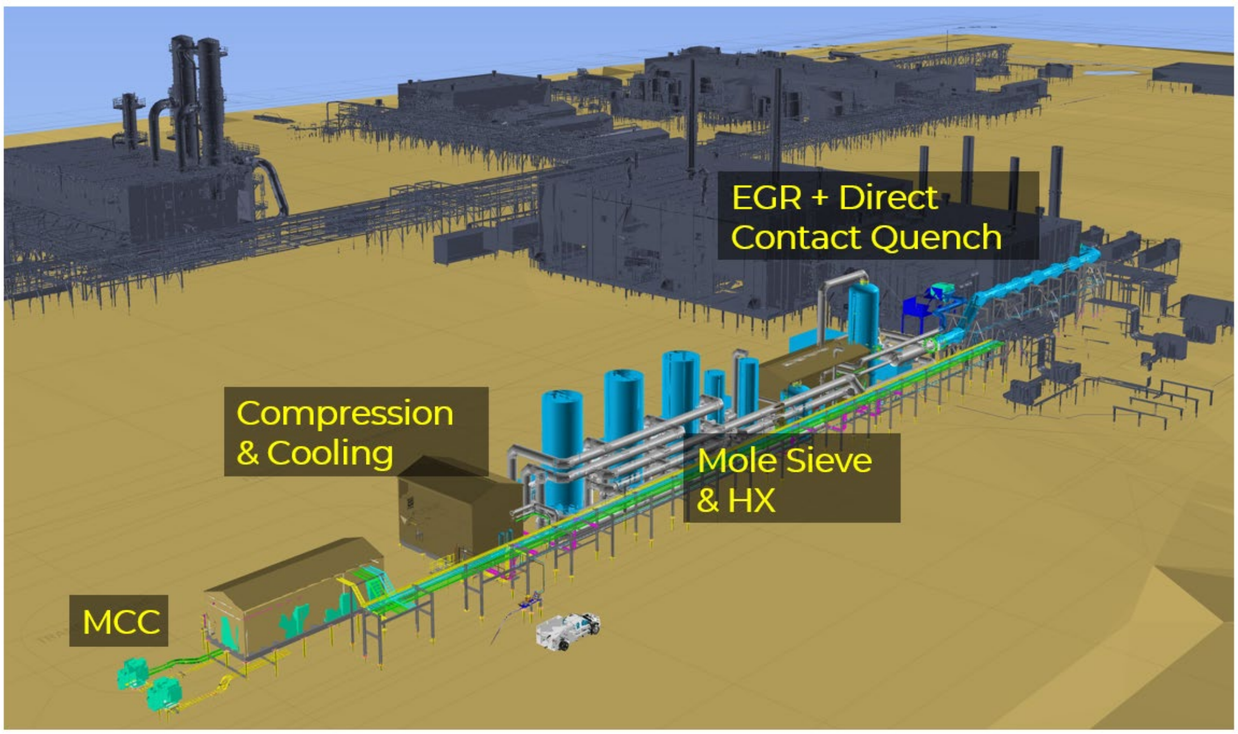

Figure 5 - Adsorption with Zeolite 13x mol sieve

Through iterative engineering between the Rev 0 and Rev 1 FEED studies, the project team achieved significant technical breakthroughs by optimizing the Solid Adsorption (Concept B) system.

Waste-Heat Integration via Absorption Chiller

A major technical achievement was the integration of an absorption chiller into the design. An absorption chiller is a cooling machine that uses heat, rather than electricity, to drive the refrigeration cycle. It uses water as the refrigerant and Lithium Bromide as the absorbent (comprising an evaporator, condenser, and absorber).

Instead of relying on high-parasitic electrical compressors for cooling, the team redesigned the system to utilize low-grade waste heat from the Lindbergh SAGD facility's existing hot glycol system. Integrating this existing industrial heat source directly into the carbon capture process vastly improved overall thermal efficiency.

Liquefaction Optimization

The increased chilling capacity provided by the absorption chiller enabled the liquefaction of the final CO_2 product. By chilling the product, the facility can pump the CO_2 rather than using large compressors to reach the required 14 MPa pipeline pressures, saving significant parasitic electrical load.

Reduced Footprint

By increasing the CO_2 concentration via EGR, the physical size of the required absorber beds and heat exchangers was materially reduced. For example, the quantity of Zeolite 13X adsorbent material required dropped from an estimated 360 tonnes down to 240 tonnes.

Main Outputs & Project Economics

The optimization effort between the initial feasibility study and the final FEED package resulted in more competitive project economics. By moving to the solid adsorbent system (Concept B) paired with EGR and waste-heat integration, capital intensity was reduced.

Key Performance Indicators (Optimized Q1 2025 Design)

Metric	Value
Total Post-Combustion Flue Gas	133.7 Tonnes/day
Net Carbon Abated (Target)	101.8 Tonnes/day (~44,000 Tonnes/yr)
Target Capture Rate	~95%
Electrical Energy Input	355.0 kWh/Tonne (Gross)
Thermal Energy Input	3.5 GJ/Tonne (Gross, LHV)
Total Installed Capital Cost	~$55 to $57 Million CAD
Capital Intensity	~$1,211 / Tonne-yr

Levelized Cost of Carbon Capture (LCOC)

The technological pivot from Advanced Solvent to the optimized EGR + TSA Molecular Sieve system drove the unsubsidized LCOC down from original estimates of $265/tonne to a more competitive ~$225 to $240/tonne, proving the fundamental hypothesis that EGR technology can lower the cost floor of post-combustion capture on gas turbines.

Key Lessons & Next Steps

Key Lessons Learned

Modularization is Critical: Cost estimates conducted during FEED revealed significant escalation in field materials and field labor in the current construction market. Future designs must focus heavily on modularization, pulling as much construction as possible out of the field and into controlled manufacturing shops to control execution costs.

Cold Weather Adaptation: Testing revealed that the EGR stream must be dehydrated prior to recirculation in cold climates. This is an essential step to prevent winter ice precipitation, which could cause severe erosion to the turbine compressor blades.

Macro-Economic Impacts: Despite removing millions of dollars in raw equipment costs through design optimization (reducing the molecular sieve quantities and shrinking heat exchangers), inflation and exchange rate variances offset a portion of these physical savings. Managing supply chain geography is critical.

Next Steps and Conclusion

The project team has successfully completed the engineering and design phases and has established a robust, optimized technical solution. Prior to advancing into procurement and construction, the focus is now on addressing remaining technical validation needs and clarifying external commercial and regulatory prerequisites that will inform further development:

1. **Economic and Policy Frameworks:** The project team is awaiting further clarity on long-term carbon policy and regulatory incentives in Alberta. A stable and predictable incentive environment, including clarity on industrial carbon pricing trajectories and investment programs, is required to ensure robust project economics and enable completion of the commercial structure.

2. **Technical Validation:** While the optimized EGR plus TSA molecular sieve concept is technically compelling, additional investigation is required to confirm molecular sieve operational reliability and long-term performance under real operating conditions, including dehydration requirements and cold weather operating considerations.

3. **Pore Space Access and Sequestration Readiness:** Progressing carbon storage readiness will require securing access to suitable long-term, permanent CO_2 storage through pore space arrangements, along with the associated regulatory approvals and commercial agreements. Establishing this storage pathway remains a key prerequisite for final project permitting and broader commercial structuring.