MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

Carbon Storage - PE5050.

ExxonMobil Shute Creek CCS: Process, Transport, EOR and Storage of Captured CO_2, Wyoming, USA.

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Executive Summary

The Shute Creek Treating Facility, run by ExxonMobil, is located near LaBarge, Wyoming, and is one of the largest and longest-operating carbon capture and storage (CCS) projects in the world. Since its commissioning in 1986, the facility has processed natural gas with a high carbon dioxide (CO_2) content of about 65% and has captured over 120 million metric tons of CO_2. Most of the captured CO_2 is transported to nearby oil fields for enhanced oil recovery (EOR), while the remainder is injected into deep geologic formations, including the Madison Formation, for permanent sequestration.

CO_2 is separated from natural gas using an amine-based treatment system and subsequently compressed for delivery. The facility's acid gas injection (AGI) infrastructure, developed to replace aging Claus sulfur recovery units, eliminates processing bottlenecks and reduces SO_2 emissions. It includes centrifugal compressors, coolers, separation equipment, and injection wells capable of handling up to 65 MMscfd of acid gas composed primarily of CO_2 and hydrogen sulfide (H_2S). A cogeneration plant was added to provide energy and steam for the site's needs.

ExxonMobil tracks and verifies CO_2 storage through a comprehensive Monitoring, Reporting, and Verification (MRV) program under EPA Subpart RR. Historically, a "sell or vent" strategy guided CO_2 management, but as part of the facility's response to environmental concerns, over 6.4 million metric tons of CO_2 have been permanently stored since 2009. Revenue from CO_2 sales, helium production, and Section 45Q tax credits supports the project. While its association with EOR raises debate regarding climate impact, the facility has yielded valuable technical and operational lessons for large-scale CCS implementation.

1. Project General Background

Site Overview. The Shute Creek Treating Facility is located in southwestern Wyoming near the LaBarge Field, one of the most CO_2-rich natural gas accumulations in North America. Discovered in the 1970s, the field contains gas with approximately 65% carbon dioxide, along with methane, nitrogen, hydrogen sulfide, and helium. The facility began operation in 1986 as part of ExxonMobil's strategy to develop these unconventional resources while managing environmental and regulatory challenges.

Purpose and Configuration of AGI. To replace aging Claus sulfur recovery units and reduce SO_2 emissions, ExxonMobil installed Acid Gas Injection (AGI) facilities. These systems eliminate process bottlenecks and support long-term acid gas management. The AGI infrastructure includes centrifugal compressors, aerial coolers, dehydration and separation equipment, and injection wells—AGI 2-18 and AGI 3-14—which inject a mixture of CO_2 and H_2S into the deep Madison Formation.

Facility Scale and Value. Shute Creek's AGI system is one of the largest in the world, with a design capacity of 65 MMscfd—far exceeding typical North American AGI capacities. Alongside cogeneration units supplying steam and power, the facility integrates gas processing, CO_2 storage, and EOR support. From 2009 to 2022, over 6.4 million metric tons of CO_2 have been permanently sequestered. The project is backed by revenue from CO_2 and helium sales and Qualify for federal tax credits under Section 45Q.

Monitoring and Operational Shift. Initially, Shute Creek operated on a "sell or vent" approach, where CO_2 was marketed for EOR and excess volumes were released when demand dropped. In response to public and regulatory concerns, ExxonMobil expanded AGI capacity and implemented an EPA-compliant Monitoring, Reporting, and Verification (MRV) plan. These upgrades strengthened the facility's environmental performance and positioned it as a reference site for large-scale CCS implementation.

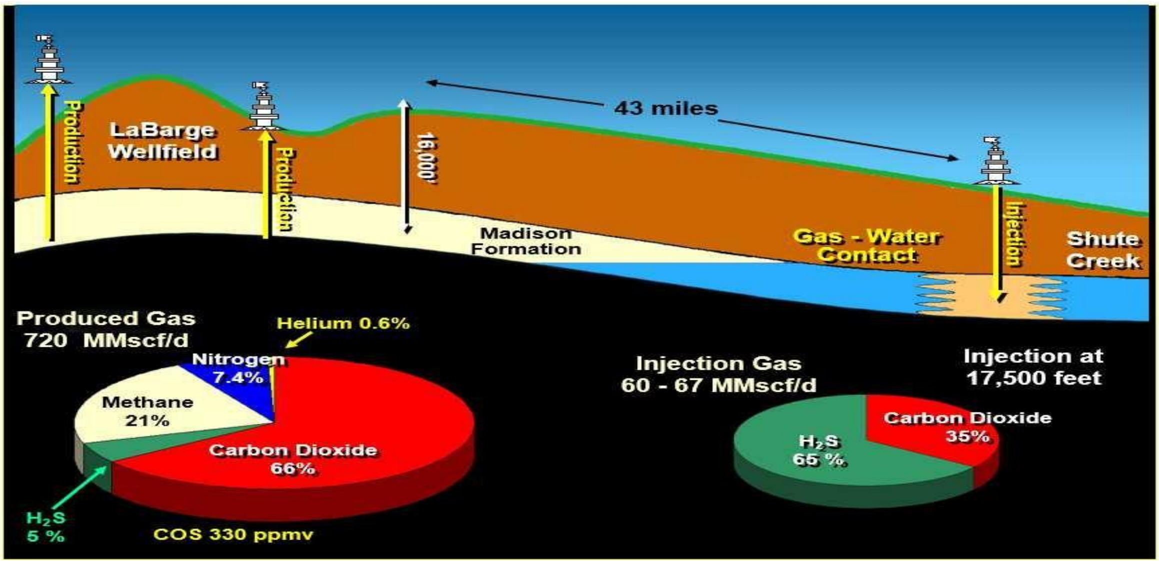

Figure 1: Schematic illustration of AGI injection program as currently used at LaBarge.

2. Financials

The Shute Creek Treating Facility required significant investment which covers major infrastructure such as the central processing unit, CO_2 pipelines, injection wells, and monitoring systems. A key source of revenue for the project is by selling captured carbon dioxide (CO_2) to regional oil producers for enhanced oil recovery (EOR). This commercial relationship has supported operations since the facility's early years.

Beginning in 2009, ExxonMobil implemented a phased expansion of the facility's acid gas injection (AGI) system to reduce CO_2 venting and comply with evolving federal standards. The upgrades included new compression trains and improvements to injection well design and measurement systems. These enhancements allowed for increased injection rates and improved reliability. The expansion also positioned Shute Creek to qualify for Section 45Q tax credits through the U.S. Internal Revenue Code.

Section 45Q provides a financial credit of up to $85 per metric ton for CO_2 that is permanently stored. In 2022, the facility reported injecting approximately 395,000 metric tons of CO_2, which could translate into over $14 million in federal tax credits. This incentive helps offset operating costs and provides stability when EOR-related CO_2 demand fluctuates due to oil price volatility.

Although revenue from CO_2 sales varies with the oil market, the combination of tax credits, long-term contracts, and helium sales contributes to the financial viability of the Shute Creek operation. The integrated nature of gas treatment, CO_2 capture, and storage makes it a unique example of how commercial and regulatory mechanisms can support CCS deployment.

3. CO_2 Capture Process

The Shute Creek Treating Facility processes gas that contains around 65% CO_2, along with H_2S, methane, nitrogen, and helium. The primary goal of the capture process is to remove CO_2 and H_2S while preserving methane for sale. The gas is sourced from the LaBarge Field and brought into the facility for separation.

Absorption and Separation

The raw gas flows into absorber towers where it comes into contact with an amine solvent. In this contactor, the CO_2 and H_2S bond with the amine solution, while methane and other light gases move downstream. The solvent is now rich in acid gas then it is pumped to a regenerator or stripper where it is heated. The heat breaks the chemical bonds and releasing the CO_2 and H_2S. The amine is recycled back into the system.

Dehydration and Compression

After separation, the acid gas mixture is dehydrated to remove water vapor. This is a necessary step to avoid corrosion during compression and pipeline transport. The dry gas is compressed in three or four stages depending on the inlet pressure. The final pressure reaches over 2,000 psi to allow transport in dense phase to either EOR fields or injection wells.

H_2S Handling and Integration

Since the Claus sulfur recovery units were shut down, Shute Creek now sends all acid gas—both CO_2 and H_2S—into the AGI system. The acid gas is injected into the Madison Formation using dedicated injection wells. This shift eliminated sulfur recovery bottlenecks and reduced SO_2 emissions from the facility.

Operations and Energy Supply

The capture process is energy-intensive, especially during solvent regeneration. To support this, a cogeneration unit supplies both steam and electricity. Instrumentation across the plant monitors pressure, temperature and gas quality to ensure smooth operations. The system is designed for continuous handling high-volume throughout the process with integrated gas treatment, capture and working in tandem compression system.

Figure 2: *Shute Creek Gas Facility in Wyoming, USA, captures CO2 from gas streams.*

4. CO_2 Transport

At Shute Creek, CO_2 and H_2S are separated from the natural gas stream and prepared for delivery either to EOR sites or for injection. Once separated, the acid gas mixture is compressed through three or four stages, depending on inlet pressure, to a final pressure of around 2,000 psi. This level of pressure is required to move the gas in dense phase to the injection wells or through pipelines for utilization.

Pipeline System Description

Two dedicated 6-inch pipelines transport the acid gas away from the treating facility. One line connects to AGI well 3-14, located about 3,200 feet away, and the second goes to AGI 2-18, which is about 12,400 feet from the plant. The pipelines are buried approximately seven feet underground to avoid damage and reduce heat loss. For above-ground segments where heat tracing is installed to prevent condensation and acid formation which could corrode the pipeline.

Now before entering the pipeline system the gas is dehydrated to remove water vapor. This step is essential because even small amounts of moisture when combined with CO_2 and H_2S which can form corrosive acids. After dehydration the gas is cooled and stabilized to ensure smooth transport and injection.

Flow Monitoring and Distribution

Flow meters are installed at key points throughout the system to track pressure, temperature and flow rate of the acid gas. Each AGI well pad is equipped with flow totalizer meters to measure the exact amount of gas injected daily. These readings are collected by field operators and logged for regulatory reporting and system performance tracking.

The injection system is designed to handle variations in CO_2 and H_2S supply, whether from direct production or recycled streams. Real-time monitoring of all flow parameters ensures operational safety helps to avoid pressure buildup and allows adjustments to be made quickly in response to system changes or gas availability.

System Reliability and Routing

The layout of the pipelines was designed to minimize environmental impact and follow the most efficient path across the site. Routing considerations included elevation changes, subsurface rock profiles and existing infrastructure. The pipeline design complies with federal and state regulations, including DOT specifications for acid gas transport. The system is integrated with the facility's control network will provide a full picture of the transport and

5. CO_2 for Enhanced Oil Recovery (EOR)

The Shute Creek Treating Facility has supplying CO_2 for enhanced oil recovery (EOR) since the late 1980s. Captured CO_2 is transported with high-pressure pipeline to nearby oil fields in Wyoming and surrounding regions where it is injected into mature reservoirs to improve oil displacement and increase recovery factors. This application has historically represented the primary commercial outlet for the CO_2 produced at the facility.

Over its operating life this facility has captured more than 120 million metric tons of CO_2. A substantial portion of this has been used in EOR operations. However, when market conditions led to reduced oil prices and lower CO_2 demand particularly in the late 2000s. This facility was unable to sell all of its captured CO_2. During these periods excess volume of $CO2$ were vented into the atmosphere drawing public and regulatory criticism. The practice raised concerns about the net climate benefits of the project and prompted calls for operational changes.

In response, ExxonMobil expanded the facility's acid gas injection (AGI) capacity to enable long-term geologic storage of CO_2. Starting in 2009, the facility began injecting larger volume of $CO2$ and $H2S$ into the Madison Formation during times when EOR demand was limited. These infrastructure improvements allowed the facility to reduce venting and meet federal requirements for permanent CO_2 storage under EPA Subpart RR. This shift also enabled the facility to qualify for Section 45Q tax credits linked to verified sequestration.

Today, Shute Creek supports both CO_2 utilization through EOR and long-term carbon storage. This dual approach allows the facility to respond to oil market variability while maintaining compliance with environmental standards. The operational flexibility gained through AGI expansion has strengthened the long-term viability and climate performance of the project.

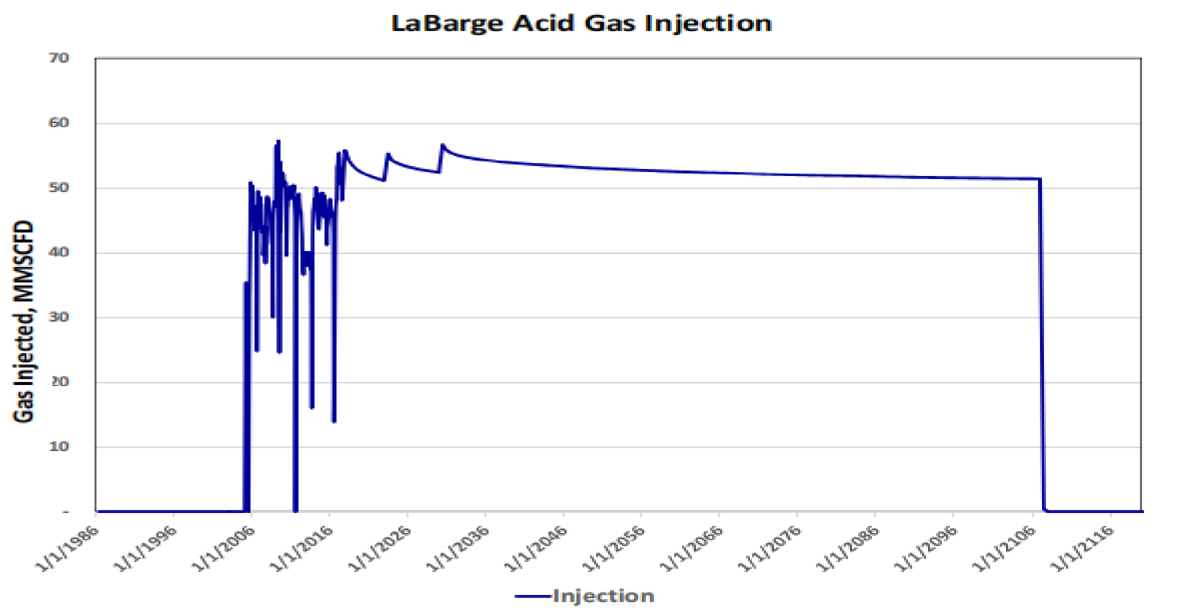

Figure 3 : Planned Acid Gas Injection Volumes at LaBarge (Shute Creek Project)

6. CO_2 Storage

CO_2 storage at the Shute Creek Treating Facility is handled through dedicated acid gas injection wells. These were installed to replace the older Claus sulfur recovery system and to allow for permanent disposal of CO_2 and H_2S when it couldn't be sold for EOR. Over time, as the volume of unsold CO_2 increased, especially after 2009 these wells became a key part of the facility's long-term carbon management.

Geological Setting

The injection zone is the Madison Formation, a deep carbonate unit located around 18,000 feet below the surface. The formation provides good porosity and permeability in the lower water leg, which supports steady injection rates. Above the Madison, layers of anhydrite and shale act as seals, reducing the risk of upward migration. Core data and pressure testing have shown the formation is suitable for long-term acid gas storage.

Injection Wells and Operations

There are two main AGI wells at the site: AGI 2-18 and AGI 3-14. Each is connected to its own six-inch pipeline and operates at injection pressures above 2,000 psi. The gas mixture typically contains about 62% H_2S and 36% CO_2. Gas is dehydrated and cooled before entering the wells to prevent corrosion. Injection rates are controlled based on pressure readings and well response. The system was built to handle continuous injection and deal with fluctuations in volume depending on sales.

Monitoring, Reporting, and Verification (MRV)

Shute Creek operates under an EPA-approved MRV plan (Subpart RR), designed to ensure the safety and environmental compliance of its CO_2 storage operations. The MRV framework includes continuous pressure and temperature monitoring at the wellhead, regular mechanical integrity tests (MITs), and modeling of plume migration based on injection data. All relevant data is logged and submitted to the EPA for annual greenhouse gas reporting.

The MRV plan outlines two zones: a Maximum Monitoring Area (MMA) and an Active Monitoring Area (AMA). The MMA includes the anticipated CO_2 plume footprint plus a regulatory buffer. This boundary is revised as injection continues, and plume behavior becomes better defined. The AMA consists of the area with real-time monitoring infrastructure, focused on detecting early migration, pressure anomalies, or containment issues. The facility's data helps verify that injection remains within the defined storage zone and that seal integrity is maintained.

Performance to Date

Since the expansion of AGI operations in 2009, Shute Creek has stored over 6.4 million metric tons of CO_2. Storage rates vary based on EOR demand and operating conditions. During periods when CO_2 could not be sold, AGI wells allowed the plant to continue operations while minimizing venting. The system has proven stable, with no reported containment failures or pressure excursions. As of now, the facility continues to use AGI for both environmental compliance and as a buffer against CO_2 market fluctuations.

7. Learnings

Integration of CO_2 Use with Oil Recovery

The use of captured CO_2 from industrial processes at Shute Creek for EOR has shown how oil production can be coupled with carbon management. This integration helps recover additional oil from mature fields while contributing to CO_2 sequestration goals. The shift to using anthropogenic CO_2 starting in the late 1980s, and scaling further post-2009, marks a practical approach to aligning production operations with environmental accountability.

Geological and Operational Insights

The Madison Formation has proven to be a suitable injection zone due to its depth, storage capacity, and sealing units. The success of acid gas injection (AGI) into this formation shows that carbonate formations with adequate confining layers can support long-term acid gas storage. Operationally, the ability to handle varying gas volumes—whether sold for EOR or injected during low-demand periods—illustrates the value of flexibility in facility design and reservoir management.

Balancing Environmental and Economic Goals

The facility's dual role in supporting EOR and permanent CO_2 storage demonstrates the potential to meet both production and emissions targets. While EOR generates revenue and improves field performance, the ability to store CO_2 under Subpart RR and qualify for tax credits like Section 45Q adds an environmental and financial buffer during market downturns. This setup provides a model for future projects seeking to combine storage and utilization pathways.

Challenges and Strategic Adjustments

Shute Creek's history has also shown that EOR-based CO_2 utilization alone may not be sufficient during price downturns or low CO_2 demand. The facility's decision to expand AGI infrastructure was a key adaptation. Similar projects should account for supply chain disruptions, sales variability, and regulatory shifts. Additionally, establishing stronger integration with carbon markets and long-term CO_2 supply agreements can improve project resilience.

Key Takeaway

What stands out about the Shute Creek project is how it blends old and new: mature natural gas processing and EOR methods are combined with modern carbon storage practices, regulatory compliance, and economic adaptation. For engineers and researchers, the project provides valuable field-scale insights into how a single facility can respond to shifting market conditions, environmental demands, and technical challenges without shutting down or compromising its original purpose. This real-world complexity makes it an excellent case study for understanding large-scale CCS integration.

8. Summary

The Shute Creek Treating Facility is a leading example of how large-scale carbon capture, utilization, and storage (CCUS) can be integrated into natural gas processing. Since 1986, the facility has demonstrated the technical and operational feasibility of capturing CO_2 and H_2S from high-content sour gas streams, supplying CO_2 for enhanced oil recovery (EOR), and permanently storing excess volumes through acid gas injection.

Key Points Covered in the Report

This report outlines the complete operation of the Shute Creek facility, from gas treatment and CO_2 separation to pipeline transport, EOR utilization and geological storage in the Madison Formation. The facility captures CO_2 using amine-based absorption systems and handles significant volumes of H_2S through AGI. When CO_2 could not be sold, particularly after 2009, the expanded AGI system allowed for long-term storage by reduce venting and supporting compliance with EPA Subpart RR.

Over 120 million metric tons of CO_2 have been captured to date, with more than 6.4 million tons injected for permanent storage since AGI expansion. The site employs continuous monitoring and reporting systems, ensuring safety and performance. The dual approach of supplying CO_2 and H_2S for EOR and injecting unsold volume of CO_2 has positioned Shute Creek as both a commercial and environmental case study.

Significance in the Context of CCS and the Energy Industry

Shute Creek illustrates how existing gas processing infrastructure can be adapted to support modern carbon management goals. It demonstrates the importance of operational flexibility in large CCS projects especially when navigating fluctuations in oil markets and CO_2 demand. The project also shows how technical improvements such as multistage compression, dedicated pipelines and formation modeling contribute to both field development and emissions reduction.

As a long-running project, it provides real-world data on how to implement large-scale CCS alongside hydrocarbon production. The facility's ability to maintain regulatory compliance, generate revenue and reduce atmospheric emissions makes it a model for future CCUS projects.

Concluding Statement

The Shute Creek Treating Facility stands out as one of the most comprehensive industrial-scale CCS operations to date. Its blend of CO_2 capture, EOR supply and deep storage reflects a practical and scalable approach to decarbonizing natural gas production. Despite challenges such as venting, fluctuating oil prices and infrastructure upgrades the project has shown resilience and adaptability. The lessons learned from Shute Creek will continue to inform both policy and engineering decisions in the growing field of CCS highlighting its role in the future of low-carbon energy systems.

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