

Gaffney  
Cline

CO<sub>2</sub> EOR & Underground Gas Storage



## About GaffneyCline

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GaffneyCline is a global consultancy that has been offering technical, commercial, and strategic advice to the oil and gas sector since 1962. GaffneyCline's reputation demonstrates that its advice, along with its insight, is high-quality, impartial, technically based, and commercially astute. GaffneyCline is often referred to as one of the leading Reserves consultants within the industry, but in reality, GaffneyCline offers a full range of upstream, midstream and downstream technical and commercial consultancy services. These range from seismic interpretation, static and dynamic reservoir modelling, field development planning, field engineering, gas monetisation, LNG/GTL, expert witness, mergers and acquisition, economics and project finance. GaffneyCline operates worldwide from three main offices in London, Houston and Singapore, and from regional offices located in Buenos Aires, Sydney and Moscow.



## CO<sub>2</sub> EOR

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As an extension of our integrated reservoir modelling capabilities, and as part of our growing carbon management practice, GaffneyCline provides services to study the benefits of carbon dioxide injection into oil reservoirs to enhance recovery as well as to sequester part of the injected volume.

While carbon capture and sequestration studies can be undertaken as a separate exercise (for instance, considering injection into aquifers), GaffneyCline has significant experience in the evaluation on CO<sub>2</sub> injection for enhanced oil recovery (EOR).

# Underground Gas Storage

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Utilizing our integrated reservoir modelling capabilities, GaffneyCline provides services to assess seasonal storage of natural gas within depleted fields, salt caverns or natural aquifers.

GaffneyCline has considerable experience in assessment and management of UGS projects.



# Our Experience

## Carbon Dioxide EOR Study

GaffneyCline was invited to provide a critical review of an intended revitalization of a CO<sub>2</sub> EOR injection program in a mature oilfield in New Mexico, USA, on behalf of a lending institution. The field was under active waterflood and there had been earlier CO<sub>2</sub> injection projects, which the current operator wished to restart. After a detailed technical review of the historical data and carrying out analog and analytical studies, GaffneyCline was able to provide an assessment of the risks involved in this venture, allowing the lender to make an informed decision about the investment opportunity.

## Review of EOR Potential of Middle East Reservoirs

GaffneyCline undertook a review of the potential for enhanced oil recovery using CO<sub>2</sub> injection in a portfolio of eight Middle East reservoirs. GaffneyCline carried out a comprehensive literature survey of EOR projects worldwide and compared key reservoir characteristics that determine the success of EOR via CO<sub>2</sub> injection of the eight reservoirs with those of existing projects. GaffneyCline used a variety of published techniques to screen the reservoirs and to rank them against each other, and against other projects worldwide. GaffneyCline developed an equation of state, matched against laboratory experimental results, for the highest-ranking reservoir fluid. This was used in an analytical slimtube model to estimate the minimum miscibility pressure between reservoir crude and CO<sub>2</sub> as well as between reservoir crude and various mixtures of CO<sub>2</sub> and hydrocarbon gases. The proposed development plan was reviewed and estimates were made of potential volumes of enhanced oil recovery, net and gross CO<sub>2</sub> utilization factors and CO<sub>2</sub> retention factors.



## Evaluation of CO<sub>2</sub> EOR in a North Sea Oil Field

A field partner requested GaffneyCline to evaluate an operator's plans for a CO<sub>2</sub> flood on a large North Sea oil field. GaffneyCline reviewed the operator's compositional simulation model to assess the reliability of the forecasts. This included a review of basic input data, including fine scale numerical simulation of slim-tube experiments, the limitations of the model to reproduce chemical processes were quantified, and quantification of further uncertainties in the full-field model through multiple sensitivity runs. This enabled GaffneyCline to provide an overall envelope of forecasts capturing the range of uncertainty that would underpin a decision.

## Due Diligence on European & African Assets

For a private operator, GaffneyCline undertook an independent evaluation of a complex mature portfolio of upstream assets in Central Europe and Angola. A Red Flag report was prepared based on information from a Virtual Data Room and management briefing. The assets under evaluation were broad ranging and included late mature oil fields just starting Carbon Dioxide floods using CO<sub>2</sub> extracted from nearby gas process plants. Limited upside potential and complex political issues meant that the client did not proceed to full due diligence or make a bid.

## Carbon Dioxide EOR Simulation Study

At the request of a large independent US operator, GaffneyCline constructed a numerical reservoir simulation model to provide a tool to match historical production from the Reeves Unit in Texas and to predict the potential recovery under a miscible carbon dioxide (CO<sub>2</sub>) injection scheme. This project included the preparation of a static (geological) model and a dynamic (simulation) model using an equation of state representation of the fluid. Several prediction cases were prepared to enable to operator to assess the most viable option. The model was also able to identify various inefficiencies in the ongoing waterflood program.

## Review of Licenses, Bulgaria

GaffneyCline performed a CO<sub>2</sub> miscible flood study for an Australian field. The reservoir had a heterogeneous low-permeability formation of low-flow capacity with a highly volatile oil. Under these circumstances CO<sub>2</sub> was seen to have many advantages. There were ample sources of CO<sub>2</sub> nearby which made the scheme look more attractive. The study included recommendations for well locations and field equipment. Waterflood and natural gas injection were also studied. Natural gas was more expensive than CO<sub>2</sub> at this location and likely to result in lower overall recovery, though it offered lower capital costs and lower technical risk.

# Our Experience

## Comprehensive UGS Subsurface Study

GaffneyCline carried out a comprehensive subsurface study for the conversion of a depleted gas field in Italy to underground gas storage. A calibrated simulation model was constructed. This included petrophysical analysis of old wireline logs, geophysical interpretation of 2D lines, construction of a geocellular model, conversion of the geocellular model to a dynamic model for reservoir simulation and history matching 40 years of production. The calibrated model was used to devise a development plan for gas storage operations comprising some 14 new wells. The final report detailed the ranges of cushion gas and working gas, working pressure, withdrawal rates and injection rates. GaffneyCline also completed an environmental study to assess the potential for ground movement.

## UGS Simulation Model Review

GaffneyCline was engaged by a Middle Eastern client to review an Eclipse simulation model of a gas storage reservoir. Gas storage had been ongoing for a number of years, and was within a depleted onshore fractured carbonate field. The reservoir simulation model had been built to justify an expansion of the storage capacity by the installation of additional gas compression. The model was also intended to be used to manage the reservoir during future storage operations. GaffneyCline conducted the review within the client's office. Ultimately GaffneyCline concluded that the model was fit for purpose, although several recommendations for possible improvements in future iterations of the model were made. GaffneyCline's report was used to support the decision to go ahead with the expansion project.

## Gas Storage Commercial/Regulatory Overview

For a major international company, GaffneyCline reviewed and advised on the regulatory and commercial issues associated with the gas storage businesses in the USA and UK.

## Technical Subsurface Due Diligence

GaffneyCline provided technical subsurface due diligence services on behalf of a bank during the possible acquisition of an onshore Italian UGS project. The field in question was a depleted gas field recently commissioned for underground gas storage. The project involved assessment of a variety of reservoir related risks including reservoir integrity, leaks, additional capex/opex/cushion gas to maintain performance and influence of operations on future reservoir performance. Each of the risks were assessed in terms of likelihood and impact upon performance. The project additionally involved assessment of the volume of cushion gas recoverable, storage performance in terms of working gas, peak delivery and operational flexibility, and investment scenarios in terms of maintaining storage performance and possible increases to capacity and performance. Lastly GaffneyCline performed an assessment on the risk of gas pollution and associated treatment, environmental risks and liabilities and initial thoughts on a possible conversion to hydrogen storage.

## Salt Cavern Storage Feasibility

Following a geological review, an outline programme of drilling and solution mining was prepared and costed by GaffneyCline for a private gas utilization company in the Arabian Gulf area.

## Gas Storage Development & Management

For several years, GaffneyCline provided reservoir management services to a domestic United States Utility. The reservoir, which was originally water filled, was developed and operated for gas storage service. Advice on development drilling density and well patterns was provided, followed by proposals for spatial gas injection and withdrawal monitoring. This work was to ensure that the cushion gas quantity was maintained within preset limits, water production during the withdrawal phase was minimized and the gas-water contact was maintained safely above the reservoir spill point.





For more information about GaffneyCline's integrated services, please contact your regional GaffneyCline office.

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