Application of CCUS for Enhanced Lithium Recovery from Subsurface Brines

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Project Highlights:

- Geochemical Reactions
- Lithium Extraction
- Carbon Capture Utilisation and Storage
- Subsurface Brine Systems
- CO_2-Enhanced Geothermal Recovery (EGR)

Overview:

With the accelerating transition to renewable energy, lithium has become a critical component of modern energy storage systems such as batteries. However, existing extraction methods often face major challenges in terms of sustainability, efficiency, and environmental impact [Disu 2024]. This PhD project offers a unique opportunity to explore how carbon capture, utilisation, and storage (CCUS) can be integrated with direct lithium extraction (DLE) and CO_2-enhanced geothermal recovery (EGR) to recover lithium from subsurface brines in an environmentally responsible and energy-efficient manner. The aim is to establish a framework in which CO_2 injection enhances geothermal energy recovery while simultaneously promoting the mobilisation and recovery of lithium and other valuable elements from the subsurface.

The research will focus on understanding the geochemical reactions that occur when CO_2 interacts with geothermal reservoir rocks and brines. When CO_2 is injected into geothermal reservoirs, it dissolves into hot saline fluids to form carbonic acid, which can react with minerals such as feldspar, micas, clays, and volcanic glass—minerals commonly found in geothermal environments. These reactions can promote mineral dissolution, releasing lithium and other valuable elements into the brine while also precipitating carbonates that contribute to long-term CO_2 storage. By experimentally studying these CO_2–rock–brine interactions, the project will improve understanding of subsurface processes relevant to both geothermal energy recovery and sustainable mineral extraction. (see Figure 1).

The project aligns with the goals of the TARGET programme, addressing the critical challenges of securing mineral resources essential for the energy transition, while minimising environmental impact and delivering positive benefits to society.

The research also aligns well with NERC's focus on physical and chemical processes occurring at the interface between rock and water at depth, as well as transformations of minerals under natural conditions. By studying CO_2-induced geochemical processes and their influence on lithium extraction, this project directly addresses the interplay of Earth's materials and fluids, a core component of NERC's remit.

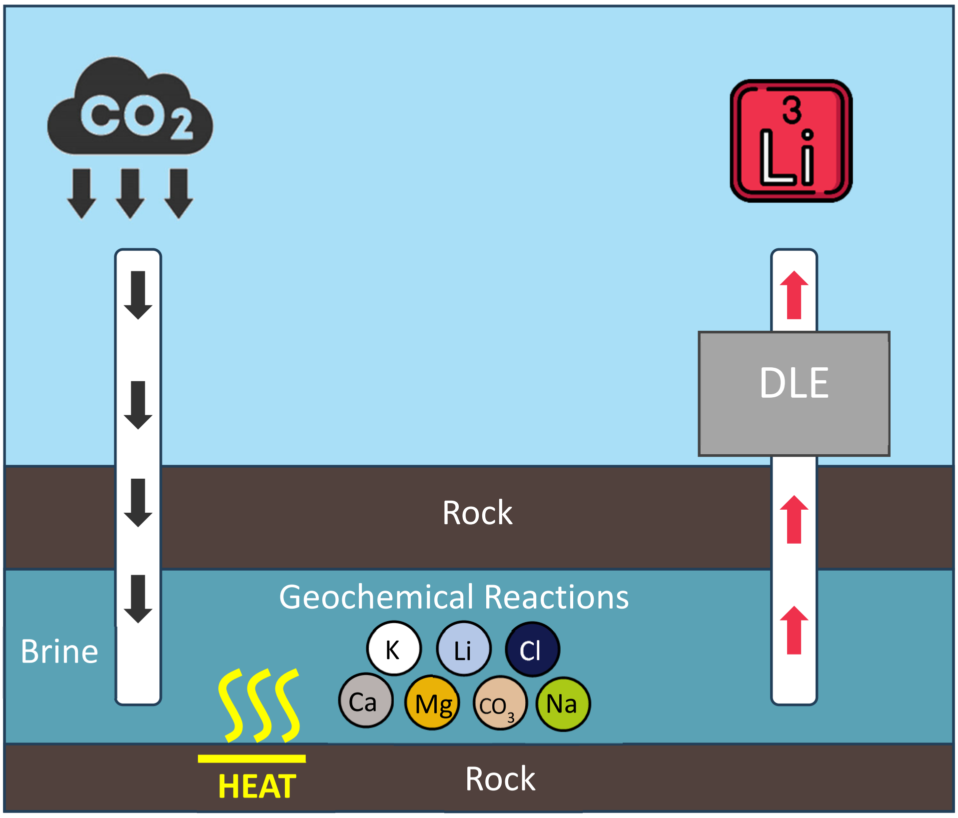

Figure 1: Schematic of CCUS-assisted lithium extraction from geothermal reservoirs. This Figure shows the interaction of CO_2 with subsurface brines, resulting in altered brine chemistry and lithium recovery efficiency.

The project has three primary objectives:

-Investigate how CO_2-induced rock weathering alters brine geochemistry, focusing on lithium mobilisation and enrichment in geothermal systems.

-Assess the impact of CO_2-modified brine composition on the efficiency and selectivity of DLE technology.

-Develop practical recommendations for integrating CCUS with lithium extraction, ensuring energy efficiency, environmental sustainability, and potential synergy with enhanced geothermal recovery (EGR).

Methodology:

This study combines experimental and analytical methods to investigate the impact of CO_2 on rock-fluid interactions and lithium recovery. A high-pressure, high-temperature reactor will simulate subsurface conditions, exposing rock and brine samples to CO_2 to examine its effects on geochemical changes, including mobilisation of lithium and other competing ions.

Analytical techniques such as X-ray diffraction (XRD), inductively coupled plasma mass spectrometry (ICP-MS), Fourier-transform infrared spectroscopy (FTIR), and scanning electron microscopy (SEM) will assess mineralogical, ion concentration, and microstructural changes.

The second stage will focus on developing and optimising a DLE process inspired by Disu et al.'s 2023 method. The extraction efficiency will be tested using brines modified through CO_2 exposure, accounting for changes in their chemical composition. Optimisation efforts will focus on maximising lithium recovery rates and ensuring the process aligns with sustainability and scalability requirements.

Possible Timeline

The project is structured into two phases over the 3.5-year duration.

In the first year, the student will begin by collecting rock and brine samples from suitable subsurface reservoirs. Laboratory simulations will follow, using the HPHT reactor to replicate subsurface conditions and expose the samples to CO_2. Initial experiments will focus on characterising the effects of CO_2 on rock dissolution, brine chemistry, and lithium concentration.

In the second and third year, the DLE process will be tested and optimised. Experiments will evaluate the efficiency and selectivity of lithium extraction under varying conditions, including different brine compositions and operational parameters. The student will identify factors influencing recovery rates and develop strategies to improve sustainability and scalability. Collaboration with industry partners (NDC and EVOVE) during this phase will ensure practical relevance and industrial scalability.

The final six months will be dedicated to completing the thesis and disseminating the findings. The student will present results at academic conferences and industry workshops, contributing to the wider conversation on sustainable lithium extraction. These outcomes will also be published in peer-reviewed journals to maximise impact.

Training and skills:

TARGET researchers will participate in a minimum of 40 days training over the 3.5 years of study composed of:

- an annual one-week workshop dedicated to their year group, and tailored to that cohort's needs in terms of skills development – *for the first three years of their study*;
- an annual all-TARGET workshop with cross-year interactions, advanced training and opportunities to specialise in particular areas – *all years of study*;
- a number of one-day workshops;
- additional online events and in-person workshops attached to relevant conferences.

In addition to the CENTA workshops and trainings:

- The student will attend Earth's Energy Resources Course at the school of Geoscience and Critical Minerals for Energy Transition at the school of Engineering at the university of Aberdeen.
- The student will be trained on advanced petrographic techniques for mineral identification.
- The student will be trained for the necessary laboratory and safety skills.
- The student will also attend other university workshops and trainings such as:
    - How to avoid plagiarism
    - How to write scientific manuscripts
    - Effective presentation skills

- etc

Partners and collaboration (including CASE):

National Decommissioning Centre (NDC): NDC will assist the PhD student in designing a pilot-scale lithium extraction process that closely mimics real operational conditions.

North Sea Transition Authority (NSTA): NSTA will provide technical support throughout the project.

Further reading:

Disu, B., Rafati, R., Sharifi Haddad, A., & Muirhead, D. (2025). Maximizing Lithium Adsorption and Selectivity on Manganese-Based Ion Sieves: Effects of Thermal Treatment, Acid Content, and Operating Conditions. Industrial & Engineering Chemistry Research, 64(24), 11961–11980. https://doi.org/10.1021/acs.iecr.5c00735

Disu, B., Rafati, R., Sharifi Haddad, A., Mendoza Roca, J. A., Iborra Clar, M. I., & Soleymani Eil Bakhtiari, S. (2024). Review of recent advances in lithium extraction from subsurface brines. In Geoenergy Science and Engineering (Vol. 241, p. 213189). Elsevier BV. https://doi.org/10.1016/j.geoen.2024.213189

Disu, B., Rafati, R., Sharifi Haddad, A., & Fierus, N. (2023). Lithium Extraction From North Sea Oilfield Brines Using Ion Exchange Membranes. In Day 2 Wed, September 06, 2023. SPE Offshore Europe Conference & Exhibition. SPE. https://doi.org/10.2118/215585-ms

Further details:

Please visit https://target.le.ac.uk/ for additional details on how to apply.

For more information about this project, please contact the main supervisor:

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