Exploring 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

Overview:

As the world transitions towards renewable energy, the demand for lithium, a key component in energy storage systems such as batteries, has surged. However, current extraction methods face environmental and sustainability challenges [Disu 2024]. This project explores how carbon capture, utilisation, and storage (CCUS) can be integrated with direct lithium extraction (DLE) technology to recover lithium from subsurface brines in a more efficient and environmentally friendly way.

The research focuses on two aspects: first, understanding of how CO_2 interactions with subsurface brine and rock alter geochemistry and mineral concentrations in both rock and brine; and second, evaluating how these changes affect lithium extraction using DLE (Figure 1). The goal is to optimise this process, producing higher yields and grades of lithium in collaboration with carbon sequestration.

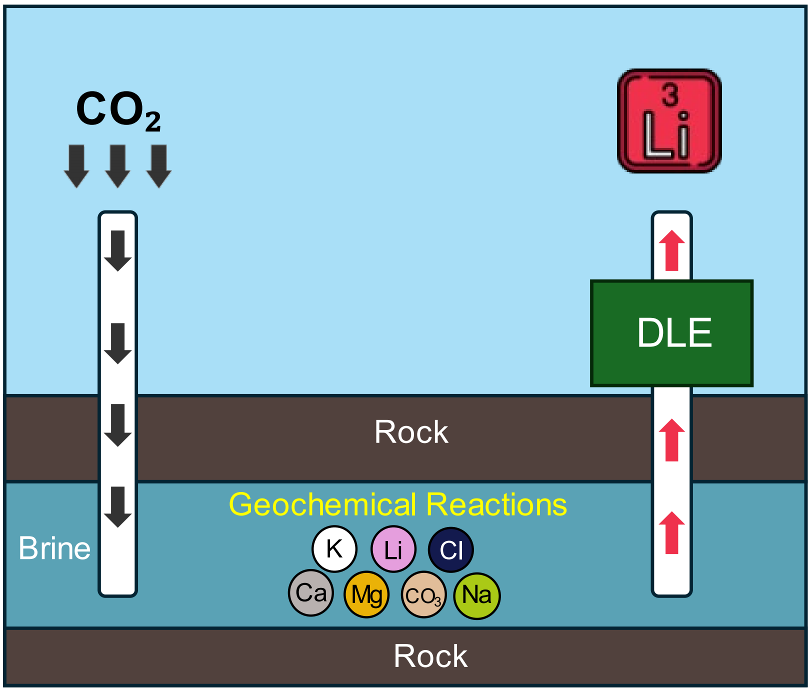

Figure 1: Schematic of the CCUS assisted lithium extraction from subsurface brines. In this Figure, injected CO_2 reacts with subsurface brine and changes its chemistry, potentially impacting lithium concentration in the brine and lithium recovery efficiency.

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.

The project has three primary objectives:

- Investigate how CO_2-induced rock weathering alters brine geochemistry, focusing on lithium mobilisation and enrichment.
- Assess the impact of CO_2-modified brine composition on the efficiency and selectivity of DLE technology.
- Develop practical recommendations for optimising CCUS integration into lithium extraction, ensuring energy efficiency and sustainability.

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 be used to 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 including 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 and resultant petrography, 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 MSc 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

Partners and collaboration (including CASE):

British Geological Survey (BGS): This project will be co-supervised in partnership with the BGS and be incorporated into their BUFI programme, providing the student with project support and access to world-class analytical facilities and the BGS core repository.

EVOVE: Samples will be collected with the help of EVOVE, who will also host the student at their Derbyshire facilities to provide insights into membrane technology and its associated challenges.

The National Decommissioning Centre (NDC) will assist the PhD student in designing a pilot-scale lithium extraction process that closely mimics real operational conditions. Additionally, we are in negotiation with the NDC to further support the student by contributing supplementary RTSG funding, which the student can use for the purchase of lab consumables, training courses, and conference attendance as necessary.

Dr Rachel Brackenridge and Professor Adrian Hartley from the School of Geosciences will provide additional support for geological aspects of the project.

Further reading:

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.

Please contact the lead supervisor Roozbeh Rafati (roozbeh.rafati@abdn.ac.uk) for more information.

https://www.abdn.ac.uk/engineering/

https://www.abdn.ac.uk/geosciences/