# Carbon Capture and Storage: The Geoscience Fundamentals (G540)

GeoLogica TRAINING

## Tutor(s)

Richard Worden: Professor in the Department of Earth Ocean and Ecological Sciences, University of Liverpool, UK.

## Overview

This course will provide participants with the fundamental geoscience concepts of Carbon Capture and Storage (CCS) projects; namely subsurface CO2 storage volumetrics, CO2 flow in the subsurface away from injector wells, the goal of safe and permanent storage of CO2 and cost-benefit issues linked to aquifer depth, well design, etc. The course is aimed at non-specialist staff so basic geoscience concepts will be explained throughout. The need for CCS will be laid out with evidence as to why geoscientists know it can be effective at mitigating greenhouse gas emissions. The course will deal with CO2 as a fluid phase and how much can be stored in the subsurface. It will deal with how quickly CO2 can be injected and the factors that influence injection rate. The range of consequences of injecting large volumes of CO2 into the subsurface will also be covered, including the risk of minor Earth tremors. The range of possible CO2 leakage mechanisms will be presented, and the course will conclude with a consideration of monitoring strategies and risk assessment approaches.

## Duration and Logistics

**Classroom version:** A 1-day course comprising a mix of lectures, case studies and exercises. The manual will be provided in digital format and participants will be required to bring a laptop or tablet computer to follow the lectures and exercises.

**Virtual version:** Two 4-hour interactive online sessions presented over 2 days. Digital course notes and simple exercise materials will be distributed to participants before the course. Some exercises may be completed by participants off-line if desired.

## Level and Audience

**Fundamental**. Intended for a non-specialist audience (technical assistants, engineers, geoscience support staff) to raise awareness of the geoscience background to CCS – how it works, possible consequences of injecting large volumes of fluid into the deep subsurface, monitoring strategies and key risks associated with it. The geoscience subject matter is covered from basic principles to make it accessible to non-specialist staff. Basic numeracy will be assumed but most exercises will be based on spreadsheet-based calculations using prepared Excel files. There will be opportunities for discussion about key topics in breakout groups, with feedback to the class. Simple group exercises will be used to illustrate key points.

## Objectives

You will learn to:

1. Appreciate why CCS is needed to cut global carbon emissions.
2. Develop an understanding of the role of geoscience in CCS and the role of CCS in CO2 emissions

reductions.

3. Appreciate what $CO_2$ injection projects have occurred so far and how they differ from industrial CCS planned in the UK.
4. Understand how and why CCS works, including basic geological concepts about rocks, fluids in those rocks and the key physical properties of rocks involved in CCS projects.
5. Understand $CO_2$ as a fluid in the subsurface and how it differs from water, oil and natural gas.
6. Build an appreciation of how much $CO_2$ can be stored in both old (depleted) oil and gas fields and saline aquifers, and understand the benefits of depleted hydrocarbon fields vs saline aquifers.
7. Develop a basic understanding of the flow properties of porous rocks and the rate at which $CO_2$ can be injected through a well during CCS, including an appreciation of the role of heterogeneity on the success of CCS projects.
8. Understand the range of detrimental and beneficial effects that $CO_2$ can have on the host aquifer, from geomechanical to geochemical.
9. Grasp the critical importance of the role of top-seal and fault-seal properties and how they influence $CO_2$ storage, from risk of fracking, or induced seismicity, to mineral dissolution.
10. Understand the ways that $CO_2$ could escape from planned CCS sites.
11. Develop an awareness of the range of monitoring strategies that could be employed to ensure safe and long-term storage of $CO_2$.

## Course Content

### Session 1: Background, context, fate of $CO_2$ in the subsurface, storage volumes (masses) and how much carbon we need to store in the ground

Lectures

- Why is CCS needed?
  How CCS fits into the bigger picture of $CO_2$ emissions-reductions and the energy transition
- Geology and CCS – some basic concepts: (i) depth, pressure and temperature regimes in the subsurface; (ii) storage rock porosity and permeability; (iii) fluids sitting in porous rocks before CCS projects are considered; (iv) sealing rock types and their key properties; (v) advantages and disadvantages of CCS in basins with a long history of hydrocarbon production; (vi) separation of $CO_2$ from produced hydrocarbons and from exhaust flues; (vii) geological and engineering risk factors and lessons from the fracking industry; and (viii) $CO_2$ physical properties
- Why we know that CCS can work
- The possible fates of $CO_2$ in the subsurface as a function of time
- Porous rocks for storage of $CO_2$ (sandstones, limestones and igneous basalt), UK reservoir options and the porosity of the UK's main
- CCS target reservoirs
- How much $CO_2$ can be stored in depleted hydrocarbon fields and aquifers

Exercises

- Estimation of mass of $CO_2$ locked away by CCS so far and assessment of how many CCS projects are needed at current rate of emission.
- Storage volume estimation – simple calculations in the context of UK's $CO_2$ emissions.

Activities

- Discussion: Who should pay for CCS?

## Session 2: Overview of geoscience context, CO2 in the subsurface and volumetrics

Lectures

- Permeability and flow of CO2 in the subsurface
- Injection well design and how pressure varies away from these wells
- Why the reservoir rocks near the injection well might ‘fail’ (frack)
- How the physical form of CO2 changes away from injection wells
- The role of geological heterogeneity in controlling outward flow of CO2 and how poorly interconnected reservoir or aquifer compartments can limit injection rate
- CO2-reservoir interactions, from mineral dissolution to salt precipitation: effects on injection rates
- Top-seal properties: why mudstones matter for CCS projects
- The role of pre-existing faults in reservoirs and top-seals for CCS site security
- Induced seismicity due to CCS: lesson from the fracking industry
- Possible leakage pathways of CO2 from a storage site: true leakage vs lateral migration
- Monitoring options: cost-benefit assessment
- Risk assessment for CCS projects

Exercises

- How permeable are the rocks planned for CCS in the UK and what are the effects on CO2 injection rate?
- Simple models for the rate of CO2 injection – how many megatons can we dispose of?

Activities

- Discussion: How long should we monitor CCS sites?
- Discussion: Assessment of leakage risk.