

StrataTrapper Annual Report 2022/23

CCUS Innovation 2.0

Key Knowledge Deliverable 5.1

Key Knowledge Deliverable Cover Sheet

This Key Knowledge Deliverable (KKD) has been produced by Imperial College London as part of the BEIS CCUS Innovation 2.0 programme. The document is reflective of the status of the project at the time of writing. The material presented could have been subject to change as the project matured. These documents should not be considered a full representation of the final project.

Description of the project: In StrataTrapper we translate cutting edge research carried out at Imperial College London and the University of Cambridge on the geological fluid dynamics and trapping of CO₂ into innovative characterisation and modelling software tools that will be used by industry to reduce risks and costs of CO₂ storage projects. The tools will be commercialised through incorporation into the CO₂ reservoir simulation platform OpenGoSim, in addition to being made open-source. We will work with industry partners bp, Storegga, and Drax power to demonstrate the applicability of these tools to the Endurance field in the Southern North Sea and the East Mey Site in the Central and Northern North Sea. The result of the work will be the commercialisation of the StrataTrapper reservoir simulation tools for the rapid screening, risking, project design, and management of CO₂ storage.

This is key knowledge deliverable 5.1, an annual report summarising the main technical and commercialisation advances achieved under StrataTrapper for the 2022/23 year

The following is the full list of KKD's to be published under StrataTrapper:

KKD1.1 Open-source research codes for the characterisation of multiphase flow heterogeneity and conversion to flow functions for reservoir simulation

KKD1.2 A report detailing the workflows for reservoir characterisation, and model creation and use

KKD2.1 Open-source research codes for the rapid estimate of the impacts of heterogeneity on lateral plume migration, residual and dissolution trapping

KKD2.2 A report detailing the use and limitations of reduced physics models for various applications, including screening and probabilistic analysis

KKD3.1 Publicly available models of the Endurance and East Mey sites

KKD3.2 A report analysing the impacts of multiphase flow heterogeneity on CO₂ migration and trapping in the case study sites

KKD4.3 StrataTrapper Workshop to CCS project developers

KKD5.1 Annual reports

KKD5.2 Project final report



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Contents

Work Package 1 – Upscaling reservoir simulations with multiphase flow heterogeneity	6
WP1 Achievements for 2022/23	6
Work Package 2 – Developing reduced physics models with multiphase flow heterogeneity	6
WP2 Achievements for 2022/23	7
Work Package 3 – Demonstrate the value of StrataTrapper on Case Study applications	7
WP3 Achievements for 2022/23	8
Work Package 4 – Commercialise the StrataTrapper Numerical Toolset	8
WP4 Achievements for 2022/23	8

Work Package 1 – Upscaling reservoir simulations with multiphase flow heterogeneity

In this Work Package led by Imperial College London we develop the core-to-field numerical upscaling techniques of Jackson & Krevor (2018) from 2D to 3D models, apply them to case studies in WP3, and provide codes for generating flow functions from field data to WP4 for commercial incorporation into OpenGoSim.

WP1 Achievements for 2022/23

A research software tool, written in Matlab, was created to facilitate the conversion of information about the properties of the reservoir to be used in the StrataTrapper modelling approach. The purpose of the software is to accurately incorporate information about the heterogeneity in the reservoir, and in particular the capillary pressure heterogeneity, into an upscaled model used for reservoir simulation. The algorithm takes as input spatial statistical information about reservoir properties, including means, variances, and correlation lengths of flow properties. The output is a 3D reservoir model with upscaled flow properties, including relative permeability and capillary pressure, that may be used for simulation.

The upscaling approach closely follows the approach presented in Jackson & Krevor (2018) but includes a few key developments: The upscaling has been extended from 2D to 3D models; the calculation of upscaled relative permeability is now performed within the code and without calls to reservoir simulation software, significantly improving the computational performance.

In the coming year, the software tool will be released on a publicly available Github repository as Key Knowledge Deliverable 1.1 from this project.

Work Package 2 – Developing reduced physics models with multiphase flow heterogeneity

In this Work Package led by University of Cambridge reduced physics mathematical models describing the multiphase flow – plume migration, and residual and dissolution trapping – of CO₂ in heterogeneous formations are further developed for more complex reservoir architectures. These complement the numerical models of WP1 in that they

are extremely computationally efficient, enabling use for site screening, probabilistic analysis, and dramatic speed up of calculations within reservoir simulation. In WP2 the current models will be extended to incorporate spatially variable reservoir architecture. We will develop automated upscaling functions for application to case studies in WP3 and incorporation into the OpenGoSim simulator in WP4. In addition, a standard methodology for characterising uncertainty will be developed and directed towards probabilistic forecasts of the plume spread.

WP2 Achievements for 2022/23

The mathematical model developed to-date as part of WP2 describes the field-scale behaviour of CO₂ injected into a subsurface, fluid-saturated reservoir, incorporating spatially variable porosity, permeability, and upper- and lower-caprock topography. By leveraging some widely applicable assumptions about the flow of the CO₂, the resulting reservoir simulations can be run quickly on a standard laptop. This model is currently being extended to include spatially varying saturation, capillary pressures, and residual permeabilities for the CO₂ and ambient brine. As part of the vertical integration involved in the model, the option to pre-compute relevant integrals is being developed in order to reduce the overall runtime when performing relevant parameter surveys.

A version of this code is also being produced to interface with software from OpenGoSim, as part of WP4. In the coming year, the software tool will be released on a publicly available Github repository as Key Knowledge Deliverable 2.1 from this project.

Work Package 3 – Demonstrate the value of StrataTrapper on Case Study applications

The Endurance field and the East Mey site are the storage targets for the full-scale deployment of CCS in the UK and have undergone extensive characterisation. In WP3 we will classify heterogeneity types within these fields, supplementing existing data with analysis of core material in WP1. We will construct models of the sites using the StrataTrapper workflow, and demonstrate the impacts of heterogeneities on flow and trapping, with implications for site development, management, and closure. We will evaluate primary and further stage development plans of the sites with injection rates ranging from 0.3 – 8 Mt yr⁻¹ by 2030.

WP3 Achievements for 2022/23

This activity has just begun in StrataTrapper. However, models and upscaled simulations of the Endurance field have been created and a model of the East Mey Site has been handed over for development.

Work Package 4 – Commercialise the StrataTrapper Numerical Toolset

In this work package led by OpenGoSim we commercialise the StrataTrapper toolset by incorporation into the software platform OpenGoSim. There are two groups of activities that will take place in parallel. One group translates techniques and research codes from WP1 and 2 into the OpenGoSim simulator, PFLOTRAN-OGS. The second develops GPU support for the simulator, dramatically enhancing the computational performance so that high spatial resolution simulations of heterogeneity can be performed.

WP4 Achievements for 2022/23

Advances were achieved in both the development of the simulation software and the development of the GPU support for the simulator.

With respect to the simulator modelling capabilities, a directional relative permeability option was implemented in PFLOTRAN-OGS. Directional relative permeability is an outcome of the StrataTrapper upscaling process (WP1) and required for software using this approach. Directional relative permeability allows different relative permeability functions to be used for different directions of flow. So, for example, gas flow in the vertical z-direction, between strata, could be given a different critical gas saturation to reflect the trapping of gas under impermeable layers or layers with widely different capillary pressures.

With respect to the development of GPU support, existing open-source GPU linear solvers were tested and found unsuitable for implementation with PFLOTRAN-OGS. As a result a customised GPU-solver was constructed and implemented in WISP, the user interface for PFLOTRAN-OGS.

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