# Geothermal potential of abandoned coalfields in the Yorkshire region: a clean source of energy

## Supervisors

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## Overview

Reducing greenhouse gas emissions is a major global challenge. Geothermal energy has a huge potential to contribute to a reduction in greenhouse gas emissions, which is a major global research challenge. To this end, the current research project aims to better understand the potential use of abandoned coal mines as a source of geothermal energy. The project will be of interest to individuals seeking a novel and innovative multidisciplinary research project involving fieldwork, laboratory analysis and numerical modelling in the broad areas of engineering and engineering geology, geothermal engineering and geomechanical modelling. The research will place the successful candidate in an ideal position to gain future employment in either industry or academia.

## Scientific background

The demand for energy has rapidly increased as technological advancements have driven a rise in energy consumption. Energy for heating accounts for almost 50% of the world's energy consumption and is expected to increase significantly in the coming decade. Traditional energy sources based on burning a variety of types of fossil fuels are increasingly recognized as an inappropriate way to meet long-term future energy demands; the need to mitigate against climate change and growing environmental awareness require us to find more sustainable solutions. Consequently, new renewable energy resources for heating are currently in demand. The coal industry thrived in the UK during the 18$^{th}$ to 20$^{th}$ centuries, contributing significantly to the national economy. However, following the rapid demise of UK coal production since the 1980s, underground mines have been abandoned and many are now flooded.

This study aims to investigate the feasibility of using the heat of mine water to produce energy. Two areas of uncertainty need to be investigated: first, the amount of energy available and the best means for its extraction; second, confirming the long-term stability of the mines and surrounding areas. This study will focus on mines of the West Yorkshire region, specifically the area between Sheffield and

Leeds. The project will use geological data from boreholes and other wells that are already available. Mine records and groundwater data will be used to assess the energy capacity of in-situ heat within the mine water. Then, the stability of the mines and open cavities will be assessed to understand the risk of possible eventual collapse and consequent ground-surface movements such as the development of sinkholes, micro-earthquakes or groundwater impacts. As well as using the mine records and associated geological data, the project will involve site visits to the abandoned mines in the Yorkshire region.

The EU's Renewable Energy directive set a new target requiring at least 27% of final energy consumption in the EU to be from renewable sources by 2030. In the UK and other developed countries (e.g. the Netherlands), approximately half of energy consumption is related to space heating and cooling. The UK has potentially large resources of low enthalpy heat suitable for district heating, utilising heat pumps as required. One largely untapped resource is water within abandoned coal mines. The temperature of the mine water in coal mines usually ranges between 12-18$^{o}$C. Extracted mine water can be passed through a heat exchanger, before connection to a heat pump and distribution system. However, despite some initial site specific studies undertaken by the British Geothermal Consortium, there have been no large-scale resource assessments in most coal-field areas. There also remain uncertainties regarding long-term mine stability, especially with regard to how this would be affected by utilisation of the thermal resource. In the Yorkshire region – the area of interest to this study – the National Mining Museum scheme at Caphouse near Wakefield has previously studied mine-water management in the coalfield but the regional extent of the geothermal resource and its potential have not been demonstrated, especially in regards to re-entering and accessing the old coal mines after they ceased operation and were abandoned.

## Methodology

This study aims to investigate the feasibility of extracting geothermal energy from abandoned coal mines that are characterised by a flooded network galleries and shafts at various depths in the West Yorkshire Coalfield area between Leeds and Sheffield. Specific research objectives are as follows:

1. assess the quantity of heat available and the most appropriate means to exploit it;
2. determine potential heat users in the adjacent communities;
3. assess the risk of future mine instability in the aging underground assets, especially given their projected change in use.

The project will examine the feasibility of using the mine water of the abandoned mines in the Yorkshire region to produce heat energy by accessing all data available from existing boreholes and

past reports (Coal Authority) and by visiting the coal mine sites wherever possible. A critical requirement is to assess the options to achieve flow within the mine water that is being assisted in the void spaces and the increased permeability of host rock resulting from the past coal mining activity.

A preliminary assessment will be conducted to estimate the potential number of heat users in the communities / urban areas contiguous to the using open street map data and a GIS platform.

The long-term stability of the coal mines will be assessed. This is essential because both pumping and re-ejection of water can deteriorate the mechanical behaviour of the shafts and might cause stability issues affecting the in-situ stress conditions. Numerical analyses (FEM, FDM models) to capture the hydromechanical and geothermal effects on the geomechanical behaviour of the coal and surrounding rocks will include sensitivity analysis.

The proposed research project aims to investigate the long-termbehaviour of rock materials by performing a number of laboratory testing at Rock Mechanics, Engineering Geology and Geotechnical Laboratory (RMEGG) at University of Leeds:

https://environment.leeds.ac.uk/see/dir-record/facilities-environment/934/rock-mechanics-engineering-geology-and-geotechnical-rmegg-laboratories

and the Wolfson Multiphase Flow Laboratory at the University of Leeds:

Numerical analyses using finite element, finite difference and distinct-element methods combined with big data analysis methods will be performed to develop a constitutive model that can capture this geomechanical and geothermal behaviour in order to be utilized from the industry to assess the overall behaviour of the coupled system in such environments.

https://environment.leeds.ac.uk/see/dir-record/facilities-environment/878/wolfson-multiphase-flow-laboratory

## Potential for high-impact outcome

A major outcome of this project will be the development of an implementation roadmap including potential scale and benefit, failure or exit criteria, decision points and risk assessments. This will require a detailed assessment of how much heat is available and the most appropriate means to sustainably exploit it; a preliminary economic screening of potential heat users in the adjacent communities matched to the heat resource; and a risk assessment of future mine instability in the aging underground assets, especially given their change in use.

Past and on-going research on similar topics to this, and also undertaken at Leeds, have been funded by NERC to address their mission aims. The appointed candidate will be expected to publish the results of their research in leading pure and applied research journals such as Engineering Geology and Nature. The principal project supervisor has a long track history of internationally recognized research publications in this field.

## Eligibility

Applicants should have a BSc degree (or equivalent) in geology, earth sciences, geophysics, civil/mining engineering or a similar discipline. An MSc in engineering geology, geological/geotechnical engineering or applied geoscience (or similar) is desirable. Skills in field-based geological data collection and field sedimentology and stratigraphy are desirable. Experience of using numerical analyses software would be useful, though is not essential.

## Training

This PhD will commence 1st October 2019 and run for 3.5 years. During this period the student will be eligible for all the postgraduate training typically provided to students attending the University as part of the NERC Doctoral Training Programme. The student will receive thorough training in the critical appraisal of subsurface data, experimental rock mechanics and finite-element based numerical modelling. The latter will be gained via extended visits to our case partner, Rockfield Software Limited, who are the developers of ELFEN, a state-of-the-art finite-element modelling package that already has advanced modelling capabilities for anisotropic elasto-plastic materials. This multi-disciplinary training will place the successful student in an ideal position to work in a range of industries or take up an = academic appointment.

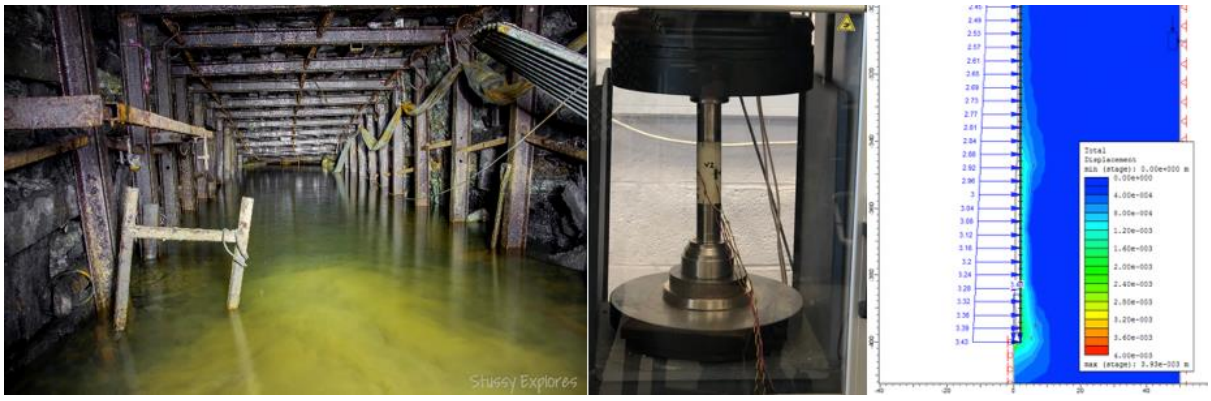


*Figure 1. The project provides the opportunity for the student to integrate results from fieldwork, laboratory analysis and numerical modelling.*

## Recommended Reading

Banks, D., 2012. An introduction to thermogeology: ground source heating and cooling, 2nd edition. Wiley Chichester, p 526

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Wang, F., Cao, P., Cao, R., Xiong, X., Hao, J., 2018. The influence of temperature and time on water-rock interactions based on the morphology of rock joint surfaces. Bulletin of Engineering Geology and the Environment

Yang, W., Marshall, A. M., Wanatowski, D. and Stace, L. R., 2017. An experimental evaluation of the weathering effect on mine shaft lining materials