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DE-RISKING GEOTHERMAL HEAT EXTRACTION FROM TIGHT HOT SEDIMENTARY AQUIFERS (GEOGUARD)

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INTRODUCTION

Most current geothermal projects are located near active volcanism or plate boundaries, yet deep sedimentary basins away from these regions also hold significant geothermal potential. Many major European cities lie above such basins, which may contain hot water suitable for direct heating (Figure 1). However, many of these reservoirs are Devonian or older (~350 Ma) and have low permeability.

The GEOGUARD project addresses the key challenge of low production flow rates from these tight reservoirs, which limit the economic viability of deep geothermal heat production. To tackle this, the project will develop a technical and economic toolbox to understand how best to improve flow rates, using case studies in Lithuania, Scotland, and Ireland.

Ultimately, GEOGUARD aims to answer four main research questions:

1) How can knowledge transfer from hydrocarbon to geothermal energy production be achieved to optimise reservoir performance and minimise uncertainties and risks?
2) How can reservoir stimulation tools be incorporated into the operation of tight Hot Sedimentary Aquifers (HSAs), balancing between the complex interplay of technical and societal risks, cost and revenue benefit?
3) How can tight HSAs be engineered into a reliable and technically feasible source of low carbon heat to create significant economic growth, jobs and support the just transition?
4) To what extent can geothermal heat be scaled when engineered tight HSAs are harnessed for large-scale decarbonisation of urban and industrial heat systems?

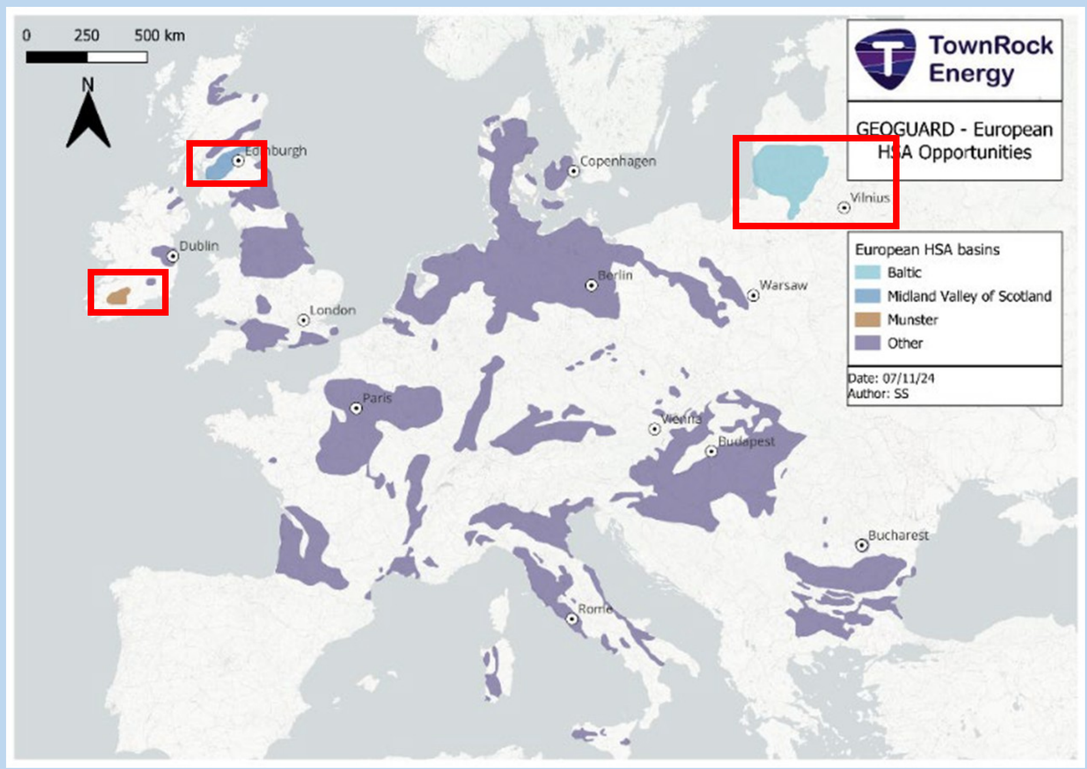


Figure 1: Hot Sedimentary Aquifer (HSA) resource areas across Europe, with the 3 case studies of Lithuania, Scotland and Ireland indicated

METHODS

Each of the 3 case studies were chosen to reflect areas with varying amounts of uncertainty:

- **Lithuania** is data rich, with significant coverage of both 2D and 3D seismic, and over 300 wells which penetrate some of Cambrian and Pre-Cambrian geothermal targets. [1]
- **Midland Valley of Scotland** has a number of connected 2D seismic lines, and a small 3D survey, but most of the data was obtained in the 1970s and is of poor quality. There are only two wells which are known to penetrate the top of the Devonian geothermal target, but both are shallow (~300m) [2]
- **Limerick Basin, Ireland** has only a small number of regional seismic lines, and so the deep subsurface is poorly constrained. There are a large number of shallow wells in the area, but most terminate in the Carboniferous, which lies above the Devonian geothermal target. [3]

Some petrophysical data exists for reservoir rocks in each of the case studies, but more will be collected through GEOGUARD, and the samples used for this will also undergo stimulation to assess how different stimulation techniques affect reservoir quality.

Geological models will be built using existing geological data, and new data and interpretations will be integrated with these to create reservoir models.

The main uncertainties for each case study will be quantified (e.g. target depth, permeability, temperature) and a range of possible values will be used in probabilistic models to optimise project configuration and energy production.

Simultaneously, a campaign on understanding some of the main societal risks with regards to geothermal will be carried out, which will include engaging with prospective stakeholders and developing a information sheet on stimulation in geothermal reservoirs, aimed at the general public.

Table 1: Methodological approach to model development in GEOGUARD

Scale	Model	Modelling goal	Modelling Concept
Fracture/core plug	Analytical stress-permeability	Flow properties	Based on available data to provide input for upscaled models
Fracture network	Discrete Fracture Network (DFN)	Uncertainty quantification for fluid and heat transfer in fractures	Based on existing networks or networks interpreted from seismic
Core-to-seismic	Analytical and statistical rock physics and seismic models	Rock physical properties and their uncertainties from seismic attributes	Calibrated models based on available data
Near-wellbore	Numerical skin model	Near wellbore modelling of skin effects based on permeability enhancement	Link physics to mineralogy/ mechanical properties
Reservoir	Darcy flow model	Industry-compliant dynamic reservoir models	Dynamic reservoir models for case studies; uncertainties for realistic parameter ranges
Uncertainty Quantification (UQ)	Probabilistic flow model	Standard probabilistic models including machine learning	Integrate all uncertainties at various spatial scales
Energy integrated	Techno-economic model	Integrate reservoir models and UQ to interface with energy demands	Integrate outputs from reservoir, skin, DFN models to assess economic case
System	Integrated workflow for scale-up	Robust and standardised protocols	Integrate components

WORKPACKAGE INTEGRATION

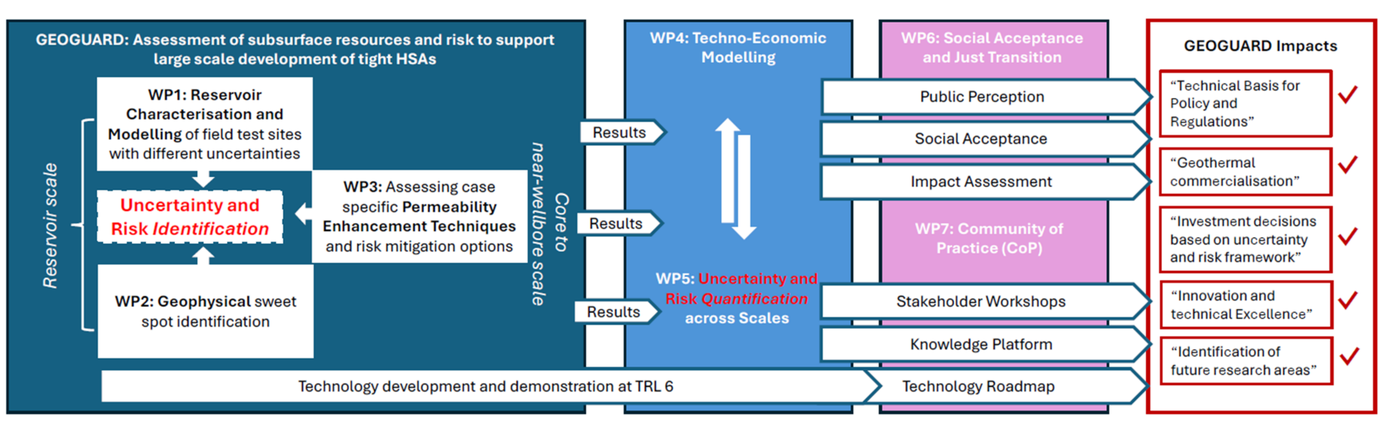


Figure 2: GEOGUARD workpackage integration and roadmap

DELIVERABLES AND IMPACT

GEOGUARD aims to reduce the technical, economical and societal risks of developing deep geothermal energy in tight HSAs. This will help unlock the potential of deep geothermal energy in many areas where it is currently considered too expensive or high risk. Some of the main deliverables of the project include:

- Geological models for each of the case study areas, along with optimised design of geothermal operations (well positions and flow rates)
- Workflow for geophysical sweetspot analysis for areas with low quality data
- Analysis of some of the current stimulation techniques in the case study areas, integrating laboratory techniques and numerical modelling
- Techno-economic models for each case study area
- Development of ML-driven proxy models to predict geothermal energy potential based on geological inputs
- Developing a social acceptance framework and impact analysis toolkit for geothermal energy projects

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