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# An assessment of the potential for deep geothermal heat resources in Dublin city

## Une évaluation du potentiel des ressources thermiques géothermiques profondes dans la ville de Dublin

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**ABSTRACT:** At present, potential deep geothermal resources in challenging, lower-enthalpy settings are poorly understood and remain largely untapped. This study has conducted an initial assessment of the potential for low-enthalpy geothermal energy in Dublin city. The region comprises a hard rock reservoir, which is a major challenge to the use of deep geothermal heat due to its low primary porosity. However, deep geothermal resources in Dublin have significant potential to be used as a renewable heat source at district scales, contributing to the decarbonisation of Ireland's heat sector. The study has examined existing drill-hole and geological data for the region and has reviewed Dublin City Council's district heating strategy. Additionally, the hydrogeological systems of a selection of analogue outcrops from Irish carbonate-hosted lead and zinc mines have been examined since there is a lack of reliable geological information available for the carbonate Dublin Basin. Based on this information, an exploration strategy has been developed for Dublin city, which will comprise novel geophysical exploration modelling techniques (integrated seismic and electromagnetic methods) that overcome the challenge of anthropogenic noise in the urban environment. The objective of this exploration strategy is to develop a geothermal reservoir conceptual model that identifies water-bearing horizons and fractures that will de-risk the commercialisation of geothermal district heating in Dublin city. This study forms part of the GEO-URBAN project (Identification and assessment of deep GEOthermal heat resources in challenging URBAN environments), funded by the European Union's GEOTHERMICA ERA-NET Cofund, which aims to accelerate the deployment of geothermal energy in Europe.

**RÉSUMÉ:** Actuellement, les ressources géothermiques profondes potentielles dans des environnements difficiles où l'enthalpie est basse sont mal comprises et restent largement inexploitées. Cette étude a réalisé une première évaluation du potentiel de l'énergie géothermique à faible enthalpie dans la ville de Dublin. La région comprend un réservoir de roches dures, qui constitue un défi majeur pour l'exploitation de la chaleur géothermique profonde en raison de sa faible porosité primaire. Cependant, les ressources géothermiques profondes à Dublin ont un potentiel considérable pour être utilisées comme source de chaleur renouvelable à l'échelle du district, contribuant ainsi à la décarbonisation du secteur de la chaleur en Irlande. L'étude a examiné les données de forage et les données géologiques existantes pour la région et a examiné la stratégie de chauffage urbain du conseil municipal de Dublin. En outre, les systèmes hydrogéologiques d'une sélection d'affleurements analogiques provenant de mines de plomb et de zinc irlandaises encaissées dans des carbonates ont été examinés en raison du manque d'informations géologiques fiables sur le carbonate Dublin Basin. Sur la base de ces informations, une stratégie d'exploration a été développée pour la ville de Dublin. Cette étude comprendra de nouvelles techniques de modélisation d'exploration géophysique (sismique et électromagnétique intégrées) permettant de surmonter le défi du bruit anthropique en milieu urbain. L'objectif de cette stratégie

d'exploration est de développer un modèle conceptuel de réservoir géothermique qui identifie les horizons et les fractures aquifères qui réduiront les risques liés à la commercialisation du chauffage à distance géothermique dans la ville de Dublin. Cette étude fait partie du projet GEO-URBAN (Identification et évaluation des ressources thermiques géothermiques profondes dans des environnements URBAN difficiles), financé par le fonds GEOTHERMICA ERA-NET Cofund de l'Union européenne, qui vise à accélérer le déploiement de l'énergie géothermique en Europe.

**Keywords:** Geothermal Energy; Urban Exploration; Geophysics; District Heating; Ireland.

## 1 INTRODUCTION

EU member states have agreed to a 40% reduction in emissions by 2030, compared to emissions in 1990, (Eurostat, 2017) in an effort to combat climate change. Many EU countries have developed strategic sustainable energy planning policies that include geothermal energy in order to decarbonise their energy sectors. Appropriately designed, large-scale geothermal heating systems can satisfy society's "energy trilemma" (Heffron et al., 2015), by providing a secure energy supply that is economical and environmentally sustainable, while reducing EU reliance on fossil fuels. The use of geothermal energy is well established in some EU countries where high-enthalpy geothermal conditions are present, including Italy and Iceland. Such countries are usually located in volcanic or tectonically active areas. The use of deep geothermal energy in low-enthalpy areas is relatively unexplored in the EU to date, although some countries such as Denmark (Rogen et al., 2015) and the Netherlands (Bakema et al., 2015) are increasing their exploitation of this low-temperature natural resource to address the heating needs of urban and industrial areas, where the demand for heat energy is greatest.

The GEO-URBAN project is a three-year initiative (2018 – 2021) funded by the EU GEOTHERMICA ERA-NET Cofund (project no. 731117), which aims to explore the potential for low-enthalpy geothermal energy in urban

environments. The project consortium consists of ten partner organisations from three EU countries, comprising industry, academia and local government. The project will focus on two target locations – Dublin, Ireland and Vallès, Catalonia, Spain (Figure 1) – and will provide a feasibility analysis for the commercial development of deep geothermal resources in these regions. Challenges to be overcome in these areas by GEO-URBAN include low- to medium-enthalpy geothermal settings, geological challenges due to the fractured nature of the bedrock in both regions (fractured limestone and metamorphic basement in Dublin, and fractured granite in Vallès), and logistical challenges for geothermal exploration due to the urban environment.

GEO-URBAN will evaluate novel geophysical exploration and modelling techniques for urban areas, which will be applied at both test locations. Geophysical data collected during GEO-URBAN will feed into a commercialisation strategy for the exploitation of deep geothermal resources in challenging urban environments, which will draw upon existing knowledge and experience from partners in Denmark, where the deep geothermal heat industry is more established. This knowledge transfer will be reciprocated by the cross-transfer of detailed geological and hydrological data on fractured limestone lithologies in Ireland, which are of interest as

ultra-deep geothermal targets in Denmark and elsewhere in Europe.

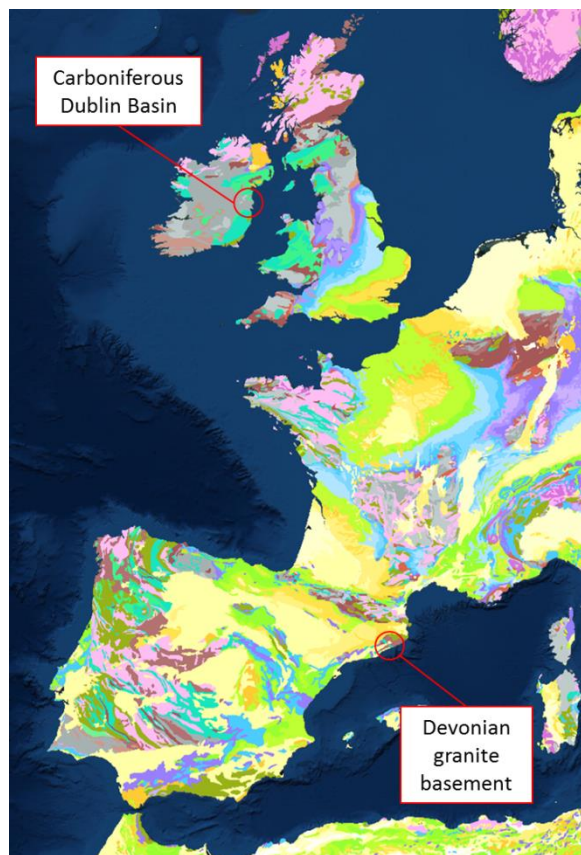


Fig. 1: Geological targets for GEO-URBAN in Dublin, Ireland and Vallès, Catalonia, Spain. Geology map from EGDI ([www.europe-geology.eu](http://www.europe-geology.eu)).

Significant local stakeholder involvement will ensure that GEO-URBAN exploration activities align with local sustainable energy plans and district heating strategies. Furthermore, policy recommendations to assist the sustainable exploitation of deep geothermal energy resources in each region will be outlined. The overall objective of GEO-URBAN is to identify the geothermal resources available in two challenging urban locations and to demonstrate a commercialisation strategy that has the potential to be adapted in other similar locations.

This paper will focus on the assessment of deep geothermal resources beneath Dublin city.

## 2 GEOTHERMAL DISTRICT HEATING FOR DUBLIN

District heating (DH) involves a thermal energy network that distributes hot water or steam through insulated supply and return pipelines to serve commercial, residential, institutional and industrial energy needs for space heating, hot water, space cooling and industrial purposes. DH systems allow heat energy to be bought and sold as a commodity and offer advantages in terms of higher energy efficiencies, reduced consumption of energy resources, and compatibility with EU and national policies and objectives for carbon reduction, energy efficiency, security of energy supply, sustainability and competitiveness (Connolly et al., 2014). DH can also offer capital cost savings and reduced operating and maintenance costs to commercial and residential customers.

DH is widely recognised as having an important role in the implementation of future sustainable energy systems within the EU (Connolly et al., 2014), and in particular 4th Generation District Heating (4GDH), which proposes to make simultaneous and integrated use of several renewable energy sources (Lund et al., 2014). The steady and secure supply of heat from geothermal sources lends itself very well to providing baseload heat in DH schemes. Cumulative improvements in DH technology have also made lower temperature geothermal resources a more attractive target for these applications (input temperatures into a 4GDH system will soon be as low as 50 °C (Lund et al., 2014)). More than 180 geothermal DH plants are already in operation in the EU, with a total installed capacity of approximately 1.1 GWth. These plants are mainly located in France, Iceland, Germany and Hungary (GeoDH, 2014). There are currently no geothermal DH projects in Ireland.

As the local governing body for Dublin, Dublin City Council (DCC) is committed to progressing a Dublin District Heating System,

initially focused in the eastern area of the Dublin Docklands, and eventually extending across the city centre. Heat demand mapping for Dublin city has demonstrated that 75 % of the city is suitable for DH (Codema, 2015). DCC has already invested in infrastructure for DH and pipes are in place in several locations. DCC are currently investigating the feasibility of a mix of renewable heat sources for the Dublin DH network.

The geothermal resource beneath Dublin city is poorly understood at present; this will be addressed through the GEO-URBAN project, with DCC as a key project partner. Previous studies in Ireland have been hampered by a lack of deep subsurface data, however an estimated geothermal gradient of 25 °C/km is quoted in the literature (e.g., Goodman et al., 2004), and measurements of the geothermal gradient on the southern margins of the Dublin basin are reportedly slightly higher (GT Energy, 2018). Given these gradients, adequate temperatures for 4GDH are likely to be achieved in the Dublin basin at depths of around 2 km.

### 3 EXPLORATION CHALLENGES

There are several barriers to geothermal exploration in the Dublin basin. The GEO-URBAN project is designed to overcome these barriers and close data gaps through a novel joint application of geophysical methods, and through the use of geological analogues to increase our understanding of the geothermal resource. The main practical challenges to geothermal exploration in Dublin are its geology and the built-up urban setting.

#### 3.1 Geology

A major challenge to the exploitation of deep geothermal heat is the inherent nature and hydraulic properties of some types of bedrock. In reservoirs with adequate primary porosity, such as sandstone, the extraction and circulation of thermal groundwater is easily modelled and

understood, thus decreasing the risk of the enterprise. In “hard rock” reservoirs (granite, metamorphic rock, limestone, etc.), i.e., those with low primary porosity, fluids move along discrete fractures in the bedrock, which are much more difficult to conceptualise and model accurately. In carbonate bedrock, there exists the potential for karstification, which can add further complexity to the geological setting.

Dublin city is located towards the southern margin of a large Carboniferous sedimentary basin, known as the Dublin basin, which contains c. 2,000 m of sedimentary infill of Mississippian (Tournaisian to Viséan) age (Figure 2). During the Viséan age, active faulting within the basin led to the development of shallow platforms and contrasting deeper regions. The platform facies are typically clean, thickly bedded, and shale-free limestones, whereas the deeper basinal facies are thinly inter-bedded, cherty limestones and shales. These Carboniferous limestone lithologies tend to exhibit low primary porosity. Permeability is greatly improved by karst and fracture development, which provide important conduits and fissures for groundwater flow. Hydrothermal springs have been recorded in the Dublin basin (e.g., Blake et al., 2016) and are frequently associated with deep-seated, high-angled faults, which transport the warm waters to the surface. These thermal springs are also associated with dominant regional NE-SW structural lineaments.

The primary target of any geothermal exploration survey in a hard rock reservoir is to identify zones of weakness in the rock at depth, through which hot fluids can flow. It is therefore imperative that the structural nature of the Dublin basin (fractures, faults, and associated karst) is well understood prior to drilling in order to have the best chance of a successful well. Accurate characterisation of the geological structures in hard rock reservoirs is usually achieved using; i) a combination of geophysical techniques (seismic and electromagnetic) to identify water-bearing horizons and fractures, ii)

geological mapping and study of analogous areas, and iii) drilling of expensive deep boreholes to ground-truth the geophysical and conceptual models.

In order to identify these zones of high permeability, this study has examined existing deep drill-hole and geological data for the region. There is a general lack of publicly available, deep subsurface data in the Dublin basin, although the relatively recent exploration study in Newcastle, South Co. Dublin in 2009 found geothermally promising temperatures and permeabilities at depths of approximately 1.4 km (GT Energy, 2018).

In reservoir analysis, it is common for data from comparable analogue geological settings to be used in the absence of sufficient data from the main target location. In the absence of deep drill-hole data, the next phase of the GEO-URBAN project aims to assess data from similar Carboniferous settings elsewhere in Ireland (the deep mine workings at Navan, Co. Meath, on the northwestern margins of the Dublin basin will provide valuable analogue outcrops and structural and hydrogeological data). This will provide a more robust understanding and conceptual model of the geothermal reservoir in Dublin.

### 3.2 Urban setting

In urban and industrial environments (where most potential end-users of geothermal energy are located), traditional geophysical techniques can be subject to anthropogenic noise, which may reduce the usefulness of electromagnetic and seismological methods. In the case of electromagnetic methods it is possible to overcome unwanted urban noise and improve the signal-to-noise ratio by using a controlled source technique. Anthropogenic and natural seismic noise (e.g., from the oceans, or from road traffic) can even be used directly as a

source of seismic energy (Roberts and Asten, 2004). The GEO-URBAN geophysical exploration programme has been designed to overcome these challenges, and is discussed further in Section 4.

The built-up nature of urban centres can also pose problems for the deployment of arrays of geophysical instruments. Dublin is the capital city of Ireland and has an urban population of 1.1 million with the highest residential density in the very centre of the city. Relevant stakeholders in Dublin, such as local planning authorities and commercial associations, have been included in the project consortium and will assist in geophysical site selection and data collection, by, e.g., providing access to green spaces and parks in the city centre. The inclusion of Dublin City Council in particular will also ensure that the geothermal exploration activities are aligned with existing local, regional and national geothermal energy and district heating strategies.

## 4 GEOPHYSICAL EXPLORATION STRATEGY

Geophysical methods are essential in the definition of potential geothermal resources and can help to identify the presence of important structures such as faults, fractured intervals, folds, stratigraphic unit depths and thicknesses (Nimalsiri et al., 2015; Soengkono et al., 2013). Recently, a new geophysical research topic called “Urban Geophysics” is gaining traction, which focuses on innovative applications of geophysical techniques in urban environments. Three different approaches are becoming increasingly relevant in unravelling the subsurface complexity in urban geophysics:

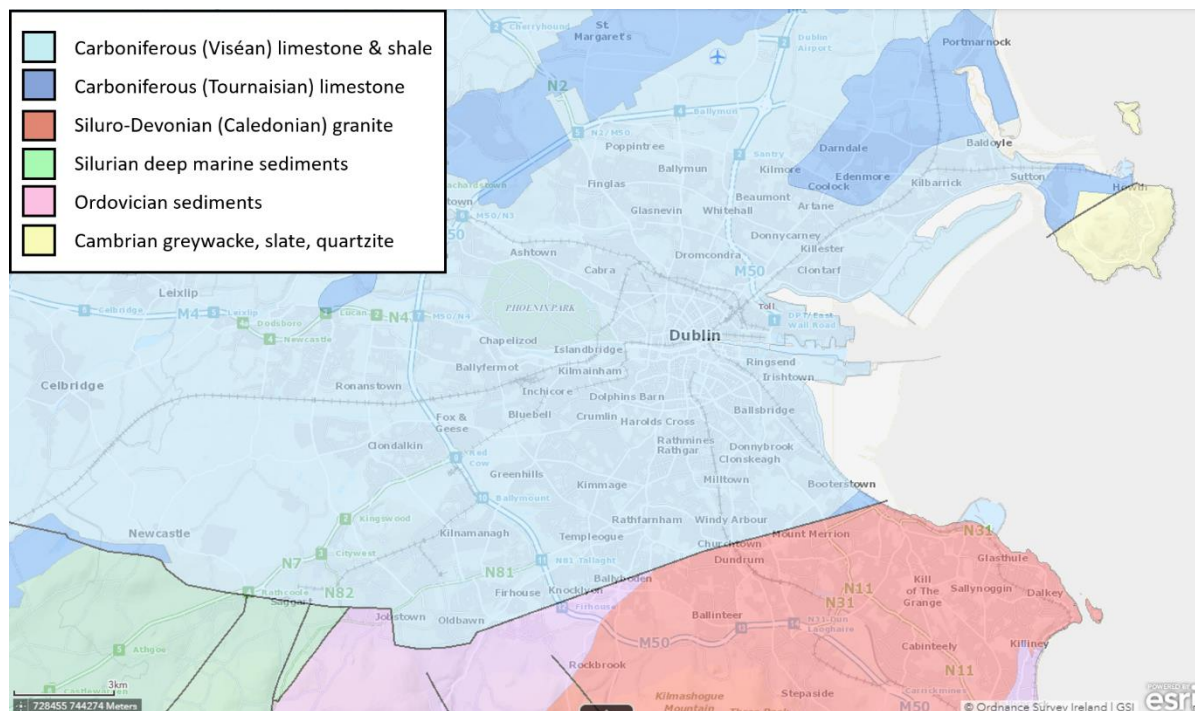


Fig. 2: Geology of the Dublin basin around Dublin city centre, 1:1,000,000 scale. (Bedrock map from [www.gsi.ie](http://www.gsi.ie).)

- adapting traditional techniques to identify the noise in the signal (Escalas et al., 2013), reducing its effects and increasing the signal-to-noise ratio;
- transforming noise into a useful signal - this is the principle behind techniques such as seismic interferometry or ambient noise analysis (Gabàs et al., 2014); and
- generating a source of signal to “drown out” the noise, in particular in the case of controlled source electromagnetic (CSEM) techniques (Vilamojó et al., 2015; Puzyrev et al., 2017).

In hard rock geothermal environments, such as in Dublin, an integration of electromagnetic and seismic methods is highly recommended as these methods provide complementary information about different physical properties of the subsurface rock.

#### 4.1 Multi-disciplinary methodology

The GEO-URBAN geophysical exploration programme for Dublin is specifically designed for use in urban areas. In GEO-URBAN, we will apply a multi-disciplinary methodology using electromagnetic techniques (magnetotellurics (MT) and CSEM), and passive seismic methods (including the H/V technique, array methods and ambient noise cross correlation). The primary targets of the exploration will be; i) to establish the depth to basement in 3-D beneath the city, and ii) to image faults and fractures in the basin.

The use of natural noise sources has now become a standard approach in passive seismology; the urban setting in which this experiment will take place will provide additional, anthropogenic noise that will be taken advantage of and used for imaging. The passive seismic method is very convenient for urban areas as the instruments can be deployed

in building basements, and therefore avoids certain logistical problems around instrument security in a city setting. CSEM is useful for avoiding anthropogenic noise as an artificial signal source is used to boost the signal-to-noise ratio. GEO-URBAN project partners in the University of Barcelona (UB), Dublin Institute of Advanced Studies (DIAS) and Institut Cartogràfic i Geològic de Catalunya (ICGC) are pioneers in the use of these techniques.

#### 4.2 3-D joint interpretation of resistivity and seismic models

The multi-disciplinary methodology for geophysical surveying will require a 3-D joint interpretation to produce a model of the Dublin geothermal reservoir. The strategy proposed for GEO-URBAN is based on a cooperative interpretation of the electromagnetic resistivity and seismic velocity models, which will be obtained by the inversion of the EM and seismic data respectively. Both types of models can be linked by considering common geological boundaries (Gabàs et al., 2016), or by means of cluster analysis using fuzzy logic (Garcia-Yeguas et al., 2017). In the framework of the GEO-URBAN project, the latter approach seems most promising. 3-D models for the Dublin basin will be available in Q1 2020, and will be used to inform the geological assessment, which will feed into the commercial feasibility study for geothermal DH for Dublin.

### 5 CONCLUSIONS

There are currently no deep geothermal projects in the Dublin basin, and this is mainly due to a lack of deep subsurface data in the area, which makes potential projects risky and therefore unattractive for developers. Other barriers to the utilisation of this natural resource in Dublin city include the lack of a regulatory or legal framework for the use of geothermal energy, and a fractured bedrock aquifer situated beneath a bustling urban environment. Previous

geothermal exploratory boreholes on the southern margins of the Dublin basin indicate that geothermal energy has real potential to decarbonise Dublin's heat energy sector. Geothermal energy should be included as part of a mix of renewable energy sources for the planned citywide DH network.

The GEO-URBAN project aims to fully assess the commercial feasibility of geothermal DH in Dublin city. The project will overcome geological data gaps by conducting a citywide geophysical survey, and will overcome the challenges of exploring in an urban environment by combining passive seismic with active and passive electromagnetic geophysics in a novel joint interpretation. 3-D models from the geophysical campaign will be available in early 2020.

### 6 ACKNOWLEDGEMENTS

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