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The potential use of shallow geothermal systems to urban acclimatization – how to evaluate and how to implement?

L'utilisation potentielle des systèmes géothermiques peu profonds pour l'acclimatation urbaine - Comment évaluer et comment mettre en œuvre?

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ABSTRACT: The research project GeoSustained, funded by the Portuguese Foundation for Science and Technology (PTDC/ECI-CON/1866/2021), aims to study sustainable solutions for using shallow geothermal systems for buildings and infrastructure acclimatization. Lisbon Municipality is a partner in the consortium, playing a particularly important role in the implementation and regulation of the mandatory elements for installing the system. For this purpose, a working group was created to collaborate with the responsible entities, namely Direção-Geral de Energia e Geologia (DGEG, a public energy and geology institution). Two priorities were established: (1) definition of the best practices for the implementation of shallow geothermal solutions; (2) development of a guide with the flow to implement the systems licensing procedure. This information will be integrated into the Municipal Regulation for Urbanization and Construction in Lisbon (Regulamento Municipal para a Urbanização e Edificação de Lisboa). It is also expected that the collaboration with DGEG will contribute to improve the implementation of this type of solution at a national level, being a critical approach to more sustainable and resilient cities to climate change.

RÉSUMÉ: Le projet de recherche GeoSustained, financé par la Fondation Portugaise pour la Science et la Technologie (PTDC/ECI-CON/1866/2021), vise à étudier des solutions durables pour l'utilisation de systèmes géothermiques peu profonds pour l'acclimatation des bâtiments et des infrastructures. La municipalité de Lisbonne est un partenaire du consortium, jouant un rôle particulièrement pertinent dans la mise en œuvre et la régulation de ce type de système à l'échelle locale. À cette fin, un groupe de travail a été créé pour collaborer avec les entités compétentes, à savoir la Direção-Geral de Energia e Geologia (DGEG, une institution publique d'énergie et de géologie). Trois priorités ont été établies: (1) définition des meilleures pratiques pour la mise en œuvre de solutions géothermiques peu profondes; (2) élaboration d'un guide avec le flux à adopter pour permettre la licence de ces systèmes. Ces informations seront intégrées dans le Règlement Municipal pour l'Urbanisation et la Construction de Lisbonne (Regulamento Municipal para a Urbanização e Edificação de Lisboa). Il est également prévu que la collaboration avec la DGEG contribuera à améliorer la mise en œuvre de ce type de solution au niveau national, étant une approche critique pour des villes plus durables et résilientes face au changement climatique.

Keywords: GeoSustained project; sustainable urban acclimatization; climate resilient cities; geothermal potential map.

1 INTRODUCTION

The GeoSustained project (CML, 2023), "Sustainability assessment of shallow geothermal systems for Lisbon. Characterization studies of the city soils thermal and thermomechanical behavior" is funded by the Portuguese Foundation for Science and Technology (FCT). Laboratório Nacional de Engenharia Civil (LNEC) leds the Consortium and Lisbon Municipality (CML), Universidade de Aveiro (UA), and Agência de Energia e Ambiente de Lisboa, Lisboa E-NOVA are partners. The GeoSustained project has two general objectives:

- To understand the thermal and thermomechanical behavior of geological formations in Lisbon through in situ and laboratory tests and mathematical modeling.
- To evaluate and contribute to the sustainability of shallow geothermal systems, considering Lisbon's geological and climatic characteristics.

This project is aligned with three Sustainable Development Goals (United Nations, 2015):

Goal 7: Affordable and Clean Energy – Ensure access to affordable, reliable, sustainable, and modern energy for all. Characterizing the thermal conductivity of Lisbon's geological formations will contribute for using shallow geothermal resources in the city, or others with similar soils and weather conditions, making it easier and more accessible for project developers to carry out feasibility studies.

Goal 9: Industry, Innovation, and Infrastructure – build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation. Thermomechanical characterization of Lisbon's soils will increase the knowledge about their behavior and how temperature affects it, particularly their strength and deformability. In addition, buildings that use shallow geothermal systems are less energy dependent infrastructures and, therefore, more resilient.

Goal 13: Climate Action – take urgent actions to combat climate change and its impacts. Shallow geothermal is a clean energy source of great importance in reducing greenhouse gas emissions and, consequently, in combating climate change.

2 APPROACH

Lisbon Municipality, as the organization in charge of managing the city of Lisbon and a partner of the GeoSustained Project, has a fundamental role in encouraging and regulating the implementation of geothermal systems. To achieve that, three significant outputs must be considered:

1. Standards for the use of shallow geothermal resources in an urban context: a guide is being developed with relevant information to encourage and simplify the evaluation of the feasibility to use geothermal resources, namely a regulatory document, references for real estate developers interested in using these systems, and information on the prospecting work to be carried out, including relevant tests.

2. Procedural workflow and licensing documents: a working group has been set up, which includes technicians of the GeoSustained project and technicians from Direção-Geral de Energia e Geologia (Directorate-General for Energy and Geology). This group's mission is to develop a guide with the procedural workflow to be adopted to simplify the licensing of these operations and a list of instructional elements to be presented by those that need to develop an urban licensing procedure. This information will soon be included in Regulamento Municipal para a Urbanização e Edificação de Lisboa (Lisbon Municipal Regulations for Urbanization and Building).

3. Geothermal Potential Map: this dynamic map will be a decision-support tool integrated into the Lisbon Geotechnical Map, making it possible to identify the shallow geothermal systems potential. The geothermal potential map is a critical output for increasing the implementation of shallow geothermal systems in Lisbon, and it is the main topic covered in this paper.

3 GEOTHERMAL POTENTIAL MAP

The Geothermal Potential Map will indicate, for each area in the city, the differences in the potential for exploiting the geothermal resource in depth, considering factors such as geology, thermal conductivity, the existence of water in-depth, and also subsoil occupation, a fundamental aspect in a densely urbanized area such as Lisbon (Figure 1). The purpose of this map is to support the preliminary assessment of the viability of shallow geothermal systems for new buildings and urban rehabilitation in Lisbon. The possibility for project developers and planners to conduct this quick assessment by consulting the geothermal potential map will incentivize them to consider using this clean energy resource in their projects.

Figure 1. Considered components of the Lisbon Geothermal Potential Map.

The Geothermal Potential Map is made up of different components that complement each other:

Three-dimensional modeling of geological formations of Lisbon: this task is being carried out using RockWorks software. It is based on the information available on the 1:10,000 scale geological

map and Lisbon Municipality's GeoSIG platform. This platform gathers geotechnical data obtained from boreholes in Lisbon and currently includes more than 13,000 entries. This information will allow the geometry of Lisbon's geological formations to be modeled at depth.

Determination of the thermal conductivity of the modeled geological formations: this task is underway and is based on a three-scale approach (Figure 2): macroscale, in which thermal conductivity values are obtained from the literature; mesoscale, in which conductivity values measured in local geological formations are used and whose values are extrapolated to other points where the geothermal potential is to be assessed; microscale, with conductivity values measured directly on representative samples of the site to be evaluated.

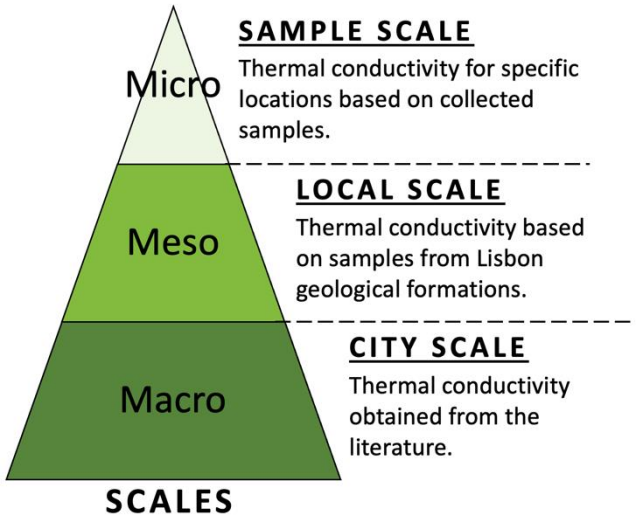

Figure 2. Three-scale approach to obtain thermal conductivity values for the Lisbon Geothermal Potential Map.

In the macroscale approach, Vieira *et al.* (2023) compiled thermal conductivity values for soils and rocks like the ones in Lisbon, allowing cartography to be drawn up on the scale of the municipality. This work assigned minimum and maximum thermal conductivity values and recommended estimates to the formations, which were grouped into ten systems based on their lithostratigraphy and mineralogy. The result was represented in a distribution of surface values (Inácio *et al.*, 2023). At this stage, parameters as compaction and water saturation were not considered.

At the microscale, where the information is being refined, the actual thermal and thermomechanical characteristics of samples collected in the project's scope are considered. Three boreholes were made in three different locations within the municipality to reach the microscale, aiming to intercept most of the Lisbon's geological formations (Figure 3).

A 65 m deep borehole was drilled in Parque da Quinta das Conchas e dos Lilases, in which 8 m of alluvium and 57 m of Lower Miocene formations were intersected. The second borehole was drilled at the Lisbon Municipality's Sewage Brigades, where is intended to install a shallow geothermal system for climatization and water heating in the framework of a rehabilitation process. An 80 m borehole was drilled at this site, in which 15 m of alluvium and 60 m of Middle Miocene formations were intersected. Finally, the third borehole was drilled at Doca de Pedrouços, next to the future "Hub do Mar" complex, where the feasibility of using shallow geothermal systems is also being studied. A 50 m borehole was drilled at this site, in which 38 m of alluvium and 12 m of the Complexo Vulcânico de Lisboa (Lisbon Volcanic Complex) were intersected. Undeformed samples were also collected at these sites and are being analyzed in laboratory to determine the thermal and thermomechanical characteristics of these formations. In addition, temperature and thermal conductivity measuring sensors were installed along the drilled depths (every 5 m) to detect seasonal and in-depth temperature variations.

Finally, to gather more information on the characteristics of Lisbon geological formations, a sampling plan is also being carried out on construction sites that are underway in the municipality, whether carried out by private or public entities, namely in the context of Plano Geral de Drenagem de Lisboa (Lisbon Drainage Master Plan). The aim is to cover possible data gaps on geological formations that were not intercepted in the boreholes. The samples will be submitted to the same tests as the ones collected in the boreholes.

The mesoscale approach will be possible considering the modeled geology, as well as the tests, carried out on the samples collected as part of the project, consisting of extrapolating the conductivity values obtained for the locations of these same formations elsewhere in the city, considering the local conditions in which these formations are present, namely depth, compaction, and saturation. Regarding water levels, existing data on the GeoSIG platform will be considered, which will also be complemented with data from Lisbon Municipality on the existence of underground structures that could influence water circulation, which has been updated through ModSub 3D Project.

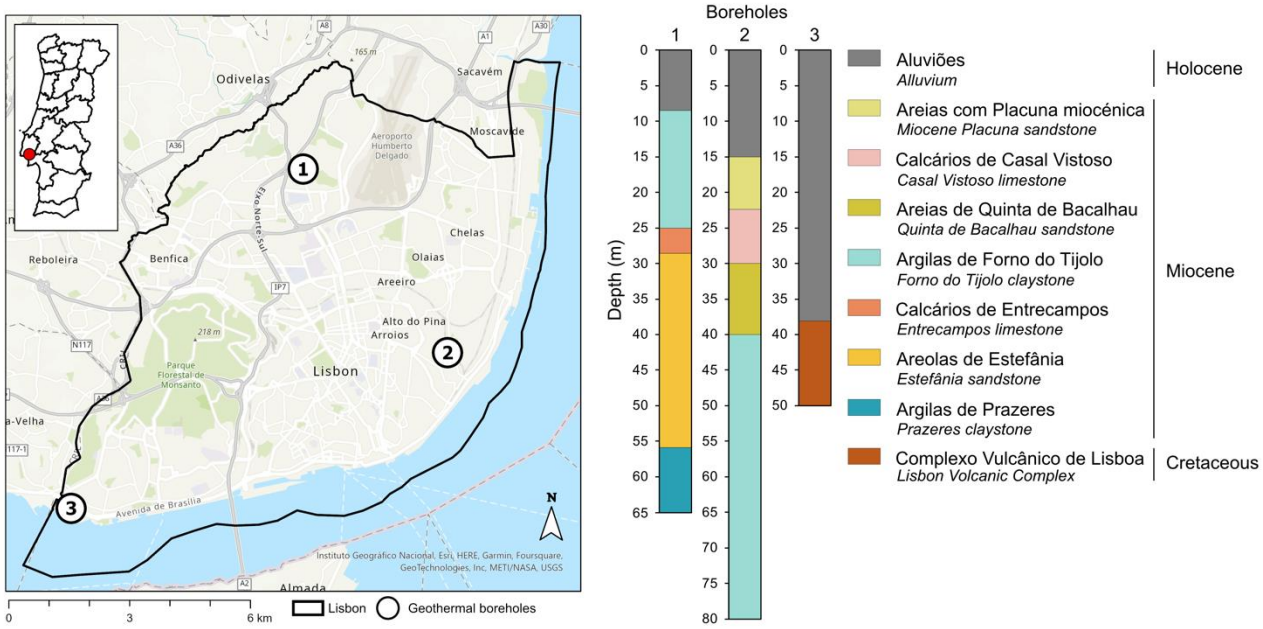

Figure 3. Location and geological logs of the boreholes performed in the scope of the GeoSustained Project.

4. CONCLUSION

The GeoSustained Project is actively contributing to increasing the use of shallow geothermal resources in Lisbon, namely through the Geothermal Potential Map. This map is currently being drawn up, and a preliminary version has already been presented on a macroscale approach with superficial information. Transposing this information in depth will be the next step, as well as assessing the potential of the Lisbon geological formations based on samples collected as part of this project. At the same time, the work being done on writing a guide to good practices and establishing regulations for projects using geothermal energy will, in the short term, make its application in a real context much simpler and faster.

Finally, the work carried out under this project can be extrapolated to other municipalities, being Lisbon a pilot city for defining the best approaches to increase the use of geothermal energy in Portugal. DGEG is also a strategic partner that will enable similar strategies to be implemented at a national level, and this approach is aligned with the best practices ongoing in other European countries.

ACKNOWLEDGMENTS

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