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Pre-study and Master Thesis  
Spring Semester 2026

## Development of a machine learning-based approach to support the design and performance analysis of borehole heat exchangers

**Supervisors:** Prof. Lyesse Laloui

**Assistant:** Dr. Elena Ravera

### Motivation of the project

The design of vertical borehole heat exchangers (BHEs) requires the use of appropriate numerical modelling procedures. Thermal interaction effects between BHEs critically affect the performance of such heat exchangers, with the potential to cause detrimental energy performance and efficiency drops during the lifetime of such energy systems. The use of numerical modelling software for multi-physics systems is therefore necessary to consider all the physical processes governing the operation of BHEs, to accurately reproduce the thermal interactions between such heat exchangers, and to analyse in detail their energy performance and efficiency with due consideration of the fluid dynamics taking place within the BHE tubes. The design and performance analysis of these systems is a complex and iterative process with simulations usually having to be done over periods of 50 years with long simulation times that in practice result in high costs. This project will investigate the use of machine learning techniques to optimize both the design and performance analysis during operation of these energy systems. The proposed approach would be used alongside numerical simulation to accelerate the optimisation process.

### Keywords

Geothermal energy, machine learning, borehole heat exchangers, Finite element analyses (COMSOL Multiphysics), Data-driven predictions.

### References

Bourhis, P., Cousin, B., Loria, A. F. R., & Laloui, L. (2021). Machine learning enhancement of thermal response tests for geothermal potential evaluations at site and regional scales. *Geothermics*, 95, 102132.

Makasis, N., Narsilio, G. A., & Bidarmaghaz, A. (2018). A machine learning approach to energy pile design. *Computers and Geotechnics*, 97, 189-203.

Zhuang, Z., Ben, X., Yan, R., Pang, J., & Li, Y. (2017). Accurately predicting heat transfer performance of ground heat exchanger for ground-coupled heat pump systems using data mining methods. *Neural Computing and Applications*, 28(12), 3993-4010.

Zhuang, Z., Zhai, X., Ben, X., Wang, B., & Yuan, D. (2021). Accurately predicting heat transfer performance of ground-coupled heat pump system using improved autoregressive model. PeerJ Computer Science, 7.

### **Goal of the project**

By the end of the project, the student is expected to be able to predict heat transfer performance of BHEs using machine learning techniques.

### **Tasks and work to carry out**

- Literature review
- Understanding of the current formulation of numerical models for BHEs
- Identification and development of machine learning technique for BHEs
- Representation of the results in a consistent and effective manner
- Compose a project report in written form
- Presenting a project orally

### **Deliverables**

- **Report**

The student will have to prepare a technical report. In the document, the student will have to clearly introduce the topic, to highlight the hypotheses made, to present the considered methodology, to discuss the obtained results and to draw the related conclusions. Particular attention will be given to the writing up of the report. The technical report will have to be prepared in an electronic format and sent to the supervisors and the responsible of the project by the end of the semester.

- **Final Presentation**

The student will have to present his work during a presentation at the end of the semester. The day and the place of the presentation will be communicated to the student.

### **Planning**

- **Meetings and presentations**

A weekly meeting (on Friday pm) with the assistant is suggested to discuss the progress of the project. One meeting per month will be organized with Prof. Laloui (dates will be communicated to the student). During the meetings with the assistant, the student will have to present (i) the progress of the work, (ii) possible questions and remarks and (iii) a summary of the next steps for the project. During these meetings, the supervisors may vary the foreseen goals of the project, if necessary. The student will have to prepare all the possible questions before the meeting in written form and a summary of each meeting for the next fixed meeting.

- **Electronic files**

At the end of the project, the student will have to send to the supervisors a folder containing a clear classification of all the electronic files developed during the project, including those related to the reports, obtained data, presentations, poster, and graphs.

- **Deadlines**

The tasks of the project should be accomplished from February 16th to June 5th, 2026. The report should be submitted to the supervisors by June 22th, 2026.

### **Grading**

The final grade will be assigned considering the following proportions of contribution:

- Technical report 70%
- Oral presentation 30%

The evaluation will also consider the work methodology, discipline, and resourcefulness of the student.

### **General rules of the project**

The schedule of the project is defined by the EPFL Academic Calendar:

<https://memento.epfl.ch/academic-calendar/?period=180>

The student signature on the submitted report certifies that the work is original and developed by him/herself. This work is property of the EPFL and cannot be disseminated without the approval of the considered Institution.

### **Contacts**

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