





# GHEtool: An open-source tool for borefield sizing in Python

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DOI: [10.21105/joss.04406](https://doi.org/10.21105/joss.04406)

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Submitted: 01 April 2022

Published: 17 August 2022

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## Summary

GHEtool is a Python package that contains all the functionalities needed to deal with borefield design. It is developed for both researchers and practitioners. The core of this package is the automated sizing of borefield under different conditions. The sizing of a borefield is typically slow due to the high complexity of the mathematical background. Because this tool has a lot of precalculated data, GHEtool can size a borefield in the order of tenths of milliseconds. This sizing typically takes the order of minutes. Therefore, this tool is suited for being implemented in typical workflows where iterations are required.

GHEtool also comes with a graphical user interface (GUI). This GUI is prebuilt as an exe-file because this provides access to all the functionalities without coding. A setup to install the GUI at the user-defined place is also implemented and available at: [https://www.mech.kuleuven.be/en/tme/research/thermal\\_systems/tools/ghetool](https://www.mech.kuleuven.be/en/tme/research/thermal_systems/tools/ghetool).

## Statement of need

The building sector uses 36 % of global energy and is responsible for 39 % of energy-related CO<sub>2</sub> emissions when upstream power generation is included, with more than half of this energy used by space heating, space cooling and water heating ([Abergel et al., 2018](#)). In order to reach the climate goals, as set by the European Green Deal, the building sector should strive towards decarbonisation in order to achieve a zero-emission building stock by 2050 ([The European Commission, n.d., 2021](#)). One of the promising ways to achieve this goal is by using shallow geothermal energy, thereby storing heat/cold in borefields, enabling seasonal thermal energy storage. Therefore, much interest exists from academia and practitioners in this field.

One of the main challenges in this domain is to size a borefield, which is critical since borefields have a very high investment cost, so we want them to be as small as possible to increase their (economic) feasibility ([Allaerts et al., 2015](#)). In all research related to optimising borefield loads ([Cupeiro Figueroa et al., 2020](#)), studying sensitivity on borefield configurations ([Fadejev et al., 2017](#)), and integrating seasonal thermal energy storage in (fifth-generation) district heating ([Hermans & Haesen, 2021](#)), etc., borefield sizing plays a central role.

GHEtool is a Python package with a graphical counterpart centred around borefield sizing and the evaluation of temperature evolution.

The main advantage of GHEtool is that the ground response functions (gfunctions ([Eskilson, 1987](#))), which are needed to size a borefield, are already precalculated for more than 140 000 borefield – ground combinations. Due to this precalculation, one can save from a couple of seconds to several minutes to calculate the gfunction for even one borefield. On the other

hand, the tool provides the option to provide your gfunction data for your own custom borefield configuration.

GHEtool aims to be used both by academic researchers in thermal systems integration and as a tool for educational purposes. It offers all the code and functions needed to size a borefield. Also, it evaluates the mean fluid and borehole wall temperature evolution. Therefore, GHEtool is beneficial for research activities relating to fifth-generation district heating, seasonal thermal energy storage and sensitivity analysis on borefield parameters.

The tool comes with a GUI. This interface is particularly beneficial for educational purposes, where students (and trained engineers) can play around to see how specific decisions influence the behaviour of the borefield. It is used at the University of Leuven (Belgium) for all master thesis students that work in the geothermal study domain and in the course B-KUL-H0H00A Thermal Systems.

Furthermore, practitioners in the heating, ventilation and air condition (HVAC) domain can use it to size their borefields correctly, so they become more economically feasible and ready to play an essential role in the energy transition of the built environment.

## Comparison with existing tools

Multiple tools are available for sizing borefields:

- EED and GLHEPRO are commercial, standalone tools for borefields. They allow the user, a.o., to plot the mean fluid and borehole wall temperature evolution ([Hellström & Sanner, 2000](#); [Spitler, 2000](#)). Furthermore, the user can size a borefield ([Hellström & Sanner, 2000](#); [Spitler, 2000](#)). The automated sizing in EED sometimes leads to an undersized borefield ([Peere et al., 2021](#)). GLHEPRO does not have this problem since it calculates the temperature in every month ([Spitler, 2000](#)).
- geoSIM is a free tool for simulating and sizing borefields but only with one particular type of tubing (geoKOAX). It is also standalone ([geoKOAX, n.d.](#)).
- Ground Loop Design software (GLDTM) “is the world’s leading commercial GHX software design tool” ([International Ground Source Heat Pump Association \(IGSHPA\), n.d.](#); [Thermal Dynamics Inc., n.d.](#)). It allows the user, a.o., to plot the mean fluid and borehole wall temperature evolution. Furthermore, the user can size the borefield.
- A commonly used package in the borefield domain is pygfunction. Pygfunction is an open-source Python package to calculate the thermal response factors of the ground. This function forms the basis of many borefield simulation and sizing programs ([Cimmino, 2018](#)). With this Python package, the data of GHEtool was precalculated.

From the mentioned tools, only EED, GLHEPRO, geoSIM and GLDTM can size borefields, but none of them is open source nor easy to be integrated into your workflow since they are standalone. From all the borefield sizing tools listed above, only geoSIM is free, but it only works with one specific type of borehole tubing ([geoKOAX, n.d.](#)). Ahmadfard & Bernier ([2019](#)) reviewed exhaustive literature of all existing borefield sizing methods and tools.

## Features

GHEtool offers functionalities of value to all different disciplines working with borefields. The features are available both in the code environment and in the GUI. These features are:

- Sizing the borefield (i.e., calculating the required depth) for a given injection and extraction load for the borefield (two sizing methods are available). The tool can work with monthly and hourly load profiles
- Finding the optimal rectangular borefield configuration for a given heating and cooling load

- Optimising the load profile for a given heating and cooling load
- Using dynamically calculated borehole thermal resistance (using directly the code from pygfunction (Cimmino, 2018))
- Calculating the temperature evolution of the ground for a given building load and borefield configuration
- Importing heating and cooling loads from \*.csv and \*.xlsx files
- Using your custom borefield configuration

## Acknowledgements

The first author would like to thank his supervisors Lieve Helsen and Wim Boydens and his coaches Damien Picard and Iago Cupeiro Figueroa for the guidance during his master thesis, which led to this package development.

The authors would like to thank Felix Arjuna and Iago Cupeiro Figueroa for the translation of the GUI.

## References

- Abergel, T., Dean, B., Dulac, J., Hamilton, I., & Wheeler, T. (2018). *2018 Global Status Report: Towards a zero-emission, efficient and resilient buildings and construction sector*. International Energy Agency; the United Nations Environment Programme. <https://www.worldgbc.org/sites/default/files/2018%20GlobalABC%20Global%20Status%20Report.pdf>
- Ahmadfard, M., & Bernier, M. (2019). A review of vertical ground heat exchanger sizing tools including an inter-model comparison. *Renewable and Sustainable Energy Reviews*, *110*, 247–265. <https://doi.org/10.1016/j.rser.2019.04.045>
- Allaerts, K., Coomans, M., & Salenbien, R. (2015). Hybrid ground-source heat pump system with active air source regeneration. *Energy Conversion and Management*, *90*, 230–237. <https://doi.org/10.1016/j.enconman.2014.11.009>
- Cimmino, M. (2018, May). pygfunction: an open-source toolbox for the evaluation of thermal response factors for geothermal borehole fields. *Proceedings of eSim 2018, the 10th Conference of IBPSA-Canada*. <http://www.ibpsa.org/proceedings/eSimPapers/2018/2-3-A-4.pdf>
- Cupeiro Figueroa, I., Cimmino, M., & Helsen, L. (2020). A methodology for long-term model predictive control of hybrid geothermal systems: The shadow-cost formulation. *Energies*, *13*(23). <https://doi.org/10.3390/en13236203>
- Eskilson, P. (1987). *Thermal Analysis of Heat Extraction Boreholes* [PhD Thesis, Dep. of Mathematical Physics, University of Lund]. <https://www.buildingphysics.com/download/Eskilson1987.pdf>
- Fadejev, J., Simson, R., Kurnitski, J., & Haghghat, F. (2017). A review on energy piles design, sizing and modelling. *Energy*, *122*, 390–407. <https://doi.org/10.1016/j.energy.2017.01.097>
- geoKOAX. (n.d.). *geoSIM - your freeware tool for simulating and sizing of borefields with geoKOAX*. Retrieved June 30, 2022, from <https://geokoax.com/en/our-products/simulation/>
- Hellström, G., & Sanner, B. (2000). *EED - Earth Energy Designer* (Version 2.0) [User Manual]. <https://buildingphysics.com/manuals/eed.pdf>
- Hermans, L., & Haesen, R. (2021). *Design and assessment of low-carbon residential district concepts with (collective) seasonal thermal energy storage* [Master Thesis, Dep. of

- Mechanical Engineering, KU Leuven (university of Leuven)]. [https://www.scriptiebank.be/sites/default/files/thesis/2021-10/Masters\\_thesis\\_RobinHaesen\\_LouisHermans.pdf](https://www.scriptiebank.be/sites/default/files/thesis/2021-10/Masters_thesis_RobinHaesen_LouisHermans.pdf)
- International Ground Source Heat Pump Association (IGSHPA). (n.d.). *Software - Tools to design and support your Ground Source Heat Pump Installation*. Retrieved June 30, 2022, from <https://igshpa.org/software/>
- Peere, W., Picard, D., Cupeiro Figueroa, I., Boydens, W., & Helsen, L. (2021, September). Validated combined first and last year borefield sizing methodology. *International Building Simulation Conference 2021*. <https://doi.org/10.26868/25222708.2021.30180>
- Spitler, J. D. (2000, August). GLHEPRO – A Design Tool For Commercial Building Ground Loop Heat Exchangers. *Proceedings of the Fourth International Heat Pumps in Cold Climates Conference*. [https://hvac.okstate.edu/sites/default/files/pubs/papers/2000/08-HPCC\\_GLHEPRO.pdf](https://hvac.okstate.edu/sites/default/files/pubs/papers/2000/08-HPCC_GLHEPRO.pdf)
- The European Commission. (n.d.). *A European Green Deal: Striving to be the first climate-neutral continent*. [https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal\\_en](https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en)
- The European Commission. (2021). *European Green Deal: Commission proposes to boost renovation and decarbonisation of buildings*. [https://ec.europa.eu/commission/presscorner/detail/en/IP\\_21\\_6683](https://ec.europa.eu/commission/presscorner/detail/en/IP_21_6683)
- Thermal Dynamics Inc. (n.d.). *GLD SOFTWARE*. Retrieved July 22, 2022, from <https://groundloopdesign.com/>