



Cyprus
University of
Technology

Faculty [Engineering
and Technology]

Doctoral Dissertation

**Experimental and Numerical Study of Ground-Source Heat
Pumps**

Christakis Christou

Limassol, May 2026

CYPRUS UNIVERSITY OF TECHNOLOGY
FACULTY OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF ELECTRICAL ENGINEERING,
COMPUTER SCIENCE AND ENGINEERING

Doctoral Dissertation

Experimental and Numerical Study of Ground-Source Heat
Pumps

Christakis Christou

Supervisor: Paul Christodoulides, Assistant Professor

Co-Supervisor: Georgios Florides, Adjunct Professor

Faculty of Engineering and Technology

Limassol, May 2026

Approval Form

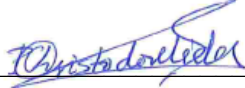
Doctoral Dissertation

Experimental and Numerical Study of Ground-Source Heat Pumps

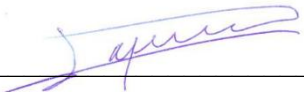
Presented by

Christakis Christou

Supervisor: Paul Christodoulides, Assistant Professor, Faculty of Engineering and Technology

Signature  _____

Member of the committee: Christakis Damianou, Professor, Faculty of Engineering and Technology

Signature  _____

Member of the committee: Rokas Valančius, Associate Professor, Kaunas University of Technology

Signature  _____

Cyprus University of Technology

Limassol, May 2026

Copyrights

Copyright© 2026 Christakis Christou

All rights reserved.

The approval of the dissertation by the Department of Electrical Engineering, Computer Science and Engineering does not necessarily imply the approval by the Department of the writer.

Publications

Journal Articles

- 2024 Christodoulides P, Christou C, Florides GA. Ground Source Heat Pumps in Buildings Revisited and Prospects. *Energies* 2024; 17(13), 3329.
- 2024 Christou C, Stylianou II, Aresti L, Florides GA, Christodoulides P. Comparison of the Energy Contributions of Different Types of Ground Heat Exchangers Related to Cost in a Working Ground Source Heat Pump System. *Energies* 2024;17(18), 4621.
- 2025 Christodoulides P, Christou C, Aresti L, Stylianou II, Florides GA. Operation performance of a ground source heat pump system in the mediterranean climate zone. First results. *Energy Efficiency* 2025; 18(3), 1-17.

Conference Publications

- 2023 Christodoulides P, Christou C, Aresti L, Stylianou II, Florides GA. Monitoring the performance of a GSHP system in the Mediterranean climate of Cyprus, 7th International Conference on Renewable Energy Sources & Energy Efficiency, Nicosia, Cyprus 2023:80–4.
- 2024 Christodoulides P, Christou C, Aresti L, Stylianou II, Florides GA. Heat Pump System in the Mediterranean Climate of Cyprus, SIAM Conference on Mathematics of Planet Earth (MPE24), Portland OR, USA 2024
- 2024 Christodoulides P, Aresti L, Christou C, Stylianou II, Florides GA. Studying a Ground Source Heat Pump System in the Mediterranean climate of Cyprus, 11th International Conference on Energy, Sustainability and Climate Change (ESCC 2024), Corfu, Greece
- 2026 Christou C, Pasias P, Aresti L, Graikos D, Filippou C, Florides GA, Christodoulides P, Performance Analysis and Dynamic Modeling of a Ground Source Heat Pump System in a Historic Mediterranean Building, 13th International Conference on Energy, Sustainability and Climate Change (ESCC 2026), Crete, Greece

Acknowledgements

I want to sincerely thank my supervisors, Professors Paul Christodoulides and Georgios Florides, for their unwavering support and encouragement, as well as for believing in me from the beginning. Their counsel and support have greatly motivated me to successfully finish this study. Lastly my family has my sincere gratitude. Thank you to my wife and life partner, Melina Neophytou, for your understanding, patience, and support during this demanding period. In addition, both of my kids, Andreas and Alexandra, for their encouragement and support through this journey.

ABSTRACT

Ground Source Heat Pump (GSHP) systems have emerged as a highly efficient and environmentally sustainable technology for heating and cooling applications in residential, commercial, and public buildings. Their growing adoption is driven by their capacity to significantly reduce energy consumption and greenhouse gas emissions while utilizing shallow geothermal energy as a renewable resource. Nevertheless, challenges associated with high initial investment costs, system optimization, and climatic adaptation continue to limit their wider implementation, particularly in Mediterranean regions. This thesis investigates the performance, design, cost-effectiveness, and dynamic behavior of GSHP systems operating under Mediterranean climatic conditions, with a particular focus on Cyprus. The research combines an extensive literature review with experimental investigation, economic evaluation, and advanced dynamic simulation of a large-scale geothermal installation located in the historic Municipal Library of Limassol, Cyprus. The study examines multiple ground heat exchanger (GHE) configurations integrated into a single GSHP system, including vertical borehole heat exchangers, double helicoidal coils installed in wells, and open-loop groundwater systems. Continuous operational monitoring through a Building Management System (BMS) enabled the collection of high-resolution data related to thermal loads, flow rates, inlet and outlet temperatures, energy transfer, and heat pump performance in both heating and cooling modes. The experimental analysis demonstrates that GSHP systems operating in Mediterranean climates can achieve high seasonal efficiencies, with seasonal coefficients of performance (SCOP) ranging between 4.5 and 5.0. Results further indicate that open-loop groundwater heat exchangers provide the highest thermal exchange rates and the lowest installation cost per unit of delivered energy when groundwater availability permits. Comparative economic analysis revealed significant differences in cost-effectiveness among the investigated GHE configurations, highlighting the importance of site-specific geological and hydrogeological conditions in system selection and design. To further investigate system behavior, a physics-based dynamic simulation model was developed in the Modelica environment using the Buildings library and validated against measured operational data. The model successfully reproduced both transient and steady-state thermal responses of the GSHP system, including borehole heat exchange processes, heat pump operation, and building thermal interactions. Good agreement between measured

and simulated results confirmed the reliability of Modelica-based approaches for predicting GSHP performance under real operating conditions. Overall, this thesis contributes to the understanding of geothermal heat pump technologies in Mediterranean environments by integrating technical, economic, and simulation-based analyses into a unified framework. The findings demonstrate that properly designed and optimized GSHP systems can provide substantial energy savings, reduced environmental impact, and long-term economic benefits. Furthermore, the work offers practical guidance for the design, operation, and optimization of geothermal systems in historic and modern buildings, supporting the broader deployment of renewable energy technologies in the built environment.