Economic Evaluation of New-type Energy Geo-structures in Residential Buildings. A Case Study in Moderate Mediterranean Climate

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Shallow Geothermal Energy Systems (SGESs) are Renewable Energy Systems (RES), which are applied in the residential sector through the use of Ground Source Heat Pumps (GSHPs). GSHPs are coupled with Ground Heat Exchangers (GHEs), where heat is absorbed or rejected through a network of pipes in the ground. GSHPs have not yet thrived in the RES market because of their high initial costs and long payback periods.

Two Energy Geo-Structure (EGS) systems, in specific the foundation (or energy) piles and the foundation bed of a residential building in moderate climate Mediterranean conditions in the island of Cyprus, were computationally modeled by Aresti et al. [1]. A theoretically typical house with nearly Zero Energy Building (nZEB) characteristics was examined, with estimated heating and cooling loads used as inputs to investigate the performance of the EGS-GSHP systems. Both systems were shown to exhibit steady performance and high Coefficient of Performance (COP) values, making them an alternative RES solution for integration in residential building.

In this study the above-mentioned systems were evaluated economically by comparison with a conventional high- and low-performance Air Source Heat Pump (ASHP) systems. Although various methods could be used to evaluate the economic benefits of the systems, to simplify the study, only the difference in the cost of the two systems is used here through the Simple Payback Period (SPP) and the Discounted Payback Period (DPP) methods. The monthly loads and average monthly COP values of each system, as well as the lifespan and the cost of the HP replacement were considered. It is noted that the costs related to grout filling and the borehole extraction are not included, as in any case the buildings foundations would be constructed, therefore no cost is added. The cost of the HPs was based on the local market (as of year 2020) at EUR8500 for a high-efficiency ASHP, EUR4500 for a low-efficiency ASHP, and at EUR6500 for a GSHP. The results of the economic comparison of the two GSHP systems against ASHP with regard to SPP and DPP are shown in Table 1.

Table 1. SPP-DPP estimates for the two GSHP systems versus high and low-performance ASHP system

Type	Cost to cover (€)	Total Savings per year (€)	SPP (years)	SPP with 2% EP inflation (years)	DPP 2% (years)	DPP 2%, with 2% EP inflation (years)	DPP 2%, with 5% EP inflation (years)	**Cash flow Return Rate per year (%)**
Energy Piles GSHP system compared to ASHP with	1065	517	2.06	2.04	2.12	2.10	2.06	48.11

high COP (3852kWh)								
Foundation Bed GSHP system compared to ASHP with high COP (3852kWh)	1020	524	1.95	1.93	2.01	1.99	1.95	51.01
Energy Piles GSHP system compared to ASHP with low COP (4727kWh)	5065	683	7.41	6.97	8.10	7.56	6.89	8.31
Foundation Bed GSHP system compared to ASHP with low COP (4727kWh)	5020	690	7.27	6.85	7.94	7.42	6.77	8.69

Both systems have proven to be attractive investments as they have yielded short payback periods. Specifically, the best-case scenario for the energy pile systems is estimated to be 2.04 years and 1.93 years for the foundation bed system, whereas the “worst” cases are 6.97 years and 6.85, respectively. In terms of cash flow return, the worst-case scenario for all systems, results in a very satisfactory rate of over 8%. Therefore, the above-mentioned “hybrid” elements (EGS) can offer a solution to overcome the barriers of high initial investments and long payback periods that have kept GSHP systems unpopular.

Key words: ground heat exchanger; energy geo structures; energy piles; foundation bed GHE

References

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