A cost and environmental impact analysis of Ground Source Heat Pumps in European climates

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Abstract:

Ground Source Heat Pumps (GSHPs) are used for space heating and cooling. They form a Renewable Energy System (RES), combined with Ground Heat Exchangers (GHEs) to extract or reject heat from/to the ground. GHEs come in various types such as vertical or horizontal. Compared to conventional Air Source Heat Pumps (ASHPs), GSHPs, although having a higher installation cost, exhibit a higher coefficient of performance (COP). The aim of this paper is to address whether it is economically feasible to install a GSHP as an alternative to an ASHP. In addition, as the environmental impact of a system does not lie in a single aspect, e.g., the cost or COP, it is also useful to identify whether a GSHP system is indeed a sufficiently overall greener solution than an ASHP system. To this end, a case study of a residential building with nearly Zero Energy Building (nZEB) characteristics, for certain heating and cooling loads is considered in Mediterranean, Central and Northern Europe climate conditions. Using GLD software, a GSHP system is studied for a typical vertical U-tube GHE configuration to estimate the length of the boreholes and the COP of the systems. Then, an environmental impact analysis is presented for different GSHP systems in comparison to ASHP systems. The systems undergo a Life Cycle Analysis (LCA), with the annual heating and cooling load as functional unit. The openLCA software is used with the ReCiPe method with a mid-point perspective. The Global Warming Potential impact category is studied. Finally, a cost analysis is presented for the GSHP systems in comparison to ASHP systems and the total energy savings is obtained per case. Hence, the cost breakeven point is estimated per case and is used to assess the viability of each system. It turns out that ASHP systems of specifically designed inverter technology ducted series HP can be highly competitive with GSHP systems.

Keywords:

Ground Source Heat Pump Systems; GSHP cost analysis; GSHP Environmental impact; Life cycle analysis

1. Introduction

The 2020-2030 projections, consistent with scenario ranges in the staff working document accompanying the ‘Fit for 55’ policy package, represent indicative intensity levels that would allow the European Union (EU) to achieve a net 55% reduction in greenhouse gases by 2030, compared with 1990 [1]. Geothermal energy is a form of renewable energy that exists for many years, but has only recently gained more attention in the fight against the greenhouse gas emissions.

Shallow Geothermal Energy (SGE) systems can be categorized as Renewable Energy Systems (RES) and find application through the use of Ground Source Heat Pumps (GSHPs) for space heating and cooling. GSHPs comprise a Ground Heat Exchanger (GHE), which is a network of tubes positioned in the ground, coupled with a heat pump. GHEs are essentially the structure where heat is rejected/extracted to/from the ground, and come in vertical or horizontal types, and several configurations. The GSHP systems outperform the conventical air-to-air heat pumps or Air Source Heat Pumps (ASHP), in terms of the efficiency [2]. However, there are several factors that affect the performance of GSHP systems, depending on the location, geothermal properties and the available land [3–6]. Residential GSHP systems conventionally use the vertical type GHEs, which are easy to install when the available land is not ample.

Recent research has focused on the optimization of GSHP systems in terms of reducing the length of the GHEs (i.e., the tubes), which constitutes the highest capital investment on a GSHP system. GSHP installations were reported to have increased with an average rate of about 20% annually since the year 2010 [7]. Based on the literature, it seems that GSHP may or may not be a cost-effective solution for heating and cooling a home, depending on many factors. One such important factor is the performance of ASHPs, which has increased significantly through technology in recent years. Other factors may be the specific area of the house, the location and the climatic conditions, the orientation, the building materials, the insulation, the behaviour of the inhabitants, the country's legislation [8]. Recently, Christodoulides et al. [9] addressed the debate on whether it is economically feasible to replace or install a GHSP as an alternative to an ASHP. The study examined two important factors, namely the efficiency of modern ASHPs, which play a crucial global role, and the heating and cooling load of a typical house in moderate climate Mediterranean conditions. More studies on whether using a GSHP is an economically favorable solution can be found in [9].

Until recently, residential heating and cooling systems used to be selected by the building's owners, based on the capital and the energy costs [10]. Nowadays such decisions are more and more frequently based upon the life cycle costs, with the environmental issue also becoming an important concern. Multi-criteria decision analysis tools have been used in the literature for the selection of either the best available RES alternatives [11] or the most appropriate technologies in residential buildings [12], considering environmental and economic criteria. A sustainable selection of a hybrid RES has become a possibility even for low income households [13]. The environmental impact of heating and cooling systems could play a key role in choosing the right energy system. Environmental impact evaluation is usually performed though the methods and tools of Life Cycle Analysis or Assessment (LCA). LCA can be divided into four steps: (i) system boundaries, (ii) life cycle inventory, (iii) Life Cycle Impact Assessment (LCIA), and (iv) analysis of the results.

A notable example of LCA comparison between ASHPs, GSHPs, Water Source Heat Pumps (WSHPs) and gas boilers was conducted by Greening and Azapagic [14]. ASHP and WSHP were the HPs with the highest and lowest environmental impact respectively. Individual environmental impacts examined included Abiotic Depletion Potential elements and fossil, Acidification Potential, Eutrophication Potential, Fresh Water Aquatic Eco-Toxic Potential, Global Warming Potential, Human Toxicity Potential, Marine Water Aquatic Eco-Toxicity Potential, Ozone Layer Depletion Potential, Photochemical Oxidant Creation Potential, and Terrestrial Eco-Toxicity Potential. The authors concluded that the gas boiler exhibited a generally better impact compared to the ASHP. Among HPs, GSHPs and WSHPs performed better than ASHPs. Operation had the main contribution on the impact, with 84%.

Another study related to the environmental impact of GSHPs was presented by Blum et al. [15] who investigated the CO2 savings of GSHPs during operation. The authors demonstrated that the use of a GSHP system, within the German electricity mix, had a CO2 saving ranging from 1800 to 4000 kg per year and 65 gCO2/kWh.

Note that, as stated by Rawlings and Sykulski [16], a "globally" accepted cost and environmental impact analysis of GSHPs is not feasible as direct comparison between different countries or regions cannot be established due to the economies of scale. Other important issues affecting the economic analysis comparison of technologies among different countries, may include macroeconomic indicators, technology maturity, energy prices, and government incentives [8,17].

The current study aims to address whether it is environmentally and economically reasonable to install a GSHP as an alternative to an ASHP. This novelty is expressed as a comparison among different case studies in Europe and whether some countries have an advantage of using the geothermal energy to address their goals for CO2 reduction. To this end, a case study of a residential building with either nearly Zero Energy Building (nZEB) characteristics, for certain heating and cooling loads is considered in both Mediterranean and Central Europe climate conditions. The methodology for the system characteristics, the environmental impact parameters and hew economic considerations are described in the next section 2, where the results are discussed in Section 3.

2. Materials and Methods

GSHPs' higher initial costs compared to ASHPs is directly related to the length of the GHEs and the proper designing of the system. In order to achieve correct estimation of the GHEs, quality data are required, such as the heating and cooling loads of the building and the ground thermal characteristics. Detailed features regarding the modeling aspects of SGE systems can be found in [3]. The buildings' heating and cooling loads vary for each case as these depend on the location of the building, the masonry characteristics, the usage of the building, and the locations' weather conditions. The Climate zones in Europe in conjunction with the energy performance of buildings were presented by Tsikaloudaki et al. [18]. The authors presented five European zones based on the Cooling and Heating Degree days. These zones were later used as a base by Rivoire et al. [19] to estimate heating and cooling loads of the same case study in six European countries, through the use of TRNSYS software.

Regarding the present study, the buildings' thermal characteristics under investigation are presented in Table 1. Note that, such highly insulated cases fall under the characteristics of the nearly Zero Energy Buildings (nZEB), which are currently (after the year 2020) mandatory in most EU countries.

Table 1. Buildings' Thermal Characteristics, modified from [19].

	U-Value [W m^{-2} K^{-1}]
External wall	0.28
Under-roof slab	0.51
Roof	0.24
Floor	0.15
Windows	1.43

The same data were incorporated by Bartolini et al. [20] into the EED (Earth Energy Designer) software for the estimation of the GHEs' length based on different refrigerants (antifreeze solutions). The authors demonstrated that using 20% calcium chloride as an antifreeze solution in the circulating fluid, leads to reduced greenhouse gas emissions compared to using 25% propylene glycol. The former is the least carbon-intensive choice for refrigerant in the northern areas (heating-dominated cases). Pure water, as a GHE circulating fluid on the other hand, is the ideal solution for the reduction of the greenhouse gas emissions, but it must be noted that it can only be used with cases that are not with high heating demand (such cases could be in southern Europe).

For the estimation of the GHEs' total length and the Coefficients of Performance (COPs) of the systems for five selected cases in Europe, the GLD (Ground Loop Design) software was employed. GLD (Thermal Dynamics Inc., MN, USA) is a commercially available package for professionals in the industry of designing GSHP systems. The heating and cooling loads incorporated were based on the data by Rivoire et al. [19]. For simplifying the study, only the vertical type GHEs are considered; specifically, the basic single U-tube GHE configuration is used for all cases/ countries. Vertical type single U-tube GHEs are widely used as conventional type GHEs in residential areas [2]. All cases were considered to have the same GHE materials and design parameters, including Calcium chloride 15% solution as refrigerant (anti-freeze fluid) to cover the low temperatures of the Northern countries. The pipes examined are the 32mm outer diameter P100 SDR11-OD, in a 200mm diameter borehole and a mixture of bentonite grout. The HP selected for each case varies with country, as there are different loads in each case and the selected HP is based on the peak loads. The selected HPs' capacity for each case to satisfy the peak heating or cooling load are 10.5 kW, 7.8 kW, 9 kW, 12.4 kW, 14.7 kW for the cases of ES, PT, IT, DE, and SE respectively.

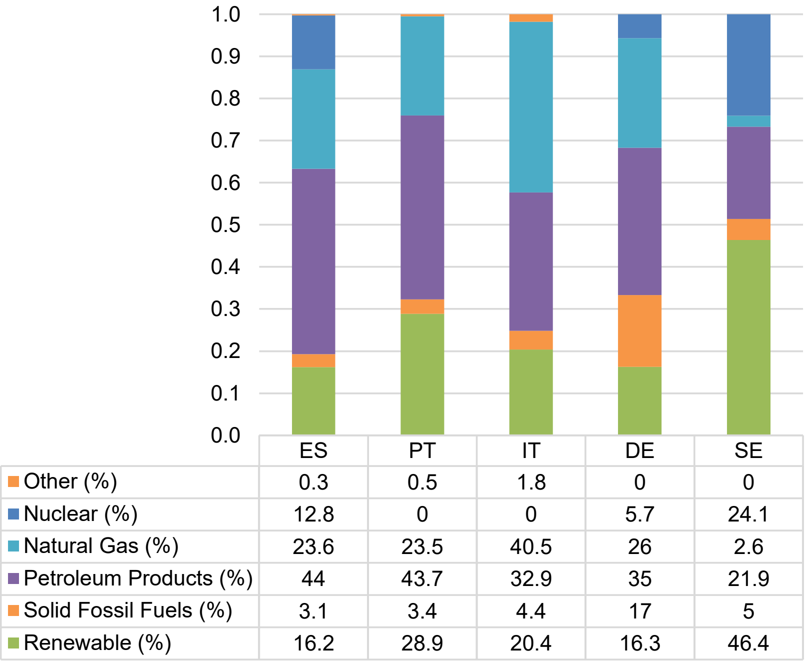
The next step is the evaluation of the environmental impact of the systems in each case. This is achieved with a Life Cycle Analysis (LCA) and a Life Cycle Impact Assessment (LCIA). The LCA method is used to determine the environmental impact of products and processes, through different inputs (flows) and outputs of each product/process. A general basic flow and the methodology followed for the LCA is similar to Aresti et al. [21], where details can be found. The LCA principles and framework are described by ISO 14040 [22] and ISO 14044 [23].

The environmental impact of the system was performed using the openLCA software with the Ecoinvent 3.6 database and the cut-off system model [24,25]. OpenLCA is a freeware platform where the user can either incorporate a commercial database, e.g., Ecoinvent 3.6, or can incorporate their own flows, processes and products. The steps to follow through the LCA method are: (i) determining the goal and scope of the system, (ii) defining the Life Cycle Inventory (LCI), and (iii) performing the LCIA; all the above are done before the analysis and interpretation of the results. During step (i) the overall scope is set along with the Functional Unit (FU) and the system boundaries, on which the following steps will rely on. The overall scope here is to compare the environmental impact difference between the GSHP systems and the ASHP system for residential use. The heating and cooling loads required to satisfy a residential 3- bedroom detached house of 220m^2 area, is set as the FU. Note that the heating and cooling loads for each country differ, but the FU does not refer to the actual values of heating and cooling loads but rather to the need to satisfy the loads required by the residential building owners. The choice of this FU is based on similar selections previously applied [21,26–28]. A cradle to the grave assessment is followed, with the processes including the manufacturing of materials and the installation of the GHEs, as well as the operation of the systems. The transportation and maintenance are not included in the boundary conditions, as they were found to be negligible in a previous study [21].

The LCI for the GSHP systems were set by selecting the required input and output flows through the Ecoinvent 3.6 database. Table 2 describes the selected inputs and processes. The processes and flows used account only the difference in materials, products or processes between the GSHP and the ASHP system. The material (products, processes and flows) are kept the same for all cases but with varying GHE length to satisfy the FU as estimated by the GLD software. Differences exist in the operation procedure as well. In order to accurately capture the difference of the renewable energy share in each case, the electricity mix of each case/country is considered by using data from Eurostat [29]. Naturally, the renewable energy share plays an important role in the reduction of kg CO2-eq. Fig. 1 demonstrates the energy mix share per country based on simplified energy balances. Note that Sweden (SE) demonstrates the highest percentage of renewable energy share, also the highest nuclear energy share, having also the highest heating demand in comparison to the other cases. It also should be noted that in practice, for cases of very low ambient temperatures (such as the SE case in this study), the ASHP system may require an additional preheating by a gas boiler, for example. Such cases are not examined in this study, and the ASHP system is assumed to cover the heating demand without any additional equipment.

Table 2. Life Cycle Inventory per FU.

Life cycle Stage / Process	Input	Amount per FU	Unit	Unit process
Materials production	HDPE pipes	Depending on the GHE type and city	[m]	polyethylene pipe production
	Tube Insulation	6	[kg]	tube insulation production, elastomer
	Refrigerant Calcium chloride	Depending on the pipe length	[kg]	Calcium chloride production
	Manifold	6.6	[kg]	brass production
	Grout	Depended on borehole length	[kg]	bentonite quarry operation
Installation	Excavation and drilling	7 hours/ 100m	[h]	machine operation, diesel ≥ 74.57kW, high load factor
Operation	Heating and Cooling	Depending on the case/ city	[kWh]	data from Eurostat [29]



	ES	PT	IT	DE	SE
🟧 Other (%)	0.3	0.5	1.8	0	0
🟦 Nuclear (%)	12.8	0	0	5.7	24.1
🟦 Natural Gas (%)	23.6	23.5	40.5	26	2.6
🟪 Petroleum Products (%)	44	43.7	32.9	35	21.9
🟧 Solid Fossil Fuels (%)	3.1	3.4	4.4	17	5
🟩 Renewable (%)	16.2	28.9	20.4	16.3	46.4

Fig. 1. Energy Mix per country/ Zone for the year 2020; data from Eurostat [29].

Moreover, the LCIA is responsible for evaluating the environmental impacts by converting the LCI data into potential impact categories. There are several methods available in the literature and in the Ecoinvent database to use for the LCIA, with each methodology based on different approaches. Two main approaches are the mid-point impact perspective and the end-point impact perspective [30–32]. ReCiPe is an available method, selected in this study, which provides a harmonized methodology for both perspectives [33]. Based on the goal and scope of the current study, the impact category of interest would be the Global Warming Potential (GWP) provided by the mid-point perspective, as GWP is possibly directly responsible for the climate change and, also, a factor related to EU's target of lowering the CO2 emissions. The indicator for GWP from a mid-point perspective is the kg CO2-eq.

Finally, in addition to the LCA for the environmental impact, in order to examine the viability of such an investment, the GSHP systems are compared against the ASHP systems. A different approach is followed here by, instead of using the initial capital cost and apply the Simple Payback Period (SPP) method, the capital cost is estimated as the value based on the cost viability of the system with 3, 4 and 5 years of steady payback periods. Details of the SPP methodology can be found, for example, in [9]. The electricity price inflation is not considered nor a bank loan interest is applied. The operating costs of the two systems under examination, namely the GSHP and ASHP systems, are calculated with the electricity prices obtained from Eurostat for the first season of year 2021 [34]; all taxes and levies are included in the available prices.

3. Results and Discussion

In order to procced with the estimation of the environmental impact of the systems and the cost analysis, firstly the sizing of the GHEs is estimated using the methodology described in the previous section with the GLD software for each case. The results are shown in Table 3, where ES and SE exhibit a higher total borehole length, due to the higher cooling and heating peak demand respectively.

Table 3. Length estimation for the GHEs for each case.

Case/ City, Country	Total Borehole length [m]
Seville, Spain (ES)	216
Lisbon, Portugal (PT)	153
Bologna, Italy (IT)	151
Berlin, Germany (DE)	161
Stockholm, Sweden (SE)	215

Additionally, based on the heating and cooling loads and the selected HPs in each case, the COPs per season per country/zone are therefore estimated and presented in Fig. 2. It should be noted that the COPs for the ASHP systems are assumed values, whereas the GSHP systems COPs are estimated by GLD. As for the most-northern case, SE, there is no demand for cooling, the cooling COP is not estimated. Very similar heating COPs are observed in all cases, in the range 3.7–4.7 for heating COPs, and 4.7–6.0 for cooling COPs.

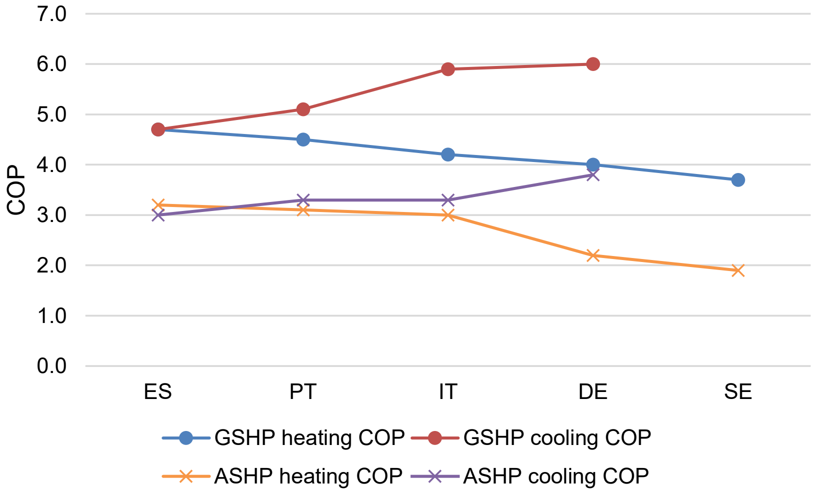


Fig. 2. Heating and cooling loads of the investigated case study in 5 different European zones.

The data estimated by GLD, namely the GHEs length and the COPs, were then used as inputs to the openLCA software to estimate the environmental impact for each system in comparison to the ASHP system. The impact category under examination is the GWP, which is directly connected with the climate change, having an impact on the air quality and the ecosystem. It can occur during all processes, but the most important one is the operation process as it is effective for the longest period of time, during the whole operating life of the system, assumed at 15 years.

The results for the mid-point perspective of the GWP for all cases/zones are presented in Fig. 3. The operation of the system, as expected, produces the highest impact among all processes, mainly due to having the longest time duration. This is in line with previous findings [14,27,28], where the operation process has recorded the highest impact among processes. This expectancy however does not apply to all cases/zones. In the case of SE, it can be seen that the operation process produces the lowest emissions among processes. This is explained by the low usage of fossil fuels and petroleum product in the electricity mix of the country. One would expect that the higher heating demand required by a northern country would also translate into higher emissions.

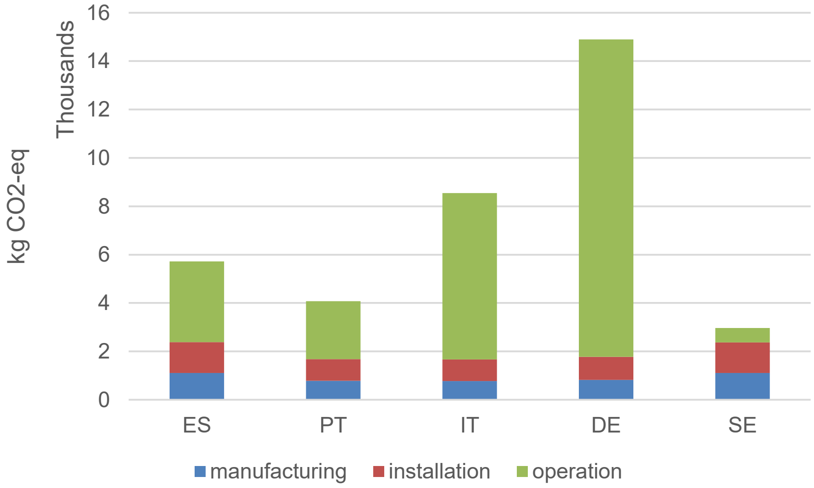


Fig. 3. GWP for the lifetime of the systems with kg-CO2-eq emissions of all GSHP system for each case/ zone for the manufacturing, installation and operation of the systems, per FU.

When the annual emissions of the GSHP systems of all cases are compared to the ASHP systems, the annual savings for the operation processes, which is essentially the difference between the GSHP system emissions and the ASHP system emissions, can be estimated, as shown in Fig. 4.

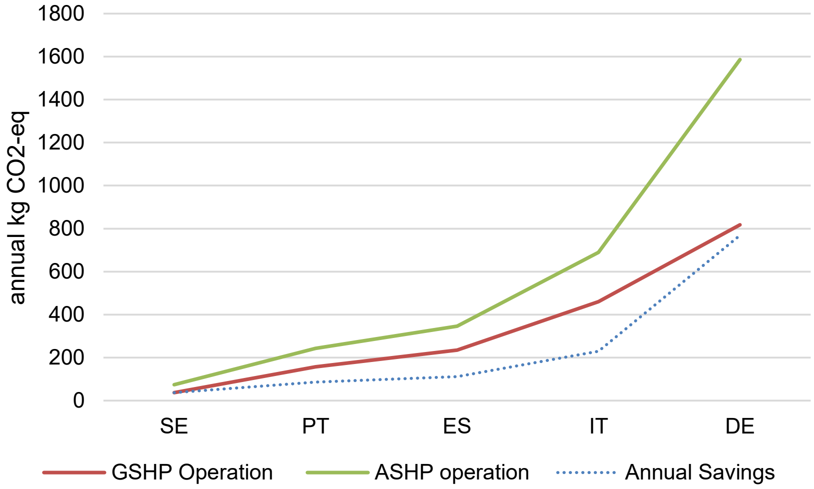


Fig. 4. GWP of annual kg CO2-eq emissions for the operation of the systems per FU.

In order to justify the switch from ASHP to GSHP systems, a direct comparison in the lifetime of the system is performed. Such comparison can be seen in Fig. 5, where a percentage difference is presented for the operation process. It is clearly illustrated that the GSHP systems of higher COP, consequently emit lower kg CO2-eq emissions. Also, where higher heating demand is required (northern countries) a further percentage reduction is achieved; see for example SE with about 50% reduction compared to ASHP. Actual values demonstrate a different story, as shown in the previous Fig. 4; see for example ES with 111 kg CO2-eq but only 32%, versus SE with 37 kg CO2-eq and 50%.

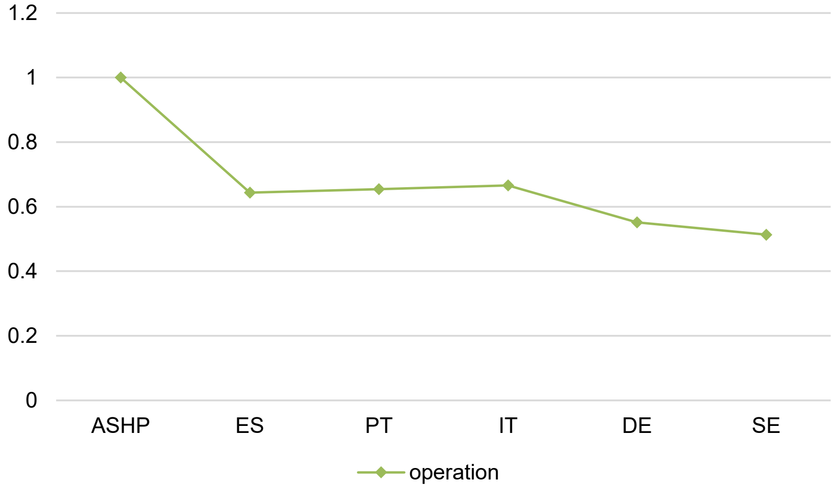


Fig. 5 Percentage difference of the GWP between the ASHP system and the GSHP system for each case/zone per FU.

In addition to the HP, a GSHP system contains the GHEs and additional equipment and materials, as discussed in Section 2. Therefore, the overall comparison between the ASHP and the GSHP systems requires the installation process and manufacturing process of the system. This comparison is presented in Fig. 6. The results now deliver a different statement compared to the previous results. When the manufacturing and the installation processes are accounted for, the overall image shows that the GSHP systems do not provide a lower environmental impact (in the lifetime of the system) in all cases/zones. The installation process, previously found in the literature to be close to 6% of the overall impact [21], can be seen to be close to 43% in the case of SE, 22% for PT, 22% for ES, 10% for IT, and 6% for DE. Therefore, the electricity mix of each country plays a vital role in the environmental impact difference between ASHP and GSHP systems. When a country exhibits an independency from fossil fuels and petroleum products in the electricity mix, as the case of SE where the environmental impact of the GSHP system exhibits four times more emissions than ASHP system, the discussion to switch from ASHP to GSHP could not be justified solely on the environmental impact on the system. However, in the cases where the electricity mix of the area relies by a high percentage to fossil fuels (examples are the IT and DE cases), then there would be a beneficial environmental investment when switching to GSHPs.

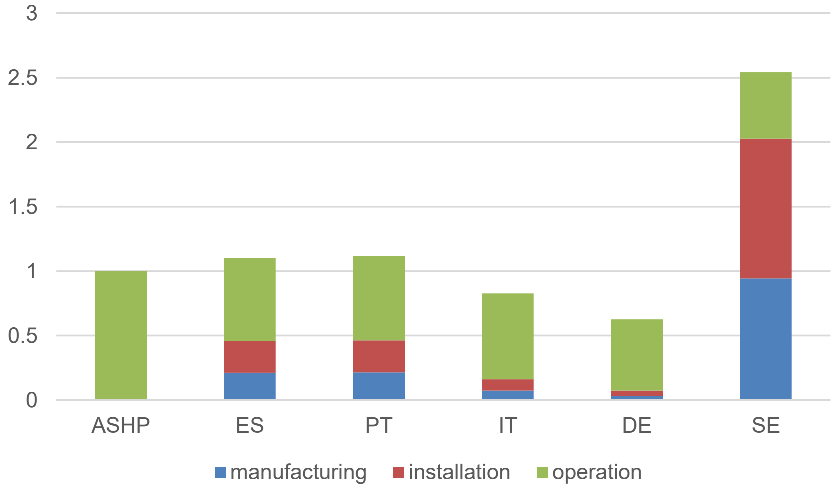


Fig. 6. GWP impact for the manufacturing process of the boreholes (GHEs), with the ASHP representing 100% per FU.

The main point in a decision making is the overall cost of the system and whether the investment would start paying off in a reasonable time frame (say, in less than five years). The methodology explained in Section 2 relies on the SPP, but instead of having as an input the capital cost, the estimation relies on what would the capital cost have to be in each case, so that the system will be profitable in the 3–5 years range of operation. Economic assessment of the GSHP systems have been performed by many researchers and the results vary, depending on the location, the design of the system, and the labor cost in each country [9,35–38].

The main difference in the cost between an ASHP and a GSHP system is because of the GHE and the associated equipment and processes, such as the borehole extraction, U-tube GHE, grout material, ground loop installation, header flow meter valves, horizontal pipe circuits, as well as other general expenses. The capital invested initial costs is the sum of the costs of the GSHP, mechanical room installation, drilling, piping, ground loop installation, fittings, etc. The operating costs include cost due to electricity consumption by the HP, the heat transfer fluid circulation pump and the backup heating/cooling system.

For the cost evaluation of the GSHP system, only the operation cost will be considered, therefore the electricity price for each location/zone is required. The electricity prices history since 2016, in euro (EUR), including all taxes and levies obtained from Eurostat [34], are presented in Fig. 7; the first season (S1) of year 2021 was used in this study, where it is assumed that the prices are steady (which in reality, this is not the case).

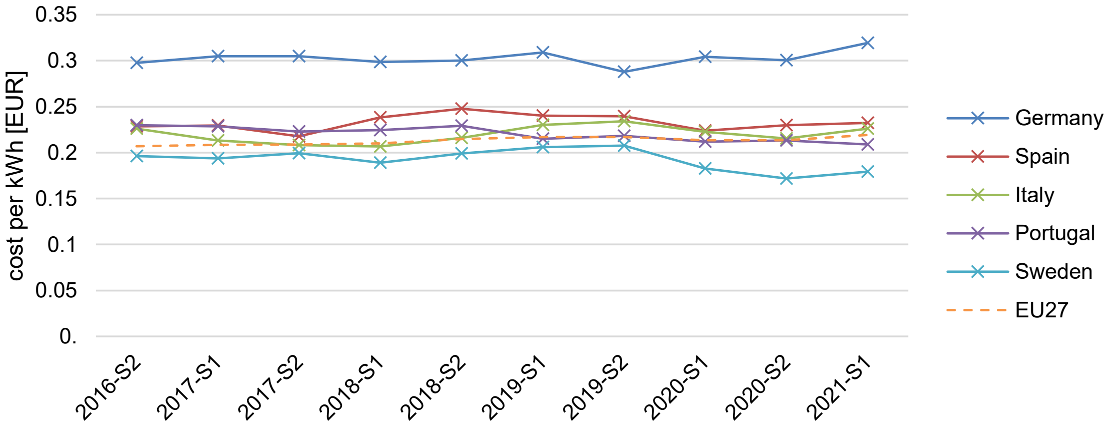


Fig. 7. Electricity prices per kWh in EUR per country, including all taxes and levies, since 2016.

Table 4 presents the proposed cost of the GSHP system, in terms of difference from the ASHP system and the annual savings achieved. The annual difference in operation between GSHP and ASHP systems depends on the efficiency difference of the systems and hence the COPs of the systems. The annual cost savings can therefore be estimated according to the prices shown in Fig. 7 and the annual operation difference in kWh (see Table 4). It can be clearly stated that the northern cases, having a higher heating demand, also have higher annual savings due to the performance difference of the systems. Another factor that has a high impact is clearly the cost per kWh. For example, the case of DE, having the highest cost per kWh (among the studied cases) suggests that the savings would also be higher. It can also be observed that the cases with a high share of renewable energy in the electricity mix do exhibit a lower cost per kWh of electricity, like the case of SE.

Table 4. Cost saving between the GSHP and the ASHP system for each system during the operation of the systems, excluding the capital cost.

	Cost per kWh [EUR]	Annual difference [kWh]	Annual savings [EUR]	Savings 3rd year [EUR]	Savings 4th year [EUR]	Savings 5th year [EUR]	Savings 8th year [EUR]	Savings 12th year [EUR]
ES	0.2323	789	183.24	549.72	732.96	916.20	1099.44	1282.68
PT	0.2089	422	88.25	264.75	353.00	441.26	529.51	617.76
IT	0.2259	1080	244.00	731.99	975.99	1219.99	1463.99	1707.99
DE	0.3193	2287	730.19	2190.56	2920.75	3650.94	4381.12	5111.31
SE	0.1791	4305	771.05	2313.16	3084.21	3855.26	4626.31	5397.37

Following the results above, it can be concluded that for the GSHP system to be cost effective compared to the ASHP system, one would expect to invest an amount lower than 550 EUR (see PT and ES), a non-realistic amount. Regarding northern countries, the cases of DE and SE, with savings higher than 3600 EUR for a 5-year payback period, could potentially be viable, considering the actual cost of a GSHP system (see [9,15]). Realistically however, for the northern countries, a payback period of 8 years or higher is required, while for the southern countries even a payback period of 12 years is not sufficient to cover the cost difference of the systems. This is in line with previous findings for a typical case study in Cyprus, where long payback periods of 20 years are recorded [9]. Other cases studied have also reported similar results for GSHP systems to become a profitable investment in comparison to ASHP systems [36,38,39].

4. Conclusions

This study has followed five case studies (one per zone) in Europe to firstly investigate the environmental impact of GSHPs in comparison to ASHPs, and secondly to assess whether the GSHP system could be a potentially viable solution. For comparison reasons the 5 case studies examined were based on the same residential building, namely a three-bedroom detached house with nZEB characteristics, but with different ambient temperatures and ground thermal characteristics. The estimation of the GHEs was performed in the GLD software environment and the environmental impact of the systems using the openLCA software.

Initially the GHEs' length and the systems' COPs were estimated in order to be used as inputs for the estimation of the environmental impact. GWP was used as an impact category with a mid-point impact perspective using the ReCiPe method. The FU for this study was set as the heating and cooling loads (demand) necessary to satisfy the need of the building for each case/EU zone. To this extent, the electricity mix of each country was incorporated for the operation process of the systems, while the manufacturing and installation was also considered. The main difference during the manufacturing and installation of the GSHP system lies in the presence of the GHEs.

GWP has indicated that in countries/cases where the renewable energy share in the electricity mix is high, like the case of Sweden (SE), a higher environmental impact is expected, of up to 2.5 times higher than for the ASHP system. The case of a GSHP system in SE on the other had exhibits also the highest heating demand and also the highest energy saving annually, in terms of percentage difference, compared to the ASHP system. In terms of actual values, the highest difference is exhibited by the case of Berlin, Germany (DE), although having a low renewable energy share compared to the other cases. It is somehow a surprise that only the cases of DE and Bologna, Italy (IT) have produced a lower environmental impact, with 62% and 83% (see Fig. 6) respectively, during the lifetime of the system compared to the equivalent ASHP system.

A cost analysis of the systems was also performed using the SPP (simple payback period) method, but without the input of the capital cost. Instead, since the capital varies from case to case and from country to country, the payback period of 3–5 years for which a system would be considered viable is set as input. The obtained results have indicated that only the northern countries, with higher heating demand than the southern countries, could potentially cover the investment from 8 years onward of the system's operation. At the same time, it seems questionable whether the GSHP system could be a viable replacement of an ASHP system in terms of environmental impact and investment in the southern EU countries.

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